Asymmetric Price Transmission

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THESIS SUMMARY

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This doctoral research reports on the presence and character of asymmetries in price dynamics of the European Union petroleum markets. We focus on the asymmetry between fast responses of downstream prices to margin-decreasing cost increases and slow adjustment after favourable cost developments as it might result in a politically sensitive welfare transfer from the end consumers to "Big Oil" companies operating upstream.

We start by proposing a classification of pricing non-linearities and use it to review previous research on this topic and to identify its deficiencies. In particular, we find that most of the studies offer limited scope for comparisons across crude oils, end products, countries and pricing tiers. Similarly, applied research suffers from the lack of in-depth analysis of the economics of petroleum markets, in particular its diversified quality / supply structures and patterns of causality and endogeneity in market prices. Furthermore, commonly used modelling techniques impose excessive assumptions about the character of pricing behaviour. Last but not least, the explanations of the asymmetry phenomena proposed in the literature have never been presented and reviewed in a coherent and consistent manner.

We rectify those issues by performing an analysis based on multi-country, -product, -tier and -crude dataset. We start by analysing the issues of causality and endogeneity in the petroleum markets and find that while the traditional benchmark oil prices still drive the EU market, the Russian crudes increase in importance both on global and European markets. In the core part of this analysis, we study price transmission using a smooth-transition modelling framework that allows us to (i) test for the presence of asymmetries in the equilibrium restoring process without imposing excessive restrictions on their nature, (ii) test for the shape and properties of those non-normalities and (iii) simulate price dynamics. We conclude that when using more detailed market data and less restrictive assumptions, non-linearities, although still widespread, are more intricate than previously assumed. Firstly, we find that apart from the traditional two-regime setting, a three-regime pricing behaviour is visible in the markets. Secondly, the regime change is found to be gradual rather than immediate and full as previously assumed. Thirdly, in many cases the existence of non-linearities does not automatically imply a significant welfare transfer but rather the presence of slow adjustment for small market disequilibria.

We finish by tackling two neglected aspects related to petroleum product pricing. Firstly, we analyse interactions between petroleum taxation and cross-country price dynamics and find that the pricing mechanism is consistent with the "fuel tourism" phenomena which can have a significant effect on taxation revenues and environment. Secondly, we review the explanations of non-linearity phenomena and find that those usually quoted in the literature (market abuse and search costs) find little support in the results obtained and industry statistics, while others should be analysed jointly so as to create a new, coherent theoretical framework that explains mechanisms of petroleum pricing.

Key Words: Oil, Petroleum, Pricing, Non-linearity, EU

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Needless to say, despite all the assistance provided, I alone remain responsible for the content of the following, including any errors or omissions which may unwittingly remain.

Work Resulting from This Research

Refereed Journals - published

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Wlazlowski, S. (2003a), 'Petrol and crude oil prices: Asymmetric price transmission', *Ekonomia / Economics* **11**, 1–25.

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Working Papers

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Practitioner Publications

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Nomenclature

$\odot$ Element-by-element multiplication

$\circ$ Hadamard Product

$\Im_t$ Borel sigma-field σ for a time series given information from t

$\mathcal{B}$ Borel Field - sigma algebra

$I(\ldots)$ Indicator Function

ADF Augmented Dickey-Fuller

AIC Akaike Information Criterion

APT Asymmetric Price Transmission

AR AutoRegressive

ARCH AutoRegressive Conditional Heteroscedascity

AT Austria

BE Belgium

BST British Summer Time

cif Cost, Insurance and Freight inclusive price as specified by INCOTERMS (International Commercial Terms) 2000

CPI Consumer Price Index

CRDW Cointegrating Regression Durbin - Watson

CUSUM Cumulative Sum of Recursive Residuals

CUSUMSQ Cumulative Sum of Squared Recursive Residuals

CY Cyprus

CZ Czech Republic

d.o.f Degrees of freedom

DE Germany

DF Dickey-Fuller

DK Denmark

DOLS Dynamic Ordinary Least Squares

DSP Downstream Price

DW Durbin Watson

ECM Error Correction Model

ECT Error Correction Term

EE Estonia

EGARCH Exponential GARCH

ES Spain

EUR Euro

EURO EURO-95 Unleaded Petrol - ULP

FI Finland

fob Free on Board conditions as specified by Incoterms

FR France

FSU Former Soviet Union

GARCH Generalized ARCH

GB United Kingdom

GBP Pound sterling

GR Greece

HGasoil Gasoil / Heating Oil

HHI Herfindahl-Hirschman Index

HQC Hannan-Quinn Information Criterion

HU Hungary

IE Ireland

Incoterms International Commercial Terms 2000

IT Italy

JB Jarque-Bera

KS Kolmogorov-Smirnov

KSS Kapetanois, Shin and Snell

LP Leaded Petrol

LPG Liquefied Petroleum Gas

LR Long Run

LS Least Squares

LT Lithuania

LU Luxembourg

LV Latvia

M-TAR Momentum Threshold Autoregressive

Med Mediterranean

MENA Middle East North Africa

MON Motor Octane Number

MPE Markov Perfect Equilibria

MSE Medium (and) Small Enterprise

MSP Midstream Price

MT Malta

NL Netherlands

NO Norway

NYMEX New York Mercantile Exchange

OLS Ordinary Least Squares

p-value probability value

PADD Petroleum Administration Defense District

PAM Partial Adjustment Model

PL Poland

PO Phillips-Ouliaris

PP Phillips-Perron

PPI Produced Price Index

ppm Particles per million

PT Portugal

PT Price Transmission

RESET Ramsey's Regression Specification Error Test

RFO Refined Fuel Oil

RLS Recursive Least Squares

RON Research Octane Number

RPI Retail Price Index

SBC Schwartz Baycsian Information Criterion

SE Sweden

SETAR Self Exciting Threshold Autoregressive Model

SG&A Selling, General and Administrative

SI Slovenia

SK Slovakia

SR Short Run

STAR Smooth Transition Autoregressive Model

SUPER SUPER-95 Leaded Petrol - LP

TAR Threshold Autoregressive Model

ULP Unleaded Petrol

USD United States dollar

USP Upstream Price

VAR Vector Auto-Regressive

VEC Vector Error Correction

VRC Vector Regime Switching

WN White Noise

Chapter 1

Introduction

This chapter describes the motivation for this PhD research, the problems tackled and methods employed for that purpose. In the first part of the chapter, we introduce basic concepts used throughout the thesis, explain the significance of the research problem and how it is usually classified in the literature. The second part of the chapter describes the petroleum markets in the European Union, summarizes the research aims and presents the outline of the rest of the dissertation.

1.1 Evidence from the Markets

Economics worldwide rely heavily on fossil fuels, especially on crude oil, the prices of which (as the experience of oil shocks in the 1970s has shown) can affect the global economic climate. Given that, no wonder that the crude oil price hikes that follow wars, hurricanes, strikes and terrorist attacks make the headlines all over the world. One of the issues that attracts consumers' attention is how those remote events affect their lives through the changes of the prices of energy products they buy every day.

This research aims to analyse those linkages for major petroleum products in the European Union. The focus is on the presence of non-linearities in the pricing process and potential welfare transfer associated with it. The following sections explain the research problem in detail and discuss its significance.

1.1.1 Illustration of the Research Problem

To familiarize the reader with the petroleum pricing terminology, it helps to visualise the pricing process occurring as crude oil and its derivatives are transported down the river - which was one of the first ways of transmitting oil from the natural seepages located *upstream* the rivers all the way down to refiners, wholesalers and final users *downstream* - Yergin (1991). In line with this analogy, the relationship between prices is called *price transmission*, initial tiers in price transmission (those related to crude oil) are labelled upstream, those for processed products - midstream and those at the retail stage - downstream. In this dissertation we abbreviate upstream, midstream and downstream prices as USP, MSP and DSP, accordingly.

More formally, the concept of price transmission could be illustrated by the following example. Given that (by definition) prices along the stream are related:

- in the absence of external shocks, some kind of equilibrium relationship between upstream and downstream prices should exist;
- external shocks should trigger short- and long-run adjustments towards the long-run equilibrium, since:
  - rational economic agents price their goods so as to maximise their underlying utility function;
  - in the long run prices of goods should reflect their scarcity.

Given the above, assume that:

- the commodities analysed are:
  - crude oil - global upstream, and
  - petroleum motor fuel - local downstream;
- the market for petroleum in question is small compared to market for crude oil - in terms of quantities traded, so that prices downstream cannot drive those upstream;
- in the short-run, only crude oil prices drive petroleum prices (i.e. prices of other inputs are assumed to be constant);
- no substitutes to petroleum are available in the short-run.

In such a setting, one might expect that:

- increases and decreases in crude oil prices trigger appropriate changes downstream;
- the resulting changes are symmetric in terms of absolute size / timing.

This Symmetric Price Transmission (here SPT) is predicted by all canonical industry / market pricing models (perfect competition, monopoly, etc. - see Kirchgassner & Kubler (1992) for a discussion). In this dissertation we focus on situations when transmission is not symmetric, in particular those when increases in crude oil prices lead to immediate increases in the petroleum prices, but decreases in crude oil prices are passed downstream with a delay. Posner (2002) refers to this phenomenon as *price hysteresis*, Deltas (2004) uses the term *price gouging*, Manning (1991) calls it *downward stickiness*, while Bacon (1991), Reilly & Witt (1998) and Galeotti, Lanza & Manera (2003) use a more graphic term - *rockets and feathers*. In this dissertation we call it simply Asymmetric Price Transmission (here APT), as this term is deeply rooted in the literature and does not have equivalents in other fields of economics.

A further discussion of types of asymmetries is presented in section 1.2, where we also develop a uniform classification of APT, necessary for the purposes of the literature review. But first, we discuss the significance of the research topic.

1.1.2 Motivation

The issue of APT deserves rigorous and in-depth research for a variety of reasons. Firstly, because of the size of the petroleum markets, the global dependence on oil products and the share of income spent by the average household on petroleum products, APT is important from the welfare point of view. One must remember that APT might imply a welfare redistribution from agents downstream to agents upstream (compared to situation prescribed by canonical theories). Because such a redistribution would be from ordinary citizens (voters) to multinational companies operating upstream, it has serious political and social consequences. Secondly, petroleum product prices can affect (at least temporarily) numerous costs in several industries, and thus affect the efficiencies and competitiveness of economic systems.

The presence of non-linearities in price transmission is clearly acknowledged by government institutions - the House of Commons Report (2001, p. 1) states that:

> The link between the oil component of petrol prices and crude prices is neither linear nor automatic.

The possible welfare transfer related to the presence of non-linearities also attracts significant attention from the public. The following quotes from Karrenbrock (1991, p. 20) cover the early 1990s, when issues about stability in the Gulf Region led to the first of many price spikes in the last two decades:

> "Those who are doing the gouging will hear from the president" - Treasury Secretary Nicholas Brady. *The Wall Street Journal*, August 9, 1990

"Retail prices go up much faster than they come down" - a spokesman for the Automobile Association for America, *The Wall Street Journal*, August 9, 1990

"Pump prices are fast to respond to rising prices but slower to fall when crude prices fall" *The Wall Street Journal*, August 3, 1989

"Whenever oil prices fall, there is always the stickiness in gasoline prices on the way down. You never see this stickiness on the way up." - *New York Times*, July 2, 1990

"When crude prices go up, product prices tend to rise with crude prices. But when crude prices go down, product prices tend to lag - they go down slowly" *St. Louis Post-Dispatch*, June 19, 1990

Thirdly, APT is still largely an unexplained phenomenon which offers plenty of room for more empirical research. This is due to the fact that the current literature offers only casual explanations of APT phenomena and, in the words of Meyer & Cramon-Taubadel (2004, p. 2):

> (...) a variety of often conflicting theories (...) co-exists. While there has been progress made in the sense of statistical and empirical sophistication (...) (*existing tests*) are not discerning in the sense that they make it possible to differentiate between competing underlying causes on the basis of empirical results.

Peltzman (2000) confirms this view by stating that (emphasis added):

> (...) Output prices tend to respond faster to input increases than to decreases (...) it is found as frequently in producer goods as in consumer goods market (...) (*and*) suggests **a gap in the essential part of economic theory.**

The above quote points to the last argument in favour of APT research. The presence of APT is not in line with canonical economic theories (e.g. perfect competition and monopoly), which predict that under some regularity assumptions (such as non-kinked, convex / concave demand function) downstream responses to upstream changes should be symmetric in terms of absolute size and timing. Therefore, research into APT offers a perfect opportunity to bring the economics closer to real business life and address issues that concern the public.

1.2 Types of Asymmetries

This section presents the proposed categorisation of APT followed in this dissertation. Such a classification is useful as a framework for the literature overview and allows us to make consistent comparisons of the results obtained by previous researchers.

The most obvious classification of asymmetries would be to split them depending on their direction which also imply the direction of the welfare transfer. This was first formalized by Peltzman (2000) and should be seen as a most fundamental way of classifying the non-linearity phenomenon. The two other attempts to categorise different kinds of asymmetries are by Meyer & Cramon-Taubadel (2004) and Frey & Manera (2007).

Meyer & Cramon-Taubadel (2004) propose the following classification criteria:

- direction of the price transmission - *vertical* (upstream to downstream) or *spatial* (e.g. geographical on the same market level or arbitrage);
- nature of the asymmetries in vertical transmission - whether the downstream adjustment to impulse shock upstream is asymmetric with respect to *time* or *size* (or combination of both);
- direction of the welfare redistribution occurring during vertical transmission - upstream (*positive asymmetry*) or downstream (*negative asymmetry*).

Obviously, given that we focus on transmission *along* one transmission chain, we focus on vertical asymmetries (the spatial price dynamics are analysed in section 6.1). The proposed classification is consistent and clear, however one should remember that under the standard PT assumptions, the size asymmetry cannot occur on its own, otherwise upstream and downstream prices would ultimately drift apart. Since they are are by definition related to each other, this cannot be the case. Accordingly, size asymmetry can occur only together with time asymmetry and only when the LR relationship between prices is restored after the impulse shock to upstream prices.

Frey & Manera (2007) distinguish no fewer than *eight* main types of asymmetry:

- contemporaneous impact (COI) - said to exist when the *contemporaneous* downstream price responses to an impulse upstream cost change at t are asymmetric in terms of the size;
- distributed lag effect (DLE) - said to exist when the *follow-up* downstream price responses to an impulse upstream cost change at t are asymmetric in terms of the size;

- cumulated impact (CUI) - said to exist when the *accumulated* downstream price responses to an impulse upstream cost change at t over a period of time are asymmetric in terms of the *size*;
- reaction time (RTA) - said to exist when the *accumulated* downstream price responses to an impulse upstream cost change at t are asymmetric in terms of *time* necessary for the completion of the transmission;
- equilibrium adjustment path (EAP) - said to exist when the downstream price responses to impulse upstream cost change at t are asymmetric in terms of size, with asymmetry depending on the size of the *disequilibrium* between actual downstream prices and their LR equilibrium levels set by upstream costs;
- momentum equilibrium adjustment path (MEAP) - said to exist when the downstream price responses to an impulse upstream cost change at t are asymmetric in terms of size, with asymmetry depending on the *change* in the disequilibrium between actual downstream prices and their LR equilibrium levels;
- regime effect (RE) - said to exist when the downstream price LR adjustment speeds differ depending on the *level* of upstream prices;
- regime equilibrium adjustment path (REAP) - said to exist when the downstream price LR adjustment speeds differ depending on the *change* in the disequilibrium between actual downstream prices and their LR equilibrium levels.

The above classification does have some drawbacks, most significantly:

- distinction between COI and DLE - one must remember that the real time or tick data are not available, so virtually every observation is *de facto* an aggregate over a period of time. Since frequency of data used in APT research differs, asymmetry classified in some cases as COI (e.g. using weekly data) would be classified as DLE in others (e.g. using monthly data), thus invalidating comparisons;
- COI/DLE, CUI and RTA all refer to the same phenomena, i.e. asymmetric SR downstream price responses to one-time impulse change in upstream costs. The difference lies only in the way asymmetry:
  - is analysed - either in terms of time (RTA) or size (CIU/DKE and CUI);
  - is presented and measured - either at even intervals (COI/DLE) or in a cumulative way (CUI); again in such a case the classification is arbitrary and rules out comparisons between different studies;

- measures of RTA asymmetry depend heavily on the units of time chosen. Since researchers utilize data with different levels of aggregation over time (daily, weekly, bi-weekly, monthly), classification based on RTA criteria hinders meaningful comparisons between studies.

For the sake of simplicity, we propose a joint classification unifying contributions by Frey & Manera (2007) and Meyer & Cramon-Taubadel (2004) in the spirit of Peltzman (2000). The proposed classification focuses on two intertwined elements of non-linearities, i.e. (i) the nature of APT and (ii) its welfare effect. Accordingly, with respect to the characteristics of asymmetry, following Meyer & Cramon-Taubadel (2004) we distinguish the following asymmetries:

- time asymmetry - referring to a situation when the downstream response is not symmetric with respect to timing of the downstream price responses to upstream cost impulse change (illustrated by the bottom right panel of Figure 1.1);
- combinations of the time asymmetry and size asymmetry above (illustrated by the bottom right panel of Figure 1.3).[1]

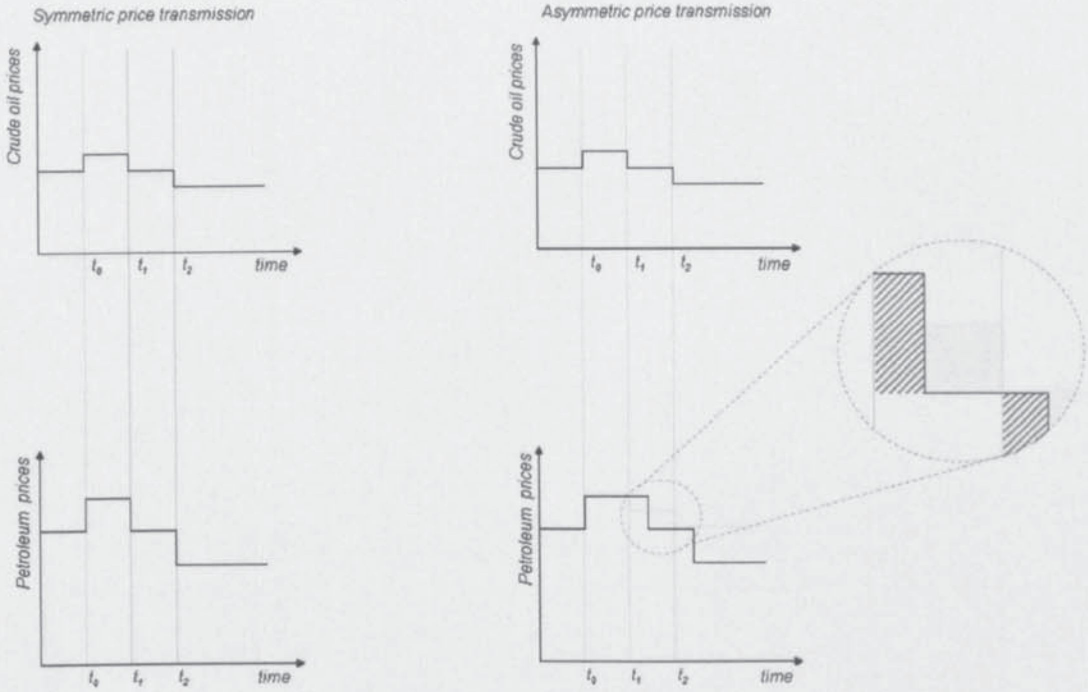
However, one has to remember that given the imperfect monitoring of prices and aggregation across transactions and over time (which cannot be easily avoided), the above distinction in most cases is purely academic - if anything, most series will display only combined time / size asymmetry as pure size asymmetry will be lost in the data.

All asymmetries described above induce welfare transfer compared to the SPT. The unit effect is represented by the shaded areas in the Figures 1.1-1.3. With respect to the welfare effect, following Peltzman (2000) and Meyer & Cramon-Taubadel (2004), we distinguish between:

- negative asymmetry, said to exist when downstream prices react more fully or rapidly to upstream price decreases as opposed to increases, thus inducing transfer of the welfare to the agents operating downstream; and
- positive asymmetry, said to exist when downstream prices react more fully or rapidly to upstream price increases as opposed to decreases, thus inducing transfer of the welfare to the agents operating upstream.

[1] Size asymmetry refers to a situation when downstream response is not symmetric with respect to size of the responses to USP impulse change (illustrated by the bottom right panel of Figure 1.2). As discussed above, this asymmetry can appear only together with time asymmetry.

Figure 1.1: Examples of SPT and APT - Time Asymmetry



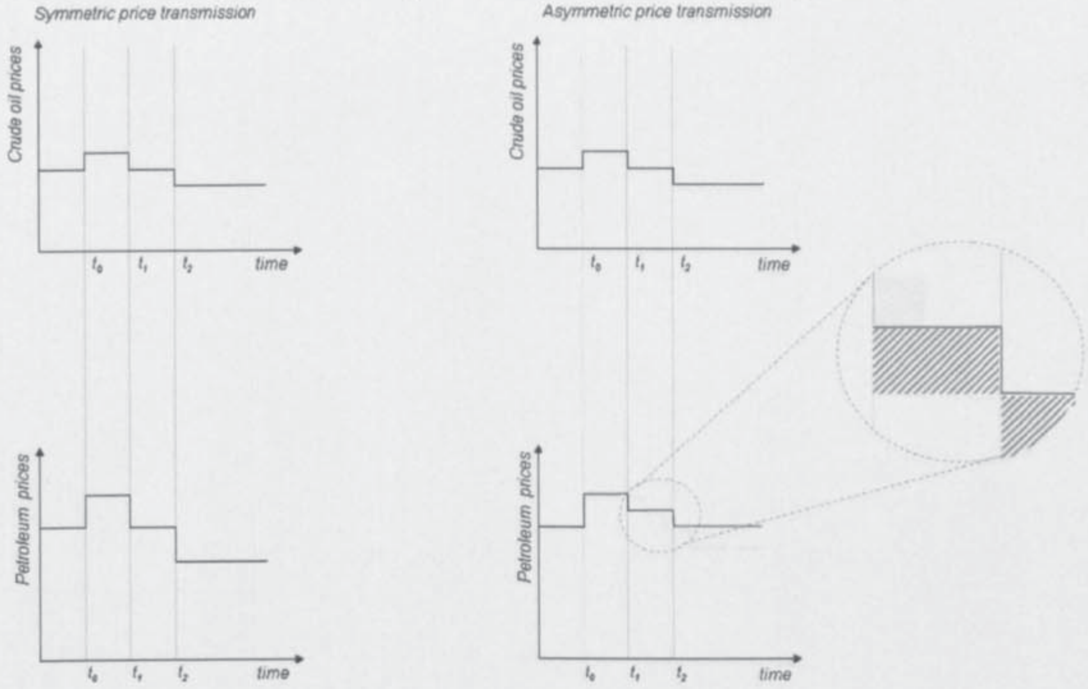
The proposed nomenclature should not be analysed from the normative point of view, as negative asymmetry implies welfare gains for downstream agents which usually is considered desired (i.e. positive), but rather in terms of additional time necessary for adjustment to upstream shocks. Figure 1.4 depicts the idea of positive and negative asymmetries (arrows represent the direction of the welfare transfer).

1.3 Petroleum and Oil Markets

This section presents the overview of the EU petroleum transmission chain. We start with a brief overview of the pricing chain and then discuss how prices are set. We continue with a discussion of various price transmission issues related to upstream, midstream and downstream tiers.

The pricing chain begins with the extraction of crude oil, which is done in numerous locations throughout the world. The crude ready to be refined (so-called feed) is then transported to refineries where it is broken into several end products. Those products are then sold either to wholesalers who supply their own chains of retailers or independent retailers. Alternatively, the finished products could be sold by the refiners themselves, again either to vertically integrated retailers or independents. Figure 1.5 presents an overview of this chain.

Figure 1.2: Examples of SPT and APT - Size Asymmetry

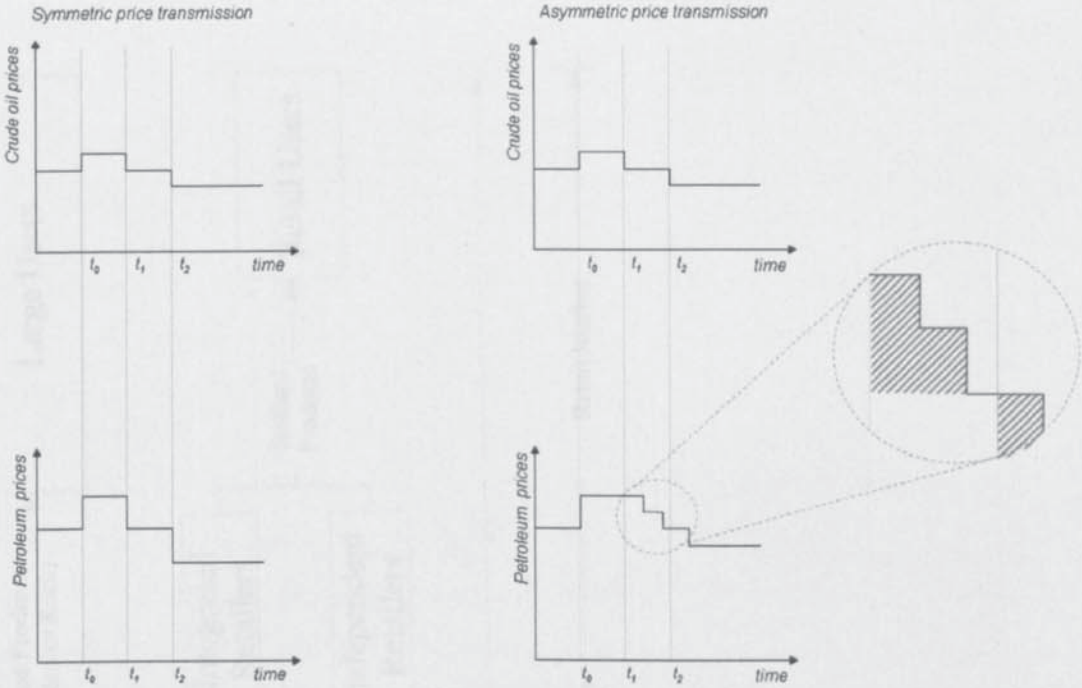


At every tier in the chain, the processed products are priced, either in an actual transaction or for bookkeeping purposes. As required by tax laws worldwide, all pricing agents set their prices as a sum of three profit and loss accounts (i) costs of good sold; (ii) SG&A portion, i.e. marketing and transportation costs; (iii) above-the-line exogenous price components, mainly taxes. Asplund, Eriksson & Friberg (2000) report that the Swedish office of Shell sets the end-product prices every day. For independent US retailers, Davis (2007) finds that prices are changed less frequently - only on 8%-14% of the days, but still often enough to reflect changes in upstream costs. Given the higher average value of the transaction, one might suspect that the frequency of price adjustments increases upstream with crude oil benchmarks being priced in real time.

Costs of goods sold include fully loaded purchase price paid on the previous tier, with the additional costs set according to the appropriate Incoterms.[2] This is the main element of price transmission and the one that links all subsequent tiers. In this dissertation we focus on that component. This is typical in the literature - Chouinard & Perloff (2007) analyse the determinants of petroleum prices in the US and find that the variation in the price of crude oil has been virtually the only major factor contributing to downstream price variations. Tax variations and mergers contribute substantially more to geographic

[2]Incoterms are sets of model contracts and sets of interpretive rules for international business, including delivery rules - Braithwaite & Drahos (2000).

Figure 1.3: Examples of SPT and APT - Combined Asymmetry



price differentials than price discrimination, cost factors, or pollution controls. A similar approach is also taken by virtually all other researchers - see chapter 3 for an overview. Therefore, given that this analysis focuses on net-of-tax prices at a national level, it is safe to conclude that retail prices of all petroleum products are driven by the upstream costs.

Other costs in this category are incurred mainly at the refining stage and include inventory and storage, chemicals and catalysts, blending component purchase and storage costs, energy inputs (gas and electricity), financing and labour - Posner (2002). Denni & Frewer (2006) proxy them into three major groups (i) transportation costs; (ii) marginal

Figure 1.4: Positive and Negative Asymmetries

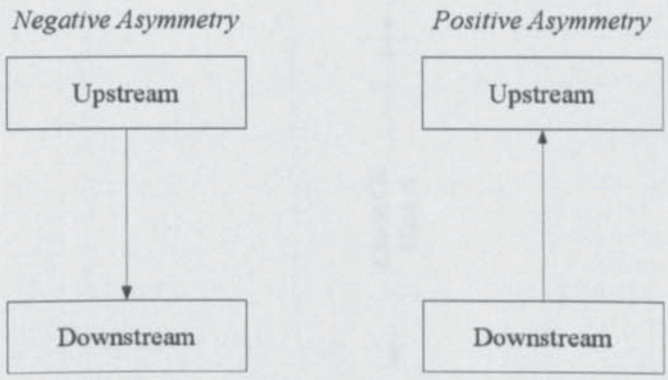


Figure 1.5: Overview of the Distribution Channels

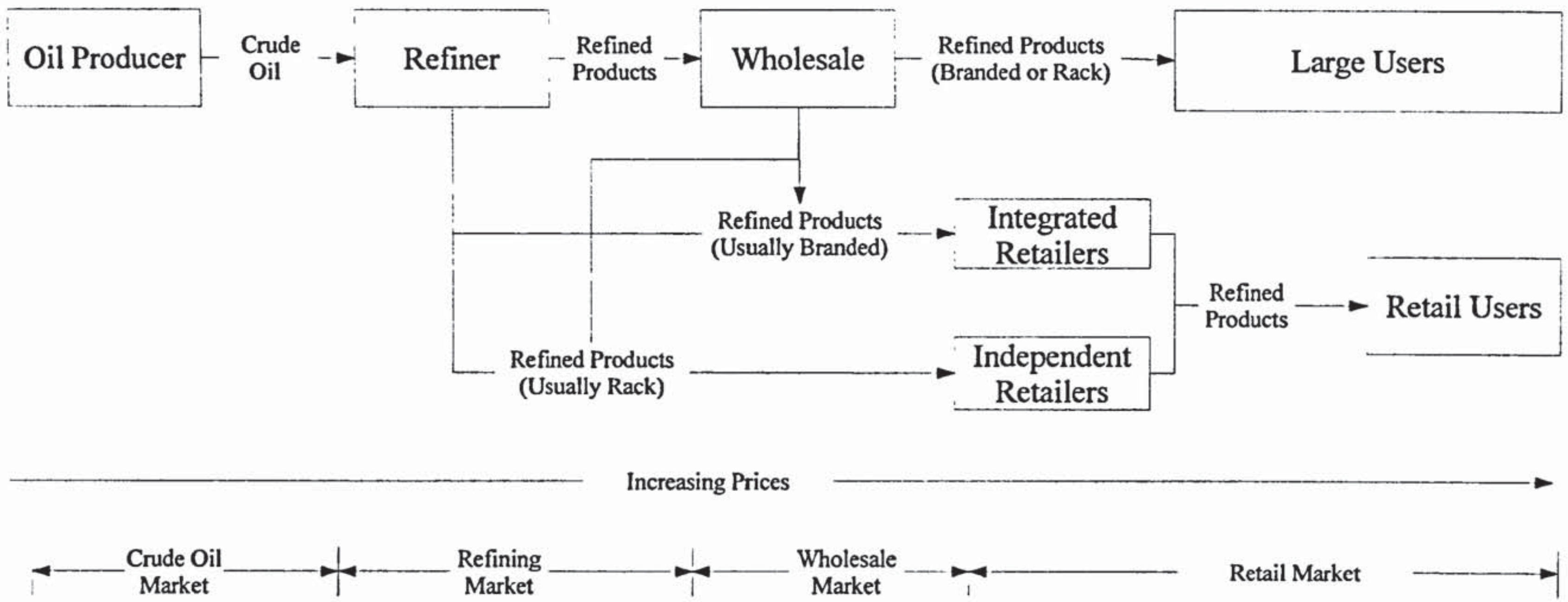


Table 1.1: Refining Costs

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Source: Denni & Frewer (2006).

refinery operating costs (related to chemicals, additives and catalyst); and (iii) credit allowance. As presented in Table 1.1, those costs are either constant or negligible compared to per-barrel upstream cost.

According to Scherer (1996), at other stages the most significant costs include (i) transportation (refinery to terminal and then station); (ii) terminal operation expenses (labour, energy, rent and some taxes); (iii) inventory, storage and maintenance costs; (iv) costs of additives (methanol) and blending. Again, those costs do not depend on upstream costs and / or remain fairly stable.

The SG&A costs originate on each transmission level as the agents finance their everyday operations. Those costs include fixed *ad valorem* depreciation and unionized labour costs, so one can assume that they change infrequently and by small amounts - see Sumner (1990) for a UK study accounting for labour costs.

Since (by definition) taxes are either *ad valorem* or infrequently adjusted lump-sum (in most EU countries the excise duty is adjusted once a year) they are of little interest in transmission analysis - Energy Information Agency (1999, p. 17). Wlazlowski, Binner, Giulietti, Joseph & Nilsson (2006) analyse the issue in greater detail.

Below we discuss several issues related to the above described pricing tiers that are important from the point of view of price transmission.

Crude Oil

Crude oil is an unprocessed mixture of hydrocarbons, found in the portions of the earth's upper strata. It is the main source of so-called petroleum products, i.e. materials containing large fractions of relatively volatile hydrocarbons, described later on. Given the global dependency on those products, crude oil is one of the most important commodities used and traded globally - Chaudhuri (2001).

The geographical and geophysical heterogeneity of its sources causes the crude oil to come in hundreds of varieties that differ with respect to their chemical composition, usually dubbed *quality* - Gülen (1997), Gülen (1999). In terms of quality, crudes are split into (i) light, medium or heavy (based on the density of the crude measured in degrees of API), and (ii) sweet and sour (based on the low / high sulphur content). Figure 1.6 presents the product yields for different qualities of crudes. The most important point is that refining of high quality crudes results in a greater share of high quality and high margin products, i.e. motor spirits (unleaded petrol - ULP and Diesel oil).[3] As new

Figure 1.6: Comparison of Refinery Yields by Crude Quality.

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Source: Natural Resources Canada (2005).

fields are discovered and utilised and old fields are depleted, this quality composition of crude oil supply constantly evolves - see Eni SpA Report (2006). Figure 1.7 presents a simplified classification of *ca.* 500 varieties of crude oil traded globally. The most visible characteristics are (i) the enormous number of different varieties, and (ii) the diversity of crudes with respect to taste, gravity and geographical origins.

Although hundreds of crude oil varieties are physically traded, only few high quality crudes are actually priced. The remaining crudes are traded on over-the-counter markets and their prices are linked to those of benchmark crudes traded in the spot market - Platt's (2006*a*). Such a situation is a result of costs necessary to price numerous products but also represents an artefact of the early days of the industry when crude oil was extracted only from easily accessible fields which offered high quality crudes. With time, however, the steadily increasing demand on the global markets emptied the old, high quality fields and caused the increase in the share of low quality crudes - according to Montepeque (2005) those crudes recently accounted for almost 50% of the general supply. Furthermore, the technological advances still increase the available supply of low quality crudes, e.g. via access to lower portions of older fields with steam flooding - Bahree & Gold (2006). Pulling in the opposite directions are the harsher environmental policies which increase the demand for high quality crudes and make it easier to supply the market with low sulphur end products - Platt's (2006*a*).

[3]For a more detailed overview of yields during topping and cracking phases see Platt's (1999), Natural Resources Canada (2005) and Health Administration (2007).

Figure 1.7: Classification of Crude Oils

Aston University

Illustration removed for copyright restrictions

Source: McQuilling Services Report (2006).

As the result, the spot market is steadily emptied of the high quality crudes which makes the traditional benchmark crudes less reliable as market indicators, since they represent only a fraction of supply to a relatively small spot market - Wilkinson (2004). This potentially might diminish their reliability for the purposes of price transmission analysis, especially with the significant reliance of over-the-counter markets on spot exchange which becomes increasingly volatile - Gülen (1997) and Gülen (1999). This issue is discussed at length in section 4.2.1.

With the exception of Denmark and the UK, none of the EU countries has any significant crude oil reserves that could satisfy the local demand. Table A.3 presents the share of imports in the overall inputs to the refineries over the sample period (in percent). It shows that all EU countries rely on imports to cover over 90% of their consumption.

The composition of those imports is diversified and difficult to re-construct based on aggregated data. Fortunately, as pointed out by McQuilling Services Report (2006), the country/region of origin is a valuable indicator of the quality of crude extracted there. Therefore, although the exact quality composition of crudes used in the EU is unknown, one can assume that the shares of the Russian, US and North Sea crudes represent the maximum shares of (respectively) Ural, WTI and Brent crudes in the EU feed.[4] Industry statistics presented in Tables A.4 - A.7 indicate that:

- FSU crudes tend to be the main source of refinery inputs in the majority of the EU countries, especially those with an easy access to the Russian pipelines (Eastern and Central Europe);

- over the last 10 years FSU crudes have gained market share, which might be due to increasing global prices and volatile supply from elsewhere. This is especially visible in Austria, Greece, Germany and the Netherlands;

- OPEC countries are the second biggest source of feedstocks. The countries most dependent on OPEC crudes are Austria, Belgium, Germany, France, Greece, the Netherlands, Spain and Portugal. The geographic pattern follows the infrastructure and proximity to major sea-routes used to transport crude from the OPEC countries (Mediterranean Sea and Atlantic Ocean);

- North Sea crude is a major source of feedstock in Denmark, Sweden, Ireland and the UK. Its share declines which might reflect closure of the fields and growing impact of the FSU crudes;

[4]The remaining imports come mainly from the OPEC countries. Because OPEC crudes do not have a marker crude (other than so-called reference basket) their prices cannot be included in the analysis (for a detailed discussion see chapter 4).

Table 1.2: Product Yields

	Product Yields	
Product	Hydroskimming	Cracking
Naptha	6.49	9.08
Petrol	17.00	28.56
Kerosene	9.39	8.88
Gasoil	35.98	37.45
Fuel Oil	28.41	14.36
Total	97.27	98.32
Refinery Fuel / Losses	2.73	1.68

Source: IEA - Monthly Oil Market Report - August 1996.

- US crudes are not used in the EU countries, with the exception of the UK.

Once domestic or imported crude oil is purchased it has to be transported to a refinery. Those complexes are one of the world's most expensive industrial plants - according to Scherer (1996) a cost of one can be anything between USD 800 million and USD 2 billion, with the minimum scale of profitable operation equal to 200,000 bpd. This effectively constrains entry into the industry and upholds the *status quo* with a handful of companies operating upstream. Traditionally, until the 1990s those companies were labelled the "Old Seven Sisters" and included ExxonMobile, Royal Dutch Shell, Anglo-Persian Oil Company, Standard Oil of New York, Standard Oil of California, Gulf Oil and Texaco. The Financial Times issue of 2007 March 11, additionally identifies the "New Seven Sisters" - Saudi Aramco (formerly Aramco), JSC Gazprom, CNPC, NIOC, PDVSA, Petrobras and Petronas. Closed entry caused by significant entry costs results in stable processing capacity - as for 2006, the USA has not build a new refinery in thirty years while in Europe no refinery was built in twenty years - Ghanem (2005). This ensures stable supply and pricing of petroleum products at a national level.

Based on the results of the analysis presented above, we start the applied analysis by examining the global crude oil market in order to identify which kinds of crude lead the price trends (section 4.2) and the nature of the relationship between crude oil prices and prices of its derivatives (section 4.3).

End Products

The refining process yields several end products. Table 1.2 presents the percentage yields and losses from the two most popular refining techniques - hydroskimming and cracking.

Since every product has different characteristics and uses, they also have distinctive markets. The only difference is with respect to low and high sulphur fuel oil, which differs mainly with respect to compliance with environmental regulations and in principle could be used interchangeably.

End Products - Midstream Prices

In Europe, finished products are refined at home from crude bought from other countries or imported from foreign refineries. In both cases, products pass through the EU trade hub located around Antwerp, Rotterdam and Amsterdam (ARA) region - Manzano (2005). The predominance of Low Countries in the petroleum trade results from (i) their geographic position which facilitates the maritime trade and ensures proximity to the key end markets (France, Germany and the UK) and (ii) their early entry into oil exploration business (Royal Dutch Shell) - Yergin (1991).

Both imported and home-refined products are priced in a similar way (via price formulae) at the same level (as the markets are liquid, some arbitrage is possible and, because of the geographical expansion of international companies, commodity swaps are widespread). Given that, the processed bulk product prices should be seen as uniform across Europe and (unlike the internationally integrated crude oil markets) separated from the global market. Hammoudeh, Li & Jeon (2003) examine the time-series behaviour of 22 daily series of spot and futures prices for three petroleum products: crude oil, heating oil and gasoline, traded at five different international trading hubs within and outside the United States (including the ARA region) over the period 1986-2001. The authors group prices into five sets based on their maturity, type and location, and then investigate horizontal / vertical links within each group using cointegration, error-correction representation and GARCH models. The authors find that for petroleum products there is no price series dominating more than one international market.

Apart from straightforward short-long transactions, players buy and sell products using invoices, remittance guides, purchase orders and swaps. As a result, fuel trade might be easily separated from its physical delivery. Accordingly, the activities on the ARA level do not involve significant sunk costs or entry barriers, which results in a large number of companies trading.

The midstream tiers comprise also national wholesale tiers on which end products are traded in the same currency as retail prices. Unfortunately, those prices are not available on any consistent basis for the EU countries. This issue is discussed at length in section 3.2.

The last remaining problem is that the wholesale prices published by the official sources do not account for inter-company (transfer) prices. This constrains the data to prices paid in transactions between independent parties and excludes prices paid in transactions between vertically integrated wholesalers or retailers. This issue cannot be dismissed lightly as the predominance of such companies in the oil sector indeed suggests that their (undisclosed) wholesale prices might be substantially lower thus giving 'tied' resellers substantial advantage. Fortunately, in this study we use prices quoted further upstream (in the ARA region) which refer to fully processed, standardized products which act as opportunity costs both for the independent and dependent companies - Hosken, McMillan & Taylor (2007).

End Products - Retail Prices

European Commission (1999) specifics seven major groups of petroleum products commonly used in the EU. Those are:

- motor fuels:
  - ULP (i.e. premium unleaded petrol);
  - LP (i.e. premium leaded petrol);
  - Diesel;
  - LPG;
- domestic heating oil - gasoil;
- industrial fuels:
  - RFO.1 - fuel oil with more than 1% sulphur for wholesale market deliveries;
  - RFO.2 - fuel oil with less than 1% sulphur for wholesale market deliveries.

The details of the data-gathering methodology are presented in Appendix B.

Unfortunately, while this group covers all the major markets, it is not complete. When refined, crude oil also yields some naphtha and kerosene (jet fuel). Those products are not covered by the standard EU statistical reporting procedures and thus are not analysed in this dissertation.

This analysis covers price transmission for the all above-listed products. This ensures sufficient market coverage and allows us to compare the results across products of different uses (motor spirits and fuel oils) and different stages of development (LP is phased out, while ULP is steadily gaining popularity).[5] Given that the EU refineries have constant

[5] One has to remember that the same product can be used for different purposes, e.g. heating oil can be burnt in domestic furnaces (legal use) or used as a motor spirit (illegal use). Given that the details about the illegal (mis)usage of energy products are not available, the above split represents the most detailed classification available for cross-national analysis in the EU.

and high utilization rates (Arpa, Cuaresma, Gnan & Antoinette (2005) claim it reaches 85%), there is also no significant room for inter-product substitution. Lastly, since the EU market has common pollution laws, *balkanization* of the market does not occur.[6]

Tables A.12 - A.16 present the yearly consumption of the products analysed (in thousands metric tonnes).[7] The most significant trends include (i) almost complete elimination of LP; (ii) growth in significance of Diesel; (iii) steady decrease in significance of less processed fuels - RFOs and gasoil.

The data indicate a steady increase in consumption of petroleum products, despite their increasing prices. The most likely explanations for this include steady economic growth, widespread dependence of modern economies on carbohydrates, steady supply (discussed before) and low elasticity of individual demand. Graham & Glaister (2002) present a comprehensive overview of *ca.* 50 international estimates of leaded and unleaded petrol price elasticities. The average short-run elasticity is -.27 with a standard deviation of .18, while those for the long-run are on average -.71 with the standard deviation of .41. However, one should remember that this range includes studies that disregard problems of stationarity and spurious regression. When those issues are properly accounted for, the elasticity of the demand for petroleum products is significantly lower. Bentzen (1994) analyses the Danish market and finds the price elasticity equal to -.32 and -.41 respectively in the short and long run. Samimi (1995) repeats the exercise for Australia and finds elasticities equal to -.02 and -.12. For Kuwait, Eltony & Al-Mutairi (1995) find elasticities equal to -.37 and -.46, while Ramanathan (1999) finds the values for India to be equal to -.21 and -.32. Posner (2002) reports values of other studies, concluding that even the doubling of retail prices would only bring a 4% decline in demand for motor spirits. While comparable elasticity estimates for petroleum products other than ULP are not available, they should not be significantly different.

Last but not least, despite ongoing integration within the EU, the member states retain significant discretion over taxation of petroleum products and use it to strengthen their national budgets. As stated by Joumard (2002, p. 112):

> (...) fuel and vehicle taxes have usually been introduced for fiscal rather than environmental reasons. (*They*) represent a much higher share of GDP in the EU countries than in most other OECD countries (...)

The resulting differences in taxation of petroleum products combined with the freedom of

[6]Balkanization of the industry refers to a situation when different countries introduce their separate laws (mainly related to environment) which prohibits products from being traded internationally. Posner (2002) argues that this might have a significant impact on pricing policies in the USA.

[7]The monthly data used for the calculations do not include MT.

movement within the EU (due to the on-going implementation of the Schengen accord) can in principle lead to some cross-border purchases of cheaper (due to lower taxation) petroleum products. This introduces a new, horizontal dimension to the petroleum price transmission.

1.4 Research Aims and Outline of the Thesis

Given the importance of analysing price dynamics in petroleum markets discussed above, this research has several aims. Firstly, to review the evidence on asymmetric price transmission presented so far and assess the economic and econometric frameworks used to date. Secondly, to analyse the patterns of causality and endogeneity in petroleum markets and address the above-described issues regarding crude oil supply structure. Thirdly, to conduct a cross-country, -product and -tier analysis of non-linearities in price transmission that accounts for the specifics of the EU markets, in particular the presence of the ARA trading hub. Fourthly, to review the theoretical underpinnings of asymmetric price transmission and assess their applicability to the case at hand. We also attempt to analyse whether the geographic and economic diversity of the EU countries (in particular differences in taxation) can affect price transmission via cross-country linkages.

This chapter has outlined the overall framework of this thesis and justified the undertaking of the research. We started with a presentation of the research problem and discussed its significance. We proceeded with an overview of different kinds of non-linearities and presented a uniform classification to be used throughout this thesis. We also sketched the EU price chain, discussing its reliance on numerous imported crudes, importance of the ARA trading hub and constraints coming from insufficient data on national wholesale market and increasing vertical integration.

The outline of the rest of this dissertation is as follows. Chapter 2 explores the estimation techniques. We review the available econometric tools employed in the literature from the point of view of their reliability and usability. The idea is to discuss their deficiencies and identify a superior set of tools that could be applied in the price transmission analysis. Chapter 3 discusses existing research utilizing those techniques. We focus on areas for improvement outside the field of econometrics, which when properly addressed could bring the research closer to the economics of price transmission. The focus is on quality and reliability of the data and the functional depiction of the transmission. Chapters 2 and 3 both draw heavily from Wlazlowski (2003*a*) and Wlazlowski et al. (2006) and aim at identifying room for improvement to be addressed further on in the dissertation.

Chapter 4 applies the econometric tools identified as appropriate in chapter 2 to analyse price transmission and to address the drawbacks in the previous literature identified in chapter 3. We start with an in-depth analysis of the global crude oil markets and identify crudes that act as markers and lead the global energy markets. Those crudes reflect the true price information and are best suited to be used in the price transmission study. Following that, we analyse the relationship between the identified marker crudes and retail prices in order to account for previously neglected issues of endogeneity and long-run relationship between prices. This allows us to analyse price transmission without the inference from other factors and in line with the economic properties of the market. Chapter 4 is based on Wlazlowski (2003*a*), Wlazlowski et al. (2006) and Wlazlowski (2007).

Chapter 5 analyses the transmission from Brent oil to retail prices via mid-stream ARA markets utilizing the set of non-linear estimation tools identified in chapter 2. Based on those tools we improve on the previous studies by:

- accounting for the non-linear cointegration with the application of tests from Kapetanios, Shin & Snell (2006);
- testing for the presence of non-linearities in the equilibrium restoring process using tools developed by Teräsvirta (1994);
- establishing the character and welfare effect of the non-linearities, by applying the testing strategy developed by Escribano & Jordá (2001);
- estimating the properties of the non-linear process of equilibrium revision and simulating the market adjustment to upstream price shocks.

The analysis presented in chapter 5 improves past research which did not test for the presence of non-linearities and / or assumed only one particular kind of non-linear behaviour. Last but not least, previous literature did not analyse the actual dynamics of the adjustment, focusing on one part of the adjustment and neglecting the impact of the auto-regressive part of the models. Our study shows that this approach might lead to overestimation of the welfare transfer and, as such, can affect the results of the analysis. Chapter 5 is based on Wlazlowski, Binner, Giulietti & Milas (2007*a*).

Finally, chapter 6 ties up the loose ends of the analysis by addressing the issues of robustness of the analysis and the impact of cross-country dynamics on price transmission. We also review the explanations of APT phenomena presented in the literature and discuss their applicability. This chapter is based on Wlazlowski, Binner, Giulietti & Milas (2007*b*).

In chapter 7 we summarise the contribution of this research, present policy implications resulting from this work and evaluate the research process.

Chapter 2

Modelling Techniques

This chapter describes the modelling techniques which can be employed in the APT studies. It draws heavily from Wlazlowski (2003*a*), Wlazlowski et al. (2006) and Wlazlowski et al. (2007*a*) and attempts to guide the reader through the developments in the estimation techniques employed in the literature since the early 1990s and to present the STAR models which were not previously applied in this context. The aim is to facilitate the understanding of the literature review presented in chapter 3 and to discuss relative strengths, weaknesses and suitability of various modelling techniques.

2.1 Notation

The following notation is used throughout this and the following chapters:

- x_t denotes the upstream price (MSP or USP) at time t (might be in logs);
- y_t denotes the downstream price (MSP or DSP) at time t (might be in logs);
- ex_t denotes an exchange rate between upstream and downstream price currencies at time t (might be in logs);
- t denotes contemporaneous time period;
- T / n stand for the length of period analysed (sample size);
- α / δ_0 stands for the constant in LR equilibrium equations or ECMs;
- δ stands for the coefficient in the LR equilibrium equation;
- Δx_t denotes backward difference, so that $\Delta x_t = x_t - x_{t-1}$;

- $(\Delta x_t)^+ = \begin{cases} \Delta x_t \text{ if } \Delta x_t > 0 \\ 0 \text{ if } \Delta x_t < 0 \end{cases}$ and $(\Delta x_t)^- = \begin{cases} 0 \text{ if } \Delta x_t > 0 \\ \Delta x_t \text{ if } \Delta x_t < 0 \end{cases}$;
- $^+$ and $^-$ denote coefficients on variables split in a Wolfram's manner as described above;
- ϵ_t / ν_t denotes a disturbance in a linear stochastic equation that is:
  - serially uncorrelated with mean zero and variance σ^2, and
  - uncorrelated with all variables on the right-hand-side of the equation;
- disequilibrium in the LR equation is said to be positive when $y_{t-1} - \delta_0 - \delta_1 x_{t-1} > 0$, i.e. when current price is above its long-run equilibrium level, distributors' margins are enlarged and the adjustment requires lowering the downstream prices;
- EU denotes the member states of the European Union, including:
  - "old" EU-15 countries, i.e. Austria, Belgium, Denmark, Germany, Finland, France, Greece, Italy, Ireland, Luxembourg, the Netherlands, Portugal, Sweden, Spain and the UK;
  - "new" EU-10 countries, i.e. Cyprus, the Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Slovakia and Slovenia;
- "Euro-zone" denotes countries that have introduced the common EU currency, i.e. Austria, Belgium, Germany, Finland, France, Greece, Ireland, Italy, Luxembourg, the Netherlands, Spain and Portugal.

When discussing statistical significance, the standard 5% is assumed, unless stated otherwise.

2.2 Price Transmission Models

This section attempts to classify various models used in price transmission analysis. We start with models of LR equilibrium relationship between upstream and downstream prices and then proceed to models of asymmetries in the revision to that equilibrium.

Following Geweke (2004), Meyer & Cramon-Taubadel (2004) and others we omit the portion of literature that disregards the issues of spurious regression, as specified by Engle & Granger (1987). The early inquiries into APT which disregard the order of integration and presence of long-run relationship suffer from issues of spurious regression which makes them unreliable for the purposes of APT analysis. For example, Karrenbrock (1991) claims to find the signs of APT in the USA, but when his dataset is revisited by Shin (1992) with the help of techniques that support use of the error-correction mechanism, the results indicate no signs of APT - see Cramon-Taubadel (1998) and section 2.2.3 for further details.

Furthermore, we focus on the methodology applied to energy markets. While this could be seen as an unnecessary constraint, cross-industry studies and meta-analyses by Meyer & Cramon-Taubadel (2004) and Frey & Manera (2007) indicate that studies in all industries share the same models and approach to APT. In fact, thanks to its importance, energy product price transmission analysis is usually the first to apply any new (usually sophisticated) methods and leads the development of methodology. As such, the decision to focus this review on models applied to petroleum markets is justified.

All of the models discussed analyse non-linearities in a deterministic framework, i.e. assume the presence of distinct regimes into which actual observations fall *with certainty*. While this strict approach does not reflect the true unpredictability of the market and imperfections in market monitoring / data gathering procedures, it has its advantages. In particular, it allows the researchers to pinpoint periods of time in which a modelled regime was observed which leads to additional conclusions with respect to origins and / or consequences of APT.

The alternative approach based on the stochastic framework introduces the element of uncertainty into the regime change process, simply by replacing the deterministic regime-switch function with a Markov process which represents the probability of switching from regime j into i at time t conditional upon the last period's state:

$$P[S_t = i|S_{t-1} = j] = p_{ij} \tag{2.1}$$

Such a stochastic approach based on Hamilton (1989) finds little application in price transmission studies - so far only Radchenko (2005*b*) and Wlazlowski et al. (2006) used it in the petroleum product price transmission analysis. The former focuses on the Bayesian estimation, while the latter uses it as an auxiliary tool, necessary to confirm the results of the deterministic tools.

2.2.1 Types of Models - Long Run Models

Although relative demand and prices of petroleum products and crude oil vary over time, thanks to low demand elasticity, stable supply and agents' ability to adjust the production

/ distribution mix and (more importantly) to store the finished products, relative prices between those commodities remain fairly stable - Denni & Frewer (2006). The above, coupled with the fact that petroleum products are used worldwide in a plethora of roles, strongly suggests the existence of a LR relationship between commodities' prices. In this section we discuss how such a relationship can be modelled within the price transmission framework.

Testing for APT hinges upon the manner in which downstream prices revert to the LR equilibrium determined by prices upstream. Therefore, to test for the presence of APT, one must first define that equilibrium relationship. In the traditional TP analysis the equilibrium is assumed to be a steady-state one, described by Noel (2007*a*, p. 4) as a "simpleton". In such a long-run state, it is assumed that in the absence of upstream shocks today, the price would stay at last period's level. This is not necessarily the case, as it is possible that downstream prices would move *on their own* in absence of upstream changes. Such a situation might exist in the SR in a small market, when retailers are engaged in undercutting exercises, modelled by so-called Edgeworth cycles - see Maskin & Tirole (1988) and section 6.2.3 for further details. The simplified version remains the standard workhorse applied to aggregated data.

The literature differs with respect to one or more of the following assumptions regarding modelling of such a steady-state equilibrium:

- number of the transmission tiers analysed;
- cost factors present at each tier;
- time structure of the transmission;
- functional form of the relationship;
- geographic scope of the research;
- product scope of the research.

Below we analyse each of them in detail.

Number of Tiers

As the first step in analysing the price transmission, one must establish between which tiers the modelled transmission takes place, i.e. define from where in the supply chain the prices should be taken. Since there is no consensus in the literature on how to define the transmission tier, in principle every single stage in the process at which a new cost is added can be denoted as one. For practical purposes, however, it is possible to determine the main stages along the transmission chain, either based on technical / chemical transformation undergone by the product (extraction of the crude oil, refinement into the end product) or on the economic transformation (sale to the end users). This is the approach we take in this study. Given such a definition, the applied literature covers transmissions between:

- crude oil and wholesale markets (direct transmission between adjacent tiers);
- wholesale and retail markets (ditto);[1]
- crude oil and retail markets (indirect transmission).

Input Costs

By definition of the price chain, prices downstream are a sum of upstream costs and value-added costs present at the appropriate transmission level(s). Based on the above, one might define $y = f(x, z)$, where z stands for a vector of other variables (in principle costs other than USPs present at analysed tier(s)).

In the simplest case $z = 0$, but whenever transmission takes place between tiers on which prices are expressed in different currencies, one can enrich the LR model by allowing for $z = ex$. On the basis of the nature of the costs present at the tier(s) analysed, LR models can be therefore divided into:

- one-input models with $z = 0$;
- models with more than one cost source with $z \neq 0$.

So far the most significant attempt to adjust the LR model by introduction of additional variables (other than the necessary exchange rate) is by Kaufmann & Laskowski (2005) (see section 3.1 for further details), who tried to introduce refineries' utilisation rates and stock levels into the LR equation.

Time Structure

In the simplest case, DSPs depend on contemporaneous USPs, so that $y_t = f(x_t, z_t)$. Since the transmission might be inter-temporal (as frequency of the data might not be in

[1] A finer distinction could be made between international wholesale markets that usually do not involve physical deliveries - spot markets, and national wholesale market, at which the physical delivery takes place. However, such a split does not facilitate cross-study comparisons as definitions of market tiers differ between countries - see chapter 3 and what is a wholesale market for one country (e.g. NY for US, ARA for Benelux), might be a spot market for the other.

line with real transmission), in some cases it might be more appropriate to assume that $y_t = f(x_t, x_{t-1}, \cdots, x_{t-i}, \cdots, x_{t-n^x}, z_t, z_{t-1}, \cdots, z_{t-i}, \cdots, z_{t-n^z})$.

Based on the assumption of the time structure, LR models can be divided into:

- one-period models $n^x = n^z = 0$;
- multi-period models $n^x > 0$ and / or $n^z > 0$.

Again, the suitability of a particular LR representation depends on the real-life market dynamics and level of aggregation of available data.

Functional Form

Most of the researchers focus on two major functional forms characterising the relationship between USP and DSP, i.e.:

- linear function, under which $y_t = \delta_0 + \delta_1 x_t$, or
- Cobb-Douglas function, under which $y_t = \delta_0 x_t^{\delta_1}$.

The choice between those functions has serious implications for the LR equilibrium price - Manning (1991). In particular:

- Cobb-Douglas function assumes:
  - constant percentage margin / mark-up on costs;
  - constant elasticity of downstream prices with respect to prices upstream;
- linear form assumes:
  - constant monetary margin;
  - variable elasticity.

The choice also affects the efficiency of estimation itself - as specified by Borenstein, Cameron & Gilbert (1997), the Cobb-Douglas function can easily transform the quadratic trends in data into linear ones which are easier to deal with using the standard OLS estimation.

Geographic Scope

Crude oil and its derivatives are traded internationally and processed / used in virtually every country around the world. The geographic scope of the applied research is, however, significantly constrained. The most commonly analysed markets include UK and US. The less popular national markets include Canada, France, Germany, Italy and the Netherlands. For a more detailed discussion see section 3.2.2. Last but not least, all previous studies analyse the price transmission in a single country setting, with no cross-border effects - see section 6.1 for details.

Product Scope

Although the crude oil refinement yields several end products, APT studies focus on only some of them. The most commonly analysed petroleum products include 4 stroke engine fuel (ULP /LP) and Diesel. The petroleum products targeted to legal entities (RFOs and gasoil) are usually not analysed. Similarly, the APT studies do not analyse more than one product.

Summary and Conclusions

The models described above are used to analyse the long-run relationship between upstream and downstream prices. In the next part of this chapter we review models used in the literature to test whether the adjustment to that equilibrium is symmetric.

2.2.2 Partial Adjustment Models

Introduction

Historically, PAMs were the first to model the revision of downstream prices to their LR equilibrium, in line with the concept of cointegration. However, those models do not allow for testing for the existence of LR equilibrium. Therefore, their uses are limited and "genuine" PAM models were quickly replaced by their descendants - ECM models. This section briefly discusses their characteristics and features, focusing on their deficiencies and the way the next generation models overcame them.

A general model of this class assumes that equilibrium is restored according to the following model:

$$\Delta y_t = \gamma(y_{t-1} - y_t^*) + \epsilon_t \tag{2.2}$$

where y_t^* describes equilibrium price at t and γ expresses the convergence speed, at which this arbitrarily defined equilibrium is restored.[2] The main difference compared to the mode developed models (ECMs) is the lack of a consistent definition of y_t^*.

[2] In (2.2), γ has to be positive, otherwise the actual and equilibrium values would diverge.

APT Analysis

Bacon (1991) proposed using PAMs in APT studies by incorporating squared disequilibria into (2.2) which results in:

$$\Delta y_t = \gamma_1(y_{t-1} - y_t^*) + \gamma_2(y_{t-1} - y_t^*)^2 + \epsilon_t \tag{2.3}$$

Bacon (1991) defined $y^* = \frac{\delta_2 x_{t-s}}{\delta_3 e x_{t-v}}$ with lags (s and v) determined so as to obtain "preferred results" - Bacon (1991, p. 17). This arbitrary choice of key estimation elements illustrates the greatest drawback of PAM, i.e. discretion in determining the equilibrium price.

The PAM model in the version proposed by Bacon (1991) assumes that the long run equilibrium is achieved by eliminating a portion (γ_1) of the disequilibrium and this adjustment is regime-specific, in the sense that this adjustment might be increased (if $\gamma_2 > 0$) or decreased (if $\gamma_2 < 0$) by a square of the disequilibrium. This additional quadratic term is supposed to capture APT, with DSPs responding faster to USPs increases than to decreases if $\gamma_1 < 0 \wedge \gamma_2 > 0$, and the opposite for $\gamma_1 < 0 \wedge \gamma_2 < 0$. However, when defined this way, the extent of asymmetry increases together with the size of disequilibrium, which might not necessarily be true.

In the late 1980s, additional models were advocated, but failed to attract any attention. In particular, Bewley & Fiebig (1990) propose an estimation of the LR coefficient using a transformation of the autoregressive distributed lag system in the form of:

$$\Phi^A(L)y_t = \Phi^B(L)x_t + \epsilon_t \tag{2.4}$$

where $\Phi^A(L)$ and $\Phi^b(L)$ are lag polynomials of orders m and n, into:

$$y_t = \Phi^C(L)\Delta y_t + \delta_1 x_t + \Phi^D(L)\Delta x_t + \nu_t \tag{2.5}$$

where δ_1 is the LR value of the coefficient, obtained using the 2SLS under the assumption that:

- the ith element of the $\Phi^C(L)$ polynomial equals $-\frac{\sum_{j=i+1}^{m}\Phi^A(j)}{\Phi^A(1)}$; and
- the ith element of the $\Phi^D(L)$ polynomial equals $-\frac{\sum_{j=i+1}^{n}\Phi^B(j)}{\Phi^B(1)}$.

In principle, as advocated in Bewley & Fiebig (1990), the above-described transformation should provide a convenient framework for estimating SR and LR elasticities, together with their standard errors. However, given the additional computational burden (estimation should be done by 2SLS or minimum expected loss estimation) and a number of unanswered questions about the model (i.e. existence of extreme estimates in the empirical work and small sample properties - see Bewley & Fiebig (1990, p. 349)), this approach failed to gather support.

Assessment

While suggestive and simple, PAMs suffer from several significant drawbacks which caused them to be quickly discarded once the ECM framework was fully developed. The most important drawback is that PAM does not offer a framework to test for the presence of spurious regression between I(1) variables. Given the widespread presence of first-order integrated series, this basically invalidates inference based on PAM results. Another drawback of general PAMs is that, given the theoretical vacuum, researchers have to arbitrarily define y_t^*, which prohibits testing for the presence of APT. Furthermore, while accounting for the LR adjustment, PAMs disregard SR adjustments. Those problems were addressed in the next generation of models, i.e. ECMs.

2.2.3 Error Correction Models

Introduction

As pointed out by Engle & Granger (1987), OLS estimation using stationary time series can lead to spurious results, unless there is a linear combination of those series that is I(0). If that is the case, the series in question are related to each other and revert to an equilibrium after shocks. This equilibrium reversion takes place in a framework described by Engle & Granger (1987) as error correction model - ECM.

Two common specifications of ECMs are based on:

- two-stage, sequential estimation of:

  1. the "long run" relationship between USPs and DSPs, i.e.:

  $$y_t = \delta_0 + \delta_t x_t + \epsilon_t \tag{2.6}$$

  from which the estimates of disequilibrium (ϵ_t) are taken and used to estimate

  2. equilibrium-reversion speed, i.e. γ in the error-correction equation:

  $$\Delta\epsilon_t = \gamma\epsilon_{t-1} + \nu_t \tag{2.7}$$

- simultaneous estimation of the "long run" relationship between USPs and DSPs, i.e. $y_t = \delta_0 + \delta_t x_t + \epsilon_t$ and the equilibrium-reversion speed, i.e. γ, as prescribed by Stock & Watson (1993):

$$\Delta y_t = \gamma(y_{t-1} - \delta_0 - \delta_1 x_{t-1}) + \nu_t \tag{2.8}$$

The differences between two specifications are related mainly to the small-sample properties. As argued by Banerjee, Dolado, Galbraith & Hendry (1993), simultaneous estimation of LR and SR parameters results in lower rate of convergence of LR elasticity of DSPs with respect to USPs. This is due to the fact that this parameter is estimated as a product of two variables with $\sqrt[2]{T}$ convergence rate. This reduces the overall convergence of LR pass-through to only T.

ECM specified according to Stock & Watson (1993) can be easily converted to ARDL specification, so that the models could account for possible production and distribution lags - see section 2.2.1. For example, the following ARDL model:

$$y_t = \gamma + \sum_{i=1}^{r} \alpha_i y_{t-i} + \sum_{j=0}^{n} \beta_j x_{t-j} + \nu_t \tag{2.9}$$

can be easily converted to the following ECM model:

$$\begin{aligned} \Delta y_t &= \gamma + (-1 + \textstyle\sum_{k=1}^{r} \alpha_k) y_{t-1} + (\sum_{i=0}^{n} \beta_i) x_{t-1} \\ &- \textstyle\sum_{j=1}^{n-1} (\sum_{i=j+1}^{n} \beta_i) \Delta x_{t-j} + \beta_0 \Delta x_t - \sum_{k=1}^{r-1} (\sum_{l=k+1}^{r} \alpha_l) \Delta y_{t-k} + \nu_t \end{aligned} \tag{2.10}$$

Equations (2.7) and (2.8) can further be enriched by allowing for short-run dynamics in:

- downstream prices:

$$\Delta y_t = \sum_{j=0}^{m} \beta_j \Delta x_{t-j} + \gamma(y_{t-1} - \delta_0 - \delta_1 x_{t-1}) + \nu_t \tag{2.11}$$

- downstream *and* upstream prices:

$$\Delta y_t = \sum_{l=1}^{n} \alpha_l \Delta y_{t-l} + \sum_{j=0}^{m} \beta_j \Delta x_{t-j} + \gamma(y_{t-1} - \delta_0 - \delta_1 x_{t-1}) + \nu_t \tag{2.12}$$

APT Analysis

Asymmetry might be introduced into ECMs in a number of ways, but the most common method includes splitting left-hand-side variables in the manner first proposed by Wolfram (1971). When applied to (2.11), such an approach can result in models accounting for:

- SR asymmetry:[3]

$$\begin{aligned}\Delta y_t = &\sum_{j=0}^{m^+} \beta_j^+ (\Delta x_{t-j})^+ + \sum_{i=0}^{m^-} \beta_i^- (\Delta x_{t-i})^- \\ &+\gamma(y_{t-1} - \delta_0 - \delta_1 x_{t-1}) + \nu_t\end{aligned} \tag{2.13}$$

- LR asymmetry (as proposed by Granger & Lee (1989)):

$$\begin{aligned}\Delta y_t = &\sum_{j=0}^{m} \beta_j \Delta x_{t-j} + \gamma^+(y_{t-1} - \delta_0 - \delta_1 x_{t-1})^+ \\ &+\gamma^-(y_{t-1} - \delta_0 - \delta_1 x_{t-1})^- + \nu_t\end{aligned} \tag{2.14}$$

- LR and SR asymmetry:

$$\begin{aligned}\Delta y_t = &\sum_{j=0}^{m^+} \beta_j^+ (\Delta x_{t-j})^+ + \sum_{i=0}^{m^-} \beta_i^- (\Delta x_{t-i})^- \\ &+\gamma^+(y_{t-1} - \delta_0 - \delta_1 x_{t-1})^+ + \gamma^-(y_{t-1} - \delta_0 - \delta_1 x_{t-1})^- \\ &+\nu_t\end{aligned} \tag{2.15}$$

Equation (2.15) represents the most general specification of the ECM class of models used to search for LR and SR asymmetries. When combined with (2.12) it becomes:

$$\begin{aligned}\Delta y_t = &\sum_{l=1}^{n} \alpha_l \Delta y_{t-l} + \sum_{j=0}^{m^+} \beta_j^+ (\Delta x_{t-j})^+ + \sum_{i=0}^{m^-} \beta_i^- (\Delta x_{t-i})^- \\ &+\gamma^+(y_{t-1} - \delta_0 - \delta_1 x_{t-1})^+ + \gamma^-(y_{t-1} - \delta_0 - \delta_1 x_{t-1})^- + \\ &+\nu_t\end{aligned} \tag{2.16}$$

which in turn might be modified to allow for asymmetry by splitting the lagged downstream price changes:

$$\begin{aligned}\Delta y_t = &\sum_{l=1}^{n^+} \alpha_l^+ (\Delta y_{t-l})^+ + \sum_{k=1}^{n^-} \alpha_k^- (\Delta y_{t-k})^- \\ &+\sum_{j=0}^{m^+} \beta_j^+ (\Delta x_{t-j})^+ + \sum_{i=0}^{m^-} \beta_i^- (\Delta x_{t-i})^- \\ &+\gamma^+(y_{t-1} - \delta_0 - \delta_1 x_{t-1})^+ + \gamma^-(y_{t-1} - \delta_0 - \delta_1 x_{t-1})^- \\ &+\nu_t\end{aligned} \tag{2.17}$$

As proposed by Borenstein et al. (1997), equation (2.17) can be used to calculate the *measures* of the degrees of APT. This measure allows the researcher to analyse the cumulative impact of APT after $i = 1, 2, \ldots, n$ periods following a unit increase in the USPs (denoted $S_i^{+/-}$) according to the following model:

[3] One has to remember that with introduction of asymmetries to ECM, the interchangeability of ARDL and ECM models does *not* follow (2.10). Instead, if one wants to add Wolfram-type variables to (2.9) the resulting model would be (2.15), rather than (2.13).

$$
\begin{aligned}
S_0^+ =& \ \beta_0^+ \\
S_1^+ =& \ S_0^+ + \beta_1^+ + \gamma^+(S_0^+ - \delta_1) + \alpha_1^+ max(S_0^+, 0) + \alpha_1^- min(S_0^+, 0) \\
S_2^+ =& \ S_1^+ + \beta_2^+ + \gamma^+(S_1^+ - \delta_1) + [\alpha_1^+ max((S_1^+ - S_0^+), 0) \\
& + \alpha_1^- min((S_1^+ - S_0^+), 0) + \alpha_2^+ max(S_0^+, 0) + \alpha_2^- min(S_0^+, 0)] \\
S_3^+ =& \ S_2^+ + \beta_3^+ + \gamma^+(S_2^+ - \delta_1) + [\alpha_1^+ max((S_1^+ - S_0^+), 0) \\
& + \alpha_1^- min((S_1^+ - S_0^+), 0) + \alpha_2^+ max((S_2^+ - S_1^+), 0) \\
& + \alpha_2^- min((S_2^+ - S_1^+), 0) + \alpha_3^- min(S_0^+, 0) + \alpha_3^+ max(S_0^+, 0)] \\
\vdots \\
S_n^+ =& \ S_{n-1}^+ + \beta_{n-1}^+ + \gamma^+(S_{n-1}^+ - \delta_1) \\
& + \textstyle\sum_{l=1}^{n^+} \alpha_i^+ max((S_{n-i}^+ - S_{n-i-1}^+), 0) \\
& + \alpha_i^- min((S_{n-i}^+ - S_{n-i-1}^+), 0)
\end{aligned} \tag{2.18}
$$

Accordingly, the cumulative APT following an unit decrease in the USPs, would be:

$$
\begin{aligned}
S_0^- =& \ \beta_0^- \\
S_1^- =& \ S_0^- + \beta_1^- + \gamma^-(S_0^- - \delta_1) + \alpha_1^+ max(S_0^-, 0) + \alpha_1^- min(S_0^-, 0) \\
S_2^- =& \ S_1^- + \beta_2^- + \gamma^-(S_1^- - \delta_1) + [\alpha_1^+ max((S_1^- - S_0^-), 0) \\
& + \alpha_1^- min((S_1^- - S_0^-), 0) + \alpha_2^+ max(S_0^-, 0) + \alpha_2^- min(S_0^-, 0)] \\
S_3^- =& \ S_2^- + \beta_3^- + \gamma^-(S_2^- - \delta_1) + [\alpha_1^+ max((S_1^- - S_0^-), 0) \\
& + \alpha_1^- min((S_1^- - S_0^-), 0) + \alpha_2^+ max((S_2^- - S_1^-), 0) \\
& + \alpha_2^- min((S_2^- - S_1^-), 0) + \alpha_3^- min(S_0^-, 0) + \alpha_3^+ max(S_0^-, 0)] \\
\vdots \\
S_n^- =& \ S_{n-1}^- + \beta_{n-1}^- + \gamma^-(S_{n-1}^- - \delta_1) \\
& + \textstyle\sum_{l=1}^{n^-} \alpha_i^+ max((S_{n-i}^- - S_{n-i-1}^-), 0) \\
& + \alpha_i^- min((S_{n-i}^- - S_{n-i-1}^-), 0)
\end{aligned} \tag{2.19}
$$

Unfortunately, both proxies are computationally burdensome and as such not widely employed in the literature.

Two different ways of introducing the APT in the ECT adjustment are proposed by Granger & Lee (1989) and Driffield, Ioannidis & Peel (2003) and involve:

- splitting ECT according to the direction of upstream price change:

$$
\begin{cases} {}^+\epsilon_t = & I(\Delta x_t > 0)\epsilon_t \\ {}^-\epsilon_t = & I(\Delta x_t \leq 0)\epsilon_t \end{cases} \tag{2.20}
$$

- or using its modulus:

$$\begin{aligned}\Delta y_t = & \sum_{j=0}^{m^+}\beta^+_{(1,j)}(\Delta x_{t-j})^+ + \sum_{i=0}^{m^-}\beta^-_{(1,j)}(\Delta x_{t-i})^- \\ & +\gamma(y_{t-1} - \delta_{(1,0)} - \delta_{(1,1)}x_{t-1}) + \gamma^{(m)}|(y_{t-1} - \delta_{(1,0)} - \delta_{(1,1)}x_{t-1})| \\ & +\nu^y_t\end{aligned} \qquad (2.21)$$

One has to remember that just as in the case of normal ECMs, also the asymmetric versions can be used for inference *only* if they account for the presence of LR equilibrium. If the lagged residuals from the level equation or lagged level variables in the form proposed by Stock & Watson (1993) are not present, the estimates of APT are biased and not reliable.

Assessment

Testing for the SR asymmetry in the ECM framework can be based on:

- individual tests of significance of difference between SR responses ($H_0 : \beta^+_i = \beta^-_i$) for a given i;
- the method proposed by Bettendorf, der Geest & Varkevisser (2003), i.e. testing the null of equality of all SR coefficients ($H_0 : \forall_{i=1,\dots,max(m^+,m^-)}\beta^+_i = \beta^-_i$);[4]
- if $m^+ \neq m^-$, using the method proposed by Ye, Zyren, Shore & Burdette (2005) ($H_0 : \forall_{i=1,\dots,min(m^+,m^-)}\beta^+_i = \beta^-_i$).

The above-listed methods allow for straightforward testing for the presence of SR APT, but their properties are far from desirable. According to Ye et al. (2005), the method proposed by Bettendorf et al. (2003) is excessively conservative, as the assumption that the coefficients on missing lags are equal to zero biases the test to under-rejecting the null of SPT. Several studies have shown that those testing strategies have low power in the asymmetric ECM framework (Cook (1999) and Cook, Holly & Turner (1999)) and both Galeotti et al. (2003) and Grasso & Manera (2007) advocate bootstrapping the standard tests to overcome that problem.

Furthermore, as described above, apart from the fact that one cannot easily and with confidence test for the presence of APT, estimating its extent is also difficult and requires simulation of convoluted models given by (2.18) and (2.19).

Similarly, one should remember that although only two regimes exist for each variable, the overall number of regimes, i.e. combinations of coefficients, is a function of past val-

[4]One has to assume that for different lags the lacking coefficients are equal to zero.

ues of USPs and DSPs which directly depends on the lag structure chosen. For example, the maximum number of regimes in (2.17) equals $2^{max(m^+,m^-)+max(n^+,n^-)}$. This prohibits tracking down the extent of APT over time and identifying the impact of economic developments on APT.[5]

The last reservation towards ECM models was voiced by Chen, Finney & Lai (2005, p. 236) and is concerned with the way those models misinterpret market behaviour. Consider two alternative situations: (i) at t costs upstream increase by 5 units and then decrease 0.1 unit at $t+1$ and (ii) at t costs increase by 4 units and then increase once more by 0.9 unit at $t+1$. The end result is exactly the same in both cases, but the ECM models (2.13) - (2.17) treat them in a different way (the first case would trigger a regime switch, the second would not).

2.2.4 SETAR Models

Introduction

The easiest way to avoid problems with unmanageable number of regimes and their inconsistent classification is to create a system in which at one point in time *all* variables belong to the same regime and where changes depend on the value of a significant market indicator. Such systems stem from simple autoregressive models. Below we discuss their main features.

Consider a simple AR(p) model, as defined by Box & Jenkins (1970) for a time series ϵ_t:[6]

$$\epsilon_t = \gamma_0 + \gamma_1\epsilon_{t-1} + \gamma_2\epsilon_{t-2} + \ldots + \gamma_p\epsilon_{t-p} + \nu_t \tag{2.22}$$

where:

- γ_i for $i = (1, 2, \ldots, p)$ are the AR coefficients assumed to be constant over time;
- $\epsilon_t \overset{iid}{\sim} WN(0, \sigma^2)$ stands for white-noise error term with constant variance,

or written in a vector form:

$$\epsilon_t = \Sigma_t\gamma + \sigma\nu_t \tag{2.23}$$

where:

- $\Sigma_t = (1, \epsilon_{t-1}, \epsilon_{t-2}, \ldots, \epsilon_{t-p})$ is a column vector of variables;

[5]A possible solution to this problem would involve recursive / rolling estimation of β^+ and γ^+. This approach is used in Reilly & Witt (1998) and Wlazlowski (2003*a*).

[6]In this section we present SETAR models for disequilibrium ϵ_t. Alternatively, one can model one ECM per regime.

- γ is the vector of parameters $\gamma_0, \gamma_1, \gamma_2, \ldots, \gamma_p$.

Since those models assume constant values of all parameters, they cannot deal with a number of real-life phenomena commonly observed in the benchmark series (the famous examples include sunspots, lynx and blowfly datasets). Such features include non-normality, asymmetric cycles, bi-modality, non-linear relationship between lagged variables and variation of prediction performance over state-space.

A simple way of overcoming those problems would be to introduce a mechanism that allows for changes in the model parameters. In the next generation of AR models, such phenomena are modelled as regime switches triggered by the weakly exogenous variable w_t surpassing a given threshold - hence the name *Threshold* AR models - TAR. In such a setting, equation (2.23) becomes:

$$\epsilon_t = \Sigma_t \gamma^{(j)} + \sigma^{(j)} \nu_t \text{ if } r_{j-1} < w_t < r_j \tag{2.24}$$

where:

- $\gamma^{(j)}$ is the vector of parameters $\gamma_0^{(j)}, \gamma_1^{(j)}, \gamma_2^{(j)}, \ldots, \gamma_{p^{(j)}}^{(j)}$ governing the process in j^{th} regime (assuming that the AR process is of the order $p^{(j)}$ in that regime);
- $-\infty = r_0 < r_1 < \ldots < r_k = +\infty$ are $k-1$ non-trivial thresholds dividing the domain of w_t into k different regimes;
- $j = 1, 2, \ldots, k$.

In each of the k regimes, the model collapses to a simple AR(p) process governed by a different set of p variables $\gamma^{(j)}$.[7] Generally, for TAR(k) models, there are $k + kp$ unknown parameters $\Theta = (\gamma^{(1)}, \gamma^{(2)}, \ldots, \gamma^{(k)}, \sigma^{(1)}, \sigma^{(2)}, \ldots, \sigma^{(k)})$.

When $w_t = \epsilon_{t-d}$, with d (called delay parameter) set to be a positive integer, the dynamics of ϵ_t are determined by its own past values. After such a self-governing mechanisms those models are dubbed *Self-Exciting* TAR or *SE*TAR.

APT Analysis

Depending on the model analysed, SETAR(k) class models can be used to test for a plethora of non-linearities in price transmission, including those causing:

- level shifts - if only γ_0 is assumed to differ between regimes;

[7] For the sake of the simplicity, it was assumed that the time series follow AR(p) in every regime. Of course, p might differ for each of k regimes.

- slope shifts - if other γ parameters are assumed to differ between regimes;
- additive outliers or innovation - if σ is assumed to differ between regimes,

or any combination of the above.

In order to develop threshold-type models, it is necessary to test for the presence of non-linearity in the series in question. The null is usually that the series follows AR(1)/SETAR(1), while the alternative assumes SETAR(j), with $j > 1$. This poses a nuisance parameter problem as certain parameters to be estimated are only identified under the alternative hypothesis (see Davies (1987) for a comprehensive overview of the traditional large-sample theory). Two distinct ways used to overcome this problem in the literature are:

- arranged autoregression and Tsay's F Test;
- Hansen's sup-LR Test.

Below we discuss both methods in detail.

Tsay's Approach

Tsay's approach centers on the use of an arranged autoregression with RLS estimation. In an arranged regression, the equations in (2.24) for $t = max(d,p)+1,\dots,n$ are sorted according to the threshold variable ϵ_{t-d}, which might take any value in $Y_d = \epsilon_h,\dots,\epsilon_{n-d}$, where $h = max(1, p-d+1)$. Those sorted equations are as follows:

$$\epsilon_{\pi_i} = \mathbf{X}_{\pi_i}\hat{\gamma} + \hat{\sigma}\nu_{\pi_i} \tag{2.25}$$

where:

- $i = 1,2,\dots,(n-d-h+1)$;
- π_i value of the index in the original sample such that ϵ_{π_i-d} is the i-th smallest value in $\mathbf{Y}_d$.[8]

In such a setting, for a SETAR(2) model, if there are $m < n$ values in $\mathbf{Y}_d$ smaller than a threshold r_1, then the first m equations in (2.25) correspond to the first regime, while remaining equations correspond to the second regime. Similar reasoning applies to the structures of higher order. Thus, a simple reordering reduces testing for non-linearities to testing for structural change of autoregressive parameters in the arranged regression.

[8]For example, if ϵ_{33} is the smallest value in $\mathbf{Y}_d$, then π_1=33+d, if ϵ_{56} is the second smallest value in $\mathbf{Y}_d$, then π_2=56+d, etc.

To test for the existence of the threshold regime, Tsay suggest computing RLS estimates of $\hat{\gamma}$ in (2.25). If no threshold non-linearity exists, the standardised predictive residuals $\hat{\sigma}\epsilon_{\pi_i}$ from (2.25) should be white noise and orthogonal to $\mathbf{X}_{\pi_i}$. However, if ϵ_t is a SETAR(j) process with $j > 1$, the RLS estimates of $\hat{\gamma}$ are biased and $\hat{\Psi}$ in the following auxiliary regression should be statistically significant:

$$\hat{\epsilon}_{\pi_i} = \Sigma'_{\pi_l}\Psi + \nu_{\pi_i} \tag{2.26}$$

To test for threshold non-linearity in the model above, a conventional $\chi_{n'-k'}$ (where n' is the number of available observations and k' is the number of regressors in $\mathbf{X}'_{\pi_l}$) could be used. Chan, Wong & Tong (2004) propose that the number of the start-up observations should be set as $(n/10) + p$.

After rejecting the null of no threshold non-linearity, the next stage is to estimate the unknown parameters of SETAR(j). Tsay suggest identifying the delay parameter (d) and the thresholds (r_j) first and then LS estimation of Θ with given thresholds and delays. Given enough observations in each regime, LS estimates are consistent.

For a given p, Tsay suggest choosing d such that:

$$d = \arg\max_{v \in s} F(p, v) \tag{2.27}$$

where:

- $F(p, v)$ is the F statistic of the auxiliary regression (2.26);
- p is the order of AR;
- v is the delay parameter;
- s is a set of values of d to consider.

Tsay (1989) also suggests use of one of the two ocular econometric tools for identifying the threshold values:

- a scatter plot of standardised predictive residuals ($\hat{\epsilon}_{\pi_i}$) versus the ordered threshold variable, and
- a scatter plot of the t-statistics of the residual LS estimates of $\hat{\gamma}$ versus the ordered threshold variable.

Both plots might reveal structural breaks in the re-ordered series occurring at the values equal to the threshold values in the original series.

Hansen's Approach

Although Tsay's procedure is simple and intuitive, it requires a number of arbitrary assumptions about the nature of the process, especially the threshold values. An alternative approach, advocated in Hansen (1997) and Hansen (1999) requires joint estimation of threshold, delay parameters and autoregressive values, together with the AR coefficients.

In Hansen's approach the vector of AR parameters Θ together with thresholds $-\infty = r_0 < r_1 < \ldots < r_k = +\infty$ a can be estimated by LS as:

$$\arg\min_{w_t,d} \hat{\sigma}^2(r_1) = \arg\min_{w_t,d} \frac{1}{n'} \sum_{t=h}^{n} \hat{\epsilon}_t^2 \tag{2.28}$$

by searching over:

- all possible delay parameters $d \in]1, \bar{d}[$; and
- all acceptable (i.e. non-trivial) threshold values w_t for each of the delay parameters;[9]

so as to minimise the RSS from the fitted model. Once the model minimising RSS is found, for a given values of w_t and d one can estimate $\Theta = (\gamma^{(1)}, \gamma^{(2)}, \sigma^{(1)}, \sigma^{(2)})$ by traditional LS. Such a procedure leads to super-consistent estimates of the threshold *and* AR coefficients in each regime - Chan (1993, p. 520) but is time-consuming and involves $\bar{d}\hat{n}$ computations, where $\bar{d}$ is the maximum delay parameter d and $\hat{n}$ is the number of possible thresholds for every delay parameter. To reduce the computational burden, instead of the full sample, w_t can include:

- trimmed sample - Abdulai (2002) recommends removing top and bottom 15% from the calculations; or
- quantiles of the sample, as advised by Harris & Silverstone (2000).

Those computational tricks work reasonably well for $k = 2, 3$. For models with a number of regimes greater than 3, Hansen (1999) suggests using a computational short-cut proposed by Bai (1997) and Bai & Perron (1998) instead of a full grid search over all possible thresholds (which would involve $\bar{d}\hat{n}^{(k-1)}$ estimations). The reasoning is that if the true underlying model of the series is in fact SETAR(3), but the mis-specified SETAR(2) model was estimated by LS:

- the delay parameter d from the SETAR(2) will be a consistent for the true delay parameter from the SETAR(3) model, and

[9] Hansen (1999) also stresses that every regime should contain a minimal number of observations, for example 10%.

- the threshold estimate r_1 will be consistent for one of two thresholds from the real SETAR(3) model - (r_1, r_2).

Given the above, one can estimate a SETAR(3) model by simply running a SETAR(2) model, obtaining d and r_1, then estimating the remaining parameter r_2 (enforcing d and r_1 to be equal to the values obtained in SETAR(2) model) and then using r_2 to get consistent estimate of r_1. This trick allows researchers to reduce the number of computations necessary to estimate SETAR(3) from $\hat{n}^2 * \bar{d}$ to approximately $\bar{d}\hat{n} + 2\hat{n}$. The same reasoning applies to higher-regime models.

Tests for SETAR type non-linearities

Although estimating SETAR models using Hansen's method is fairly straightforward, the testing of whether a non-linear class of models should be employed in the first place is far more complicated. To test for SETAR(i) against SETAR(j), where $i = 1, 2$ and $j = 2, 3$, the following test can be used:

$$F_{ij} = n * \frac{RSS_i - RSS_j}{RSS_j} \tag{2.29}$$

where:

- RSS_i is the RSS from SETAR(i);
- RSS_j is the RSS from SETAR(j) given the estimated $k-1$ thresholds r_i;
- n is the sample size.

One has to remember that $F_{ij}(\gamma, d)$ is effectively an increasing function of the term $RSS_i - RSS_j$ over the plane spanned by (γ, d). Because this pair is chosen by (2.28), effectively:

$$F_{ij} = \arg\min_{w_t, d} F_{ij}(\gamma, d) \tag{2.30}$$

In such a setting, every $F_{ij}(\gamma, d)$ can be thought of in a more traditional sense, i.e. as a conventional χ^2 test for the exclusion of regressors specific for SETAR(j) model (i.e. gk extra parameters compared to SETAR(i)=SETAR(j-g) model) with gk d.o.f.

Since the final test value is the maximum of a number of χ^2 variables, the distribution of F_{ij} statistic is different than that of χ^2 with gk dof (i.e. shifted to the right). In other words, when the F_{ij} test statistic is not significant compared to the traditional $\chi^2(kg)$ distribution it is certainly not significant when compared to the true distribution. However, when F_{ij} values are significant compared to $\chi^2(kg)$ applying the same logic is not possible. In such a case, inference must be based on the asymptotic distribution of F_{ij} or on bootstrap as asymptotic distributions are not readily available.

Hall (1992), Shao & Tu (1995) and Davison & Hinkley (1997) show that in finite samples it leads to a better approximation than first-order asymptotic theory. Also the convergence rate might be faster (although this needs to be verified for the SETAR class of models) and is allowed for near unit root or unit root processes Hansen's approximation works only for stationary processes). However, some bootstrap techniques impose harsh conditions (such as independence of ϵ_t on $\Im_{t-1}$). For the details on bootstrap procedure applicable for SETAR class - see Hansen (1999, p. 566).

Grasso & Manera (2007) suggest to bootstrap by drawing from a random uniform]0; 1[sample, multiply the regressors by it and repeat the estimation of the parameter vector (Θ together with thresholds $-\infty = r_0 < r_1 < \ldots < r_k = +\infty$) and the test statistic F_{ij} an appropriately high number of times. It remains to be seen if this approach is picked up in the literature.

In traditional SETAR models the indicator is established based on the lagged *levels* of the analysed variable. Enders & Granger (1998) suggest an alternative approach in which the indicator triggers the regime switch when the *changes* of the variable exceed the threshold. In such a setting the indicator function becomes:

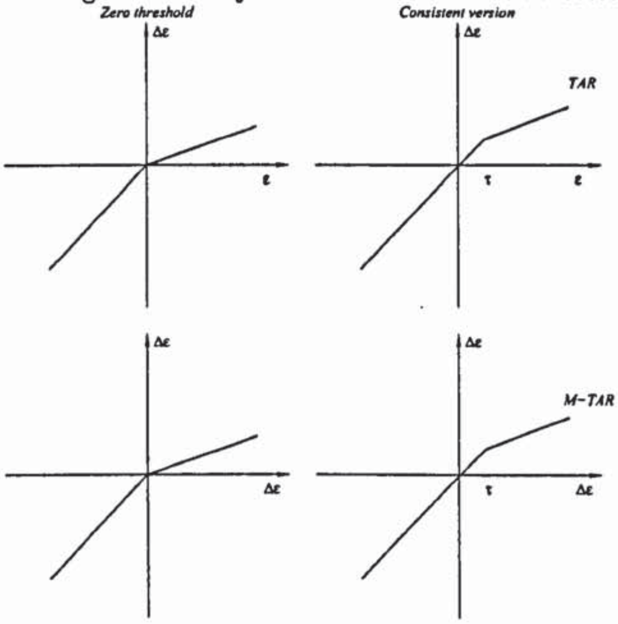
$$I(\hat{\epsilon}_{t-1}) = \begin{cases} 1 \Leftrightarrow \Delta\hat{\epsilon}_{t-1} > \tau \\ 0 \Leftrightarrow \Delta\hat{\epsilon}_{t-1} < \tau \end{cases} \tag{2.31}$$

This class of models is called Momentum Threshold Autoregressive (M-TAR) Models.[10]

The difference between TARs and M-TARs in both consistent and normal versions is illustrated diagrammatically in Figure 2.1. Despite the apparent similarity, both models differ with respect to some key characteristics. In particular, the TAR model is designed for the potential asymmetric "deep" movements with the LR residuals, while the M-TAR model is useful to take into account sharp or "steep" variations in residuals. As demonstrated by Sichel (1993), negative "deepness" (i.e. $|\pi^1| < |\pi^2|$) of $\hat{\epsilon}_t$ implies negative skewness relative to the mean or trend - similarly to the "rockets and feathers" phenomena. The deviation of observations below this mean or trend exceeds in such case the average deviation of observations above. Of course, positive deepness suggests the opposite. "Steepness" of the time series implies that its first differences exhibit negative skewness. In such a case the sharp decreases in the series are larger but less frequent than

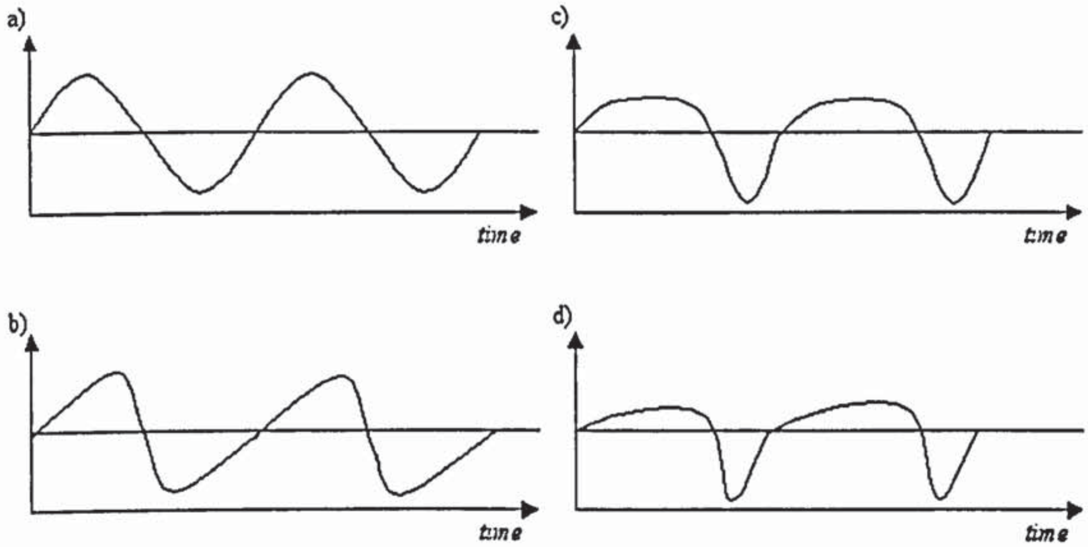
[10]These should not be confused with Multivariate TAR models (also denoted M-TAR) proposed by Chen et al. (2005) and not discussed here.

Figure 2.1: Adjustment in TARs and M-TARs



more moderate increases. The distinction between those cases is presented in Figure 2.2.

Figure 2.2: Deepness and Steepness in Time Series



Cases presented are: a) symmetric; b) steep; c) deep; d) steep and deep.

Given the lack of clear guidelines for application of TAR and M-TAR models in APT testing, it is up to the researcher which model to use (although TAR models fit the traditional understanding of rockets and feathers phenomena better than M-TAR models). The usual technique, employed by Grasso & Manera (2007) is to compare the AIC of both models and pick the one better suited to the data.

APT Analysis

Since SETAR models are based on traditional AR framework, their application to APT testing boils down to fitting each of the regimes to one particular pricing mechanism and testing for the presence of threshold-type non-linearity in the adjustment towards LR equilibrium.

For simplicity, below we analyse (SE)TAR(2,1) without a constant:

$$\Delta\hat{\epsilon}_t = \begin{cases} \pi^1\hat{\epsilon}_{t-1} + \sigma^{(1)}\hat{\nu}_t \text{ when } \hat{\epsilon}_{t-d} \geq r_1 \\ \pi^2\hat{\epsilon}_{t-1} + \sigma^{(2)}\hat{\nu}_t \text{ when } \hat{\epsilon}_{t-d} < r_1 \end{cases} \quad (2.32)$$

where $\pi^j = \gamma^j - 1$. In such a setting, with the null of no cointegration ($H_0 : \pi^1 = \pi^2 = 0$), the conditions for stationarity (H_1) can include either:

- those with full regime-wide stationarity, proposed e.g. by Cramon-Taubadel & Meyer (2001, p. 6):

$$H_1 : \pi^1 < 0 \wedge \pi^2 < 0 \wedge (1 + \pi^1)(1 + \pi^2) \quad (2.33)$$

  which can be tested using:

  - modified t tests (called $t - max$ for $\tau = 0$ and $t - max^*$ for $\tau \neq 0$), based on the maximum (in *modulus*) t statistic of estimate of γ_1 and γ_2 and critical values tabulated by Enders & Granger (1998);
  - non-conventional F-test (called ϕ for $r_1 = 0$ and ϕ^* for $r_1 \neq 0$) of the null, with critical values tabulated by Enders & Siklos (2001);

- those proposed by Caner & Hansen (2001), assuming partial stationarity:

$$H_1 : \begin{cases} \pi^1 < 0 \text{ and } \pi^2 = 0 \\ \pi^1 = 0 \text{ and } \pi^2 < 0 \end{cases} \quad (2.34)$$

  which require test statistic $R_{2T} = t_1^2 I(\hat{\epsilon}_{t-d} \geq r_1) + t_2^2 I(\hat{\epsilon}_{t-d} < r_1)$ or its one-sided alternative $R_{1T} = t_1^2 I(\hat{\pi}^1 < 0) + t_2^2 I(\hat{\pi}^2 < 0)$, bootstrapped for better results.

Gouveia & Rodrigues (2004) report that the power of all of the above tests increases with the size of asymmetry and average adjustment speed. For testing for the presence of non-linear adjustment, the conventional unit root tests are also used (see Balke & Fomby (1997)), despite the fact that they were designed for linear processes.

After ascertaining the presence of equilibrium reverting mechanism - either linear or asymmetric, the testing for the presence of threshold behaviour utilizing Tsay's or Hansen's approach is allowed.

Since M-TAR models form a subclass of general SETAR class of models:

- they can be extended in a similar fashion as (SE)TAR models, e.g. by introducing the lagged explanatory variables;
- utilising Chan's approach to finding the estimate of the τ is allowed;
- testing for cointegration can also involve:
  - F tests for null of $\gamma_1 = \gamma_2 = 0$, described as $\phi^*(M)$ and $\phi(M)$ (for τ equal zero);
  - t-max tests for null (this time denoted $t-max(M)$ for $\tau = 0$ and $t-max^*(M)$ for $\tau \neq 0$).

Before applying M-TAR models to price data, one has to remember that under the *momentum* approach, a correction to the margin between prices at different levels of the transmission chain does not depend on the size of this margin at a given point in time but rather on the magnitude and direction of its change in the previous period.

Godby, Lintner, Stengos & Wandschneider (2000) propose a combination of the traditional ECM model, such as (2.11) and SETAR(2) model, designed to capture non-linearities both in LR and SR adjustments, via modelling one ECM per regime. Such a combination results in:

$$\Delta y_t = \begin{cases} \sum_{l=1}^{n^{(1)}} \alpha_l^{(1)} \Delta y_{t-l} + \sum_{j=0}^{m^{(1)}} \beta_j^{(1)} \Delta x_{t-j} + \\ \gamma^{(1)}(y_{t-1} - \delta_0 - \delta_1 x_{t-1}) + \nu_t \text{ when } w_{t-d} < r \\ \sum_{l=1}^{n^{(2)}} \alpha_l^{(2)} \Delta y_{t-l} + \sum_{j=0}^{m^{(2)}} \beta_j^{(2)} \Delta x_{t-j} + \\ \gamma^{(2)}(y_{t-1} - \delta_0 - \delta_1 x_{t-1}) + \nu_t \text{ when } w_{t-d} \geq r \end{cases} \tag{2.35}$$

where:

- $k = 1, 2$ stands for regime;
- w_{t-d} is the threshold variable (e.g. which could be any exogenous variable in first differences or the ECT either in the version by Stock & Watson (1993) or Engle & Granger (1987));
- r is the threshold;

- $n^{(k)}$ and $m^{(k)}$ denote maximum lags of upstream and downstream prices in regime k;

- $\gamma^{(k)}$ denote speed of adjustment to the LR equilibrium in regime k;

- $\alpha^{(k)}$ and $\beta^{(k)}$ denote SR adjustment in regime k.

As specified by Lewis (2004), (2.35) could be further enhanced by allowing APT within each regimes, which results in:

$$\Delta y_t = \begin{cases} \sum_{l=1}^{n^{(1,+)}} \alpha_l^{(1,+)} \Delta y_{t-l}^{+} + \sum_{j=0}^{m^{(1,+)}} \beta_j^{(1,+)} \Delta x_{t-j}^{+} \\ + \sum_{l=1}^{n^{(1,-)}} \alpha_l^{(1,-)} \Delta y_{t-l}^{-} + \sum_{j=0}^{m^{(1,-)}} \beta_j^{(1,-)} \Delta x_{t-j}^{-} \\ + \gamma^{(1)} (y_{t-1} - \delta_0 - \delta_1 x_{t-1}) + \nu_t \text{ when } w_{t-d} < r \\ \sum_{l=1}^{n^{(2,+)}} \alpha_l^{(2,+)} \Delta y_{t-l}^{+} + \sum_{j=0}^{m^{(2,+)}} \beta_j^{(2,+)} \Delta x_{t-j}^{+} \\ + \sum_{l=1}^{n^{(2,-)}} \alpha_l^{(2,-)} \Delta y_{t-l}^{-} + \sum_{j=0}^{m^{(2,-)}} \beta_j^{(2,-)} \Delta x_{t-j}^{-} \\ + \gamma^{(2)} (y_{t-1} - \delta_0 - \delta_1 x_{t-1}) + \nu_t \text{ when } w_{t-d} \geq r \end{cases} \tag{2.36}$$

This class of models can be estimated using the approach proposed by Enders & Granger (1998) and Dibooglu & Enders (2001).

Assessment

SETAR models were developed to counter the most significant drawbacks of the traditional AR/ECM framework visible in the sample datasets. Accordingly, they are well-suited to model some of the most common non-linearity phenomena and correctly identify underlying market regimes (see example presented on page 50). However, their ability to estimate the market behaviour is limited for two main reasons. Firstly, they assume that market behaviour changes drastically as the threshold variable exceeds the predetermined level. Such an abrupt change might be applicable to natural sciences (gas physics and chemistry), but is less likely to occur in the pricing behaviour. Secondly, testing for the presence of non-linearities is computationally burdensome and not significantly developed due to convoluted asymptotics. Furthermore, as proven by Enders, Falk & Siklos (2007), construction of confidence intervals is problematic.

2.2.5 New Models - Smooth Transition Models

Similar to SETAR models, Smooth Transition AR (STAR) models can be thought of in terms of an extension to a standard AR model, allowing for changes in the model parameter. In contrast to SETAR models, however, STAR models assume that such a change is gradual (hence the name) - van Dijk, Teräsvirta & Franses (2002). A simple model of this family can be depicted as the following modification of (2.23):

$$y_t = \mathbf{X_t}\gamma^{(0)}(1 - G(w_t, \zeta, c)) + \mathbf{X_t}\gamma^{(1)}G(w_t, \zeta, c) + \sigma^{(j)}\epsilon_t \tag{2.37}$$

or equivalently:

$$\hat{\epsilon}_t = \mathbf{X_t}\gamma^{(0)} + \mathbf{X_t}(\gamma^{(1)} - \gamma^{(0)})G(\hat{\epsilon}_{t-d}, \zeta, c) + \sigma^{(j)}\epsilon_t \tag{2.38}$$

where:

- $G(w_t, \zeta, c)$ is the continuous transition function, bounded between 0 and 1 (described in more detail below);
- w_t is the transition variable, which can be:
  - a delayed endogenous variable analogous to SETAR models, i.e. $w_t = y_{t-d}$, with d (called the delay parameter) set to be a positive integer such that $d \in]1, \bar{d}[$;
  - an exogenous variable;
  - possibly a non-linear function of lagged endogenous variables involving the parameter vector (ϖ), i.e. $w_t = h(\tilde{x}_t; \varpi)$.

Given the above specification, STAR models could be interpreted either as:

- a regime-switching model, with two regimes (associated with extreme values of transition function), where the transmission between regimes is smooth; or
- a continuum of regimes, each of them associated with different values of transmission function.

Transition Functions

Regardless of the interpretation used, the exact properties of the model are determined by the transition function. Most commonly applied functions include:

- first-order logistic function:

$$G(w_t, \zeta, c) = \frac{1}{1 + e^{-\zeta(w_t - c)}} \tag{2.39}$$

  which results in logistic STAR (LSTAR) model, or

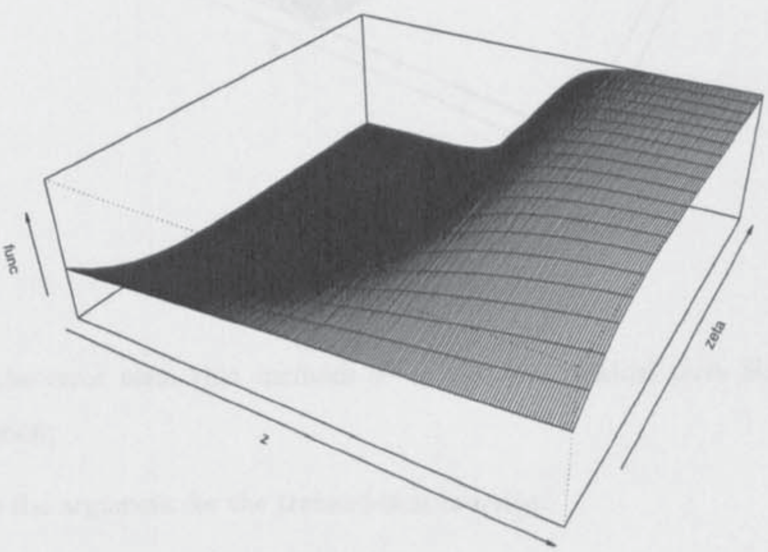
- second-order exponential function:

$$G(w_t, \zeta, c) = 1 - e^{-\zeta(w_t - c)^2} \tag{2.40}$$

which results in exponential STAR (ESTAR) model.

Figures 2.3-2.4 present the values of functions depending on their parameters and inputs. For simplicity they were centered around $c = 0$.

Figure 2.3: LSTAR Transition Function



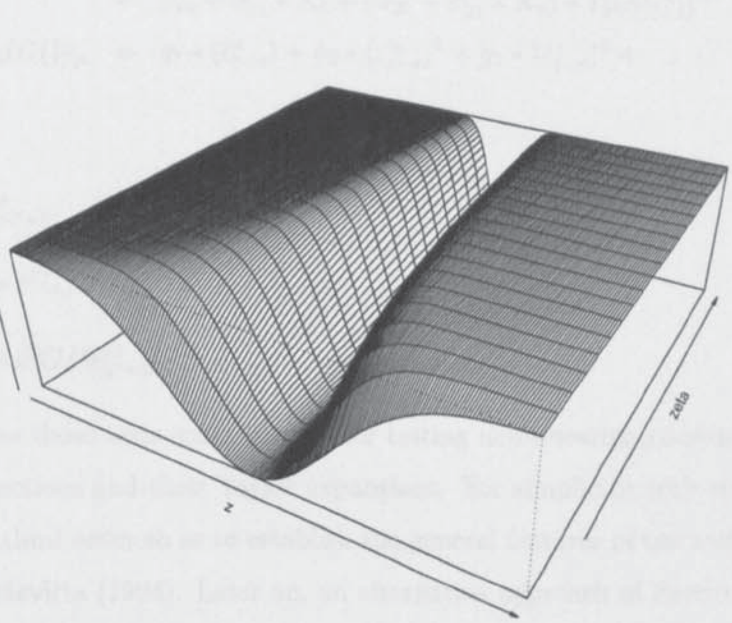
Testing for non-linearity in STAR models

The STAR model rewritten as (2.38) can be tested against the linear alternative by approximating the transition function $G(\hat{\epsilon}_{t-d}, \zeta, c)$ with the help of Taylor expansion around $\zeta = 0$. This leads to an auxiliary regression of the form:

$$\hat{\epsilon}_t = \mathbf{X_t}\beta^0 + \mathbf{X_t}[\hat{\epsilon}_{t-d}\beta^1 + \hat{\epsilon}_{t-d}^2\beta^2 + \hat{\epsilon}_{t-d}^3\beta^3 + \ldots] + \nu_t \tag{2.41}$$

where:

Figure 2.4: ESTAR Transition Function



- ν_t is the error term that includes $\sigma^{(j)}\nu_t$ and the residual term from the Taylor expansion;
- $\hat{\epsilon}_{t-d}$ is the argument for the transmission function.

One has to remember that since the transition variable $\hat{\epsilon}_{t-d}$ is set in the self-exciting way, the first element in the β^1 coefficient vector has to be set equal to zero, as perfect multicollinearity might occur otherwise. Furthermore, in such a setting $\mathbf{X}_t * \hat{\epsilon}_{t-d} = (\hat{\epsilon}_{t-1}, \hat{\epsilon}_{t-2}, \ldots, \hat{\epsilon}_{t-p}) * \hat{\epsilon}_{t-d}$ and we have $(\hat{\epsilon}_{t-1} * \hat{\epsilon}_{t-d}, \hat{\epsilon}_{t-2} * \hat{\epsilon}_{t-d}, \ldots, \hat{\epsilon}^2_{t-d}, \ldots, \hat{\epsilon}_{t-p} * \hat{\epsilon}_{t-d})$. As such there is some interdependency between parameters when higher-than-one Taylor approximation is used. To account for that a dummy e_d, i.e. a vector of length p, consisting of zero, except for the d-th element which is set to unity, is used.

To understand the testing strategy, consider a Taylor approximation of the ESTAR or LSTAR transition function:

$$\begin{aligned} T_n(f(x)) &= \textstyle\sum_{n=0}^{\infty} \frac{f^{(n)}(a)}{n!}(x-a)^n \\ T_n(G())_{|a} &= G(a) + G'(a)(x-a) + \frac{G''(a)}{2}(x-a)^2 + \frac{G^{(3)}(a)}{3!}(x-a)^3 + \ldots \end{aligned} \tag{2.42}$$

Now substituting the transition function one can obtain:

$$\begin{aligned} \hat{\epsilon}_t &= \pi_{10} + \pi'_{11} * \mathbf{X}_t + (\pi_{20} + \pi'_{21} * \mathbf{X}_t) * T_3(\gamma(\hat{\epsilon}^*_t)) \\ T_3(G())_{|a} &= g_1 * (\hat{\epsilon}^*_{t-d}) + g_2 * (\hat{\epsilon}^*_{t-d})^2 + g_2 * (\hat{\epsilon}^*_{t-d})^3 + \dots \end{aligned} \tag{2.43}$$

Where:

- $g_1 = \delta G / \delta \hat{\epsilon}^*_{|\hat{\epsilon}^*=0}$;
- $g_2 = (1/4) * \delta^2 G / \delta \hat{\epsilon}^{*2}_{|\hat{\epsilon}^*=0}$;
- $g_3 = (1/6) * \delta^3 G / \delta \hat{\epsilon}^{*3}_{|\hat{\epsilon}^*=0}$;

To analyse how those tests could be used for testing non-linearity, consider two different transition functions and their Taylor expansions. For simplicity, let's start with the expansion of the third order so as to establish the general features of the testing strategy attributed to Teräsvirta (1994). Later on, an alternative approach of Escribano & Jordá (2001) is discussed.

LSTAR In this model the transition function is:[11]

$$G(x, \zeta, c) = \frac{1}{1 + e^{-\zeta(x-c)}} - \frac{1}{2} = \frac{1}{1+E} - \frac{1}{2} \tag{2.44}$$

Where $E = e^{-\zeta(x^*)}$, $E' = e^{-\zeta(x^*)} * -\zeta = -\zeta * E$, $E'' = \zeta^2 * E$. After taking the derivatives and expanding the transition function around c, we obtain:

1. $E(0) = e^{-\zeta * 0} = 1$
2. $G(0) = 1/2 - 1/2 = 0$
3. $g_1 = G'(0) = \zeta/4$
4. $4 * g_2 = G''(0) = -\zeta^2 * [-2/8 + 1/4] = 0$
5. $6 * g_3 = G'''(0) = -\zeta^3/4 * [3 + 6/4 - 1] = -1/8 * \zeta^3$

The end result is the following auxiliary regression (for simplicity the numerical con-

[11] For the sake of simplicity, the function was scaled by 1/2, as this significantly simplifies the calculations for the Taylor expansion (see below).

stants from Taylor approximation were grouped and denoted s).

$$
\begin{aligned}
\epsilon_t &= \zeta_0 + \zeta_1' * \mathbf{X_t} + \zeta_2' * (\mathbf{X_t} * \hat{\epsilon}_{t-d}) + \zeta_3' * (\mathbf{X_t} * \hat{\epsilon}_{t-d}^2) + \zeta_4' * (\mathbf{X_t} * \hat{\epsilon}_{t-d}^3) + \nu_t \\
\zeta_0 &= \pi_{10} - \pi_{20} * \zeta/4 * c - \pi_{20} * -1/8 * \zeta^3 * c^3 \\
\zeta_1 &= \pi_{11}' - \pi_{21}' * \zeta/4 * c - \pi_{21}' * -1/8 * \zeta^3 * c^3 \\
&\quad e_d * [\pi_{20} * \zeta/4 + \pi_{20} * -1/8 * \zeta^3 * 3 * c^2] \\
\zeta_2 &= \pi_{21}' * \zeta * s + 3 * c^2 * \pi_{21}' * \zeta^3 * s \\
&\quad + e_d * [3 * c * \pi_{20} * \zeta^3 * s] \\
\zeta_3 &= -3 * c * \pi_{21}' * \zeta^3 * s \\
&\quad + e_d * [\pi_{20} * \zeta^3 * s] \\
\zeta_4 &= \pi_{21}' * \zeta^3 * s
\end{aligned}
\tag{2.45}
$$

The extra terms that appear in [...] denote 'extra' slope coefficients that occur due to the fact that in multiplication $\mathbf{X_t} * \hat{\epsilon}_{t-d} = (\hat{\epsilon}_{t-1}, \hat{\epsilon}_{t-2}, \ldots, \hat{\epsilon}_{t-p}) * \hat{\epsilon}_{t-d}$ in effect we have $(\hat{\epsilon}_{t-1} * \hat{\epsilon}_{t-d}, \hat{\epsilon}_{t-2} * \hat{\epsilon}_{t-d}, \ldots, \hat{\epsilon}_{t-d}^2, \ldots, \hat{\epsilon}_{t-p} * \hat{\epsilon}_{t-d})$. To account for that we introduced the dummy e_d, described previously.

ESTAR The transition function is:

$$G(x, \zeta, c) = 1 - e^{-\zeta(x-c)^2} \tag{2.46}$$

Taking the derivatives and expanding the transition function we have:

1. $G(0) = 0$
2. $g_1 = G'(0) = 0$
3. $4 * g_2 = G''(0) = 2 * \zeta$
4. $6 * g_3 = G'''(0) = 0$

Substituting Taylor-expansion into the model and re-arranging, we obtain:

$$
\begin{aligned}
\hat{\epsilon}_t &= \zeta_0 + \zeta_1' * \mathbf{X_t} + \zeta_2' * (\mathbf{X_t} * \hat{\epsilon}_{t-d}) + \zeta_3' * (\mathbf{X_t} * \hat{\epsilon}_{t-d}^2) + \nu_t \\
\zeta_0 &= \pi_{10} + \pi_{20} * \zeta * c^2 \\
\zeta_1 &= \pi_{11}' + \pi_{21}' * \zeta * c^2 + e_d * [-4 * \pi_{20} * \zeta * c] \\
\zeta_2 &= 2 * \pi_{21}' * \zeta * c \\
&\quad + e_d * [\pi_{20} * \zeta] \\
\zeta_3 &= \pi_{21}' * \zeta
\end{aligned}
\tag{2.47}
$$

Distinguishing between LSTAR and ESTAR Comparison of coefficients in the above expansions can be used to distinguish between LSTAR and ESTAR. Table 2.1 presents the comparison of the values of coefficients in three different settings. The settings correspond to the standard setting (i.e. with constant and non-zero threshold in the transition function) and settings more geared towards residual analysis (i.e. with constant and/or threshold set to zero).

The most striking difference is that in every setting the coefficient ζ_4 is equal to zero for the ESTAR model and different from zero in the LSTAR model. Therefore a simple test for the presence of non-linearity (as proposed by Teräsvirta (1994)) would involve estimation of a model given by (2.45) and then testing for the null of $\zeta_2 = \zeta_3 = \zeta_4 = 0$. If the null is rejected it implies non-linearities of either ESTAR or LSTAR type. If the null is not rejected, a simple AR(p) model could be used. Once the existence of non-linearities is confirmed, a simple test of ζ_4 could be used to test for whether the ESTAR family (with threshold and constant) fits the data.

To summarize the testing strategy:

1. $H_0 : \zeta_4 = \zeta_3 = \zeta_2 = 0$ - if rejected proceed, if not use AR;
2. $H_1 : \zeta_4 = 0$ - if rejected ESTAR model with constant and threshold cannot be used (this is since the cubic powers of $\hat{\epsilon}_{t-d}$ are zero when $c = 0$);
3. $H_2 : \zeta_3 = 0 | \zeta_4 = 0$ - since the squares of $\hat{\epsilon}_{t-d}$ are zero if $\pi_{20} = c = 0$ if rejected LSTAR model with no constant and no threshold or ESTAR with just a threshold cannot be used and proceed; rejection is not very informative;
4. $H_3 : \zeta_2 = 0 | \zeta_4 = \zeta_3 = 0$ - if not rejected the ESTAR model can be used, if rejected LSTAR with constant and threshold can be used *or* ESTAR with no threshold and no constant.

Table 2.1: Comparison of Expanded LSTAR and ESTAR Models

	$c \neq 0 \vee \pi_{20} \neq 0$		$c = 0 \vee \pi_{20} = 0$		$c = 0 \wedge \pi_{20} = 0$	
	LSTAR	ESTAR	LSTAR	ESTAR	LSTAR	ESTAR
ζ_4	$\neq 0$	0	$\neq 0$	0	$\neq 0$	0
ζ_3	$\neq 0$	$\neq 0$	0	$\neq 0$	$\neq 0$	$\neq 0$
ζ_2	$\neq 0$	$\neq 0$	$\neq 0$	0	$\neq 0$	$\neq 0$
ζ_1	$\neq 0$	$\neq 0$	0	0	$\neq 0$	$\neq 0$
ζ_0	$\neq 0$	$\neq 0$	0	0	$\neq 0$	$\neq 0$

Note: Teräsvirta (1994, p. 211) claims that failure to reject H_2 is a sign of LSTAR in the traditional non-zero threshold with constant case.

Since under the null the Taylor expansion equals zero, the traditional testing strategy can be applied and testing for normality boils down to traditional LM test of $H_0 : \beta^1 = 0 \wedge \beta^0 \neq 0$, which has the standard χ^2 distribution with $p-1$ dof. The statistic is usually denoted LM_1.

Although the method proposed by Teräsvirta (1994) is simple and intuitive, it has its drawbacks. For example, when expanding the exponential transition function to the third-order one might not capture the dynamics of the underlying data as the third-order expansion has only one local extremum, while the fourth-order extension has three. Simple changing of the expansion order is not sufficient since the elements of Taylor expansions contain lower powers of $\hat{\epsilon}$ - for example see the discussion about elements in square parentheses in (2.45) and (2.47). Therefore, as advocated by Escribano & Jordá (2001), the revised testing procedure involves estimation of:

$$\begin{aligned} \hat{\epsilon}_t &= \zeta_0 + \zeta_1' * \mathbf{X}_t + \zeta_2' * (\mathbf{X}_t * \hat{\epsilon}_{t-d}) + \zeta_3' * (\mathbf{X}_t * \hat{\epsilon}^2_{t-d}) + \zeta_4' * (\mathbf{X}_t * \hat{\epsilon}^3_{t-d}) \\ &\quad + \zeta_5' * (\mathbf{X}_t * \hat{\epsilon}^4_{t-d}) + \nu_t \end{aligned} \tag{2.48}$$

and the following testing strategy:

1. test $H_0 : \zeta_5 = \zeta_4 = \zeta_3 = \zeta_2 = 0$ - if rejected proceed, if not conclude that no non-linearities are present in the reversion of non-linearities towards their LR equilibrium;
2. test $H_{0L} : \zeta_5 = \zeta_3 = 0$ with the help of an F-test denoted F_L;
3. test $H_{0E} : \zeta_4 = \zeta_2 = 0$ with the help of an F-test denoted F_E;
4. if the minimum p-value corresponds to F_E select LSTAR, otherwise select ESTAR.

This methodology is also effective when $c \neq 0$ because the linear and cubic trends are then reduced to zero while the underlying model is ESTAR and quadratic and fourth-order terms are reduced only when the underlying model is LSTAR. In such a setting the test for no constant in the model involves the following steps:

1. test $H_0 : \zeta_5 = \zeta_4 = \zeta_3 = \zeta_2 = 0$ - if rejected proceed, if not use AR;
2. test $H_{0L} : \zeta_5 = \zeta_3 = 0$ with the help of an F-test denoted F_L;
3. test $H_{0E} : \zeta_4 = \zeta_2 = 0$ with the help of an F-test denoted F_E;
4. rejection of H_{0E} and failure to reject H_{0L} suggests LSTAR with $c = 0$ (LSTAR*);
5. rejection of H_{0L} and failure to reject H_{0E} suggests ESTAR with $c = 0$ (ESTAR*).

Once the shape of the transition function is determined, the γ, ζ and c parameters can be estimated using the non-linear least squares so as to minimize the squared sum of residuals $\sigma^{(j)}\epsilon_t$. The estimates can be obtained using any conventional optimization procedure - see Hamilton (1994) for a survey of available tools. The γ and c parameters can be further scaled by the standard deviation and percentiles of the threshold variable $\hat{\epsilon}_{t-d}$ to facilitate the optimization procedure - van Dijk et al. (2002, p.21). This allows for cross-model comparisons without the significant loss in accuracy, as even big changes in smoothing parameter have "only a minor effect on the transition function". Generally, the optimization procedure is non-trivial, in particular for the smoothing parameters, the estimates of which are inherently imprecise - see Bates & Watts (1988) for a general discussion and van Dijk et al. (2002) for a discussion of numerical issues related to non-linear estimation. Eitrheim & Teräsvirta (1996) point out that problems with optimization might result from the fact that the available tools might fail to identify the extremes if residuals ϵ_{t-d} may not always be exactly orthogonal to the gradient matrix, especially in the two-regime models. Unfortunately, this issue is not sufficiently addressed in the literature, especially with respect to the bounded (constrained) optimization tools, which should be used for parameters scaled with percentiles - see discussion of numerical aspects of estimation in Appendix C.

2.2.6 Combination of STAR and ECM models

As described in section 2.2.4, combining non-linear models and ECM framework offers a convenient way to test for non-linear cointegration. However, as opposed to the approach advocated by Enders & Siklos (2001), thanks to using the Taylor expansion (described in section 2.2.5) the STAR framework covers straightforward cointegration tests against non-linear alternatives. This is a clear advantage over previous studies which allowed for non-linearities only after the linear cointegration was ascertained using the traditional linear cointegration techniques. In principle this allows for analysing systems that revert to equilibrium in a manner that is so non-linear that traditional tools fail to recognize it.

A!9 set of such tools was first proposed by Kapetanios et al. (2006) for analysing the systems in which the correction to equilibrium is slower when the cointegrating residual is close to zero and increases gradually with the deviation from the equilibrium. The resulting Kapetanois, Shin and Snell (KSS) testing strategy involves the null of no cointegration against an alternative of a globally stationary smooth cointegration with the use of tests similar in design to those of Engle & Granger (1987). To analyse this framework consider $z_t = (y_t, x_t')'$ and rewrite (2.12) with equal lag lengths for RHS and LHS variables

$(n = m = p)$ as:

$$\Delta\hat{\epsilon}_t = \omega\Delta x_t + \sum_{l=1}^{p}\psi_l\Delta z_{t-l} + \pi z_{t-1} + \nu_t \tag{2.49}$$

where:

- ω is β_1;
- ψ is $(\alpha', \beta'_{-1})'$;
- π is $-\gamma * (\delta_0, \delta 1, \ldots,)$;

or equivalently using EG specification, rather than that of Stock & Watson (1993):

$$\Delta y_t = \omega\Delta x_t + \sum_{l=1}^{p}\psi_l\Delta z_{t-l} + \delta_0\hat{\epsilon}_{t-1} + \nu_t \tag{2.50}$$

where $\hat{\epsilon}_{t-1}$ are the residuals from the OLS level estimation.

In such a setting, Kapetanios et al. (2006) suggested introducing the transition function (2.40) with $c = 0$, so that the standard ECM becomes:

$$\Delta y_t = \omega\Delta x_t + \sum_{l=1}^{p}\psi_l\Delta z_{t-l} + \delta_0\hat{\epsilon}_{t-1} + \gamma\hat{\epsilon}_{t-1}G(w_t,\zeta) + \nu_t \tag{2.51}$$

where:

- $G(w_t,\zeta) = 1 - e^{-\zeta(w_t)^2}$;
- $\zeta = \hat{\epsilon}_{t-d}$.

Given that the bulk of the economic theory does not predict any particular form of the threshold variable or the non-linearity, Kapetanios et al. (2006) conclude that $d = 1$ in (2.51) results in a parsimonious and reasonably flexible framework.

Such testing can be easily performed using Taylor expansion for the transition function around $a = 0$, i.e.:

$$\sum_{n=0}^{\infty}\frac{f^{(n)}(a)}{n!}(x-a)^n \tag{2.52}$$

$$G(0) + G'(0)(\hat{\epsilon}_{t-1} - 0) + \frac{G''(0)}{2}(\hat{\epsilon}_{t-1} - 0)^2 + \frac{G^{(3)}(0)}{3!}(\hat{\epsilon}_{t-1} - 0)^3 + \frac{G^{(4)}(0)}{4!}(\hat{\epsilon}_{t-1} - 0)^4 \tag{2.53}$$

Using such expansion (since by the chain rule $\frac{d(1-e^{f(x)})}{dx} = -f'(x)e^{f(x)}$ and $e^0 = 1$) one can obtain:

$$G(0)[1 + G'(0)(\hat{\epsilon}_{t-1} - 0) + \frac{G''(0)}{2}(\hat{\epsilon}_{t-1} - 0)^2 + \frac{G^{(3)}(0)}{3!}(\hat{\epsilon}_{t-1} - 0)^3 + \frac{G^{(4)}(0)}{4!}(\hat{\epsilon}_{t-1} - 0)^4] \tag{2.54}$$

Based on those explanations, the following tests are possible:

- t-test type statistic on the lagged cubed residuals $\hat{\epsilon}_{t-1}^3$ in the following regression:

$$\Delta y_t = \omega \Delta x_t + \sum_{l=1}^{p} \psi_l \Delta z_{t-l} + \gamma \hat{\epsilon}_{t-1}^3 + \nu_t \qquad (2.55)$$

  in this setting, the test of the null hypothesis of no cointegration ($H_0 : \gamma = 0$) against the alternative of ESTAR-type cointegration ($H_1 : \gamma < 0$) is denoted $t - neg$;

- t-test type statistic analogue to the one described above but similar to the standard EG methodology:

$$\Delta \hat{\epsilon}_t = \gamma \hat{\epsilon}_{t-1}^3 + \sum_{l=1}^{p} \psi_l \Delta \hat{\epsilon}_{t-1} + \nu_t \qquad (2.56)$$

  with the same null and alternative hypotheses as $t - nec$, this test is denoted $t - neg$;

- assuming a non-instant adjustment in the outer regime:

$$\Delta y_t = \omega \Delta x_t + \sum_{l=1}^{p} \psi_l \Delta z_{t-l} + \gamma_1 \hat{\epsilon}_{t-1} + \gamma_2 \hat{\epsilon}_{t-1}^3 + \nu_t \qquad (2.57)$$

  in this setting, the test of the null hypothesis of no cointegration ($H_0 : \gamma_1 = \gamma_2 = 0$) against the alternative ($H_1 : \gamma_1 \neq 0 \vee \gamma_2 \neq 0$) is denoted F_{NEG};

- assuming a non-zero threshold c in the transition function (2.40) F_{NEC} becomes F_{NEC}^* in the following equation:

$$\Delta y_t = \omega \Delta x_t + \sum_{l=1}^{p} \psi_l \Delta z_{t-l} + \gamma_1 \hat{\epsilon}_{t-1} + \gamma_2 \hat{\epsilon}_{t-1}^2 + \gamma_3 \hat{\epsilon}_{t-1}^3 + \nu_t \qquad (2.58)$$

  and the null hypothesis becomes $H_0 : \gamma_1 = \gamma_2 = \gamma_3 = 0$.

If one wants to analyse the logistic alternative to (2.40), it is enough to replace $\hat{\epsilon}_{t-1}^3$ with $\hat{\epsilon}_{t-1}^2$ in (2.57), (2.55) or (2.56). It is important to remember, however, that the application of LSTAR type non-linearities in the case of cointegration is less obvious than in the ESTAR case and the critical values change - Kapetanios et al. (2006, p. 10).

Although STAR models offer a significant improvement over previously used tools, they are not without flaws. Firstly, the non-linear cointegration tests are likely to pick up outliers as signs of non-linear cointegration - see van Dijk, Franses & Lucas (1999) and Koop & Potter (2001). Possible solutions to that problem involve Bayesian estimation of space-state models in a manner proposed by Giordani, Kohn & van Dijk (2007), robust estimation or testing for cointegration in models with additive dummies accounting for said outliers and verifying if inference on non-linearities changes. The last solution is the most intuitive (and simpler to compute) but requires arbitrary assumptions about a number and position of outliers to be eliminated. Robust estimation discussed in van Dijk et al. (2002, p. 17) involves less assumptions, but it involves a significant decrease of the power of the tests in situations when only few outliers are present. Secondly, diagnostics of STAR models involve are computationally burdensome and non-trivial. This is particularly dangerous as mis-specified models might lead to incorrect inference about the presence and extent of non-linearities. The most significant issues in that regard involve neglected non-linearity, parameter constancy, autocorrelation and heteroscedasticity. van Dijk et al. (2002) discusses the impact those issues can have on the reliability of the analysis. Wlazlowski, Binner, Giulietti & Milas (2007*c*) analyses price transmission using daily data and notices that heteroscedasticity-adjusted non-linearity tests yield results similar to the standard tests.

2.2.7 Multivariate Framework

Above described models are by design single-equation, and do not take into account the interdependencies among USPs, DSPs and (possibly) other exogenous variables. Three classes of models that account for those possibilities and allow for APT testing are:

- VAR models,
- VEC models;
- VRS models.

Below we discuss their applicability to APT analysis.

VAR and VECM Models

VAR models of order q can be presented as:

$$\mathbf{Y_t} = \Phi_1 \mathbf{Y_{t-1}} + \Phi_2 \mathbf{Y_{t-2}} + \ldots + \Phi_q \mathbf{Y_{t-q}} + \epsilon_t \tag{2.59}$$

where $\mathbf{Y_t}$ is x×1 vector of variables of interest, ϵ_t is x×1 vector of error terms and $\Phi_1, \ldots, \Phi_q$ are n×n coefficient matrices. In such a setting, each element of $\mathbf{Y}$ is a symmetric function of its own variables and (possibly) other elements incorporated in $\mathbf{Y}$.

A simple modification of the above, necessary to incorporate APT into it, involves splitting the vector according to Wolfram, so that it results in:

$$\mathbf{Y_t} = \Phi_1^+\mathbf{Y}_{t-1}^+ + \Phi_1^-\mathbf{Y}_{t-1}^- + \ldots + \Phi_q^+\mathbf{Y}_{t-q}^+ + \Phi_q^-\mathbf{Y}_{t-q}^- + \epsilon_t \tag{2.60}$$

As discussed above, VAR models can capture similar types of asymmetries as their univariate counterparts, however, they also allow for relaxation of two significant assumptions:

- exogeneity of all variables - all prices are treated as endogenous;
- closed nature of the system - models might include some other non-price variables which affect PT indirectly.

Radchenko & Tsurumi (2006) try to model DSPs and USPs together with petrol consumption per vehicle (here G), petroleum inventories (here I) and production (here Q). The explanatory variables also included income (here Z) and seasonal variables (D_s and D_w, for summer and winter respectively). The final VAR model estimated by Bayesian Monte Carlo Markov Chains is:

$$\begin{cases} \Delta y_t = & \omega_{(1,1)} + \sum_{j=0}^{m^+}\beta_{(1,j)}^+(\Delta x_{t-j})^+ + \sum_{i=0}^{m^-}\beta_{(1,i)}^-(\Delta x_{t-i})^- + \\ & \omega_{(1,2)}\Delta I_t + \omega_{(1,3)}\Delta D_{st} + \omega_{(1,4)}\Delta D_{wt} + \epsilon_{1t} \\ G_t = & \omega_{(2,1)} + \omega_{(2,2)}y_t + \omega_{(2,3}Z_t + \omega_{(2,4)}D_{st} + \omega_{(2,5)}D_{wt} + \epsilon_{2t} \\ I_t = & \omega_{(3,1)} + \omega_{(3,2)}I_{t-1} + \omega_{(3,3)}D_{st} + \omega_{(3,4)}D_{wt} + \epsilon_{3t} \\ Q_t = & G_t + I_t - I_{t-1} + \epsilon_{4t} \end{cases} \tag{2.61}$$

This approach allows the researchers to incorporate other, potentially important, factors into PT, however, attention must be paid to model formulation. The testing framework in (2.61) does not account for LR equilibrium (first equation is in first differences without the ECT) and as such cannot form a basis for inference on APT. The same reservations apply to a class of VAR models proposed by Radchenko (2005*b*):

$$\begin{bmatrix} \Delta y_t^+ \\ \Delta y_t^- \\ \Delta x_t^+ \end{bmatrix} = c + \Phi(L) \begin{bmatrix} \Delta y_t^+ \\ \Delta y_t^- \\ \Delta x_t^+ \end{bmatrix} + \epsilon_t,\ t = t_0, \ldots, t \tag{2.62}$$

One significant area where VAR models could be used is related to testing the possible explanations for VAR. One of such theories links APT with volatility of upstream prices (see sections 6.2.1 and 6.2.2 for a more detailed discussion). It is possible by e.g. simultaneous estimation of proxies for the degree of APT and indicators of market situation.

The example below taken from Radchenko (2005*b*) models APT proxies and upstream volatility measures:

$$\begin{bmatrix} VOL_t \\ APT_t \end{bmatrix} = c + \Phi(L) \begin{bmatrix} VOL_t \\ APT_t \end{bmatrix} + \epsilon_t \tag{2.63}$$

where VOL_t stands for a scalar measuring volatility at t, APT_t is a scalar measuring the degree of APT, $\Phi(L)$ is a lag polynomial of order p, c stands for a bivariate constant. The analysis is made via Choleski decomposition and the identification via variable ordering.

VEC model of order q can be presented as:

$$\Delta\mathbf{Y_t} = \Pi\mathbf{Y_{t-1}} + \Phi_1\Delta\mathbf{Y_{t-1}} + \Phi_2\Delta\mathbf{Y_{t-2}} + \ldots + \Phi_q\Delta\mathbf{Y_{t-q}} + \nu_t \tag{2.64}$$

where $\mathbf{Y_t}$ is x×1 vector of variables of interest, ν_t is x×1 vector of error terms, $\Phi_1, \ldots, \Phi_q$ are n×n coefficient matrices, and Π is the n×n long-run coefficient matrix, which could be decomposed into product of matrices α and γ (matrix of r cointegrating vectors):

$$\Pi = \alpha_{n\times r}\gamma'_{r\times n} \tag{2.65}$$

Those models could be used to estimate non-linearities both in the LR and SR transmission. Below, we present bivariate extensions of models (2.13), (2.14) and (2.15).

$$\begin{cases} \Delta y_t = & \sum_{j=0}^{m^+}\beta^+_{(1,j)}(\Delta x_{t-j})^+ + \sum_{i=0}^{m^-}\beta^-_{(1,i)}(\Delta x_{t-i})^- \\ & +\gamma(y_{t-1} - \delta_{(1,0)} - \delta_{(1,1)}x_{t-1}) + \nu^y_t \\ \Delta x_t = & \sum_{j=0}^{m^+}\beta^+_{(2,j)}(\Delta y_{t-j})^+ + \sum_{i=0}^{m^-}\beta^-_{(2,i)}(\Delta y_{t-i})^- \\ & +\gamma(x_{t-1} - \delta_{(2,0)} - \delta_{(2,1)}y_{t-1}) + \nu_{1t} \end{cases} \tag{2.66}$$

$$\begin{cases} \Delta y_t = & \sum_{j=0}^{m}\beta_{(1,j)}\Delta x_{t-j} + \gamma_1^+(y_{t-1} - \delta_{(1,0)} - \delta_{(1,1)}x_{t-1})^+ \\ & +\gamma^-(y_{t-1} - \delta_{(1,0)} - \delta_{(1,1)}x_{t-1})^- + \nu^y_t \\ \Delta x_t = & \sum_{j=0}^{m}\beta_{(2,j)}\Delta y_{t-j} + \gamma_2^+(x_{t-1} - \delta_{(2,0)} - \delta_{(1,1)}y_{t-1})^+ \\ & +\gamma^-(x_{t-1} - \delta_{(2,0)} - \delta_{(2,1)}y_{t-1})^- + \nu^x_t \end{cases} \tag{2.67}$$

$$\begin{cases} \Delta y_t = & \sum_{j=0}^{m^+}\beta^+_{(1,j)}(\Delta x_{t-j})^+ + \sum_{i=0}^{m^-}\beta^-_{(1,i)}(\Delta x_{t-i})^- \\ & +\gamma^+(y_{t-1} - \delta_{(1,0)} - \delta_{(1,1)}x_{t-1})^+ + \gamma^-(y_{t-1} - \delta_{(1,0)} \\ & -\delta_{(1,1)}x_{t-1})^- + \nu^y_t \\ \Delta x_t = & \sum_{j=0}^{m^+}\beta^+_{(1,j)}(\Delta y_{t-j})^+ + \sum_{i=0}^{m^-}\beta^-_{(1,i)}(\Delta x_{t-i})^- \\ & +\gamma^+(x_{t-1} - \delta_{(2,0)} - \delta_{(2,1)}y_{t-1})^+ + \gamma^-(x_{t-1} - \delta_{(2,0)} \\ & -\delta_{(2,1)}y_{t-1})^- + \nu^x_t \end{cases} \tag{2.68}$$

VRS Models

Regime switching models extend multivariate framework provided by VAR and VECM models to a case of more than one regime. As an example, consider extension of (2.64):

$$\begin{aligned}\Delta \mathbf{Y_t} = {} & \Pi^{(j)}\alpha\gamma'\mathbf{Y_{t-1}} + \Phi_1^{(j)}\Delta\mathbf{Y_{t-1}} + \Phi_2^{(j)}\Delta\mathbf{Y_{t-2}} \\ & + \ldots + \Phi_q^{(j)}\Delta\mathbf{Y_{t-q}} + \nu_t \text{ if } r_{j-1} < \gamma'\mathbf{Y_{t-1}} < r_j\end{aligned} \tag{2.69}$$

where:

- $\mathbf{Y_{t-1}}$ is the vector of level variables lagged one period;
- γ' is the cointegrating vector, assumed to be the same in all regimes;
- $\Delta\mathbf{Y_{t-i}}$ is the vector of first differences lagged i periods;
- $\Phi_i^{(j)}$ are the SR dynamics coefficients governing the process in j^{th} regime;
- r_j are the switch triggering thresholds;
- it is assumed that the switch is triggered by the value of disequilibrium, i.e. $\gamma'\mathbf{Y_{t-1}}$.

This model can be estimated using either the approach proposed by Enders & Granger (1998) or the one developed by Hansen & Seo (2002). Unfortunately, despite their possible advantages, those models failed to attract significant attention.

Assessment

Multivariate models are not widely used for a number of reasons. Firstly and most importantly, they require data series of equal frequency and time span which is rarely available (e.g. in the sample used in this study only few series are temporarily aligned - see panel A.21). Secondly, their properties crucial from the point of view of APT analysis (such as regime identification, response patterns, etc.) were not addressed by econometric theory which still focuses on single-equation models.

2.3 Summary and Conclusions

In this chapter we analysed the econometric tools which could be used in the applied APT studies. Our review was focused on (i) assumptions on the nature of SPT and APT those tools imposed, (ii) their reliability when testing the null hypothesis of symmetric price transmission and (iii) their ability to assess the size and nature of APT.

The results of this analysis indicate that previously used tools suffer from several shortcomings. In particular, the ECM models can incorrectly categorize market situations and prohibit efficient identification of the pricing regime and the simulation of pricing responses. The SETAR models do not suffer from those problems, but instead assume sudden and full regime switch and their application to testing the null of SPT is problematic. Multivariate models are still underdeveloped in terms of key requirements for APT studies and require high-quality data, which are not readily available. The analysis indicate that the STAR models, which were not previously applied for APT analysis, rectify some shortcomings of previously used tools, in particular burdensome testing, unrealistic or harsh assumptions about the regime switch (SETAR), and untraceable regime history (ECM).

In the next chapter we continue with the review of the literature, this time with the focus on the economic analysis of price transmission.

Chapter 3

Overview of Previous Empirical Research

This chapter describes previous research into the asymmetric price transmission phenomenon. It draws heavily from Wlazlowski (2003*a*) and Wlazlowski et al. (2006) and attempts to familiarize the reader with the state of research into APT on petroleum markets and to introduce elements tackled in the applied part of this thesis - chapters 4 - 6.

The first part of the chapter identifies the key literature on testing for the presence of APT (section 3.1). In section 3.2 we discuss possible room for improvement.

3.1 Testing for the Presence of APT

This section presents a chronological overview of the most significant contributions to the APT literature. As in chapter 2, we omit studies which disregard the issue of spurious regression.

Unless stated otherwise, throughout this chapter: (i) the term *price* means *net-of-tax price*; (ii) the term *APT* means *positive APT*; (iii) a hypothesis is said to be rejected if the testing statistic is not significant at 5%; (iv) if upstream and downstream prices are expressed in different currencies, the appropriate FEX is involved in the estimation.

Table 3.1 presents a summary of empirical work, in particular geographical / temporal coverage of each study (*Country / Coverage* columns), testing framework and data used (*Model*, *Tiers* and *Frequency* columns). We also indicate if the issues of order of integration and causality are addressed (*Integration* and *Causality* columns) and what is the final conclusion on the presence of APT (*Results* column).

Table 3.1: Testing for APT - Overview

Authors	Model	Integration[1]	Causality	Product[2]	Tiers[3]	Country	Frequency[4]	Coverage	Results[5]
Sumner (1990)	2.13/2.15	Y	N	LP	C→R	UK	M	III'82-XXI'89	Y
Bacon (1991)	2.3	N	N	LP	C→R	UK	2W	VI'82-I'90	Y
Manning (1991)	2.13	Y	N	LP	C/T→R	UK	M	I'73-XII'88	Y
Norman & Shin (1991)	2.3	N	N	LP	C→W→R	US	M	I'82-XII'90	N
Kirchgassner & Kubler (1992)	2.68	Y	Y	HO/LP	S→R	DE	M	I'72-XII'89	M
Borenstein & Shephard (1996)	2.13	N	N	ULP	C→ R	US	M	I'82-XII'91	Y
Borenstein et al. (1997)	2.13	N	Y	ULP	C→S→W→R	US	2W	III'86-XII'92	M
Balke, Brown & Yucel (1998)	2.13	Y	Y	ULP	C→S→R	US	W	I'87-IIX'96	Y
Eltony (1998)	2.13	Y	N	LP	C→R	MN	M	I'80-VI'96	Y
Reilly & Witt (1998)	2.13	Y	N	LP	C→R	UK	M	I'82-VI'95	Y
Energy Information Agency (1999)	2.13	Y	N	ULP	C→S →R	US	W	X'89-IV'93	Y
Asplund et al. (2000)	2.13	Y	N	LP	C/T→R	SE	D	I'80-XII'96	Y
Berardi, Franzosi & Vignocchi (2000)	2.15	Y	N	LP/ULP	C/T→R	IT	W	X'91-II'00	M
Godby et al. (2000)	2.35	Y	N	ULP	C→R	CA	W	I'90-XII96	N
Indejehagopian & Simon (2000)	2.13	Y	Y	HO	W→R	MN	M	I'87-XII'97	M
Bremmer & Christ (2002)	2.15	Y	N	ULP	C→W→R	US	DWM	Other	Y
Eckert (2002)	2.13	Y	N	ULP	W→R	CA	W	XII'89-X'94	Y
Galeotti et al. (2003)	2.15	Y	N	LP/ULP	C→S →R	MN	M	I'85-VI'00	Y
Johnson (2002)	2.13	Y	N	ULP/DO	W→R	US	W	VII'96-VI'98	Y
Salas (2002)	2.13	Y	N	ULP	C/T→R	Ph	W	I'99-II'02	Y
Bachmeier & Griffin (2003)	2.13/2.15	Y	N	ULP	C→S→W→R	US	DW	II'85-XI'98	M
Driffield et al. (2003)	2.21	Y	N	LP/ULP	C→R	UK	M	I'73-IV'00	Y
Wlazlowski (2003*a*)	2.13	Y	Y	LP	C→R	UK	M	I'78-XII'02	Y
Contin, Correlj & Palacios (2004)	2.15	Y	N	ULP	C→R	SP	W	I'93-XII'02	Y

Continued on next page

Table 3.1 – continued from previous page

I	II	III	IV	V	VI	VII	VIII	IX	X
Deltas (2004)	Other	Y	N	ULP	W→R	US	M	I'88-XII'02	Y
Lewis (2004)	2.35/2.36	Y	N	ULP	W→R	US	W	I'00-XII'01	Y
Arpa et al. (2005)	2.35	Y	N	MN	C→R	MN	W	I'96-VI'05	
Chen et al. (2005)	2.35	Y	N	ULP	C→S→R	US	W	I'91-III'03	
Kaufmann & Laskowski (2005)	2.14	Y	N	ULP/HO	C→W→R	US	M	I'86-XII'02	M
Radchenko (2005*a*)	2.13	N	N	ULP	C→S→R	US	M	III'91-II'03	Y
Radchenko (2005*b*)	2.13/VAR	Y	N	ULP	C→R	US	M	III'91-II'03	Y
Rao & Rao (2005*a*)	2.15	Y	N	LP	C→R	US	M	I'78-XII'04	N
Rao & Rao (2005*b*)	2.15	Y	N	ULP	S→R	FJ	M	I'97-IX'04	Y
Ye et al. (2005)	2.15	Y	N	ULP	W→R	US	W	I'00-XI'03	Y
Denni & Frewer (2006)	2.15	Y	N	MN	C→R	NL	M	I'90-IX'05	M
Verlinda (2006)	2.13	N	N	ULP	W→R	US	W	I'02-V'03	Y
Wlazlowski et al. (2006)	2.32	Y	Y	ULP	W→R	US	W	VI'00-XI'05	Y
Grasso & Manera (2007)	2.15/2.35	Y	N	(U)LP	C→S→R	MN	M	I'85-III'03	M
Hosken et al. (2007)	2.13	Y	Y	ULP	W→R	US	W	I'97-XII'99	M
Lewis (2007)	Various	Y	Y	ULP	W→R	US	D	VI'00-XI'05	

[1] Integration - testing for the order of integration;
[2] Product: LP - leaded petrol, ULP - unleaded petrol, HO - gasoil / heating oil, DO - Diesel oil, MN - various products;
[3] Tiers: C - market level on which crude is traded, R - retail, W - wholesale, EX - the exchange rate;
[4] Frequency: D - daily, W - weekly, 2W - bi-weekly, M - monthly;
[5] Results: Y - the null of SPT rejected in favour of APT, N - the null of SPT not rejected, M - mixed results.

The first APT study that recognized the necessity of accounting for the presence of a LR relationship between prices was by Sumner (1990). In his research into the UK petroleum market, he introduces a number of concepts crucial to the APT analysis. Firstly, the author recognizes that the assumption of a constant monetary margin is unattainable in periods of variable inflation so Cobb-Douglas functions should be used instead to model pricing relationship. Secondly, he estimates pass-through rates, understanding that in the presence of other costs the Cobb-Douglas specification excludes full pass-through. Thirdly, he introduces other costs (proxied by labour costs) into the pricing mechanism. With hindsight, some of the other assumptions might be criticized (especially decisions to use PAMs alongside ECMs and to introduce arbitrary thresholds into Wolfram's variable split). However, given how many later studies fail to recognize and rectify similar shortcomings, this study should be praised for being well ahead of its times.

Bacon (1991) revisits the UK market but using USD-denoted ARA crude oil prices as USP proxy, as opposed to the GBP-denoted purchasing costs borne by the UK refiners employed by Sumner (1990). This constitutes an improvement as FEX can affect petroleum prices directly (through changes of crude prices evaluated in home currency), indirectly (through other open positions) and be a separate source of APT. However, since the research uses an inferior modelling framework ((2.3) instead of ECMs) the reliability of the results might be challenged for several reasons. Firstly, the modelling strategy does not sufficiently address the issues of spurious regression. Secondly, to identify the dynamics of the system, Bacon uses the specific-to-general approach and undertakes *"considerable experimentation"* with lag lengths so as to get *"preferred results"* - Bacon (1991, p. 17). Thirdly, the functional form of (2.3) is linear, thus implying a constant nominal crude-petrol margin. Given that the sample covers years of variable inflation, this assumption might be too strict - see section 2.2.2 for a discussion. The results confirm those of Sumner (1990), except for the pass-through, as Bacon concludes that changes in upstream costs (caused by exchange rates or crude prices changes) are passed downstream fully.

Despite those shortcomings, the paper significantly contributes to APT modelling. In particular, the author correctly identifies that the downstream prices in Europe depend on prices quoted in the ARA area and accounts for the effects of foreign exchange, realizing that it is a separate source of volatility which affects agents directly via crude oil terms-of-trade or through their total open positions.

Bacon (1991) is also the first to quantify APT - based on the estimates of mean response time (infinite sum of step-by-step adjustments) for increases and decreases, he concludes that the difference in adjustment speeds equals one week. This estimate, however, might be challenged as the result is based on bi-weekly data. Maddala (1977) indicates that whenever a study utilizes data with sampling interval longer than adjustment period, it might bias the estimates.

Manning (1991) advances the APT research by accounting for issues of taxation and causality price transmission.[1] The author agrees with Bacon (1991) on the presence of APT, but differs drastically in estimates of the extent of APT (4 months as opposed to one week) and pass-through (only 27%-36% as opposed to full pass-through).

Norman & Shin (1991) apply Bacon's (1991) framework to a superior US dataset and extend the APT estimation to data of different frequencies quoted at more than two tiers in more than one location. The authors conclude that APT is *not* present in the USA and attribute the discrepancies with Bacon (1991) to the fact that the US market is more competitive than the UK one. Interestingly, when the original dataset used in this study is re-visited by Shin (1992) with a different methodology, the null of SPT *is* rejected.

Kirchgassner & Kubler (1992) are the first to analyse transmission in a non-Anglo-Saxon country (Germany) for a product other than ULP (heating oil). The authors attempt to test for the structural change in price transmission following the sudden increase in liquidity in January 1980 by estimating (2.68) before and after the suspected structural break. Since APT is found in the first and not in the second of the sub-samples, the authors conclude there is a link between liquidity and asymmetries. Unfortunately, no formal tests of this hypothesis (or the existence of structural breaks for that matter) are reported. Regardless of whether the structural change really took place, Kirchgassner & Kubler (1992) should be credited as the first study to point to possible linkages between market liquidity and non-linearities in price transmission.

Borenstein & Shephard (1996) re-phrase the problem of APT in terms of changes in margins earned on transmission between two tiers. This approach is commonly used later on, as it allows for straightforward analysis of APT as a problem of disequilibrium (residual) elimination and a shift from ECMs towards SETAR models. The authors focus on the behaviour of the retail mark-up, defined as the difference between terminal and retail prices. In particular, they analyse how mark-ups respond to *expected* changes in demand and upstream costs.[2] The authors conclude that the non-linearities are present

[1] The author correctly states that cointegration techniques do not specify the direction of causality. However, his solution is to evaluate all possible equations thus covering different directions of causality, express them in terms of downstream prices and then choose the best fit among different specifications. This technique however must be criticized as fuel taxes are expressed *ad valorem* (VAT), so causality from taxes to crude / retail prices is impossible and should not even be analysed.

[2] The expected consumption is instrumented by lagged data on actual consumption, retail prices and seasonal / trend variables. The expected costs are instrumented by modification of (2.15) with the LHS

in transmission as margins increase whenever wholesale prices are expected to decline and decrease in the opposite case. Furthermore, contrary to the predictions of standard non-cooperative models but in line with collusion theories, margins *do* respond positively to anticipated changes in demand and input prices.

Several comments about this conclusion should be made. Firstly, the models used have some variables in constant feedback which is likely to affect the results.[3] Secondly, the expectations are assumed to cover only one period, while most sources claim that collusion is enforced over a longer time horizon. Thirdly, margins are proxied by the difference between USPs and DSPs, which implies a full pass-through. This is not tested and is often contested in the literature. Fourthly, petroleum markets do not resemble a typical setting for collusion. In retail petroleum markets, collusive behaviour would have to be a result of a world-wide coordination, otherwise the revision to the one-shot Nash equilibrium level would occur immediately. The authors seem to acknowledge that such a perfect collusion is not possible, and instead propose a slightly different explanation of the traditional collusion story, in which sellers understand that by lowering their prices immediately after upstream cost decreases they induce price cuts at other stations and risk triggering retaliation. In such a setting, profit-maximising agents are less willing to lower the prices, thus creating APT. Unfortunately, they do not present any formal model for such a situation.

Borenstein et al. (1997) conduct the most comprehensive analysis of US price transmission up-to-date. The article uses disaggregated data on retail, terminal, NY spot and WTI spot and futures prices that cover the entire US market. The framework of the analysis is also innovative, as it accounts for the previously ignored issues of endogeneity of prices and causality in price transmission. The authors conclude that APT is widespread across the markets and tiers, however, they do not present any rigorous tests for the presence of APT other than graphs with confidence intervals. The reliability of the results is also diminished as some assumptions made in the study are disputable. In particular:

- the specific-to-general approach used to establish the lag lengths invalidates the modelling exercise, as it creates dependence in terms of the individual tests used;
- the constant nominal margin assumed in the linear LR pricing functions is often criticized as improbable.

variable replaced by contemporaneous upstream prices.

[3]This is indirectly supported by the fact that the change of the estimation method from OLS to 2SLS leads to the change of sign of certain estimates - Borenstein & Shephard (1996, p. 444).

Balke et al. (1998) revisit the work of Borenstein et al. (1997) but using new causality tests and (for the first time) weekly data. The results of Granger causality tests and variance decomposition indicate that USPs Granger-cause DSPs in all possible tier pairings except for the direct transmission from net-of-tax to all-inclusive retail prices.[4] The APT tests based on (2.13) and (2.15) give mixed results.

Eltony (1998) introduces multi-national datasets for APT analysis - he covers transmission in US and UK markets. The results indicate the presence of SR APT in both countries, but, surprisingly, the estimates indicate no cointegration - as the ECT coefficients are *not* negative - for example see equations 8 & 9 in the article.

Reilly & Witt (1998) revisit the work of Sumner (1990) but utilizing (2.13) with the pricing model given by a Cobb-Douglas function encompassing the exchange rate mechanism and with a linear trend proxying all other costs. The authors reject the null of SPT in both USP and FEX transmission. They are the first to analyse the evolution of APT over time - the recursive estimation indicates that the coefficients on APT parameters evolve over time.

The Energy Information Agency (1999) follows in the steps of Borenstein et al. (1997) and Balke et al. (1998) by meticulously modelling the US transmission chain. The sample attempts to cover all physical transmission tiers present along US Midwest transmission chains, i.e. pump, Chicago rack and pipeline, Gulf Coast spot and WTI prices. The results of the testing procedure indicate widespread APT in all transmissions except for the retail-crude, rack-pipeline, rack-spot, rack-crude, pipeline-spot and spot-crude. The results indicate that the adjustment is completed after 7-9 weeks but also that some of the transmissions have more than full pass-through, which might imply that their over-specified models are unreliable.

Asplund et al. (2000) introduce firm-level data into APT analysis. The results of the estimation confirm that the retail price response to cost shocks is stickier downwards than upwards. The results also indicate that FEX transmission is faster than product transmission, which is explained by the volatility of the series. This link is characterised as follows: spot prices expressed in USD are more volatile than USD-to-local-currency exchange rate, creating more uncertainty for the firm. Therefore, sellers expect spot prices to revert and postpone price adjustments. Conversely, less volatile exchange rates are less likely to revert, so that firms pass on the changes to end customers faster.

[4]While some authors find it puzzling (Balke et al. (1998, p. 5)), this should hardly be a surprise - Wlazlowski et al. (2006) shows that while DSPs respond to tax changes, the responses are not homogeneous with respect to the direction of changes and include mainly change in the adjustment regime - this is confirmed by the results of variance decompositions which shows a drop in the proportion of retail price variance explained by the crude oil variance from 63.3% to 45.8% after inclusion of taxes.

Godby et al. (2000) extend the price transmission analysis to Canada with the aim of (i) testing the possibility of price asymmetries being triggered by a minimum absolute increase in crude cost, (ii) assessing the impact of deregulation of crude oil markets markets in Canada (see Competition Bureau (1997) for details), (iii) analysing the impact of concentration in the industry on the pass-through rates. To obtain those aims, the authors introduce SETAR-type models into APT analysis. The results do not identify any non-linearities but should be treated with caution as all series are de-seasonalised via regression on a constant number of weekly dummies, which might bias the results since the sample does not contain equal numbers of weekly observations in every year.

Bremmer & Christ (2002) analyse the effects of temporal and geographical data aggregation. The intertemporal comparisons are based on daily, weekly and monthly prices. To tackle the issue of spatial aggregation, the authors analyse the prices aggregated across (i) the USA as a whole; (ii) five multi-state regions;[5] (iii) 3 sub-regions; (iv) five states;[6] (v) six cities.[7] The authors test the null of SPT using (i) Wolfram-type split of series in levels (resulting in 2.15) and (ii) Wolfram-type split of first differences in series. Unfortunately, inference based on the latter model is invalid as it disregards the LR equilibrium revision - Cramon-Taubadel & Meyer (2001). Results based on the former model indicate that the estimated response to increases in the crude price is larger for daily data than for weekly data, which (given that SPT was not rejected for monthly data) might indicate that asymmetries are transitory and short-lived.

Eckert (2002) revisits the Canadian market with the aim of testing for the presence of price cycles, which could be mistaken for APT - see chapter 6.2. Since the research is mainly concerned with sources of APT, it is discussed in greater detail later on in this thesis. His contribution to the APT testing framework is the application of the Kolmogorov-Smirnov (KS) test for the null of symmetric distribution of runs in USPs / DSPs decreases and increases. This simple and straightforward tool allows for quick-and-dirty testing for the possible presence of APT and / or pricing cycles. Since the core APT testing procedure used by Eckert (2002) follows Borenstein et al. (1997), the same reasoning applies. Furthermore, the inference on APT should be treated with caution as:

- no formal tests for cointegration between series were reported;
- all-but-one variable in ECM were found to be statistically insignificant at 5% which suggests spurious regression.

[5]The East, the Midwest, the Gulf, the Rockies and the West regions.
[6]California, Colorado, Minnesota, New York and Texas.
[7]Chicago, Denver, Houston, Los Angeles, New York City and San Francisco.

The study by Galeotti et al. (2003) constitutes a first attempt to present a cross-national picture of price transmission in Europe - it covers five key EU countries (Germany, France, Italy, Spain and the UK). Furthermore, the authors are the first to identify problems with the low power of the ECM tools and introduce bootstrap to overcome this problem. The results should be treated with caution as the data are not economically linked (US prices chosen as proxies for USP do not necessarily drive EU prices - see import data in section 1.3) and the lag structure used allows only for the one-month SR adjustment, which might lead to estimation bias. Furthermore, some coefficients on LR ECM terms split in Wolfram's manner (γ^+s and γ^-s) are either *not* statistically different from zero at 5% and 1%, which casts doubt regarding the existence of LR relationship or are greater than unity, suggesting explosive behaviour - see Galeotti et al. (2003, p. 177).

Johnson (2002) analyses price transmission within a two-product framework in order to check for differences between Diesel and ULP. The research is motivated by a casual observation that end users purchase ULP frequently (which is costly) and therefore might have little incentive to search, as opposed to Diesel users who typically buy more fuel and do it less frequently. Johnson (2002) tests this hypothesis using the model by Borenstein et al. (1997) with the proxies for upstream variance from the estimation of (2.18). The results are mixed and the author concludes that they indicate less pronounced APT in Diesel transmission and support the existence of a direct link between search costs and the degree of APT via Bayesian learning search model (see section 6.2.2).

Bachmeier & Griffin (2003) illustrate the effect of data aggregation bias by re-visiting the models by Borenstein et al. (1997), but using daily data and OLS instead of 2SLS. The results indicate no APT and are interpreted as evidence of a very efficient market with few rigidities. Indirectly, this proves that the methodology applied by Borenstein et al. (1997) is fragile, as either usage of daily data or application of traditional ECM framework with OLS estimation results in the failure to reject the null of SPT from crude oil to the wholesale market. The superiority of ECM OLS estimation is also demonstrated by better out-of-sample forecasting properties. The forecasts are also used to further support the null of SPT, as both symmetric models (two-stage and proposed by Stock & Watson (1993)) performed *better* than their asymmetric counterparts.

Driffield et al. (2003) revisit the UK market using a framework similar to that of Sumner (1990) and Reilly & Witt (1998), i.e. assuming the presence of other costs in transmission (proxied by CPI), utilizing innovative techniques (2.21) and (2.68) to reject the null of SPT. The testing strategy, however, suffers from extensive assumptions, in particular those of (i) full pass-through of upstream costs, (ii) lack of asymmetries coming from the FEX, (iii) usage of CPI, rather than PPI which affects oil companies and (iv) choice of crude oil (Saudi oil) which does not necessarily drive UK prices.

Wlazlowski (2003*a*) revisits the UK market with an updated dataset and methodology that includes (2.13) and (2.32). The author introduces the momentum TAR model into petroleum price transmission, recognizing that for determining the pricing response, a change in margin might be as important as the size of the margin. Results confirm those obtained previously, in particular less-than-full pass-through and widespread APT both in the short and the long run. The results from the M-TAR model estimation indicate that the pricing of petroleum products holds more intricacies than previously believed.

Deltas (2004) attempts to link state-specific wholesale-retail margin (proxied by the difference between USPs and DSPs over the sample period) to US state-specific economic indicators. The analysis is based on panel estimation of (2.13) enriched by the margin data, which results in:

$$\begin{aligned} \Delta y_{(k,t)} = \; & \textstyle\sum_{j=0}^{m^+}((\overline{y_k} - \overline{x_k})\beta^+_{(k,j)}(\Delta x_{(k,t-j)})^+ + \sum_{i=0}^{m^-}((\overline{y_k} - \overline{x_k})\beta^-_{(k,i)}(\Delta x_{(k,t-i)})^- \\ & \textstyle\sum_{j=0}^{n^+}((\overline{y_k} - \overline{x_k})\alpha^+_{(k,j)}(\Delta y_{(k,t-j)})^+ + \sum_{i=0}^{n^-}((\overline{y_k} - \overline{x_k})\alpha^-_{(k,i)}(\Delta y_{(k,t-i)})^- \\ & +\gamma(y_{(k,t-1)} - \delta_{(k,0)} - \delta_{(k,1)}x_{(k,t-1)}) + \epsilon_{(k,t)} \end{aligned} \tag{3.1}$$

Deltas (2004) claims that inclusion of margins terms allows for analysis of APT sensitivity to:

- retail market power - the argument is that markets with lower margin exhibit little local market power, so the presence of APT should indirectly support the explanations that focus on market power;
- search costs - the argument is that the non-idiosyncratic components of the price become common knowledge with time and in equilibrium customers with high / low search costs buy more / less expensive products. When USPs increase, consumers increase the amount of search, which decreases the margins.

The conclusions of the study are not credible as (3.1) links mark-ups with *transmission* and not to the *asymmetries in transmission.* If one re-writes it using the indicator function depending on the contemporary direction of upstream changes - $I(\Delta x_{(k,t-i)})$, so that it becomes:

$$\begin{aligned} \Delta y_{(k,t)} = \; & \textstyle\sum_{j=0}^{m}((\overline{y_k} - \overline{x_k})\beta_{(k,j)}(\Delta x_{(k,t-j)}) + \sum_{i=0}^{m'}((\overline{y_k} - \overline{x_k})\beta_{(k,i)}(\Delta x_{(k,t-i)})I(\cdot) \\ & \textstyle\sum_{j=0}^{n}((\overline{y_k} - \overline{x_k})\alpha_{(k,j)}(\Delta y_{(k,t-j)}) + \sum_{i=0}^{n'}((\overline{y_k} - \overline{x_k})\alpha_{(k,i)}(\Delta y_{(k,t-i)})I(\cdot) \\ & +\gamma(y_{(k,t-1)} - \delta_{(k,0)} - \delta_{(k,1)}x_{(k,t-1)}) + \epsilon_{(k,t)} \end{aligned} \tag{3.2}$$

and compares two imaginary "states" a near-zero margin state and "normal" one, it is clear that the model (incorrectly) assumes that in the first case the transmission would take almost forever to be completed, while in the second case, the SR adjustment would be almost instantaneous. Furthermore, the inherent assumption in the model is that the margins are uniform across stations which is clearly not the case, as some of them face additional costs (e.g. franchise costs for lessees).

Lewis (2004) is the first to analyse price transmission using station-level data covering a distinct geographic area. The author uses weekly wholesale and retail ULP prices charged by 420 retail stations in the San Diego area over the period January 2000-December 2001. The APT testing is done with the help of panel estimation of (2.35) and (2.36) with station-specific variables added, threshold r arbitrarily set to 0, and ECT calculated as in Engle & Granger (1987) but under the assumption of full pass-through and linear pricing function.[8] Although interesting from the point of the data used, this study should be treated with caution as it suffers from arbitrary assumptions (such as those of full pass-through and of linear pricing specification) and lack of tests for the presence of non-linearities. Similarly to Wlazlowski (2003*a*), the non-linear framework is based only on the Wald-test of the null of equality of coefficients in both regimes.

Further advance in terms of geographic coverage is made by Arpa et al. (2005) who attempts to analyse price transmission in 25 EU countries. Although the issue of APT is not central to the analysis, the authors apply (2.35) with the indicator function mirroring that of Godby et al. (2000) (i.e. set to unity for $\Delta x_{t-1} \leq 0$) for the ECT only. Unfortunately, the manner in which this ambitious task is executed casts doubts on the credibility of the results. In particular, the authors do not present any information on the exact kind of crude oil and exchange rates used in the analysis. Furthermore, the LR analysis is based on Bewley's transformation - an old time series technique, briefly popular in the late 1980s - see (2.4) and (2.5) for a discussion of disadvantages of this technique.

Grasso & Manera (2007) revisit the updated dataset analysed previously by Galeotti et al. (2003), but using a framework that involves typical ECM models, TAR / M-TAR similar of those used by Wlazlowski (2003*a*) and combinations of those. Interestingly, the study shows that APT inference depends on the modelling framework chosen. On the basis of the estimation, the authors conclude that there is a temporal delay in the reaction of retail prices to changes upstream but the estimates vary across countries and methodologies used. In particular:

[8]Full pass-through is not substantiated by the data, which indicates only 48% pass-through.

- the asymmetric ECM supports some degree of APT in all countries, mainly at the distribution stage;
- the threshold ECM strongly rejects the null of SPT for France (all 3 cases), Germany (spot-retail and crude-retail) and Italy (spot-retail);
- the ECM model with threshold cointegration indicates LR asymmetries in crude oil - retail transmission for all the countries.

Kaufmann & Laskowski (2005) attempt to enrich price transmission analysis with refinery utilisation rates and stock levels. The authors estimate only direct transmissions and disregard the indirect one from crude oil to retail. Surprisingly, all price series are used in levels and Kaufmann & Laskowski (2005, p. 1588) claim that:

> (...) industry definition of refinery margins (which) are calculated as the difference between the price of crude oil and refined petroleum products. As such, the (*coefficient on USPs in the level equation*) represents the change in refinery margins that is associated with the price of crude oil. The price of crude oil has no effect on refinery margins if (*the coefficient*) equals zero. A value of (...) 1 indicates that refinery margins change by the same quantity as crude oil prices.

Unfortunately, the interpretation should in fact be opposite - in the setting presented, the coefficient of unity implies a full pass-through and no effect on margin, while the coefficient equal to zero implies that margins fully absorb changes in USPs.

The analysis of the LR level equation reveals:

- insignificant inter-state and inter-product differences in the pass-through rates. Those rates for all but two cases are *not* significantly different from unity at 5%;
- statistically insignificant impact of petroleum stock variables on DSPs (significantly different from zero only in one out of 26 cases);
- significant (in 11 out of 26 cases) and negative impact of utilisation rate on the DSPs. The results can be interpreted as a support for the notion that increased demand lowers prices.

The analysis of the ECM models reveals no APT in the LR adjustment, which indicates that the adjustment speed is the same at times of increasing and decreasing USPs. However, the authors lower the significance threshold to 10% and then conclude that

APT is present in the gasoil price transmission and missing for ULP price transmission. The reasoning is based solely on the fact that in 5 out of 13 cases the null of SPT is rejected in the case of gasoil price transmission, as compared with 4 rejections for ULP price transmission - (p. 1592). After that conclusion, the authors try to analyse (i) why the null of APT is not rejected for ULP and (ii) what causes APT in the gasoil market and what welfare impact it causes.

The authors conclude that the most likely explanation for the failure to reject SPT in ULP transmission is the introduction of new variables. The reasoning is that previous research did not account for utilisation and stock variables, the series used did not cointegrate, which in turn lead to over-rejection of the null - (p. 1593). This claim is dubious as:

- only one of the additional variables introduced in the study is found to be significant (and even that not in all of 26 cases);
- the models presented also did not cointegrate in all cases (e.g. in the case of gasoil price transmission the null of no-cointegration is rejected at 5% for only 3 cases).

All in all, if the lack of cointegration results in over-rejection of APT, the authors should first re-visit their claims that the transmission in the gasoil market is asymmetric.

The most likely reason for the unorthodox results is the flawed nature of data used. Most importantly, the definition of utilisation used does not account for the increases in the short-run *level* of supply, but instead for the current utilization *rate* which means that if some new refining capacity becomes available in the short-run and is utilised at the normal rate (which is only to be expected as refineries cannot operate below a certain break-even point) it will not be reflected in the model, although it might have a significant impact on the market.

Radchenko & Tsurumi (2006) extend the analysis by Kaufmann & Laskowski (2005) by adding additional series on average per vehicle consumption and average earnings of industrial workers. The authors also deflate the series using CPI index and exclude the utilization rates from the analysis. The estimation is done using the highest posteriori density estimates from a Bayesian Monte Carlo Markov Chains algorithm (2.61). The results lead to rejection of the null of SPT. Unfortunately, the model used (2.61) does not account for LR equilibrium (first equation is in first differences without the ECT) and as such it cannot form a basis for inference on APT.

Ye et al. (2005) continue the research into the effect of geographical aggregation on APT. This is done using typical ECM fitted for ten different pricing areas (PADDs) in the USA. The results indicate widespread APT and differences in pass-through patterns (degree of pass-through, lag structure, speed of adjustment, etc.) between the analysed regions. Interestingly, the pan-regional cumulative pass-through estimate is greater than the volume-weighted regional pass-through estimates, suggesting spatial aggregation bias.

Denni & Frewer (2006) are the first to focus solely on international petroleum markets with the analysis of crude oil - ARA transmission. Furthermore, they introduce a GARCH mechanism into ECM models. The results do not allow for rejection of the null of SPT for all series in both SR and LR (except for RFO1 in SR and RFO2 in SR and LR). The authors continue with the help of an enhanced model that contains additional information on the refiners' margins (calculated using additional data and methodology provided in IEA Energy Statistics (2004)). The enriched model rejects the null of SPT for naphtha, kerosene, gasoil and RFO1/2.

Verlinda (2006) introduces a Bayesian framework to the spatial analysis of price transmission between wholesale and retail ULP in California, USA. The APT part of the analysis is performed using (2.13) estimated in the Bayesian framework. The results indicate widespread APT which disappears after three weeks and (interestingly) depends on the brand identity of the station and the degree of local competition.

Wlazlowski et al. (2006) are the first to focus solely on one distinct market using prices of three different varieties of ULP and to verify the results of traditional, deterministic APT estimation framework (2.24) with the stochastic framework developed by Hamilton (1989). The results are coherent across methodologies and indicate significant cross-product differences, including co-existence of positive and negative APT on adjacent markets for close substitutes (for example regular and premium petrol). Again, the full pass-through assumption is taken, but this time it finds support in the estimates.

Hosken et al. (2007) analyse the transmission wholesale and retail prices charged in 272 stations around Washington, DC. The analysis is focused on pricing behaviour in general, but the authors apply (2.13) with ECT set according to Stock & Watson (1993) (in the spirit of Borenstein et al. (1997)) and to Engle & Granger (1987) (in the spirit of Bachmeier & Griffin (2003)). The SPT tests give mixed results, and only faint traces of APT in SR adjustments are found.

In the second part of the article, Hosken et al. (2007) conclude that the distribution of retail gasoline prices has relatively thick tails. The authors also find that while the median retail margin changes substantially over time (by more than 50%), the shape of the distribution remains relatively constant. Furthermore, they find that there is substantial heterogeneity in pricing behaviour: stations charging very low or very high prices are much more likely to maintain their pricing position over time than stations charging prices near the mean, even after controlling for permanent differences in marginal costs. Using the panel version of pricing model, the authors find that most of the inter-station variance can be explained by brand affiliation, local competition or other station-specific attributes.

Lewis (2007) revisits the issue of APT at the level of US cities. The study focuses on the price hikes following hurricane Rita in 85 Midwest, Mid Atlantic and Southern US cities. This is done by analysing the relationship between wholesale, and retail prices of unbranded ULP using separate LR price equations for every city with data in levels, daily trends, additional variables designed to capture the height of the peak prices and the effects of Edgeworth cycles. The results indicate that the manner in which the price hikes are eliminated differs across geographical locations and the pattern of adjustment reflects the nature of retail price competition. Furthermore, the Edgeworth cycle proxy estimation indicates that cities with cyclical patterns are faster to lower their prices after a shock. No direct inference on the presence of APT is reported.

3.2 Potential for Improvements

In this section we review the applied research described above in order to identify possible shortcomings which could be rectified in this analysis.

3.2.1 Introduction

As seen in Table 3.1, the picture of non-linearities that emerges from the applied literature, although wide and comprised of many studies, is also fragmented. As a result, despite more than 40 articles published on the topic, there is no consensus on where APT is present and how significant it is. The extent of this fragmentation can be illustrated by data and tools used and assumptions applied in the literature.

Below we discuss those issues in greater detail. In particular, in Tables 3.2 - 3.9 we present the meta-analysis of applied research which substantiate conclusions on the current state of the knowledge of APT.[9]

3.2.2 Data Used

As discussed by Shin (1992), the data used in price transmission research can significantly affect the outcome of APT analysis. A striking feature of datasets used in applied APT

[9]Please note that some studies utilize two or more datasets, estimation techniques, etc. Thus, the total number of studies in every table might differ.

studies is a high degree of their temporal, product and geographical aggregation. Below we discuss how each type of aggregation can be introduced into APT study and how it can affect its results.

Temporal Aggregation Since transaction (tick) data on petroleum prices are not readily available, a certain degree of aggregation over time cannot be avoided. Here we focus on two kinds of temporal aggregation - one related to the frequency of the series and one to the relative position of observations with respect to time.

Table 3.2 presents the summary of frequency of data used in applied studies. The results indicate that petroleum price transmission studies rely mainly on monthly data. Although higher frequency data gains popularity, only half of studies utilizes weekly and daily data, and those are confined mainly to the Northern American markets.

Table 3.2: Applied Research - Temporal Aggregation

Frequency	Number of Studies
Monthly	21
Weekly	16
Daily	4
Bi-weekly	2
Total	43

Since Theil (1954) it is widely acknowledged that econometric techniques are sensitive to the choice of the unit in which the data are expressed, including time frequency. This potentially adverse impact is even more pronounced for APT studies, as the standard APT models (asymmetric ECMs in the form of (2.13), (2.14) and (2.15)) are not covered by approximation theorems, which mitigate aggregation problems in their symmetric / linear counterparts - Geweke (2004). This is clearly illustrated by Karrenbrock (1991) and Bachmeier & Griffin (2003) who re-visit older studies with data of higher frequency, only to obtain contradictory results.

For APT studies, Lyon & Thompson (1993) confirm the superiority of high frequency data by using monthly, quarterly and semi-annual milk prices to show that margin modelling becomes less informative with higher aggregation. This can be applied to petroleum product pricing, as:

- high volatility of energy prices and the volume of trade forces agents to respond to market developments quickly;
- low average lengths of runs up and down suggest frequent reversals of price trends (for EU petroleum prices see Tables A.17 and A.18).

Temporal aggregation can affect the APT studies also in an indirect fashion. As proved by Blank & Schmiesing (1990), excessive temporal aggregation distorts lead-lag relationships and leads to inconclusive or even incorrect results of causality tests, commonly used to establish the direction of transmission. For a discussion on causality in APT - see section 3.2.3.

Furthermore, if the data are excessively aggregated the researchers have to widen the time coverage of the study (time span of series analysed) which increases the probability of structural changes occurring in pricing relationships. For a discussion of possible impact of structural changes on APT tests see section 3.2.3.

A broader view on the temporal aggregation is voiced by Rao & Rao (2005*a*) who revisits the works of Borenstein et al. (1997) and Bachmeier & Griffin (2003) to show that if the underlying APT model is properly specified, the temporal aggregation does not affect the results. The results of (2.15) with ECT specified as described by Engle & Granger (1987) and Stock & Watson (1993) do not support the rejection of the null of SPT and the authors conclude that model specification, not data frequency, is the key influence in the APT tests.[10] Asplund et al. (2000) claim that vertically integrated retailers in Sweden change their prices every day, which would suggest that daily data should be used. In contrast, Davis (2007) finds that independent US retailers change their prices on only 8%-13% of days, which suggests that weekly data could be used.

The second type of temporal aggregation occurs when observations on upstream or downstream prices are gathered at different points in time but nonetheless are all treated as economically linked. This is more likely to adversely affect the results as the upstream and downstream prices analysed might not be related, so the transition mechanism is misrepresented. Combined with a lower frequency of data, this kind of aggregation blurs the picture of price transmission. Applied research largely neglects this issue - see discussion in Wlazlowski et al. (2006).

Cross-Product Aggregation Prices of oil derivatives vary not only between different products, but also between brands or even uses - as in the case of Diesel and gasoils, discussed on page 32. As Table 3.3 shows, researchers tend to use data on few key products, disregarding not only their perfect substitutes (as in the case of regular and premium gasoline), but also other products (e.g. Diesel, kerosene, RFO1/2, gasoil, which are covered in less than three studies).

In principle, as long as oil prices are exogenous, all petroleum products should be

[10]One reservation applies - Rao & Rao (2005*a*) claims that Borenstein et al. (1997) incorrectly applies the Wolfram split (p. 3) which is not the case.

Table 3.3: Applied Research - Product Coverage

Product	Number of Studies
ULP	24
LP	14
Gasoil	4
Total	42

priced simultaneously and follow the same trend, so that the cross-product aggregation should not lead to significant bias in the estimation.[11] Interestingly, some recent studies do show significant differences in the degree of asymmetry between different product categories (e.g. regular and premium ULP - see Wlazlowski et al. (2006), or even brands - see Verlinda (2006)). However, those issues are not yet fully addressed in the literature.

Tier Aggregation The majority of APT studies uses only two tiers (usually the extreme ones, i.e. crude oil and retail). This might blur the picture of price transmission, especially when the frequency unit chosen is higher than the length of the physical refinement process (reported by Yergin (1991) to reach one month).

Table 3.4 presents the overview of a number of tiers used in previous studies.[12] The results indicate that the majority of the studies utilize only two tiers. Furthermore, the results of meta-analysis support the earlier observations about incomparability of tiers in Canada / the USA and Europe - studies utilizing four tiers cover only North America.

Table 3.4: Applied Research - Tiers Covered

Method	Number of Studies
Two Tiers	29
Three Tiers	9
Four Tiers	2
Total	40

This issue is also related to establishing the direction of causality and endogeneity of price series (see section 3.2.3 for details).

Spatial Aggregation Similarly to intertemporal aggregation, the lack of transaction-level data makes a certain degree of spatial aggregation unavoidable. Unfortunately, the impact of spatial data aggregation on price transmission has not been studied in detail

[11]The only exception would apply to aggregating leaded and unleaded petrol. Whenever LP is phased out through the EU, its pricing becomes more erratic and less synchronised with the common market trend. Therefore, studies that sum the prices of those products (e.g. Grasso & Manera (2007)) should be treated with caution as they not investigate the true market situation, but rather a function of unrelated pricing decisions.

[12]Given that some studies use different definitions of wholesale and spot markets, comparing the number of tiers might be more meaningful than listing the names tiers covered.

so far, although Ye et al. (2005) claim that spatial aggregation might adversely affect reliability of APT studies. Other studies indicate that city-sized markets do follow some common trends, so aggregating over them should not affect the results of APT - see Godby et al. (2000), Bremmer & Christ (2002), Eckert (2002) and Noel (2007*b*). Table 3.5 presents the results of meta-analysis of geographical coverage of APT studies.

Table 3.5: Applied Research - Country Coverage

Country	Number of Studies
US	21
UK	12
Germany	5
the Netherlands	3
Canada	2
Total	42

Note: Other countries were covered in one study. They include Fiji, Philippines, Sweden and Spain.

Applied research covers only seven EU countries and out of that number only five countries are analysed within a coherent framework (Galeotti et al. (2003) and Grasso & Manera (2007) each cover five countries).[13] Arpa et al. (2005) utilize a EU-wide dataset but not with APT in mind and in a manner that suffers from omissions (information on foreign exchange and crude oil was left out) and weaknesses (utilizing the completely abandoned Bewley's transformation). The scant coverage of the EU shows how fragmented the picture of APT is and how rare are cross-country, -product and -tier comparisons.

Regional data are the only alternative to national price data, however, geographically disaggregated datasets are rare, expensive and constrained to North America.[14] Table 3.6 presents the results of appropriate meta-analysis.

Table 3.6: Applied Research - Spatial Aggregation

Country	Number of Studies
National Level	30
Regional Level	10
International	1
Total	41

Because of the size and the degree of integration of oil business, petroleum price transmission is not a local phenomena. Although some of the final users will never buy petroleum products outside their immediate neighbourhood, the size of oil companies, the

[13]These are respectively Germany, France, Italy, the Netherlands, Spain, Sweden and the UK and Germany, France, Italy, Spain and the UK.

[14]Asplund et al. (2000) is the only one to utilize European data at this level of disaggregation. However, his data are constrained to one chain of Swedish filling stations.

degree of their integration and the uniform nature of the products makes pricing a pan-regional act. As such, the fact that most of the studies use national data should not be a significant problem as even the aggregated data should give a coherent picture of pricing behaviour. Bearing that in mind, one has to remember that regional studies are superior whenever researchers are interested in specific mechanics of pricing (e.g. the value of retail branding) or testing some of the sophisticated theories attempting to explain APT (see section 6.2 for details).

Sen (2003) analyses the transmission in Canada using city-level data. Using the modelling framework in a form of a panel of the LR price equations, enriched by lags of explanatory variables, city-specific effects, measures of retail market concentration (Herfindahl index, numbers of competitors and gas stations, volume of sales, etc.) and the economic climate (unemployment rate), the author finds that both local retail market concentration and wholesale prices are significantly associated with trends in retail prices. In the wholesale market, changes in both the number of local wholesalers and crude oil price are significantly associated with movements in wholesale prices. However, the results show that the variance of wholesale prices is a more important determinant of the variance of retail prices than the variance of local market concentration. Similarly, trends in average crude oil prices are a more important determinant of wholesale price relative to local market competition. As such, as long as markets are integrated, even local differences in economic conditions should not affect price transmission.

3.2.3 Estimation Methods

Integration and Cointegration

Since every APT study utilizes time series, issues of spurious regression and cointegration are of uttermost importance. Given that the review of applied work presented in section 3.1 focuses solely on the research that used models consistent with the idea of cointegration, the issue of spurious regression does not have to be addressed here. However, one must remember that although some studies do use cointegration-consistent models, they nonetheless neglect testing for the order of data integration and the presence of cointegration between the series. While this doesn't invalidate their results, the failure to analyse and account for the order of data integration could affect the efficiency of estimation or reliability of tests performed.

Table 3.7: Applied Research - Order of Integration

Method	Number of Studies
Tested	32
Neglected	8
Total	40

Causality and Endogeneity

As pointed out by Geweke (2004), it is possible (although not likely) that prices downstream can cause those upstream. Similarly, the problem of endogeneity of variables might also occur, especially if some (unobservable) determinants of the downstream prices are correlated with upstream prices, either because of omitted seasonality / cyclicity or demand shocks. This results in measurement error or simultaneous equations biases (depending on the source of endogeneity). Therefore, correct identification of causality and endogeneity of the series is a prerequisite for obtaining credible results.

Unfortunately, those issues are largely neglected in the literature - see discussions in Borenstein et al. (1997, p. 316-317) and Geweke (2004, p. 8). Apart from those two studies, only Balke et al. (1998) and Wlazlowski et al. (2006) account for those issues in a comprehensive manner.

Table 3.8: Applied Research - Direction of Causality

Method	Number of Studies
Tested	8
Neglected	32
Total	40

Stability of Pricing Relationships

As pointed out by Cramon-Taubadel & Meyer (2001) (see section 6.2.3 for details), stability of LR pricing relationship is crucial for maintaining a prescribed size of some of the APT tests. The presence of structural changes might affect the size of the APT tests and lead to erroneous inference. Furthermore, as shown by Johansen, Mosconi & Nielsen (2000), the presence of structural changes may lead to potential over-rejection of cointegration hypothesis.

Despite the seriousness of the above, with the exception of Sumner (1990), Manning (1991), Reilly & Witt (1998), Driffield et al. (2003) and Wlazlowski et al. (2006), the existing literature disregards the of structural changes in price relationships.

Models Applied Table 3.9 shows that among all models described in chapter 2, the most commonly used are those based on the augmented ECM.

Table 3.9: Applied Research - Estimation Methods

Method	Number of Studies
ECM (2.13, 2.15)	29
TAR (2.35, 2.36)	6
Other (2.3 and VARs)	5
Total	40

Given the drawbacks of ECM-based models described in section 2.2.3, one has to conclude that a significant portion of applied literature has to be treated with some caution. In particular, the ECM-based models utilize a framework with potentially low power, do not allow for efficient assessment of the excess of APT or regime identification and could lead to incorrect economic interpretation - see discussion on page 50. Other estimation techniques suffer either from arbitrary assumptions (PAMs) or difficulties in testing the null of SPT (SETAR models, discussed in section 2.2.4).

Testing for Non-linearities

Some of the articles attempt to measure APT without testing the null of SPT first. This is mainly because they use TAR models, which invalidate traditional testing framework (see Davies (1987)) and require derivation of asymptotics or computationally-burdensome bootstrap methods (see Hansen (1997)). The past research either neglects this crucial element (Wlazlowski (2003*a*) or Lewis (2004)) or misrepresents SPT tests.[15] Notable exceptions include Godby et al. (2000), Grasso & Manera (2007) and Wlazlowski et al. (2006).

3.2.4 Assumptions Made

In every piece of applied research, certain assumptions and simplifications are unavoidable. In this section we discuss those that could potentially adversely affect the reliability of APT studies. We separately discuss assumptions taken directly and those resulting from tools used in the research.

[15]This involves reporting aggregate responses to upstream increases and decreases with appropriate confidence intervals - Borenstein et al. (1997).

Direct Assumptions

The choice of economic tiers, between which the transmission is assumed to take place, can drastically affect the results of APT analysis. This mainly applies to the choice of particular crude oil price series, as prices of many different varieties are available to researchers. The problem is only worsened as crudes are traded internationally, publicly priced and are believed to be perfect substitutes (for a discussion of this claim see section 1.3). While the majority of the studies seem to analyse transmission between related tiers, Galeotti et al. (2003) link ULP in the EU with US crude oil and Driffield et al. (2003) links ULP in the UK with Saudi crude.

Similarly to temporal aggregation, aggregation of data across transmission tiers is an outcome of limited data availability. This in particular applies to middle tiers, which are difficult to identify (see section 1.3) and are not covered by the traditional data sources.[16]

Indirect Assumptions

Estimation techniques introduce indirect assumptions either through the pricing function employed in the analysis or through the framework used to test the null of SPT.

The first set of assumptions is related to the pricing function modelled. As discussed in section 2.2.1, the choice is between linear and Cobb-Douglas functions. This choice determines: (i) elasticity and flexibility of pricing function; (ii) the pass-through and whether the mark-up is expressed in constant monetary or percentage units; (iii) how the foreign exchange variable is introduced into the relationship.

Some authors decide to assume full pass-through between upstream and downstream prices, which is disputable - especially when in order to include the foreign exchange rates, they also use Cobb-Douglas pricing function. Since this function expresses downstream prices as a percentage of upstream prices, if fixed costs are present, the full pass-through should not to be expected. Accordingly, if transmission originates from the crude oil, regardless of the pricing function, it is hard to expect the full pass-through since several products are obtained from the same crude.

Accordingly, the assumption of constant monetary margin might be criticised, even in cases when upstream and downstream prices are expressed in the same currency. This might be for two reasons: (i) the pass-through estimates often diverge from unity (see discussion Lewis (2004) and Verlinda (2006)) and (ii) the microanalysis indicates that the

[16]This is clearly visible when comparing EU and US - see Borenstein et al. (1997) and Denni & Frewer (2006). While in the US there are several similar wholesale (PADD-level) markets, EU countries have largely independent and incomparable national wholesale markets.

assumption of constant monetary mark-up *misses important aspects of gasoline station's pricing behaviour* - Hosken et al. (2007, p. 20).[17] Furthermore, the assumption of variable elasticity implied by the linear function does not find support in the literature.

The pricing function could also be enriched by introduction of other costs. This solution, first proposed by Sumner (1990) involves taking some far-reaching assumptions about the nature of other costs present and the way to proxy them (for example Sumner (1990) utilizes labour costs). Reilly & Witt (1998) and Wlazlowski (2003*a*) proxy all other costs by a linear trend, but this assumption implies a constant rate of cost inflation, which is disputable. Furthermore, inclusion of a linear trend means de-trending the data, which might be challenged as petroleum prices do not exhibit a significant and common trend.

A typical assumption induced by SPT testing framework is that of a bi-polar shape of non-linearities and sudden change of the pricing regimes. It implies that pricing agents focus on one dimension of the market situation (such as the direction of the price change) and disregard the intricacies of the market situation (such as the size of the change, past trends, etc.). While some researchers acknowledge that there is more to pricing than a simple bi-polar model (for example Godby et al. (2000) and Wlazlowski (2003*a*)), tools that assume sudden shifts between a discrete number of pricing regimes are still commonly used.

The sudden change of pricing behaviour is inherent in almost all models utilized in the applied literature - see Table 3.9 for an overview. This is either done directly - as implied by the regime change in SETAR models or indirectly - through the numerous regimes of ECM-based models, caused by the SR and LR variables, each split in two. In both cases, it implies that pricing agents operate in a binary fashion, which is highly unlikely given the plethora of agents operating in every market and their diversity - McFadden (2001).

One has to remember that whenever prices at different tiers are expressed in different currencies, an appropriate exchange rate *must* be included in the analysis, as neglecting that fundamental aspect of the study invalidates the inference - see Contin et al. (2004). A similar but less dangerous assumption is to limit the source of APT only to upstream prices and not FEX - this applies to Driffield et al. (2003). This could be either rectified in a direct manner - as advocated in Reilly & Witt (1998) or indirectly - through estimation of SETAR/STAR models for residuals from Cobb-Douglas level equation.

[17] The most significant elements might include return on variable costs.

3.2.5 Proposed Improvements

In this section we discuss the key improvements introduced in this research. They are addressed in detail in the next three chapters.

Data

Since we use multi -country, -product and -tier dataset of high frequency, we are able to obtain a comprehensive overview of petroleum markets in the EU. Furthermore, we use the same-day daily data which guarantees that the economic linkages between prices are preserved. The dataset used in this dissertation is discussed in greater detail in section 4.1.1.

Estimation

For the core analysis and testing the null of SPT we utilize smooth transition models (STAR) which allow us to analyse for a wider range of non-linearities without imposing a particular shape of non-linearities (see discussion about transition functions given by (2.39) and (2.40)). Such a framework involves straightforward testing for the presence of non-linearities, without computationally complex simulations and bootstrap. Furthermore, unlike previously applied techniques, STAR models do not imply sudden and dramatic changes in pricing regime, but rather smooth transition between two sets of pricing behaviours. An additional advantage of those models is that they depend on contemporaneous disequilibria, rather than on a long price history and cope better with imperfections of the data, such as intertemporal aggregation and structural changes. Last but not least, STAR models offer a reasonably straightforward framework for simulation of pricing responses to market developments of different character and magnitude. A detailed discussion of the proposed econometric framework is presented in sections 4.1.1, 4.2 and 5.2.1.

Assumptions

Compared to the previous research, we do not impose significant restrictions on the nature of the pricing relationships and the shape of APT. Whenever this is not possible, we verify the validity of the assumptions made. In particular, given the conflicting evidence on full pass-through assumption given by Norman & Shin (1991), Wlazlowski (2003*a*), Kaufmann & Laskowski (2005) and Ye et al. (2005) on one hand and Borenstein & Shephard (1996), Driffield et al. (2003), Lewis (2004) and Wlazlowski et al. (2006) on the other, we attempt to perform the appropriate tests. Accordingly, we recognize that the sample used in this research covers times of changing prices so that a constant monetary-margin assumption made e.g. by Bacon (1991) and Borenstein et al. (1997) is not credible. Therefore, we utilize a Cobb-Douglas function which assumes constant percentage mark-up - which allows for cost-plus pricing, which is common within integrated companies - Holmstrom & Tirole (1991). Furthermore, the pricing function used allows for straightforward incorporation of foreign exchange rates, necessary given that EU prices are not denominated in USD.

Perhaps more importantly, we utilize the framework that allows us to test the null of SPT without specifying the alternative. We utilize the procedure that can help us to distinguish between LSTAR and ESTAR type of non-linearities. The correct formulation of the transition function is of uttermost importance as it allows us to distinguish between welfare decreasing non-linearities (proxied by LSTAR model) and more mundane non-linearities caused by market frictions (proxied by ESTAR model).

In the next chapter we attempt to rectify the first two issues identified here - i.e. those related to suboptimal pricing data and the issues of endogeneity and causality in crude oil prices.

Chapter 4

Long-run Equilibrium in Petroleum Markets

This chapter describes the first part of the applied analysis of the EU price transmission and is based on Wlazlowski (2007) and Hagströmer & Wlazlowski (2007). Firstly, we present the dataset used and discuss in what ways it constitutes an improvement over data used in previous studies. Secondly, we discuss the issues of causality between different crude oil prices and problems with the choice of the crude for the analysis. Next, after identifying crudes from which price transmission should originate, we analyse if this transmission is properly defined. Once the issue of exogeneity of upstream prices is addressed, we check for the properties of the price series and whether the relationship we analyse is not spurious. After ascertaining that indeed upstream prices define prices downstream we analyse the properties of the long-run relationship between those series.

4.1 Midstream and Downstream Data

4.1.1 Introduction

Our data cover the period 1995-2005 (for the "old" EU countries) and 2004-2005 (for the "new" EU countries). The dataset comprises daily observations taken at weekly intervals for four major groups of series: (i) retail prices - DSPs, (ii) midstream prices - MSPs, (iii) crude oil prices - USPs and (iv) appropriate foreign exchange rates. In this section we analyse DSPs and MSPs, and the choice of crude oil is described in detail in the next section.

DSPs

DSPs come from the Oil Bulletin published by the European Commission. For all Euro-zone countries, prices denoted in Euro after January 1, 2002 are translated into the original currencies using fixed parities established by the European Central Bank. This is the standard practice in price transmission studies, used e.g. in Grasso & Manera (2007).[1]

Prior to the analysis, all DSP series were revised to assure consistency and applicability of statistical techniques. The following actions were taken:

- $y_t^{(CY,LP)}$, $y_t^{(BE,LP)}$, $y_t^{(EE,RFO-1)}$, $y_t^{(HU,RFO-2)}$, $y_t^{(EE,RFO-1)}$ and $y_t^{(LV,RFO-2-1)}$ were removed from the sample (those series had less than five observations or no price variance);
- $y_t^{(IE,RFO-1)}$ and $y_t^{(IE,RFO-2)}$ were identical, so only one of them was used.

USPs

USPs quotes come from two sources: (i) weekly prices of 32 varieties of crudes spanning the period January 1997 - March 2006 come from the Energy Information Agency, (ii) daily prices of three major benchmark crudes from January 1994 to December 2005 come from the DataStream database. The observations used in the analysis are taken for the same (or the earliest available) day as the DSPs. When the data were not available on that particular day, the previous calendar day's prices are used. This approach is common in the literature, and advocated e.g. by Garber (1986). It allowed us to solve the intertemporal alignment problem described in section 3.2.2.

Additional information on quality of the crudes (as described by light/medium/heavy varieties) was also gathered from industry publications. The classification adopted is described in section 4.2.1.

MSPs

Usage of a comprehensive MSP dataset constitutes one of the improvements over the previous studies. In this analysis we use mid-stream price data provided by Platt's - a leading industry consultancy and popular price data provider.

The price series represent a true market assessment of the value of petroleum products. Platt's (2006*b*, p. 2) defines the observations as:

[1]In principle, the introduction of Euro could have affected the price transmission via the "money illusion" phenomenon and higher real mark-ups. In practice, the whole process was closely monitored by the authorities in order to prevent it. Their success is confirmed for example by Glauben, Loy & Meyer (2005) who fails to find any evidence that introduction of EUR affected symmetry of price transmission.

(...) transactable value prevailing at 16.30:00 (*British Time, which*) reflects values on a market-on-close basis. (...) Platt's considers transactions, bid/offer levels and market indications that are reflective of typical conditions and originating from sources deemed reliable.

Furthermore, Platt's data are widely used as a reference point in so called price formulae used to price the over-the-counter transactions - see Claessens & Varangis (1995) and Bacon & Kojima (2006). Given the above, the data used in this dissertation offer a comprehensive and reliable coverage of the medium stage in price transmission. Table 4.1 presents the details of the prices chosen for the analysis.

Table 4.1: Description of the MSP Series

Name	Code	Location[2]	Description	From-To	
ULP	PGABM00	AR-	The barge assessments represent 95 RON, 85 MON German grade material with a specific gravity basis of 0.755 g/ml. The maximum sulphur is 10 ppm. Aromatics limit is 35 max.	3/1/1994	30/12/2005
Diesel			No consistent assessment available		
HO	POAAG00	-R-	The barge assessments represent heating oil grades with a specific gravity of 0.845 g/ml with a maximum sulphur content of 0.2%.	3/1/1994	30/12/2005
RFO.1	PUAAP00	ARA	The assessment reflects Belgium specification fuel oil with a maximum sulphur of 1%. German specification material is not reflected. The quality represented is, however, in line with power plant requirements in the region. This results in the price of the material being influenced by specification such as metals content s much as the sulphur content. The metals content in the 3.5% sulphur is tighter than the specifications in 1.0% barges. This may result in 1.0% sulphur being at times cheaper than 3.5%, but the cause is the metals content, obviously not the sulphur.	3/1/1994	30/12/2005
RFO.2	PUABC00	-R-	3.5% sulphur barges reflect RMG 35 bunker grade material. Typical specifications are 3 to 4% sulphur content, specific gravity of 0.991 g/ml, and viscosity of around 380 centistokes at 50 degrees C.	3/1/1994	30/12/2006
LPG [3]	PMAAS00	ARA	Propane Pressurised vessels including both field-grade and refinery material with a minimum of 93% C3s and a maximum of 30% olefinic content.	7/1/1994	30/12/2005
LP[4]	PGABV00	MED	Prem 0.15 FOB	3/1/1994	31/3/2005

Before the analysis, the dataset was reviewed so as to ascertain consistency with other series and ability to reflect the economic character of the APT phenomenon analysed. Below we summarize steps taken.

All Series By default, Platt's presents daily high and low quotes. Garman & Klass (1980) claim that utilising high/low quotes instead of open/close can give significantly better estimates of the market situation and therefore it is advised e.g. for the purposes of volatility testing. Accordingly, we used the daily high-low averages.

[2] ARA - Amsterdam-Rotterdam-Antwerp.

[3] Until December 1995, the data were published on a weekly basis (every Thursday).

[4] Data for the last 9 months of 2005 is not available.

LP In 2002 the changes in the EU environmental regulations rendered the use of lead in petroleum illegal. However, EU granted some member states the right to sell motor spirits in which environmentally harmful substances were replaced and which could be used in older cars. For all the practical purposes, the trade in those products should be considered a continuation of the trade in leaded petrol. This was recognised by Platt's and reflected in its assessments - Platt's (2006*b*, p. 69).

LPG LPG began to be widely used as a motor spirit relatively late (in the late mid-1990s). Therefore, the official data for the years 1994-1995 were published on a weekly basis (every Thursday). From 1996 onwards, the daily data were available. This should not affect the results of the analysis - as DSP data were also presented on the weekly basis (earlier day) and the USP data are available on a daily basis.

Apart from issues with availability of price data, LPG stands out compared to the other products as it can be obtained from two sources - from crude oil refinement or natural gas extraction (associated gas). Worldwide, about 40% of the LPG is produced in crude oil refining and 60% is produced during crude oil and natural gas extraction - Hekkert, Hendriks, Faaij & Neelis (2005). Those two sources differ significantly in terms of production technology (associated gas does not have to be processed unlike crude oil) and economic properties (transporting LPG from the extraction site to the consumer is less efficient than transporting crude oil to the refiner). Therefore, although crude oil remains the main source of LPG, its pricing mechanism is unique in some aspects. The empirical analysis presented in the following chapters confirms this.

Diesel Because of the increasing popularity of Diesel engines and related changes in the local and EU-wide environmental regulations, more than one series should be used to cover trade in this motor spirit. Platt's publishes the following assessments:

- AFI - Gasoil EN590 FOB Rotterdam - Barges, starts on 02/09/1996, ends on 31/03/2003;
- AQF - Gasoil EN590 FOB North-West Europe Cargo Hi, starts on 01/07/1994, ends on 31/12/2004;
- GMK - Diesel 50ppm FOB Amsterdam Rotterdam Antwerp - Barges, starts on 02/04/2001, ends on 16/02/2007;
- KWR - Diesel 10ppm FOB North-West Europe, starts on 02/12/2002, ends on 16/02/2007;

- OQA - Diesel 50ppm FOB North-West Europe - Cargoes, starts on 01/07/2004, ends on 16/02/2007;
- JUS - Diesel 10ppm FOB Amsterdam Rotterdam Antwerp - Barges, starts on 01/10/2002, ends on 16/02/2007;
- IKM - Diesel 50ppm UK Cargoes, starts on 01/02/2002, ends on 16/02/2007.

The results of the chemical analysis presented in Platt's (2006*b*) indicate that all the above-listed products are perfect substitutes, differentiated only by the sulphur content. Furthermore, the assessments refer to products traded in close geographical proximity. In order to ascertain that the series were indeed similar, we calculated the correlation coefficient for the *changes* in the series. Table 4.2 presents the results.

Table 4.2: Diesel Series - Correlation of First Differences

Codes	Correlation	Begin	End
AFI-AQF	0.843	03/09/1996	31/03/2003
AFI-GMK	0.967	03/04/2001	31/03/2003
AFI-KWR	0.613	03/12/2002	31/03/2003
AFI-JUS	0.976	02/10/2002	31/03/2003
AFI-IKM	0.698	04/02/2002	31/03/2003
AQF-GMK	0.781	03/04/2001	31/12/2004
AQF-KWR	0.937	03/12/2002	31/12/2004
AQF-OQA	0.946	02/07/2004	31/12/2004
AQF-JUS	0.747	02/10/2002	31/12/2004
AQF-IKM	0.927	04/02/2002	31/12/2004
GMK-KWR	0.888	03/12/2002	16/02/2007
GMK-OQA	0.937	02/07/2004	16/02/2007
GMK-JUS	0.979	02/10/2002	16/02/2007
GMK-IKM	0.884	04/02/2002	16/02/2007
KWR-OQA	0.988	02/07/2004	16/02/2007
KWR-JUS	0.879	03/12/2002	16/02/2007
KWR-IKM	0.978	03/12/2002	16/02/2007
OQA-JUS	0.934	02/07/2004	16/02/2007
OQA-IKM	0.984	02/07/2004	16/02/2007
JUS-IKM	0.871	02/10/2002	16/02/2007

The correlation between changes in price series is high, confirming that all products are close substitutes. Given the above, the series could be combined into one series that would reflect the market situation while accounting for the changing environmental policies. Based on the results presented above and industry information provided in Platt's (2006*a*), the final series for Diesel oil was obtained by merging three sub-series for different qualities of Diesel - AQF (complying with the EN590 regulations), IKM (the first series accounting for the strict environmental laws introduced in the EU) and KWR (a series which which reflects the introduction of 10ppm rule). The time domains of the sub-series are: (i) July 1, 1994 - February 1, 2002 (AQF), (ii) February 1, 2002 - December 1, 2002 and (iii) December 2, 2002 - December 30, 2005 (KWR). The resulting series is used throughout the entire analysis.

Exchange Rate

Data on the exchange rates between local currencies and USD come from the DataStream database. The data follow the official exchange up till the introduction of EUR, after which the exchange rate follows the EUR/USD exchange rate. Similarly to MSP / USP data, the exchange rate quotes are taken for the same (or the earliest available) day as the appropriate USD upstream assessment.

4.1.2 Properties of the Data

Summary Statistics

Tables A.17, A.18 and A.19 present the summary statistics of the DSPs, MSPs and USPs, respectively. The series are found to exhibit non-normality (as indicated by skewness and kurtosis estimates - γ_1 and γ_2) which is typical for high frequency market series - Chan (2002).

Order of Integration

Table A.22 presents the results of the ADF tests for all the series and their first differences. The tests of the null hypothesis of stationarity, with the lag order k equal to $\lfloor((n_x-1)^{\frac{1}{3}})\rfloor$ utilize the critical values taken from Banerjee et al. (1993, Table 4.2, p. 103). Virtually all series are found to be integrated of order one and their first differences are found to be stationary (as is the case for most price data).[5]

Runs

Following Eckert (2002), we analyse the distribution of price runs in DSPs, i.e. the empirical distribution of lengths of periods in which the prices continuously increased or fell. Table A.70 presents the data on:

- number of runs and their average length (split between runs up, runs down and constant runs);

[5]The only exception is for the Czech Republic, for which the first difference was found to be also I(1), this however, might be due to the short sample. Since standard ADF tests are susceptible to volatility clustering and structural breaks, the results were also verified with the help of Phillips-Perron tests for the null hypothesis that a series has a unit root - Perron (1988). The results remained unchanged.

- average increase and average decrease;
- number of increases and decreases, together with the KS test of the null that in absolute terms increases and decreases come from the same distribution.

Based on the results obtained we have no reason to reject the null that all price increases and decreases are drawn from the same (in absolute terms) distribution. While the significance of this finding is discussed at length in section 6.2.3, it is enough to state here that the results suggest that price cycles (if present at all in the sample) are fairly symmetric in terms of their lengths and sizes.

4.2 Crude Oil Data

4.2.1 Motivation

Any analysis of the energy markets must address the peculiarities of crude oil supply described in the section 1.3. Failure to identify the correct starting point of price transmission (e.g. the right variety of crude oil) might invalidate the inference as prices analysed are not linked according to economic transactions.

The biggest challenges in terms of reliability are posed by (i) the existence of a plethora of different varieties of crudes, some of which are only imperfect substitutes for each other, and (ii) difficulties in finding the crude oil whose prices represent the market and can be used for the purposes of the analysis of price transmission. Below, we address those issues.

Varieties of Crude Oil

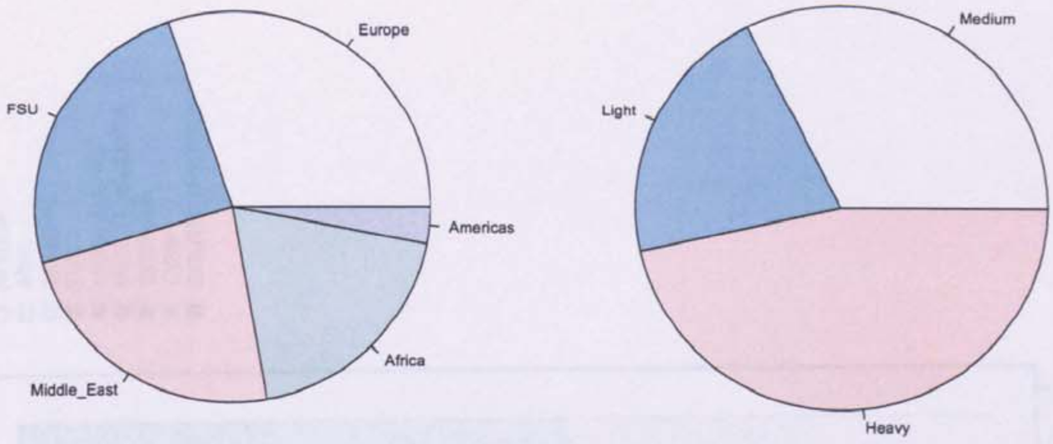
Crude oil comes in a plethora of varieties usually distinguished based on their country/region of origin and chemical properties. Given the costs of adjusting the refining process to a different quality of crude oil, any detailed analysis of crude oil markets must involve the discussion of crude oil quality - see section 1.3. Since different varieties of crude oils are only imperfect substitutes and there are over 500 of them traded internationally, one has to identify which crudes most closely represent the prevalent market behaviour.

The perfect solution to the problem would be to analyse the actual crude oil feeds into EU refineries and choose the most popular one. Unfortunately, the feed structure evolves and the consistent data on the 25 EU countries comprising the sample are not available - see Antill & Arnott (2000, p. 42) for a discussion about data availability. Furthermore, given the technological diversity of EU refineries, no single crude is used in *all* countries.[6]

The available data suggest that the EU enjoys disaggregated supply of crude oil, both in terms of geography and quality. Figure 4.1 shows the sources of crudes in the EU-15, split between geographic regions and quality. Figures 4.2 - 4.4 present the evolution of the supply structure over time - they indicate that the diversification of the EU supply is fairly stable over time and offers no support for the claims that a particular crude / class of crudes dominates the supply. The increase in the usage of low quality / heavy crudes, although clearly visible, is still not large enough to make those crudes dominate the market.

[6] The most striking feature of the market is the continuing East-West split, with ex-Communist countries still feeding the Russian high sulphur oil using technologies supplied by the FSU countries - Antill & Arnott (2000).

Figure 4.1: Supply of European Crude Oil



Source: Eurostat.

Importance of Price Benchmarks

Given how diversified the supply structure is, it impossible to find one crude or class of crudes that could be considered to be the main feed for the EU refineries. Therefore, it is necessary to find a reliable market indicator that can be applied for the purposes of the analysis. Such crude, while not *physically* and *directly* driving the prices of the petroleum products in the EU, could cause changes in the prices of *other crudes* and thus affect the whole EU market.

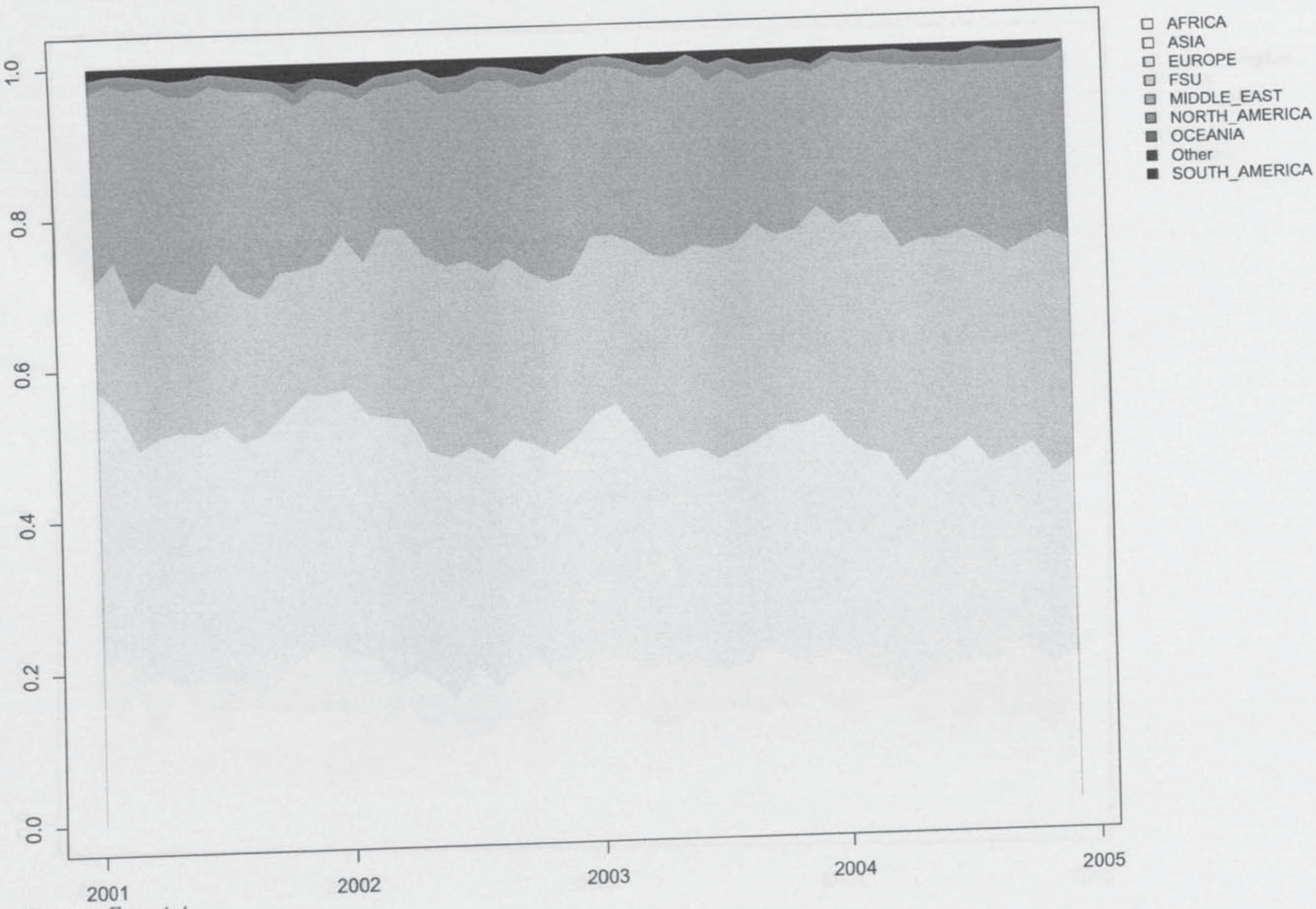
The easiest criterion for establishing such a crude is to analyse which crude *leads* others with respect to prices, i.e. initiates the market changes. Such crude would capture the market trends and drive other crudes. Obviously, its prices would proxy prices of other crude oils and could be easily used for the purposes of price transmission analysis.

This is also important given the trends visible in the global markets - in particular (i) increasing share of low quality crudes in the global supply, and (ii) strong focus on high quality crudes, which although in short supply, are still considered to be the reliable indicators of the market situation.

With global energy demand soaring, more and more reservoirs of different varieties of crude oils enter the energy markets (see Bahree & Gold (2006), for most recent examples). In the increasingly volatile crude oil market, the differences in crudes' qualities (light/medium/heavy, sweet/sour, etc.) prevent straightforward observations of *which* crudes swiftly reflect changes in market segments and can be regarded as benchmark crudes - see Wilkinson (2004).

There are three well-established *benchmark* crudes on the market: Brent, WTI and

Figure 4.2: Supply of European Crude Oil by Region



Source: Eurostat.

Figure 4.3: Supply of European Crude Oil by Country

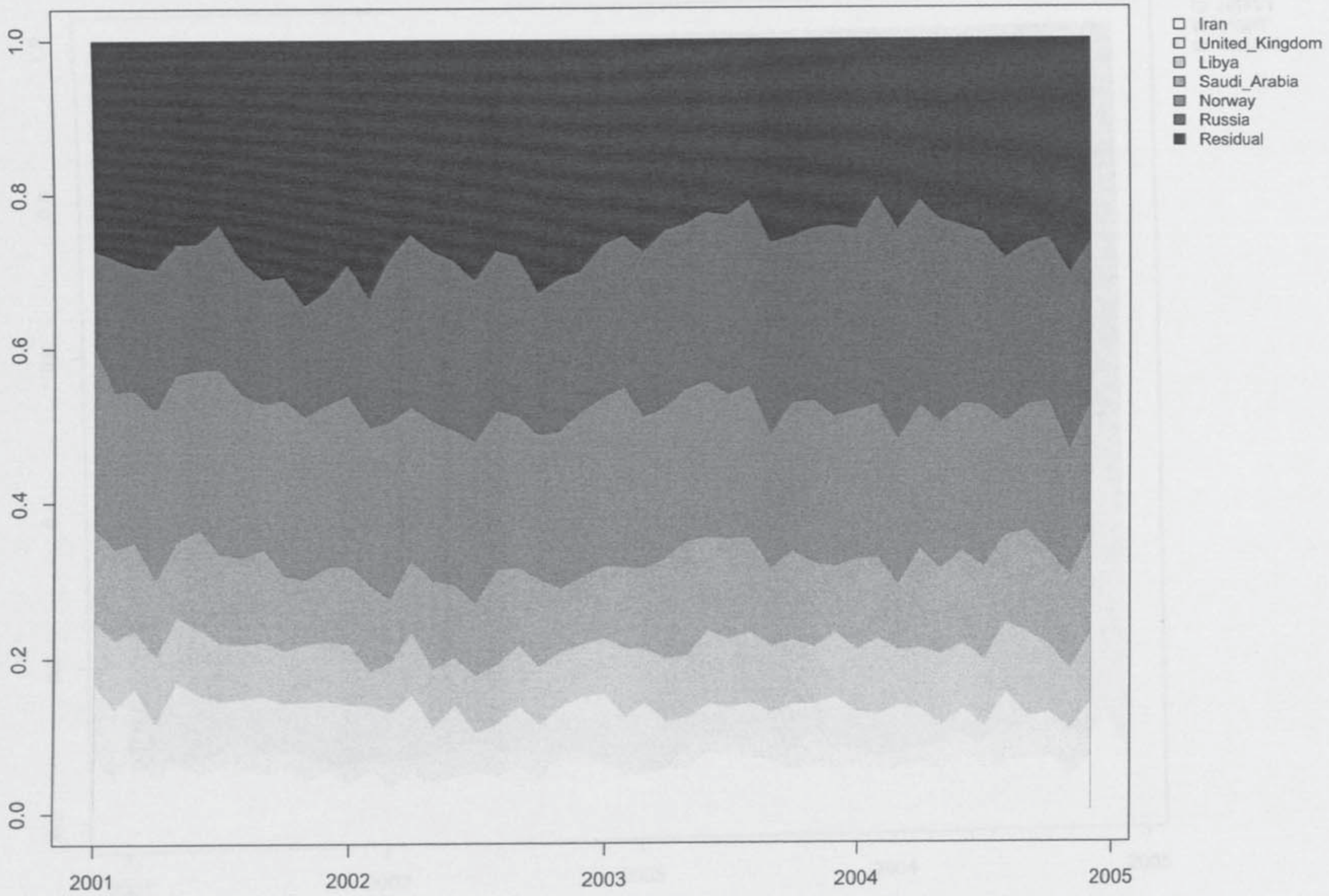
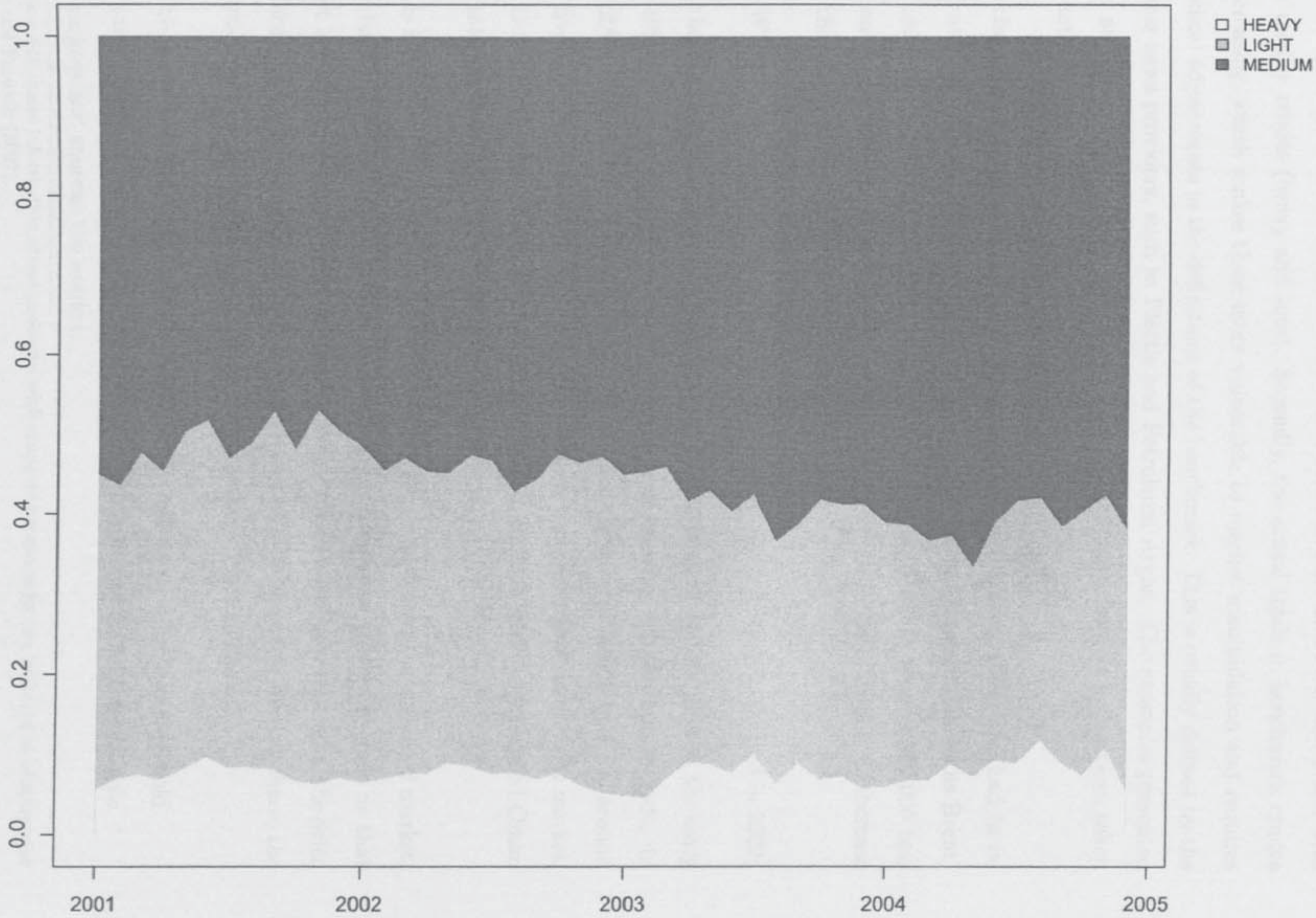


Figure 4.4: Supply of European Crude Oil by Quality



Dubai Fateh. In practice, these served as guidelines for price-setting since the mid-1980s - Platt's (2006*a*), but their relevance cannot be taken for granted. In fact, their leading role has declined over the years because of the two main reasons - see Wilkinson (2004) and Montepeque (2005). Firstly, Brent and WTI are both high quality crudes (light and sweet), whereas the global crude oil market is more and more concerned with lower quality crudes (heavy and sour). Secondly, the actual trade in benchmark crudes is decreasing, which makes them more vulnerable to market manipulation and requires periodical adjustments in the definitions of the benchmark. This is usually defined by the business news providers, such as Platt's and Petroleum Argus. The examples presented below are taken from Fattouh (2006) and illustrate potential dangers and actions taken to counter them:

- the Brent system witnessed a decline in supply in the early 1990s and had to be mingled with the Ninian system. The combined production (still known as Brent) increased to around 900,000 bpd in 1992, but by 2002 fell to around 350,000 bpd and again had to be mingled with other crudes (Forties and Oseberg) to increase the supply to 60-70 cargoes per month;
- WTI sources steadily depleted until they reached the level of 400,000 bpd in 2002;
- the volume of Dubai supply has dropped from a peak of 400,000 bpd in the early 1990s to under 120,000 bpd in 2004, with production at 100,000 bpd in 2005. In 2006, Dubai crude continued to fall and reached the level of 90,000 bpd, i.e. around five cargoes each month, with only four of these cargoes traded on the spot market. Due to this rapid fall in Dubai's oil production, in 2001 Platt's introduced Oman into the assessment mechanism.[7]

It is important to remember that the benchmarks are traded on the organized market, which balances and clears supply and demand. Even though the volume of trade on that market is minute compared to the market for term / over-the-counter contracts, the price is determined at the margin, i.e. in the spot market. Given their low market share, the benchmark crudes are more susceptible to manipulation - Platt's (2006*a*):

> Volume of oil available for spot trading may fall below a critical threshold (*and*) it may become possible for companies to buy or control all the available cargoes and squeeze the market.

[7]Some additional information about problems with crude oil benchmarks can be found in Montepeque (2005) and Fattouh (2007).

Last but not least, for some crudes (most notably WTI), the pricing is partially dictated by the infrastructure logistics. For example, the 2007 bottleneck around Cushing, Oklahoma caused the decoupling of WTI prices from worldwide markets with potentially disastrous results - Fattouh (2007). Similarly, prices of benchmarks crudes are increasingly vulnerable to manipulation. How dangerous such a situation could be is illustrated by the 2008 oil price record which was caused by *one* trader who intentionally pushed the WTI prices over the 100 USD per barrel record with one very small order at the personal expense of 600 USD - BBC (2008).

These weaknesses of established benchmarks indicate that the relationships between prices of different crudes should be analysed so as to establish which crudes drive overall market prices and thus correctly represent market behaviour. Those crudes might serve if not as benchmarks then at least as robust indicators of the market situation. In this section, we seek to identify these indicator crudes.

Given the importance of identifying linkages between various kinds of crude oils, causality in crude oil prices has received surprisingly little attention. Previous research has stated various price setting relationships between oil qualities, but the investigation was constrained with respect to geographical markets and number of crudes.

Horsnell (1990) states that Dubai tends to be followed by Suez Blend. Montepeque (2005) states that Brent is followed by Mediterranean Russian Urals and that WTI is followed by Mars (an American sour crude benchmark, virtually unknown in Europe). Lin & Tamvakis (2004) argue that the price changes of Brent in London follow the price changes of WTI in New York. While previous research provides valuable insight into the global mechanisms of crude oil pricing, it covers only parts of the market.

4.2.2 Empirical Analysis

For the purposes of the analysis, the issue of finding a benchmark crude has to be analysed in a comprehensive manner, accounting for the entire global market. To meet that challenge, this analysis approaches the issue of causality in the crude oil market in a way that is unique in two respects:

- firstly, we model 32 different kinds of crudes, thus obtaining a complete picture of global interdependencies;
- secondly, we account for several characteristics of different crude oils, effectively analysing both the global market and its segments, such as:
  - quality segments (sweet and sour, and light, medium and heavy density crudes);

- geographical segments;
- segments for OPEC and non-OPEC products.

Our analysis is based on Granger causality tests which have been previously used to analyse the direction of causality in energy markets - see Manning (1991).

Montepeque (2005) provides a list of features that a good benchmark crude ideally should fulfill, but to the best of author's knowledge no empirical work exists which explicitly addresses the global market price dependencies. The question therefore remains about which varieties of crude first respond to changing market conditions (and therefore represent useful indicators for practitioners and policy makers), and which simply follow them (as one would expect in a closely integrated global market). However, a distinction should be made between *benchmarks*, that are used in practice for price setting and quality reference, and *price setters*, i.e. the crudes actually showing price changes first. In this section we focus on the latter. We identify crude oils which can be defined as *price setters* in the world markets and in different market segments.

The main motivation of the work is to identify the drivers of market trends in the global and local oil markets. The identification of these factors can be seen as relevant to companies worldwide when attempting to form expectations about future energy costs and to policy-makers when forecasting fuel and transport costs within the economy and their role in creating inflationary pressures.

Our approach does not involve a shift from the principle of a physical marker crude to futures-based market formula since it does not address the problems of speculative influence, physical manipulation and quality differentials (see Rehaag (1999) for a discussion). To obtain a complete overview, the testing framework was applied to each pair of 32 different crude oil qualities. The results are interpreted globally and in various subgroups, by splitting the crudes according to geographical origin, crude oil characteristic (API and sulphur content) and OPEC membership of the origin country. This allows us to establish:

- which crudes first respond to changes in the market environment - and therefore are *price setters*;
- which crudes mainly follow others - and therefore are *price takers*.

Based on the crude oil classification provided by OPEC (2005), we classified various crudes according to their:

)

- quality - the quality segments considered are *light density & sweet*, *medium density & sweet*, and *medium density & sour*;
- geographical source - the regions considered are *Europe*, *Middle East & Northern Africa* (the MENA countries), *Americas* (including North, Central and South America), *Sub-Saharan Africa*, and *Asia & Australia* (excluding Middle East);
- whether they were supplied by an OPEC member state.

Light density and sweet segments contain 9 crudes each; medium density / sour segment contains 13; and medium density / sweet segment contains 6. The sample for the quality segments of light density, sweet crudes and heavy density, sour crudes is too small for any practical purposes. The geographical segments are Europe (4 crudes), North and South American (8), Middle East and North Africa (13), Sub-Saharan Africa (4), and Asia and Australia (4). There are 17 crudes produced in non-OPEC countries, while the remaining 15 come from OPEC countries.

Table 4.3 presents details of the classification followed in this analysis.

Table 4.3: Crudes Analysed - APT and Sulphur Content

Symbol	Crude	API	Sulphur (%)
		Non-OPEC	
$x_t^{(1)}$	WTI Cushing	40° - light	0.2 - sweet
$x_t^{(2)}$	Europe Brent	38° - light	0.4 - sweet
$x_t^{(3)}$	Europe Norwegian Ekofisk	43° - light	0.1 - sweet
$x_t^{(4)}$	Canadian Par	40° - light	0.3 - sweet
$x_t^{(5)}$	Canada Lloyd Blend	22° - heavy	3.1 - sour
$x_t^{(6)}$	Mexico Isthmus	35° - medium	1.5 - sour
$x_t^{(7)}$	Mexico Maya	22° - heavy	3.3 - sour
$x_t^{(8)}$	Colombia Cano Limon	30° - medium	0.5 - sweet
$x_t^{(9)}$	Ecuador Oriente	29° - medium	1.0 - sour
$x_t^{(10)}$	Angola Cabinda	32° - medium	0.2 - sweet
$x_t^{(11)}$	Cameroon Kole	35° - medium	0.3 - sweet
$x_t^{(12)}$	Egypt Suez Blend	32° - medium	1.5 - sour
$x_t^{(13)}$	Oman Blend	34° - medium	0.8 - sour
$x_t^{(14)}$	Australia Gippsland	45° - light	0.1 - sweet
$x_t^{(15)}$	Malaysia Tapis	44° - light	0.1 - sweet
$x_t^{(16)}$	Mediterranean Russian Urals	32° - medium	1.3 - sour
$x_t^{(17)}$	China Daqing	33° - medium	0.1 - sweet
		OPEC	
$x_t^{(18)}$	Saudi Arabia Saudi Light	34° - medium	1.7 - sour
$x_t^{(19)}$	Saudi Arabia Arab Medium	31° - medium	2.3 - sour
$x_t^{(20)}$	Saudi Arabia Saudi Heavy	28° - medium	2.8 - sour

Table 4.3: Crudes Analysed - APT and Sulphur Content

Symbol	Crude	API	Sulphur (%)
$x_t^{(21)}$	Asia Murban	40° - light	0.8 - sour
$x_t^{(22)}$	Asia Dubai Fateh	32° - medium	1.9 - sour
$x_t^{(23)}$	Qatar Dukhan	40° - light	1.2 - sour
$x_t^{(24)}$	Mediterranean Seri Kerir Iran Light	34° - medium	1.4 - sour
$x_t^{(25)}$	Mediterranean Seri Kerir Iran Heavy	31° - medium	1.6 - sour
$x_t^{(26)}$	Kuwait Blend	31° - medium	2.5 - sour
$x_t^{(27)}$	Algeria Saharan Blend	44° - light	0.1 - sweet
$x_t^{(28)}$	Europe Nigerian Bonny Light	37° - light	0.1 - sweet
$x_t^{(29)}$	Europe Forcados	30° - medium	0.3 - sweet
$x_t^{(30)}$	Europe Libyan Es Sider	37° - light	0.4 - sweet
$x_t^{(31)}$	Indonesia Minas	34° - medium	0.1 - sweet
$x_t^{(32)}$	Venezuela Tia Juana	31° - medium	1.1 - sour

For each pair of the series, a Granger causality test was performed. Bivariate Granger causality tests for a pair of variables ($x_t^{(i)}$ and $x_t^{(j)}$) evaluate whether the past values of $x_t^{(i)}$ contain information useful for predicting $x_t^{(j)}$ once $x_t^{(j)}$'s history has been modelled. The null hypothesis, evaluated at a significance level of 5%, is that the past p values of $x_t^{(i)}$ do not help in predicting the value of $x_t^{(j)}$. The test is implemented by regressing $x_t^{(j)}$ on p past values of $x_t^{(i)}$ and p past values of $x_t^{(j)}$. An F-test is then used to determine whether the coefficients of the p past values of $x_t^{(i)}$ are jointly zero - Granger (1969). Each pair is evaluated as follows:

$$\begin{aligned} x_t^{(i)} &= \sum_{l=1}^{p} a_l x_{t-l}^{(i)} + \sum_{m=0}^{p} b_m x_{t-m}^{(j)} + e_t^{(i)} \\ x_t^{(j)} &= \sum_{l=0}^{p} c_l x_{t-l}^{(i)} + \sum_{m=1}^{p} d_m x_{t-m}^{(j)} + e_t^{(j)} \end{aligned} \tag{4.1}$$

In that setting, significant values of the coefficients of interests (b_m and c_l) indicate causality. If $x_t^{(j)}$ Granger causes $x_t^{(i)}$ then at least one element of b must be different from zero. In the same way, if $x_t^{(i)}$ Granger causes $x_t^{(j)}$ then at least one element of c must be different from zero. The F test of the null hypothesis that all elements of b (or c) vectors help to distinguish which crudes are price setters (i.e. Granger causes other prices) and which are takers (i.e. are Granger caused by other prices).

The p parameter was set at 16 (4 months), which is reasonable given the rapid developments on the markets.[8] A total of 992 tests were conducted. Each test shows (a) whether $x_t^{(i)}$ is a price setter of $x_t^{(j)}$ and accordingly (b) whether $x_t^{(j)}$ is a price taker. This

[8]The calculations were repeated for different values of p with no relevant changes in the results.

yields 31 tests for each crude oil's price setter characteristics and 31 tests of whether it is a price taker.

Furthermore, crudes were separated in accordance with the segments presented above, and appropriate tests were repeated, but this time to see if prices of crude from a particular group Granger cause prices of other crudes from that segment only.

4.2.3 Discussion of Results

Table 4.9 presents the results of all tests. To facilitate interpretation, it presents the percentages of Granger tests statistics in which the null was rejected for each crude in its respective group. In such a setting, a ratio equal or close to 1 in the price setter (price taker) section of Table 4.9 implies that the crude is causing (is being Granger caused by) all the other crudes in the group, whereas a number closer to 0 implies the opposite.

On the assumption that all crude prices eventually will follow the market movements, high price setter factors combined with low price taking factors are interpreted as a sign of ability of the crude to quickly respond to market changes. Low price setter factors combined with high price taker factors, on the other hand, are taken as indications of slow market adaptation.

For example, in Table 4.4 which summarizes the main results, West Texas Intermediate ($x_t^{(1)}$) is a price taker in 13% of the cases and a price setter in 100% of the cases which makes it a clear world-wide price setter. Conversely, Malaysia Tapis ($x_t^{(15)}$) is a price taker in 100% of the cases and price setter only in 13% of the cases. This makes this crude a clear price taker.

The general results that can be observed from Table 4.4 are that:

- the acclaimed benchmarks, WTI ($x_t^{(1)}$) and Brent ($x_t^{(2)}$), are price setters both in a global sense and within their quality segment (light and sweet);
- Mediterranean Russian Urals ($x_t^{(16)}$) is, in spite of little public attention, a third global price setter;
- Asia Dubai Fatch ($x_t^{(22)}$) and Oman Blend ($x_t^{(13)}$) do not display price setter properties on the world market.

With respect to quality segments, the results indicate that:

- the nine light density and sweet crudes (presented in Table 4.5) are, as expected, dominated by WTI and Brent. Norway Ekofisk ($x_t^{(3)}$), Australia Gippsland ($x_t^{(14)}$), Algerian Saharan Blend ($x_t^{(27)}$), Nigeria Bonny Light ($x_t^{(28)}$), and Libya El Sider

Table 4.4: Granger Causality Percentages - World

Symbol	Crude	Taker	Setter
$x_t^{(1)}$	West Texas Intermediate	0.13	1
$x_t^{(2)}$	Europe Brent	0.26	0.97
$x_t^{(3)}$	Europe Norwegian Ekofisk	0.68	0.71
$x_t^{(4)}$	Canadian Par	1	0.65
$x_t^{(5)}$	Canada Lloyd Blend	1	0.94
$x_t^{(6)}$	Mexico Isthmus	0.45	0.87
$x_t^{(7)}$	Mexico Maya	0.16	0.71
$x_t^{(8)}$	Colombia Cano Limon	0.26	0.84
$x_t^{(9)}$	Ecuador Oriente	0.87	0.68
$x_t^{(10)}$	Angola Cabinda	0.74	0.65
$x_t^{(11)}$	Cameroon Kole	0.87	0.74
$x_t^{(12)}$	Egypt Suez Blend	0.84	0.55
$x_t^{(13)}$	Oman Blend	0.84	0.77
$x_t^{(14)}$	Australia Gippsland	0.77	0.61
$x_t^{(15)}$	Malaysia Tapis	1	0.13
$x_t^{(16)}$	Mediterranean Russian Urals	0.42	1
$x_t^{(17)}$	China Daqing	1	0.35
$x_t^{(18)}$	Saudi Arabia Saudi Light	0.48	0.58
$x_t^{(19)}$	Saudi Arabia Arab Medium	0.52	0.65
$x_t^{(20)}$	Saudi Arabia Saudi Heavy	0.52	0.61
$x_t^{(21)}$	Asia Murban	0.81	0.84
$x_t^{(22)}$	Asia Dubai Fatch	0.81	0.68
$x_t^{(23)}$	Qatar Dukhan	0.84	0.77
$x_t^{(24)}$	Mediterranean Seri K Iran Light	0.61	0.84
$x_t^{(25)}$	Mediterranean Seri K Iran Heavy	0.77	0.84
$x_t^{(26)}$	Kuwait Blend	0.9	0.87
$x_t^{(27)}$	Algeria Saharan Blend	0.58	0.61
$x_t^{(28)}$	Europe Nigerian Bonny Light	0.81	0.58
$x_t^{(29)}$	Europe Forcados	0.71	0.68
$x_t^{(30)}$	Europe Libyan Es Sider	0.9	0.77
$x_t^{(31)}$	Indonesia Minas	1	0.48
$x_t^{(32)}$	Venezuela Tia Juana	0.94	0.52

Table 4.5: Granger Causality Percentages - Light Density & Sweet

Symbol	Crude	Taker	Setter
$x_t^{(1)}$	West Texas Intermediate	0.25	1
$x_t^{(2)}$	Europe Brent	0.25	1
$x_t^{(3)}$	Europe Norwegian Ekofisk	0.62	0.62
$x_t^{(4)}$	Canadian Par	1	0.5
$x_t^{(14)}$	Australia Gippsland	0.75	0.62
$x_t^{(15)}$	Malaysia Tapis	1	0.12
$x_t^{(27)}$	Algeria Saharan Blend	0.5	0.62
$x_t^{(28)}$	Europe Nigerian Bonny Light	0.62	0.5
$x_t^{(30)}$	Europe Libyan Es Sider	0.88	0.88

Table 4.6: Granger Causality Percentages - Medium Density & Sour

Symbol	Crude	Taker	Setter
$x_t^{(6)}$	Mexico Isthmus	0.31	0.85
$x_t^{(9)}$	Ecuador Oriente	1	0.46
$x_t^{(12)}$	Egypt Suez Blend	1	0.46
$x_t^{(13)}$	Oman Blend	0.92	0.85
$x_t^{(16)}$	Mediterranean Russian Urals	0.54	1
$x_t^{(18)}$	Saudi Arabia Saudi Light	0.62	0.62
$x_t^{(19)}$	Saudi Arabia Arab Medium	0.62	0.62
$x_t^{(20)}$	Saudi Arabia Saudi Heavy	0.62	0.62
$x_t^{(22)}$	Asia Dubai Fateh	0.92	0.62
$x_t^{(24)}$	Mediterranean Seri K Iran Light	0.46	0.85
$x_t^{(25)}$	Mediterranean Seri K Iran Heavy	0.69	0.77
$x_t^{(26)}$	Kuwait Blend	1	0.85
$x_t^{(32)}$	Venezuela Tia Juana	1	0.46

Table 4.7: Granger Causality Percentages - Medium Density & Sweet

Symbol	Crude	Taker	Setter
$x_t^{(8)}$	Colombia Cano Limon	0.15	0.85
$x_t^{(10)}$	Angola Cabinda	1	1
$x_t^{(11)}$	Cameroon Kole	1	1
$x_t^{(17)}$	China Daqing	1	0.75
$x_t^{(29)}$	Europe Forcados	0.5	1
$x_t^{(31)}$	Indonesia Minas	1	0.75

Table 4.8: Granger Causality Percentages - OPEC

Symbol	Crude	Taker	Setter
$x_t^{(18)}$	Saudi Arabia Saudi Light	0.5	0.71
$x_t^{(19)}$	Saudi Arabia Arab Medium	0.57	0.79
$x_t^{(20)}$	Saudi Arabia Saudi Heavy	0.5	0.71
$x_t^{(21)}$	Asia Murban	0.86	0.93
$x_t^{(22)}$	Asia Dubai Fatch	0.86	0.79
$x_t^{(23)}$	Qatar Dukhan	0.86	0.86
$x_t^{(24)}$	Mediterranean Seri K Iran Light	0.64	1
$x_t^{(25)}$	Mediterranean Seri K Iran Heavy	0.86	0.93
$x_t^{(26)}$	Kuwait Blend	0.93	0.86
$x_t^{(27)}$	Algeria Saharan Blend	0.5	0.71
$x_t^{(28)}$	Europe Nigerian Bonny Light	0.86	0.64
$x_t^{(29)}$	Europe Forcados	0.57	0.71
$x_t^{(30)}$	Europe Libyan Es Sider	0.93	0.79
$x_t^{(31)}$	Indonesia Minas	1	0.5
$x_t^{(32)}$	Venezuela Tia Juana	1	0.5

($x_t^{(30)}$) adjust quickly to benchmark price changes, whereas Canada Par ($x_t^{(4)}$) and Malaysia Tapis ($x_t^{(15)}$) respond more slowly;

- for medium density and sour crudes (presented in Table 4.6), Asia Dubai Fatch ($x_t^{(22)}$) is the benchmark in practice, but, according to Montepeque (2005), it should be treated with caution due to the low trade volume. The results of the analysis indicate that Dubai Fatch does not display a strong price setting position. Instead, Mediterranean Russian Urals is a very clear price setter in the segment. Oman Blend ($x_t^{(13)}$) and Kuwait Blend ($x_t^{(26)}$) respond quickly to price changes, whereas Ecuador Oriente ($x_t^{(9)}$), Egypt Suez Blend ($x_t^{(12)}$), and Venezuela Tia Juana ($x_t^{(32)}$) are apparent price takers in the segment, responding slowly to market changes;

- in the segment of medium density and sweet crudes (presented in Table 4.7), Colombia Cano Limon ($x_t^{(8)}$) and Europe Forcados from Nigeria ($x_t^{(29)}$) indicate a price setting influence, but all the other crudes in the segment follow very quickly. None of the crudes in the segment is a price setter in the world-wide comparison, indicating that the whole segment follows price setters in some other quality segment, probably WTI and Brent.

Table 4.9: Granger Causality Percentages - Results of Granger tests

Symbol	Price Taker				Price Setter			
	Overall	OPEC	Region	Quality	Overall	OPEC	Region	Quality
Non-OPEC								
$x_t^{(01)}$	0.13	0.25	0.29	0.25	1.00	1.00	1.00	1.00
$x_t^{(02)}$	0.26	0.19	0.50	0.25	0.97	0.94	0.50	1.00
$x_t^{(03)}$	0.68	0.75	1.00	0.62	0.71	0.69	0.00	0.62
$x_t^{(04)}$	1.00	1.00	1.00	1.00	0.65	0.69	0.57	0.50
$x_t^{(05)}$	1.00	1.00	1.00	1.00	0.94	0.88	1.00	1.00
$x_t^{(06)}$	0.45	0.62	0.43	0.31	0.87	0.75	0.71	0.85
$x_t^{(07)}$	0.16	0.31	0.43	1.00	0.71	0.75	0.71	1.00
$x_t^{(08)}$	0.26	0.38	0.29	0.15	0.84	0.75	0.57	0.85
$x_t^{(09)}$	0.87	0.81	1.00	1.00	0.68	0.69	0.43	0.46
$x_t^{(10)}$	0.74	0.81	0.00	1.00	0.65	0.56	0.00	1.00
$x_t^{(11)}$	0.87	0.94	0.00	1.00	0.74	0.75	0.00	1.00
$x_t^{(12)}$	0.84	0.81	1.00	1.00	0.55	0.56	0.50	0.46
$x_t^{(13)}$	0.84	0.88	0.83	0.92	0.77	0.69	0.83	0.85
$x_t^{(14)}$	0.77	0.75	0.67	0.75	0.61	0.56	1.00	0.62
$x_t^{(15)}$	1.00	1.00	1.00	1.00	0.13	0.19	0.67	0.12
$x_t^{(16)}$	0.42	0.38	0.00	0.54	1.00	1.00	1.00	1.00
$x_t^{(17)}$	1.00	1.00	1.00	1.00	0.35	0.44	1.00	0.75
OPEC								
$x_t^{(18)}$	0.48	0.50	0.58	0.62	0.58	0.71	0.75	0.62
$x_t^{(19)}$	0.52	0.57	0.67	0.62	0.65	0.79	0.75	0.62
$x_t^{(20)}$	0.52	0.50	0.58	0.62	0.61	0.71	0.75	0.62

Continued on next page

Table 4.9 – continued from previous page

Symbol	Price Taker				Price Setter			
	Overall	OPEC	Region	Quality	Overall	OPEC	Region	Quality
$x_t^{(21)}$	0.81	0.86	0.83	0.00	0.84	0.93	0.83	0.00
$x_t^{(22)}$	0.81	0.86	0.83	0.92	0.68	0.79	0.75	0.62
$x_t^{(23)}$	0.84	0.86	0.92	0.00	0.77	0.86	0.83	0.00
$x_t^{(24)}$	0.61	0.64	0.58	0.46	0.84	1.00	1.00	0.85
$x_t^{(25)}$	0.77	0.86	0.75	0.69	0.84	0.93	0.92	0.77
$x_t^{(26)}$	0.90	0.93	1.00	1.00	0.87	0.86	0.83	0.85
$x_t^{(27)}$	0.58	0.50	0.67	0.50	0.61	0.71	0.75	0.62
$x_t^{(28)}$	0.81	0.86	0.00	0.62	0.58	0.64	0.00	0.50
$x_t^{(29)}$	0.71	0.57	0.00	0.50	0.68	0.71	0.00	1.00
$x_t^{(30)}$	0.90	0.93	1.00	0.88	0.77	0.79	0.75	0.88
$x_t^{(31)}$	1.00	1.00	1.00	1.00	0.48	0.50	1.00	0.75
$x_t^{(32)}$	0.94	1.00	1.00	1.00	0.52	0.50	0.43	0.46

The results of the analysis show that from the plethora of crude oils quoted on the world market only three (WTI, Brent and Urals), display *price-leading* properties. This makes them suitable for the purposes of the analysis of price transmission. The lack of a dominant benchmark in the segment of medium density, sour crude, pointed out by Montepeque (2005), is confirmed. The benchmark in practice for that segment, Dubai Fateh, does not turn out to be a price setter. Given such results, the choice of the crude is narrowed down to Brent, WTI and Urals.

4.3 Long-run Relationship and Endogeneity

4.3.1 Motivation

Given the properties of the series established in 4.1.2, the APT analysis has to be performed within the cointegration framework, so that the spurious regression could be ruled out.

Similarly, as discussed in section 3.2.3, the issue of endogeneity of price series has a significant impact on the precision of estimation and reliability of inferences on APT, yet it is commonly neglected - see the discussion in Frey & Manera (2007, p. 34, p. 42) and Geweke (2004, p. 8).

On the rare occasions when it is addressed, downstream prices were found to affect upstream prices or remain in a bi-variate relationship (e.g. see Balke et al. (1998) and Borenstein et al. (1997, p. 316-317)). In such a situation, the reliability of the price transmission estimation techniques described in chapter 2 decreases, since they assume one-directorial causality and no feedback mechanism.

As pointed out by Lanza, Giovannini & Manera (2003), the general economic literature on the topic of upstream-downstream linkages is not substantial. Furthermore, it tends to be focused on the applications to the financial markets rather than markets for physical products. The APT literature reviewed in chapter 3 (with the exceptions listed above) neglects the issue of causality of prices altogether and does not approach the issue of the choice of upstream price. Luckily, since the over-the-counter markets are geographically constrained their choice is rather obvious. That leaves the problem of choosing the right variety of the crude oil.[9]

One reason to suspect benchmark crudes to be endogenous with respect to EU products

[9]The correct choice of the crude oil and its possible endogeneity is also of some significance outside the field of energy economics. In particular, recent proposals for inclusion of crude oil prices in macroeconomic inflation targeting models - Krichenel (2005) - should be implemented with care, as the results could be potentially misleading.

is that the popular benchmarks are rather niche products - see section 4.2.1. This in principle could make them responsive to the local market situation. Even if it is not the case (because the benchmark crudes are not commonly used in the EU refineries), the benchmark crudes are of high quality (sweet and light), whereas the global crude oil market is increasingly comprised of lower quality crudes (see section 1.3 for a discussion). This could make them subject to manipulation and/or worldwide demand shocks.

Needless to say, the price of every crude is uniquely set by the changing forces of supply and demand and can fluctuate - Energy Information Agency (1999) and Bacon & Tordo (2005). Together with prices, transportation costs and technical constraints, the quality parameters directly influence refineries' choices of inputs (see van den Berg, Kapusta, Ooms & Smith (2003) for a discussion), which in turn affects the end prices of a wide array of products. The final result of this process determines which varieties of crude oil are used for refining. Oil companies could choose a well known global benchmark crude(s) (which are however supply constrained), local crude(s) or a combination of both.

Energy economists and macro-economists usually assume that the choice could be simplified by assuming that oil companies use only one kind of crude oil for which price data are readily available, disregarding the complexities described above. However, when one combines the notion that different varieties of crude oil can be used to produce the same products with the fact that prices of different qualities of crudes often diverge for long spells it is clear that proxying the crude oil - product link with one exogenous global benchmark might be an oversimplification. Below we discuss those issues from the point of view of price transmission.

4.3.2 Previous Research

Gjolberg & Johnsen (1999) analyse the existence of a long-run relationship between monthly prices of benchmark crude oil (Brent) and end products (premium leaded petrol, naphtha, jet fuel, gas oil and light / heavy fuel oils quoted in North-Western Europe, FOB, cargoes) over the period January 1992 - August 1998. The results point to the existence of a relationship between crude oils and end products which can be effectively used for hedging purposes. While no formal discussion on the direction of that relationship is presented, Gjolberg & Johnsen (1999, p. 527) conclude that:

> (...) the current product - crude margin deviations from a long-run equilibrium may contain significant information about the future changes in product prices and margins (...)

which for practical purposes indicates that DSPs are endogenous while USPs are exogenous.

Indejehagopian & Simon (2000) analyse prices of Brent crude oil and gasoil in Germany and France over the period January 1987-December 1997. The analysis of exogeneity indicates that the German market directly affects the Rotterdam markets (feedback relationship), while the French market follows both German and Rotterdam markets.

Adrangi, Chatrath, Raffiee & Ripple (2001) also focus on one crude only (Alaska North Slope) and its relationship with one product (US West Coast Diesel). The results, obtained using VARs and a bivariate GARCH model, indicate the presence of a unidirectional relationship between the prices, but the paper contains no discussion about the choice of the crude and possibility that other crudes can drive the product prices.

Asche, Gjolberg & Volker (2003) use a multivariate VAR to test for the relationship between Brent oil and several end products in North-West Europe. The results indicate that the Brent oil is weakly exogenous, but no discussion of the possible impact of other crudes is presented. Asche et al. (2003, p. 298) state that:

> (...) weak exogeneity cannot be rejected for crude oil, while it is clearly rejected for the other three products. (...) It indicates that the relationship between crude oil and the refined products can be modelled in single equation specifications (...)

Lanza et al. (2003) compare the prices of ten different kinds of crude oils and prices of fourteen end products worldwide (i.e. in Mediterranean, North West Europe, Latin America and North America regions) over the period 1994-2002. This analysis explains prices of local crudes with the help of the prices of petroleum products and benchmark crudes. The results of the cointegrating analysis indicate that the differences in the quality of crude oil varieties determine their behaviour - crudes similar to the global benchmarks return more quickly to their long-run values, compared to the crudes of significantly different quality.

Denni & Frewer (2006) analyse the transmission between monthly prices of Brent crude and gasoline, gasoil, kerosene, RFO1/2 and naphtha. The results obtained using single-equation models (similar to those described below) suggest that Brent is a weakly-exogenous price leader which leads the prices of downstream products.

4.3.3 Empirical Analysis

Cointegration and Endogeneity

Since the series we intend to consider are integrated of order one, they have to be analysed in the cointegrating framework - Maddala & Wu (1999). Only when a common stochastic trend between the series in question exists, the possibility of spurious regression is rejected and an economically valid link between crude oil and end product prices can be identified.

As specified by Engle & Granger (1987), cointegration implies an error correction mechanism, which describes short and long run responses of prices to external shocks and allows us to test for endogeneity of the variables. Intuitively, variables that do react to shocks in other variables should be modelled on the left-hand side, while those which remain exogenous (determined outside the system), should be treated as explanatory and the model should be conditioned upon them.

As the first step in the analysis, we estimate the following cointegrating equations for every upstream-downstream pair (i.e. DSPs-USPs, MSPs-USPs and DSPs-MSPs):

$$\begin{aligned} ln(y_t^{DSP-(j,k)}) &= \alpha_{(j,l,k)} + \beta_{(j,l,k)} ln(x^{USP-l}) + \gamma_{(j,l,k)} ln(ex^k) + \epsilon_t \\ ln(y_t^{MSP-j}) &= \alpha_{(j,l)} + \beta_{(l)} ln(x^{USP-l}) + \epsilon_t \\ ln(y_t^{DSP-(j,k)}) &= \alpha_{(j,k)} + \beta_{(j,k)} ln(x^{MSP-j}) + \gamma_{(j,k)} ln(ex^k) + \epsilon_t \end{aligned} \tag{4.2}$$

where:

- j stands for product;
- k stands for country;
- l stands for oil.

For every equation, we conduct the Phillips-Perron Z_α test for cointegration, under the null hypothesis of no cointegration, the long truncation parameter $(n/30)$ and a constant.[10] For the product-crude pairs for which the null of no cointegration was rejected at 5%, we estimate the following VAR(p) model:

$$B(\mathcal{L})\mathbf{z_t} = \mathbf{z_t} - \Phi_1 \mathbf{z_{t-1}} - \ldots - \Phi_p \mathbf{z_{t-p}} = \epsilon_t \tag{4.3}$$

where:

[10] The Z_α test is similar to typical ADF tests, i.e. it is also based on residuals from level estimation. However it has slower rate of divergence and better small-sample properties, i.e. higher power - Phillips & Ouliaris (1990).

- $B(\mathcal{L})\mathbf{z}_t$ is the lag polynomial;
- $\mathbf{z}_t$ is the column vector of the variables (per country, per product and per crude);
- ϵ_t is the disturbance vector.

Based on the results of the VAR model estimation we confirm the results of the test for cointegration with the help of eigenvalue and trace tests - i.e. rejection of the null of $r = 0$ and failure to reject $r \leq 1$ and $r \leq 2$ as specified in Johansen & Juselius (1990). This should be interpreted as a confirmation that the relationship between prices is not spurious.

As the next step, (4.3) was transformed into the VECM model:

$$\Delta\mathbf{z}_t = \Pi\mathbf{z}_{t-1} - \sum_{i=1}^{p-1}\Gamma_i\Delta\mathbf{z}_{t-i} + \epsilon_t \tag{4.4}$$

where:

- $\Pi = B(1)$;
- $\Gamma_i = -\sum_{i+i}^{p}\Phi_i$.

and conduct the endogeneity analysis using the Π matrix, which contains the information about the dynamic stability of the system. When normalised, Π can be rewritten as $\alpha\beta'$, where β contains the cointegrating vector and α represents the speed of adjustment from the errors ($\beta'\mathbf{z}_{t-1}$) towards the long-run equilibrium. If a particular coefficient is zero in the α vector, the corresponding variable is considered to be weakly exogenous, i.e. determined outside the system and thus appearing as a right-hand-side variable.

In order to test the hypothesis of weak exogeneity of the crude oils, the α vector was constrained to have zero values for upstream prices (and the exchange rate whenever necessary) and the χ^2 tests were performed. The calculations were performed for p equal to 4, i.e. full month coverage.

To facilitate interpretation, the results are presented in the form of maps. The colours indicate the cases when the null of exogeneity of a given crude oil and exchange rate was rejected.[11] The results indicate that within the EU, the national markets could be generally split into three major groups: East, Mediterranean and North-West. This intuitively reflects the state of the infrastructure and geographical accessibility to different crudes and transportation routes (for landlocked countries).

[11]Markets with no data are marked as *NAs*, while those for which the null of no-cointegration was not rejected are marked as *spurious*.

Furthermore, at the product level, the results could be divided into two groups - for those products which are popular and require high quality crudes (unleaded petrol, Diesel and low sulphur fuel oil) and those for niche products which could be obtained from lower quality crudes (leaded petrol, high sulphur fuel oil and heating oil). LPG seems to behave in a different manner from the other products which reflects its peculiarities, described in section 4.1.1.

4.3.4 Discussion of Results

Long Run Relationship

USP to MSP Transmission Table A.23 presents the results of Phillips-Perron Z_α tests for the null hypothesis of no cointegration between USPs and MSPs. For all pairs it was possible to reject the null of no cointegration at the standard 5% significance level. This suggests that crude oil and spot markets are well integrated.

MSP to DSP Transmission Panel A.24 and Table A.27 present the results of Phillips-Perron Z_α tests for the null hypothesis of no cointegration between MSPs and DSPs. The results confirm that the national markets are well integrated with European spot market for the finished products. The only significant deviation occurs for LPG, which is only to be expected given that the transportation of LPG involves additional costs (pressurising and making it liquid) and dangers (volatile and transported one way only in pipelines) - Brito, Littlejohn & Rosellon (2000).

For the vast majority of the products, the Phillips-Perron Z_α tests imply a rejection of the null hypothesis of no cointegration. The cases of spurious regression are limited to some of the EU-10 countries, for which only limited data (less than one year) are available.

USP to DSP Transmission Panel A.25 presents the results of Phillips-Perron Z_α tests for the null hypothesis of no cointegration. The results confirm that the end product prices stay in the long-run relationship with the prices of their principal input - crude oil. The only significant deviation occurs for LPG, which is only to be expected given its peculiarities described above.

Endogeneity of Crudes

MSP to DSP Transmission Panel A.26 presents the results of endogeneity tests on the MSP to DSP transmission.

The results are intuitive and support the notion that MSPs are exogenous and drive DSPs (see discussion in chapter 3). The significant deviations from that trend involve:

- LPG - here the reservations described in section 4.3.4 (mainly duality of supply) apply;
- fuel oils - this changes when the lower order of the VAR model is utilised and might indicate that fuel oil market adjusts in less than 4 weeks.

MSP to DSP Transmission Panel A.28 presents the results of endogeneity tests on the MSP to DSP transmission. The results of the tests for the null of crude oil and the exchange rate exogeneity are also intuitive. Brent and WTI are global high quality crudes, which lead the global markets and are commonly used as reference worldwide. As such they are exogenous in all markets in which they are cointegrated with retail products.

The results for Ural crude are more surprising and possibly of some importance to energy economists and policy makers. The failure to reject the null of exogeneity of Ural crude indicates that prices of that crude are endogenous, possibly because of local demand shocks that could affect upstream prices if those become decoupled from global markets due to transportation lags or politically-driven increases in supply.[12] This indicates that local retail market conditions do play an important role in local crude oil markets. Given that, any simplification based on the assumption that upstream prices can be perfectly proxied by global benchmarks should be treated with caution.

For the Brent crude, the results closely mirror those obtained in the literature. In particular, following Asche et al. (2003) and Denni & Frewer (2006) we find Brent to be a weakly exogenous price leader.

USP to MSP Transmission Table A.29 presents the results of the endogeneity tests for the null that upstream prices (in this case crude oil prices) are exogenous. For both global benchmarks - WTI and Brent the null of exogeneity cannot be rejected, while the Russian Urals seem to be heavily dependent on the spot prices in the EU.

This suggests that for the purposes of the analysis the endogenous Russian crude oils should not be used as explanatory variables in price transmission analysis. The results were corroborated by estimation with different order of the VAR (i.e. the p parameter in (4.4) and (4.3)). We address this issue later on in this dissertation, when we confirm the results for Brent oil with the help of instrumented Ural prices.

[12] For a discussion of possible sources of endogeneity of upstream prices see Borenstein et al. (1997, p. 316).

Transmission Estimates

In this section, we present the OLS estimates obtained from estimation of (4.2). The t-statistics were not reported as the series were found to be integrated of order one, which invalidates traditional statistical inference.

USP to MSP Transmission Table A.30 presents the OLS estimates of the elasticity of MSPs with respect to USPs. As expected, for the most popular products the elasticity is lower than unity. In the case of Diesel the elasticity is greater than unity but this could be due to changes in the environmental regulations which require extra purchases to replenish inventories or to an overshooting phenomenon, visible in some instances of price transmission.

Our results for ULP/LP, gasoil/Diesel and RFO2 closely mirror those by Gjolberg & Johnsen (1999) who found them to be equal to 0.76, 0.99 and 0.54 respectively. Conversely, the effect for RFO2 is much higher than that by Gjolberg & Johnsen (1999) - *ca.* 0.8 against 0.06. Our results are also in line with Denni & Frewer (2006) who also find elasticities are lower for heavier products, but still significantly greater than zero.

MSP to DSP transmission Tables A.31 and A.34 present the estimates of upstream prices and foreign exchange rate elasticities.

One should note some negative estimates of foreign exchange elasticity for LPG - they further confirm the peculiarity of this product mentioned a number of times before.

USP to DSP transmission Tables A.32 and A.33 present the estimates of upstream prices and foreign exchange rate elasticities. The elasticity estimates are lower than those for upstream markets, which is understandable given the lower liquidity of the market and the fact that while the USP-MSP transactions are often "virtual" (i.e. are used in refineries' production management and do not involve the physical delivery of the goods), MSP-DSP transactions might also involve physical handling of the subject of the transaction.

4.4 Summary and Conclusions

4.4.1 Causality

The Granger causality tests indicate that out of all crudes traded globally there are several price-setters which pass market information first and influence other prices. Those price-setters could be thought of in terms of benchmarks as they set the market trends. Given the composition of refining feeds in the EU and the patterns uncovered in the data, for the purposes of this study, three crudes - Brent, WTI and Urals should be watched more closely.

4.4.2 Endogeneity

The results show that, out of the three potential EU price-setters, only Brent can be considered as an exogenous crude that influences the downstream prices. This is visible both for middle tier and for retail prices and is fairly consistent across the products. The interesting side-note is that prices of many products in the Eastern European member states are in endogenous relationship with Ural crudes, but they remain exogenous towards Brent.

The findings regarding the Brent crude support the previous studies which identified the price transmission effects stemming from this crude - among other Sumner (1990), Reilly & Witt (1998), Godby et al. (2000), Wlazlowski (2003*a*), Contin et al. (2004), Grasso & Manera (2007). The importance of the Ural crude was long recognized by the practitioners (see Antill & Arnott (2000), Montepeque (2005)), but was nonetheless neglected in the price transmission literature. To the best of the author's knowledge, this study is the first to include Russian crudes in the EU petroleum price modelling.

4.4.3 Linear Cointegration

Our results confirm that the downstream and upstream prices remain in a long-run relationship, both in case of crude oil - retail products (which was confirmed before in the literature), but also for transmissions involving the ARA region, which represents an innovative contribution of this work.

The long-run elasticities are fairly uniform across the countries (with the exception of new EU-10 countries which might be due to the shorter time-span), but not across products (those for individual consumer products - ULP and Diesel are generally lower than those for industrial products - fuel oil / heating oil). LPG and leaded petrol are less likely to be in a long-run relationship and exhibit erratic cross-country patterns compared to the core products traded in the EU.

The cross country and cross product cointegration patterns closely match those reported in the literature with the exception of UK unleaded petrol for which the null of no cointegration was not rejected. This is in stark contrast with the previous studies

Table 4.10: USP to DSP Transmission - Linear Cointegration Tests (PO)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	√	√	√	NA	√	NA	NA
BE	√	√	√	√	√	×	√
CY	√	√	×	NA	NA	×	NA
CZ	×	×	√	×	×	×	×
DE	√	√	√	×	√	NA	√
DK	√	√	√	NA	√	NA	√
EE	×	×	×	×	NA	NA	NA
ES	√	√	√	√	√	√	√
FI	√	√	√	NA	√	NA	NA
FR	√	√	√	√	√	√	√
GB	√	√	√	NA	√	√	×
GR	√	√	√	NA	√	√	√
HU	×	√	×	×	√	NA	NA
IE	√	√	√	NA	NA	√	√
IT	√	√	√	×	√	√	√
LT	×	×	√	×	√	×	NA
LU	√	√	√	√	√	√	√
LV	×	√	×	×	NA	NA	√
MT	×	×	×	NA	NA	×	×
NL	√	√	√	√	√	NA	√
PL	×	×	√	×	×	√	NA
PT	√	√	×	×	√	√	√
SE	√	√	√	NA	√	NA	NA
SI	√	×	×	×	×	NA	NA
SK	×	×	×	×	×	×	×

Notes:NA - data not available, × - no cointegration, √ - linear cointegration.

Table 4.11: MSP to DSP Transmission - Linear Cointegration Tests (PO)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	√	√	√	NA	√	NA	NA
BE	√	√	√	√	√	√	√
CY	√	√	√	NA	NA	×	NA
CZ	×	×	√	×	×	×	×
DE	√	√	√	×	√	NA	√
DK	√	√	√	NA	√	NA	√
EE	×	√	×	×	NA	NA	NA
ES	√	√	√	×	√	√	√
FI	√	√	√	NA	√	NA	NA
FR	√	√	√	√	√	√	√
GB	√	√	√	NA	√	√	×
GR	√	√	√	NA	√	√	√
HU	√	√	√	×	√	NA	NA
IE	√	√	√	NA	NA	√	√
IT	√	√	√	√	√	√	√
LT	√	√	√	×	√	√	NA
LU	√	√	√	√	√	√	√
LV	×	×	×	×	NA	NA	×
MT	×	×	×	NA	NA	×	×
NL	√	√	√	√	√	NA	√
PL	×	×	√	×	×	×	NA
PT	√	√	×	×	√	√	√
SE	√	√	√	NA	√	NA	NA
SI	√	√	√	×	×	NA	NA
SK	√	√	×	×	×	×	×

Notes:NA - data not available, × - no cointegration, √ - linear cointegration.

by Bacon (1991), Manning (1991), Eltony (1998), Reilly & Witt (1998), Driffield et al. (2003) and Wlazlowski (2003*a*). The most likely explanation is the span of the sample - the dataset starts in 1995 and ends in 2003, while the above-mentioned studies utilize local data that span the 1980s and in some cases even 1970s, when leaded petrol was common.

The results are also consistent with the bulk of the literature covering the late 1990s onwards. In particular, the cointegration pattern confirms studies by Kirchgassner & Kubler (1992) for Germany, Galeotti et al. (2003) and Grasso & Manera (2007) for France, Germany, Italy Spain, and the UK, Bettendorf et al. (2003) for the Netherlands and Contin et al. (2004) for Spain.

4.4.4 Summary and Conclusions

The results discussed in this chapter confirm that among the plethora of different crudes, Brent and WTI still remain the most important, despite their decreasing supply and related problems. Surprisingly, the Russian Urals, as suggested by industry statistics, was found to grow in importance and lead prices in its quality segment.

The discovered geographic pattern of causality and exogeneity indicates that EU countries rely to a different extent on different sources of crudes and that local crudes can be endogenous. This needs to be recognized and accounted for in a number of applications, for example inflation modelling.

Furthermore, the results indicate that following political and economic integration within the European community, petroleum markets tend to display similar patterns with respect to the relationship between upstream and downstream prices. This suggests integration with international oil markets (reflected by cointegration of USPs and DSPs) and with the pan-European ARA trading hub (reflected by cointegration between MSPs and DSPs). While the relationship is strong and consistent across countries for high-volume products (mainly motor spirits), it is not visible for LPG, which stands out as an outsider, most likely because it is also obtained from natural gas.

The results presented in this chapter justify the choice of studying the LR and SR price dynamics using more sophisticated time-series techniques identified in chapter 2. Accordingly, in the next chapter we continue the analysis by looking at the dynamic adjustment of downstream prices following the upstream cost change.

Chapter 5

Price Dynamics

In the previous chapter we analysed the core properties of the price transmission in the EU petroleum market. The results confirm the industry statistics presented in section 1.3 and indicate that the EU countries rely heavily on imported energy products. Over the past years, this situation forced them to integrate their local markets with global energy trading hubs, which led to a creation of linkages between their local downstream prices and international upstream and midstream prices. This finding constitutes the starting point of the analysis to be carried out in this chapter.

The second cornerstone of the analysis is that the most significant sources of freely-traded (non-OPEC) feed-stocks for the EU are the Russian and North Sea crudes. The results of the VAR analysis indicate that the Brent crude is an exogenous global marker whose prices are not affected by DSPs and MSPs, while Urals crude remains endogenous.

In this chapter we continue the analysis of price transmission between the three tiers described previously using two groups of tools:

- standard linear time series techniques based on the work of Engle & Granger (1987) described in section 2.2.1, and
- more recent techniques based on STAR models, described in section 2.2.5.

The standard techniques allow us to analyse the properties of the LR relationship between prices on different tiers. In particular, we:

- estimate the pass-through rates for upstream prices and the exchange rates;
- test the hypothesis of full pass-through of upstream costs in multi-national and multi-product setting;
- simulate the linear ECM adjustment following upstream cost change.

Given that price elasticities determine the end-user welfare change due to price shocks, the estimates obtained in the multi-national, multi-product and multi-tier setting form a significant contribution to knowledge and are of some interest to policy-makers. Their interest might be motivated by a variety of reasons, for example by the recent proposals for inclusion of crude oil prices in macroeconomic inflation targeting models - Krichenel (2005). Therefore, the findings offer significant room for cross-country and cross-product analyses and formulation of various policy responses to developments in the oil markets.

Another use for the estimates is to verify the assumptions about the complete pass through in the relationship between prices. Those claims are commonly made for the US market (see Deltas (2004), Arpa et al. (2005), Kaufmann & Laskowski (2005)) and are sometimes unquestioningly used also for the EU (see Bacon (1991) and Driffield et al. (2003) for the UK). Our study is the first to assess those claims in the multi-national and multi-product framework, utilizing both traditional OLS and ECM tools. Last but not least, using the linear tools we estimate the ECM adjustment to upstream cost changes, which allows us to compare price dynamics across countries, products and tiers.

By using the second set of tools we seek to:

- confirm the results of linear cointegration analysis presented in section 4.3.4 and expand them with the help of the non-linear cointegrating tools developed by Kapetanios et al. (2006);
- test for the presence of non-linearities in price transmission using the smooth transition approach by Teräsvirta (1994);
- establish the nature of non-linearities using the framework by Escribano & Jordá (2001);
- measure the excess of non-linearities and assess their impact on price transmission through the simulation of price adjustments in a simplified STAR-ECM framework.

The first point constitutes an improvement over the previous studies in the sense that it allows us to widen the sample by inclusion of additional cases of price transmission. This is possible as the traditional cointegration tools might mis-identify signs of APT as spurious regression (see Monte Carlo comparisons in Kapetanios et al. (2006, Tables 1-3)), so when relying solely on linear tools, one might be excluding asymmetric transmissions from the study. Utilizing non-linear cointegration tools we ascertain that such cases would not be incorrectly labelled as spurious regressions.

The second goal boils down to identification of transmissions where the equilibrium-reverting process is non-linear and can potentially be a welfare-decreasing APT. Similar tools were previously used in the literature, but were focused on SETAR models and boot-strapping testing techniques proposed by Hansen (1996) and Hansen (1997). Given the size of the sample and flexibility of the smooth transition models (see Strikholm & Teräsvirta (2005)) we decided to use STAR models and testing techniques based on the Taylor-expansion of the transition function. These techniques are better suited for the purposes of PT analysis as:

- STAR models are more flexible, allowing the non-linearities to take logistic or an exponential shape (see Figure 5.1 for an overview);
- STAR models encompass SETAR models as an extreme case (with logistic transmission function and smoothing parameter set to ∞ - see section 2.2.5);
- STAR models allow for smooth transition between the regimes which is a more realistic assumption than the complete and instantaneous regime change characteristic of the SETAR models;
- the tests for non-linearities do not involve simulation and bootstrap which makes them less computationally burdensome.

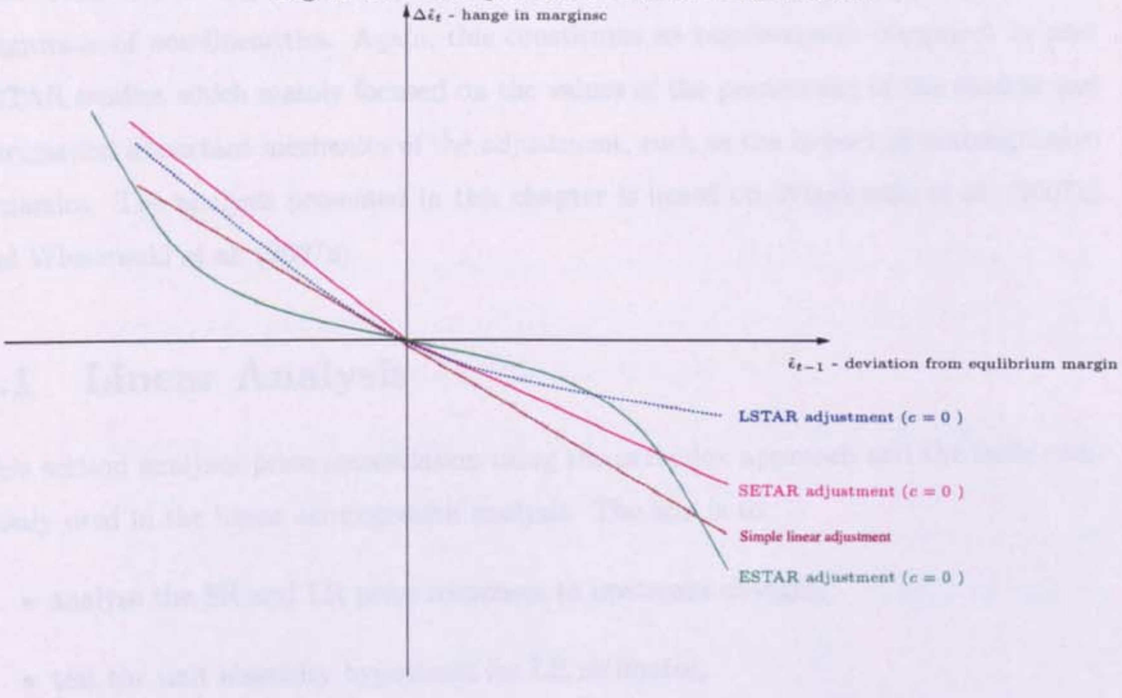
The third point involves utilizing the testing strategies proposed by Teräsvirta (1994) and Escribano & Jordá (2001) to identify the nature of asymmetries. These tools allow us to categorize the nature of asymmetries described in the STAR models as either:

- of LSTAR type, which involves the smooth transition between two regimes and can be seen as an extension of traditional SETAR models;
- of ESTAR type, which involves the smooth transition between the two outer regimes and the central regime.

In this chapter the non-linear testing and estimation framework is employed to address the issue of disequilibrium adjustment within the augmented Dickey-Fuller version of the ECM model. Those models differentiate the speed with which the disequilibria are eliminated depending on their absolute size and sign.

Figure 5.1 presents the different adjustments for ESTAR, LSTAR and SETAR models. For simplicity, it is assumed that the threshold parameters (c's) are the same across models and all equal zero, so that the SETAR/LSTAR regimes are symmetric around zero and the ESTAR adjustment is symmetric with respect to the distance from zero.

Figure 5.1: Comparison of Non-Linear Models



In economic terms the situations depicted in the Figure 5.1 correspond to:

- for SETAR models - faster elimination of the negative disequilibrium (equivalent to squeezed margins for the transmission agents) compared to the positive disequilibria (which imply swollen margins - positive APT);
- for LSTAR models - a situation similar to that with the SETAR model but with the attractor strength depending on the magnitude and size of the disequilibrium - large negative disequilibria are eliminated much faster than small negative disequilibria - heterogeneous APT;
- for ESTAR models - a situation when large disequilibria (both positive and negative) are eliminated faster than the smaller ones - increased price inertia.

So far, the applied research focused on the SETAR models. The LSTAR models were not used although the smooth transmission between the regimes implied by them is more likely in economic terms than the instant and complete regime change implied by the SETAR models. Similarly, the ESTAR models were largely disregarded although the economic phenomena giving rise to them (transaction costs and market frictions) are much more likely to occur than collusion and market imperfections commonly labelled as responsible for SETAR-type asymmetries.

As the last exercise, using the estimates of the transition function and transmission parameters, we simulate the shock responses from the non-linear DF model. This is done while accounting for the dynamics of the system, mainly to assess the order of magnitude of non-linearities. Again, this constitutes an improvement compared to past SETAR studies which mainly focused on the values of the parameters of the models and disregarded important mechanics of the adjustment, such as the impact of autoregressive dynamics. The analysis presented in this chapter is based on Wlazlowski et al. (2007*c*) and Wlazlowski et al. (2007*a*).

5.1 Linear Analysis

This section analyses price transmission using the orthodox approach and the tools commonly used in the linear cointegration analysis. The aim is to:

- analyse the SR and LR price responses to upstream changes;
- test the unit elasticity hypothesis for LR estimates;
- simulate the market responses to upstream changes.

Those goals are pursued for all cases in which the null of no cointegration is rejected (the test was calculated as described in 4.3.3) and the analysis is based on the estimates of the ECM model given by (2.12) with the n parameter set to 4 weeks and dynamics set so as to minimize the AIC criterion.

5.1.1 LR Elasticity

As described in Stock & Watson (1993), the ECM framework offers a way of obtaining the estimates of LR elasticities (pass-through rates) supplementary to the estimates obtained in the traditional OLS level estimation. Those estimates can be extracted from the ECM models (2.8) and should in principle proxy the pure LR impact, free of SR fluctuations which could affect the traditional OLS estimates.

We performed both ECM and the conventional analyses for transmission between the three available tiers. Tables A.35 - A.43 present the results. Figures A.1 and A.2 present the graphical overview of the results illustrating the distribution of the results.[1]

The elasticity estimates are consistent with the technology constraints and the results of previous studies. In particular:

[1] The diagnostics of linear models indicate good fit and no problems with heteroscedasticity. Non-normality of residuals remains both in long-run and ECM price equations but this is only to be expected in models with non-linear features - see Fisher & Salmon (1986).

- with respect to estimation method - in all cases, ECM-based LR elasticities are higher than the traditional estimates, which is due to SR dynamics being accounted for in the ECM estimation;
- with respect to the transmission tiers:
  - product elasticities for USP to MSP transmission are much higher than the respective MSP to DSP elasticities, confirming that crude oil is the single most important variable input in refining, with other variable costs present mostly at distribution stage (price incentives, additives, etc.);
  - upstream product price and FEX elasticities (both in the OLS and ECM versions) are similar for the MSP to DSP and USP to DSP transmissions, with the differences lower than 0.05. This is only to be expected as crude oil is the main variable cost at the refinery stage and the remaining costs of refining are constant per unit of input or output mix - see Table 1.2;
- with respect to products:
  - elasticities for the motor spirits (Diesel oil and ULP) are broadly similar across countries, with differences in values of less than 10%;
  - lower quality products (RFOs and gasoil) have higher crude oil elasticities, most likely because they are the main outputs of the refining process (see Figure 1.6);
  - elasticities for leaded petrol are the most volatile, which might be due to the fact that this product is commonly being phased out of the distribution;
  - with the low elasticities, LPG stands out as an outlier, again most likely due to the fact that it is obtained from two sources (crude oil and natural gas), so its prices do not depend solely on crude oil prices.

Our estimates offer an interesting insight into the European price transmission. The fact that the results are internally consistent makes them useful as a basis for multinational comparisons and policy-making - see Wlazlowski (2007) and Wlazlowski et al. (2007*a*) for discussion of possible applications.

5.1.2 Unit Elasticity

This section analyses the results of the test for the null hypothesis of unit elasticity in price transmission. The tests are performed in the classic t-student framework (for the

OLS level estimation) and in the F-test framework (for the ECM models the null of unit elasticity can be defined as $\delta_1 = 1/\gamma$ in (2.8)). Tables A.35-A.43 present the results.

The results of the analysis overwhelmingly support the rejection of the null hypothesis of full pass-through of upstream costs, both in terms of upstream prices and exchange rate. This is only to be expected since the technicalities of the refining process determine that:

- crude oil is not the only cost in the refinery process - so the end price does not change in the same proportion as the crude oil price;
- the refining process results in output of more than one product - so crude oil price changes are spread between prices of several products.

5.1.3 Adjustment to Upstream Changes

In order to further analyse the adjustment path, the ECM models are used to simulate the adjustment to a unit shock. Based on the adjustment path we calculate the half-life and 90% decay of the adjustment. The calculations of those measures assume linear change within periods.[2]

The results obtained constitute an improvement over previous studies as they offer a pan-EU, multi-product set of measures of downstream price adjustment. Unlike the commonly reported LR adjustment speed (γ parameters in (2.7) and (2.8)), the simulated responses include both LR and SR changes in a manner advocated by Borenstein et al. (1997). In particular, the results indicate that:

- with respect to transmission tiers:
  - MSP to DSP adjustment is faster compared to the indirect USP to DSP adjustment;
  - USP to MSP adjustment is faster than the difference between USP to DSP transmission and MSP to DSP, which could be a sign of some rich dynamics in the transmission between higher market tiers that should be accounted for using higher-frequency data - Wlazlowski et al. (2007*c*) analyse this issue in greater detail;
- with respect to products:

[2] For example, if 40% of the disequilibrium was eliminated after 4 weeks and 60% after 5 weeks it was assumed that the half-life of the shock equals 4.5 weeks. Similarly, if in period 6 the disequilibrium increased to 50%, it was assumed that the half-life equals 6.

  - ULP, Diesel and gasoil are the fastest to adjust to upstream shocks with country patterns following the relative differences in volume traded (see section 1.3);
  - LPG and LP represent outliers in the analysis, for the same reasons as those described in the previous section;

- with respect to countries:
  - countries closer to the center of the EU and the Benelux ARA hub of trade enjoy faster adjustment of prices compared to peripheral EU countries most likely due to additional transportation costs;
  - the countries from Eastern Europe exhibit more volatile estimates, which might be partially due to the fact that the models were estimated over a shorter sample.

Previous studies utilized lower-frequency data and as such are not directly comparable with the results obtained. The only study that attempts to compare the adjustments between countries/products using weekly data and therefore could be deemed comparable is by Arpa et al. (2005) - see section 3.1. The results are similar to ours, thus further corroborating the analysis presented in this section.

The interesting element of the findings is that prices of retail products react to upstream cost changes faster than those of industrial products. This might indicate that consumer prices indices (such as CPI) might react faster to crude oil changes than indices based on producers' prices (PPI).

5.2 Asymmetric Case

5.2.1 Non-linear Cointegration

As argued by Balke & Fomby (1997), the standard cointegration tests remain useful in the presence of asymmetric adjustment. The reasoning behind this is that if the traditional tools have power in the linear case they should also retain it in the presence of moderate piecewise linear adjustment. Given that, we decided to test for cointegration in the traditional framework first (see section 4.3.3) and test for non-linear cointegration later. This approach allows us to verify the bulk of the literature based on the linear cointegration, and add transmissions that would be incorrectly labelled as spurious otherwise.

The testing framework used builds upon the traditional EG tests, yet avoids the pitfalls of nuisance parameters identified by Davies (1987) (see section 2.2.4) without the computationally burdensome simulations and bootstrap. It was proposed by Kapetanios et al. (2006) and models the equilibrium process in a way that links the strength of the equilibrium attractor to the sign and size of the residual - see section 2.2.6. Similarly to the linearity tests described in Section 2.2.5, the results of the tests for non-linear cointegration might be affected by the presence of outliers or structural changes - see van Dijk et al. (1999) and Koop & Potter (2001). This deficiency is recognized in the literature but has not been addressed until recently - see Giordani et al. (2007) for a proposed solution to this problem based on Bayesian estimation of state-space models.

Tables 5.1-5.2 summarize the results of conventional Phillips-Ouliaris (PO) and asymmetric (KSS) tests. The general pattern of results is consistent across products and countries and involves:

- strong rejection of no cointegration in favour of non-linear cointegration indicated by significant values of t_{NEC} and t_{NEG} statistics;
- rejection of no cointegration in favour of non-linear ESTAR-type cointegration with additional linear component indicated by the significant values of F_{NEC} statistics;
- failure to reject the null of no cointegration against the null of non-linear cointegration with non-zero threshold indicated by insignificant F^{*}_{NEC} statistics.[3]

The non-linear cointegration tests closely mirror the classical linear results obtained using the PO/ADF test. The differences include mainly rejection of the null of no asymmetric cointegration in cases when the linear test failed to reject the null of symmetric cointegration. This allowed us to cover additional countries in the sample. Since the results are similar for both linear and non-linear cointegration tests, we conclude that previous studies utilizing linear tools should be regarded merely as conservative, not incorrect. An additional contribution resulting from this portion of the analysis is that the Taylor expansion of the smooth-transition mechanism suggested that the starting values for the estimation of the c parameter should be set to zero.

Testing for Nonlinearities

The previous research into APT (see Table 3.1 for overview of previous research) either:

- assumed that the asymmetries are present in the price transmission and estimated their extent without first testing for their presence;

[3]Non zero transition value c involves $\hat{\epsilon}^2_{t-1}$ in the Taylor approximation, i.e. in the F^{*}_{NEC} test. Since those are rejected for almost all of the cases (e.g. F_{NEC} and t_{NEC} and t_{NEG} tests) it implies that the coefficient on $\hat{\epsilon}^2_{t-1}$ is indeed zero which suggests $c = 0$. This is an additional reason for setting the starting point for the c parameter in the ESTAR and LSTAR estimation equal to zero.

Table 5.1: USP to DSP Transmission - Linear and Non-Linear Cointegration Tests

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	√√	√√	√√		√√		
BE	√√	√√	√√	√√	√√	×√	√√
CY	√×	√√	×√			××	
CZ	×√	××	√×	××	××	××	××
DE	√√	√√	√√	××	√√		√√
DK	√√	√√	√√		√√		√×
EE	×√	×√	××	××			
ES	√√	√√	√√	√×	√×	√√	√√
FI	√√	√√	√√		√√		
FR	√√	√√	√√	√√	√√	√√	√√
GB	√√	√√	√√		√×	√×	××
GR	√√	√√	√√		√√	√√	√√
HU	××	√×	××	××	√√		
IE	√√	√√	√√			√√	√×
IT	√√	√√	√√	×√	√√	√√	√×
LT	×√	××	√×	××	√×	××	
LU	√√	√√	√√	√√	√√	√√	√√
LV	××	√×	××	××			√×
MT	××	××	××			××	××
NL	√√	√√	√√	√√	√√		√√
PL	×√	×√	√√	××	××	√√	
PT	√√	√√	××	××	√√	√√	√√
SE	√√	√√	√√		√√		
SI	√√	×√	××	××	××		
SK	××	××	××	××	××	××	××

Notes: Symbols summarize the results of PO and KSS tests, respectively. √ indicates rejection of the null of no cointegration, × failure to do so.

Table 5.2: MSP to DSP Transmission - Linear and Non-Linear Cointegration Tests

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	√√	√√	√√	NA	√√	NA	NA
BE	√√	√√	√√	√√	√√	√×	√×
CY	√×	√√	√√	NA	NA	××	NA
CZ	××	××	√√	×√	××	××	××
DE	√√	√√	√√	××	√√	NA	√×
DK	√×	√√	√×	NA	√√	NA	√×
EE	××	√√	××	××	NA	NA	NA
ES	√√	√√	√×	××	√√	√√	√√
FI	√√	√√	√√	NA	√√	NA	NA
FR	√√	√√	√√	×√	√√	√√	√√
GB	√√	√×	√√	NA	√√	√√	××
GR	√×	√×	√×	NA	√×	√√	√×
HU	√√	√√	√√	×√	√√	NA	NA
IE	√√	√√	√√	NA	NA	√√	√√
IT	√√	√√	√×	×√	√√	√√	√√
LT	√×	√×	√×	×√	√×	√×	NA
LU	√√	√√	√√	√√	√×	√√	√×
LV	××	××	××	××	NA	NA	××
MT	××	××	××	NA	NA	××	××
NL	√√	√×	√√	√√	√√	NA	√×
PL	×√	×√	√×	××	××	×√	NA
PT	√√	√√	××	××	√√	√√	×√
SE	√√	√√	√√	NA	√√	NA	NA
SI	√×	√√	√√	×√	××	NA	NA
SK	√×	√×	××	××	××	××	××

Notes: Symbols summarize the results of PO and KSS tests, respectively. √ indicates rejection of the null of no cointegration, × failure to do so.

- tested for one type of asymmetry without considering asymmetries of other nature.

As discussed by Geweke (2004), the lack of thorough testing for the presence of and the nature of non-linearities pose perhaps one of the greatest deficiencies of price transmission studies. In this chapter we tackle this issue in a manner which allows for:

- comprehensive testing for non-linearities in price adjustments;
- establishing the nature of the non-linearities, i.e. whether they are of the logistic or exponential nature.

The focus of the analysis is on the mean-reversion process analogous to the models by Dickey-Fuller, Enders & Granger (1998), Caner & Hansen (2001) and Cramon-Taubadel & Meyer (2001). While those models represent the simplified picture of the price adjustment, inferior to that offered by fully-fledged ECM models in the tradition of Engle & Granger (1987) and Stock & Watson (1993), they have several advantages over more sophisticated methods that make them useful for the purposes of this analysis.

Firstly, since most price transmission studies use k non-stationary variables (k equal to 2 or 3 depending on the presence of the exchange rate), accounting for their dynamics requires a significant reduction in the number of degrees of freedom. As the tests based on the Taylor-expansion require at least a fourth order approximation and n lags, the testing for non-linearities in the full-blown ECM would be based on the model with $[k + (n-1) + 2 * n] * 5$ variables. This results in lower power of tests for non-linearities and potentially the exclusion of short-sample transmissions. The simplified DF model requires only $[n+1] * 5$ variables.

Secondly, from the practical point of view, the estimation of non-linear models boils down to multi-dimensional optimization. In the case of the fully-scaled ECM models, this optimization is computationally burdensome and poses a number of practical issues, including:

- incomparability between models with different set of variables (in particular USP to MSP and MSP to USP);
- partially indefinite Hessians which prohibits calculation of standard errors of the parameters.

Last but not least, since the nature of the research requires that the results are easily comparable between tiers, countries and products, some parameters have to be brought to a common denominator (e.g. smoothing parameters in the STAR models and the thresholds in the models). While maintaining such a degree of uniformity might be difficult in the full ECM model, which contains two variables (prices and FEX) with different units and lags, it is manageable in the DF model. One example of such a simplification, is expressing the smoothing parameter as a divisor of one standard deviation of the residuals, so that only the quotient has to be estimated - as specified in Teräsvirta (1994) (see Appendix C).

In line with the above, we estimated the following DF ECM model:

$$\Delta\hat{\epsilon}_t = [1-G(\hat{\epsilon}_{t-d},\zeta,c)][\delta_0^L\hat{\epsilon}_{t-1}+\sum_{i=1}^{m}\delta_i^L\Delta\hat{\epsilon}_{t-1}]+G(\hat{\epsilon}_{t-d},\zeta,c)[\delta_0^H\hat{\epsilon}_{t-1}+\sum_{i=1}^{m}\delta_i^H\Delta\hat{\epsilon}_{t-1}]+\nu_t \quad (5.1)$$

where:

- $G(\hat{\epsilon}_{t-d},\zeta,c) = 1 - e^{-\zeta(\hat{\epsilon}_{t-d}-c)^2}$ for ESTAR estimation; or
- $G(\hat{\epsilon}_{t-d},\zeta,c) = \frac{1}{1+e^{-\zeta(\hat{\epsilon}_{t-d}-c)}}$ for LSTAR estimation.

To test for the adequacy of the above model over the simple DF linear model, following Escribano & Jordá (2001), we replaced the transition function by its fourth-order Taylor approximation so that equation (5.1) becomes:

$$\begin{aligned}\Delta\hat{\epsilon}_t &= \zeta_0+\zeta_1'*\mathbf{X}_t+\zeta_2'*(\mathbf{X}_t*\hat{\epsilon}_{t-d})+\zeta_3'*(\mathbf{X}_t*\hat{\epsilon}_{t-d}^2)+\zeta_4'*(\mathbf{X}_t*\hat{\epsilon}_{t-d}^3)\\ &\quad+\zeta_5'*(\mathbf{X}_t*\hat{\epsilon}_{t-d}^4)+\nu_t\end{aligned} \quad (5.2)$$

where $\mathbf{X}_t = (\hat{\epsilon}_{t-1},\Delta\hat{\epsilon}_{t-1},\cdots,\Delta\hat{\epsilon}_{t-p})$, and then perform the following step-by-step testing procedure:

1. for all possible d, test $H_0 : \zeta_5 = \zeta_4 = \zeta_3 = \zeta_2 = 0$ - if rejected proceed, if not conclude that asymmetries are not present in the equilibrium reversion;
2. choose the value of d for which the null of non-linearity is rejected *most* significantly;
3. test $H_{0L} : \zeta_5 = \zeta_3 = 0$ with the help of an F-test denoted F_L;
4. test $H_{0E} : \zeta_4 = \zeta_2 = 0$ with the help of an F-test denoted F_E;
5. if the minimum p-value corresponds to F_E select LSTAR, otherwise select ESTAR.

Tables 5.3 and 5.4 present the results. To facilitate comparisons, the results for tests applied to DSP to USP and MSP to USP transmissions are presented back-to-back, with L and E denoting LSTAR and ESTAR type of non-linearities (respectively) and $\times$ denoting cases when the null of linearity was not rejected.

Table 5.3: Non-Linearities in USP to DSP and MSP to DSP Transmission

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	× / ×	× / ×	× / ×	- / -	*E* / *L*	- / -	- / -
BE	*E* / *E*	*L* / *E*	× / *E*	× / ×	× / *L*	*L* / *E*	*E* / *L*
CY	× / ×	*E* / ×	*E* / ×	- / -	- / -	- / -	- / -
CZ	× / -	- / -	× / ×	- / *L*	- / -	- / -	- / -
DE	× / ×	× / *E*	*E* / *E*	- / -	*E* / *L*	- / -	*L* / ×
DK	*E* / ×	× / ×	*L* / *E*	- / -	× / ×	- / -	× / ×
EE	*E* / -	× / ×	- / -	- / -	- / -	- / -	- / -
ES	*E* / ×	× / *E*	*L* / *E*	× / -	× / ×	× / *E*	× / ×
FI	*E* / *E*	× / *L*	*E* / *E*	- / -	*E* / *L*	- / -	- / -
FR	*L* / *L*	× / *L*	*L* / *L*	× / ×	× / ×	× / ×	× / ×
GB	× / ×	*E* / ×	× / ×	- / -	× / ×	× / ×	- / -
GR	*L* / *L*	*E* / ×	× / *L*	- / -	× / ×	× / *E*	*L* / *L*
HU	- / ×	× / ×	- / ×	- / *L*	× / *E*	- / -	- / -
IE	*E* / *E*	× / ×	× / ×	- / -	- / -	× / *E*	× / ×
IT	× / ×	*E* / ×	*L* / ×	× / *L*	× / ×	× / ×	× / *L*
LT	× / ×	- / ×	× / *L*	- / ×	*L* / ×	- / ×	- / -
LU	*E* / *L*	*E* / *E*	*E* / ×	× / *L*	× / *L*	× / *E*	× / *E*
LV	- / -	× / -	- / -	- / -	- / -	- / -	× / -
MT	- / -	- / -	- / -	- / -	- / -	- / -	- / -
NL	*E* / *L*	× / ×	*E* / ×	*E* / *E*	*E* / *E*	- / -	× / ×
PL	× / ×	× / ×	× / ×	- / -	- / -	× / ×	- / -
PT	*E* / *E*	*E* / *E*	- / -	- / -	*E* / *E*	× / ×	*E* / *E*
SE	*L* / *L*	× / ×	*E* / *L*	- / -	*E* / *E*	- / -	- / -
SI	× / *L*	*E* / ×	- / ×	- / ×	- / -	- / -	- / -
SK	- / ×	- / ×	- / -	- / -	- / -	- / -	- / -

Notes: For each country-product pair, the first symbol refers to USP to DSP transmission and the second one to MSP to DSP transmission. Symbols used: L - LSTAR, E - ESTAR, × - linear cointegration, – no cointegration or data on prices in neighbouring countries not available.

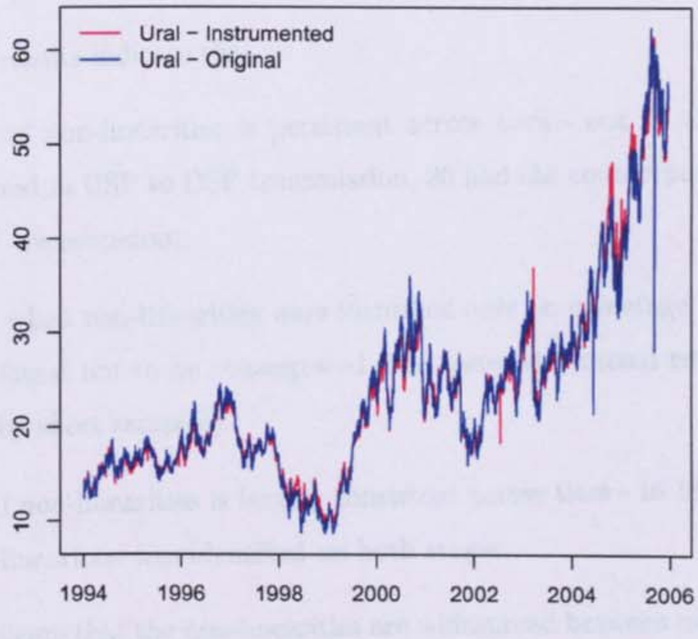
Table 5.4: USP to MSP Transmission - Nonlinearity Tests

Products	
DIESEL	ESTAR
ULP	
GASOIL	
LPG	ESTAR
RFO.1	
RFO.2	
LP	

The results presented above do not fully correspond to the cointegration patterns indicated by the non-linear cointegration tools presented in Tables 5.1-5.2. In particular, the transmissions deemed as non-linear by KSS tests are not classified as ESTAR by the methodology of Escribano & Jordá (2001) - this applies e.g. to ULP transmission in AT, DE and DK. This situation is most likely due to different treatment of Taylor expansion used by both tools and the fact that the non-linear cointegration tools find signs of linear cointegration as well as non-linear ESTAR-type cointegration. Given the above, a more meaningful comparisons should instead be made for cases when KSS tests find non-linear cointegration and inference from PO tests does not indicate cointegration (e.g. Portuguese MSP to DSP LP or BE USP to DSP RFO.2 transmissions). For those transmissions, the results are coherent as our STAR models generally confirm the results of KSS tests.

To check if the results are influenced by the choice of the crude oil (see section 4.3), we repeated the calculations but instrumented endogenous Russian crude oils with exogenous WTI and Brent prices. To account for possible endogeneity of Urals crudes, we instrumented their prices with prices of Brent and WTI over the sample period - $\hat{x}_t^{Urals} = \hat{\beta}_0 + \hat{\beta}_1 x_t^{Brent} + \hat{\beta}_2 x_t^{WTI} + \hat{\nu}$. Figure 5.2 presents the original and instrumented series, confirming good fit.

Figure 5.2: Ural Crudes - Instrumented and Original Values



The most striking pattern visible in the results is the widespread presence of exponential non-linearities (ESTAR), compared to those of logistic nature (LSTAR) which were similar to SETAR models commonly used in the literature. This result is only to be expected as the reasons for ESTAR-type non-linearities (e.g. adjustment costs, market frictions, and such) are more likely to occur than those responsible for LSTAR-type non-linearities (e.g. market collusion). This implies that by constraining the nature and shape of asymmetries to SETAR models, the previous studies misrepresented the nature of asymmetries and, as a result, their potential causes and effects.

Table 5.5 presents the results. The changes compared to the Brent analysis are insignificant and related to:

- with respect to countries - increase in the presence of non-linearities in countries that rely on Russian crudes (Germany and Finland);
- with respect to products - increase in the presence of non-linearities in the low quality products (RFOs and LP), most likely based on low quality Russian feed.

The overall conclusion is that introduction of Russian crudes does not change significantly the results of the non-linearity testing. This should be seen as further confirmation of the results of the analysis based on Brent data, described previously. Again, further developments of the econometric toolbox (in particular, STAR-type cointegrating VARs) would facilitate new research into the impact of Russian crudes on European price transmission.

In general, the results indicate that:

- the presence of non-linearities is persistent across tiers - out of 43 cases of non-linearities found in USP to DSP transmission, 26 had the counterparts in the direct MSP to DSP transmission;
- for the cases when non-linearities were identified only on one stage, the other stage was usually found not to be cointegrated (the cases with mixed results are mostly constrained by short samples);
- the nature of non-linearities is largely consistent across tiers - in 18 cases the same type of non-linearities was identified on both stages.

The results indicate that the non-linearities are widespread between markets, products and tiers. The following patterns are visible:

- with respect to transmission tiers:

Table 5.5: Non-Linearities in USP to DSP and MSP to DSP Transmission

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	× / ×	× / ×	× / ×	- / -	*E* / *L*	- / -	- / -
BE	*E* / *E*	*L* / *E*	× / *E*	× / ×	*E* / *L*	*L* / *E*	*E* / *L*
CY	× / ×	*E* / ×	*E* / ×	- / -	- / -	- / -	- / -
CZ	× / -	- / -	× / ×	- / *L*	- / -	- / -	- / -
DE	× / ×	× / *E*	*L* / *E*	- / -	*L* / *L*	- / -	*L* / ×
DK	*E* / ×	× / ×	*L* / *E*	- / -	× / ×	- / -	× / ×
EE	*E* / -	× / ×	- / -	- / -	- / -	- / -	- / -
ES	× / ×	× / *E*	*L* / *E*	× / -	× / ×	× / *E*	× / ×
FI	*L* / *E*	× / *L*	*E* / *E*	- / -	*E* / *L*	- / -	- / -
FR	× / *L*	× / *L*	*L* / *L*	× / ×	× / ×	*E* / ×	× / ×
GB	× / ×	× / ×	× / ×	- / -	× / ×	× / ×	- / -
GR	*L* / *L*	× / ×	× / *L*	- / -	× / ×	× / *E*	*E* / *L*
HU	- / ×	× / ×	- / ×	- / *L*	× / *E*	- / -	- / -
IE	*E* / *E*	*E* / ×	× / ×	- / -	- / -	× / *E*	× / ×
IT	× / ×	*E* / ×	*L* / ×	× / *L*	× / ×	× / ×	× / *L*
LT	× / ×	- / ×	× / *L*	- / ×	*L* / ×	- / ×	- / -
LU	*E* / *L*	*E* / *E*	*E* / ×	*L* / *L*	× / *L*	× / *E*	× / *E*
LV	- / -	× / -	- / -	- / -	- / -	- / -	× / -
MT	- / -	- / -	- / -	- / -	- / -	- / -	- / -
NL	*E* / *L*	× / ×	*L* / ×	*E* / *E*	*E* / *E*	- / -	× / ×
PL	× / ×	× / ×	× / ×	- / -	- / -	× / ×	- / -
PT	*E* / *E*	*L* / *E*	- / -	- / -	*E* / *E*	× / ×	*E* / *E*
SE	*L* / *L*	× / ×	*E* / *L*	- / -	*E* / *E*	- / -	- / -
SI	× / *L*	*E* / ×	- / ×	- / ×	- / -	- / -	- / -
SK	- / ×	- / ×	- / -	- / -	- / -	- / -	- / -

Notes: For each country-product pair, the first symbol refers to USP to DSP transmission and the second one to MSP to DSP transmission. Symbols used: L - LSTAR, E - ESTAR, × - linear cointegration, – no cointegration or data on prices in neighbouring countries not available.

- non-linearities concentrate downstream - there is a slightly higher percentage of non-linear cases in the MSP to DSP transmission - 50 out of 175, compared with 43 out of 175 for the indirect USP to DSP and 2 out of 7 for the USP to MSP transmission;
- potentially welfare-decreasing non-linearities (LSTAR) are more widespread than ESTAR at the retail level (24 out of 50 in the case of MSP to DSP transmission compared to 12 out of 43 for the indirect transmission);

- with respect to products:
  - non-linearities are particularly common in the retail products - ULP, Diesel, gasoil and LP,
  - products with industrial uses (RFO-1/2) exhibit fewer non-linearities;
  - LPG again stands out in terms of results, with no signs of non-linearities in the indirect (from crude oil) transmission and non-linearities in the direct (from wholesale) transmission. This should be considered as a further confirmation of the results of the analysis presented in the section 4.3.4 and an indicator that there are substitutes to crude oil in obtaining this product (LPG can be obtained from natural gas);
- with respect to national markets - the non-linearities spread fairly evenly across countries, with the exception of Eastern Europe, which might be due to the different time span of the sample or specific characteristics of countries undergoing economic transition.

The testing results closely follow the existing literature. In particular, the results support the non-linearities found in the crude to unleaded petrol transmission in the UK (Reilly & Witt (1998), Eltony (1998), Galeotti et al. (2003), Wlazlowski (2003*a*), Driffield et al. (2003),Grasso & Manera (2007), Hosken et al. (2007, p. 2)), crude to leaded petrol in Germany (Kirchgassner & Kubler (1992)), wholesale to retail in Germany and France (Grasso & Manera (2007)), crude to unleaded petrol in Spain (Contin et al. (2004)), crude to unleaded petrol in Italy (Berardi et al. (2000) and Galeotti et al. (2003)).

Furthermore, these findings support the results of the studies that *failed* to find non-linearities in price adjustment, e.g. in the wholesale to unleaded petrol transmission in the Netherlands (Bettendorf et al. (2003)), in the crude to leaded petrol in Italy (Berardi et al. (2000)), in the crude to retail and in the wholesale to retail and crude to wholesale transmissions for Spain, France and Germany (Galeotti et al. (2003)).

The most significant departure from the literature is the failure to reject the null of spurious regression in the crude to retail leaded petrol transmission for the UK. Both Bacon (1991) and Manning (1991) found this transmission to be asymmetric, but they were using a significantly different sample (covering data from the 1970s and 1980s), and without testing for cointegration.

5.2.2 Estimating the Non-linear Long-Run Adjustment

For all transmissions identified as non-linear in section 5.2.1 we estimated model (5.1) using the methodology described in Appendix C. The results are summarized in Table A.71 and Panel A.72.

To facilitate the interpretation, below we analyse two sample STAR models (one with exponential and one with logistic transmission function).

Example of the ESTAR model

As the first example consider the indirect crude oil to retail unleaded petrol price transmission for Cyprus. The results are summarized in Table 5.6 and should be interpreted as follows. The left half of the table identifies the transmission tier, product and country and presents the basic description of the model. The most important elements include:

- the smoothing parameter (ζ), which determines how dramatic is the switch from one adjustment regime to the other - the closer it is to zero the smoother the transition is. When the value of the parameter approaches ∞, the LSTAR model collapses to the SETAR model and the ESTAR model collapses to the linear model;
- the delay for the transition value (d), which determines how responsive the adjustment is to lagged developments;
- the threshold value and the percentile of the threshold that identifies it in the sample (c and c^{th} respectively).[4] Those values determine the position of the transition function in the sample;
- the standard deviation of the residuals ϵ_t;
- the percentage of observations on the transition variable for which the appropriate LSTAR / ESTAR functions yields values lower than .5, which defines the share of observation that are influenced by each regime.

[4]The percentiles were scaled around 0 by subtracting 0.5 from their values. For example, -0.051 stands for 0.449^{th} percentile. This is done in line with 5.2.1 so as to facilitate testing and interpretation of the model - zero corresponds to median dis-equilibrium, which should equal zero.

The right half of the table summarizes the autoregressive portion of the piece-wise linear STAR model. The first column presents the direct estimates of the adjustment speed (i.e. the percentage of disequilibrium eliminated each term), and the remaining columns present the lagged explanatory variables, designed to capture the dynamics of the system.

The results indicate that the Cypriot crude to retail unleaded petrol price transmission is non-linear, with the transition determined by the exponential function of the disequilibrium lagged by one period ($d = 1$) and centered around -0.01 (corresponding to the disequilibrium of 1%, which corresponds to the 45^{th} percentile). The lagged dynamics favoured by the AIC criterion include only the lagged disequilibrium level and no lagged autoregressive changes. The adjustment process is found to be strong for significant disequilibria (23% of disequilibrium eliminated, with the estimate significantly different from zero at 1%) but non-existing for small disequilibria, where the estimate of the cointegrating pull was found to be insignificantly different from zero at all significance levels. This finding corresponds to an adjustment model in which large positive and negative disequilibria are eliminated with equal strength, but small, insignificant disequilibria are left unchanged.

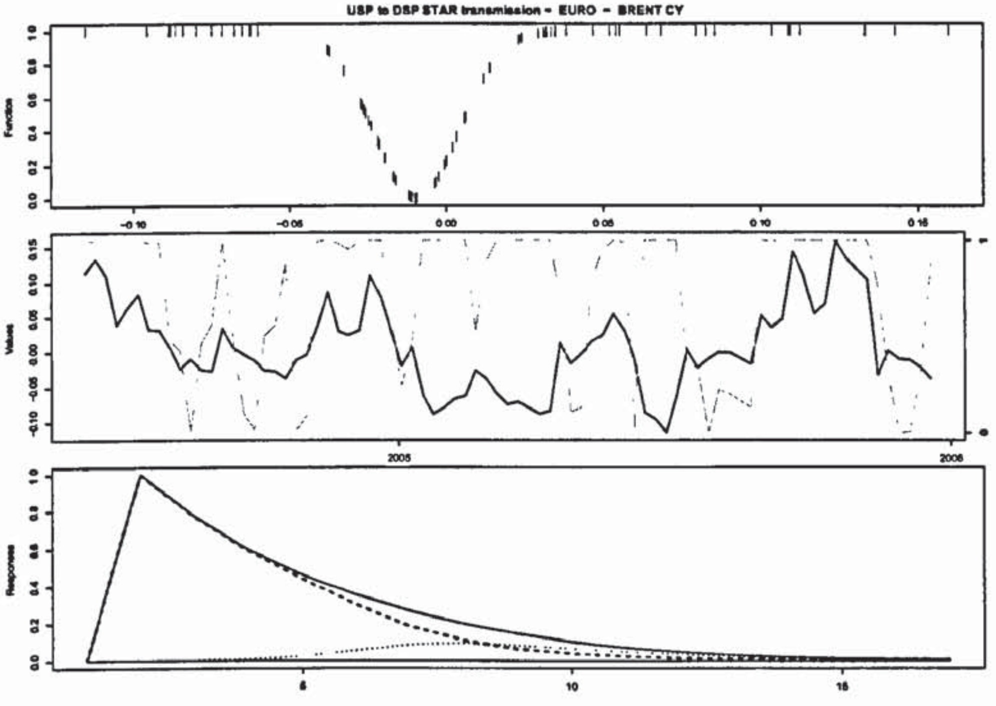
Table 5.6: ESTAR Model of Adjustment for Cypriot ULP USP to DSP Transmission

Transition Country	Product Transition	ζ d	c c^{th}	$< 1/2$ $sd(\hat{u}_t)$	γ_1^L γ^H	ψ_1^L ψ_1^H	ψ_2^L ψ_2^H	ψ_3^L ψ_3^H	ψ_4^L ψ_4^H
USP→DSP	ULP	3.212	-0.01	0.312	-0.427				
CY	ESTAR	1	-0.051	0.065	-0.23***				

Figure 5.3 presents a graphical overview of the model. The first panel presents the transition function of the $\hat{\epsilon}_{t-d}$ with the observations marked as short vertical lines. The middle panel presents the values of disequilibria ($\hat{\epsilon}_t$) over time (black line and the left scale) and imposes the transition function on it (grey line and the right scale). The bottom panel presents the simulated adjustment to the positive and negative shocks equal to two standard-deviations (respectively green and red). To facilitate comparisons the response to negative shocks was scaled by -1, and the difference between the two is presented as a blue line. Whenever the blue line is above the horizontal axes it denotes that a positive disequilibrium is eliminated slower than the negative one, so that the prices rise faster than they fall and the market participants protect artificially increased profits.

The results of the analysis point to a ESTAR model giving rise to moderate APT, as the positive disequilibria are eliminated more slowly than the negative ones. As opposed to the predictions of the traditional SETAR models, the difference seems to be small.

Figure 5.3: ESTAR Model of Adjustment for Cypriot ULP USP to DSP Transmission



Example of the LSTAR model

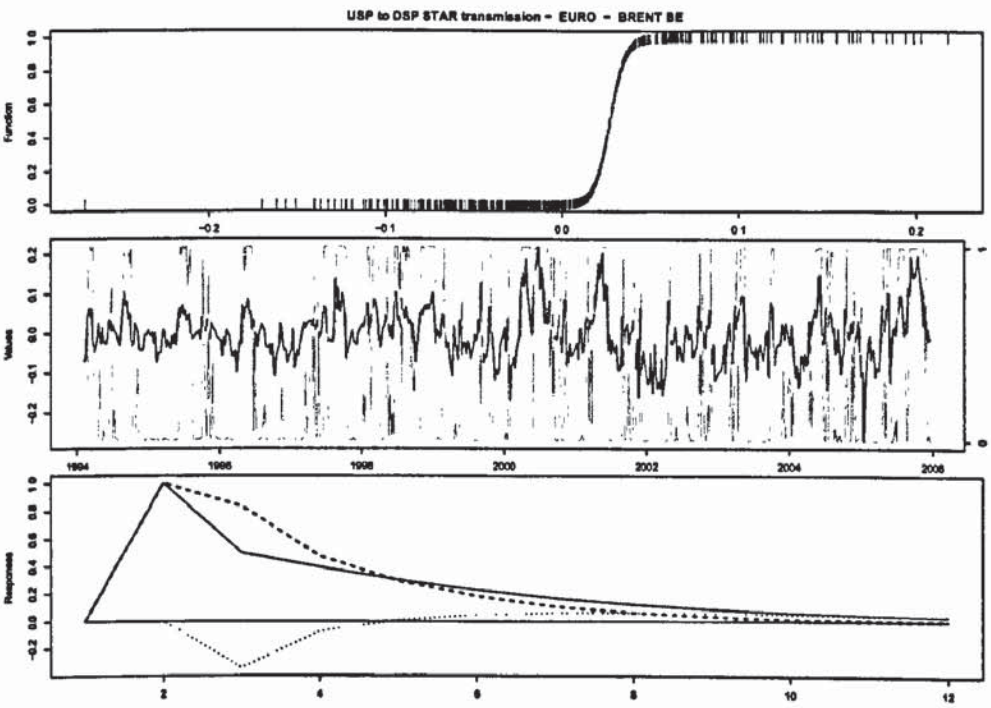
As a second example, consider crude oil to retail unleaded petrol price transmission for Belgium. Table 5.7 summarizes the results of the estimation. The estimates indicate that the transmission follows the LSTAR function that *could* give rise to APT with faster immediate adjustment for negative disequilibria (-.335) compared to the positive ones (-.204). However, one should notice the presence of the lagged LHS variable, which could affect the actual adjustment process. The results of the simulation of adjustment presented in Figure 5.4 show that although the SR adjustment speeds for the LSTAR model suggest that negative disequilibria are eliminated faster than the positive ones, but once the autoregressive elements are taken into account, the reverse is true. This should be seen as another innovative contribution of this analysis. So far, researchers have focused on the values of the parameters, disregarding the necessity of checking for the end effect of adjustment e.g. via simulation of price adjustment. The results of this analysis show that the end result might be less pronounced than assumed in the existing literature.

All other models summarized in Table A.71 and Figure panel A.72 should be interpreted in a manner similar to the one described above.

Table 5.7: LSTAR Model of Adjustment for Belgian ULP USP to DSP Transmission

Transition Country	Product Transition	ζ / d	c / c^{th}	$< 1/2$ / $sd(\hat{u}_t)$	γ^L / γ^H	ψ_1^L / ψ_1^H	ψ_2^L / ψ_2^H	ψ_3^L / ψ_3^H	ψ_4^L / ψ_4^H
USP→DSP	ULP	15.004	0.027	0.704	-0.335***	-0.172***			
BE	LSTAR	2	0.205	0.064	-0.204***	0.004			

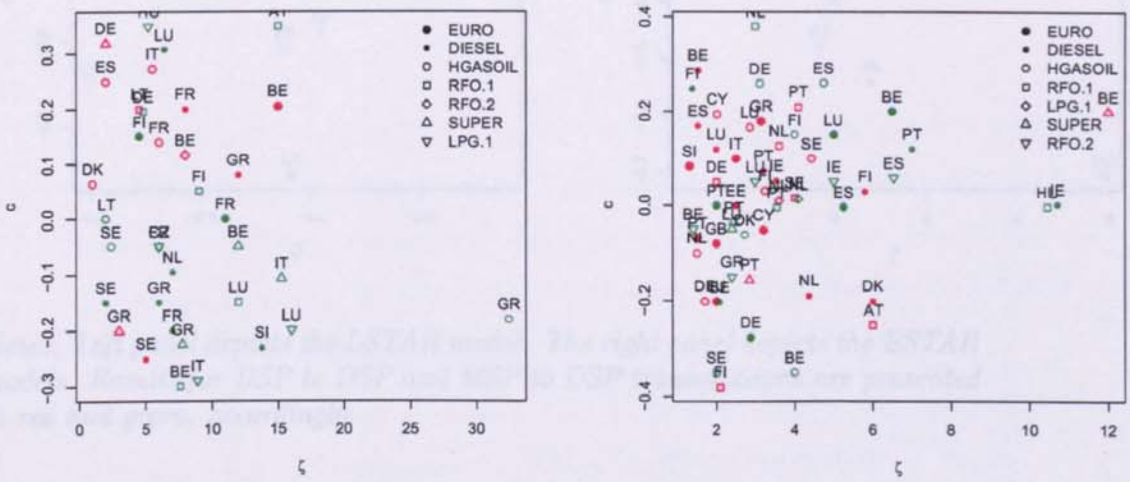
Figure 5.4: LSTAR Model of Adjustment for Belgian ULP USP to DSP Transmission (Example)



Overview of all results

Figures 5.5 - 5.6 summarize the results of estimation of ζ, c^{th} and γ parameters for USP to DSP and MSP to DSP transmissions (presented in red and green respectively).[5]

Figure 5.5: Threshold and Smoothing Parameters



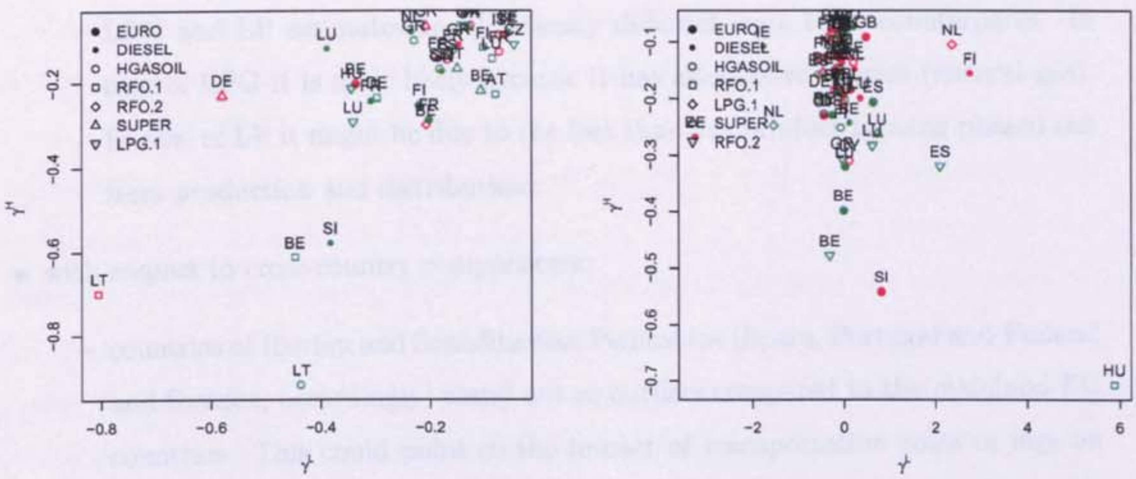
Notes: Left panel depicts the LSTAR model. The right panel depicts the ESTAR models. Results for USP to DSP and MSP to DSP transmissions are presented in red and green, accordingly.

The most visible patterns in the results of the estimation of STAR models are:

- the estimates of all models - both exponential and logistic - are coherent and consistent with the theory of non-linear cointegration. The crucial elements are the following:
  - the LSTAR models have highly significant negative coefficients on lagged-residuals (γ^L and γ^H), confirming that equilibrium is restored after an exogenous shock;
  - the ESTAR models have highly significant negative coefficients in the outer regimes (i.e. one for significant residuals - γ^H) and insignificant in the middle regime (i.e. one for small residuals γ^L);
  - the parameters responsible for non-linear behaviour are consistent with economic theory and all regimes are represented (as shown by the percentage of

[5]The right panel of Figure 5.5 was restricted to the cases when inner regime γ was between ±1. This is done to facilitate interpretation of the graph only, parameters outside ±1 were all found to be insignificantly different from zero at 10% - see Table A.71.

Figure 5.6: γ Parameter Estimates



Notes: Left panel depicts the LSTAR model. The right panel depicts the ESTAR models. Results for USP to DSP and MSP to DSP transmissions are presented in red and green, accordingly.

observations for which the transition function is lower than .5);

- the threshold value is well centered around the median disequilibrium (50^{th} percentile);
- autoregressive dynamics (i.e. parameters ψ^H and ψ^L) differ between products, countries and tiers and significantly affect the adjustment process;

- with respect to cross-tier comparisons:
  - MSP to DSP transmission is generally faster to adjust back to the equilibrium and exhibits a greater degree of non-linearity than USP to DSP;
  - MSP to DSP transmission parameters indicate more abrupt regime transitions, with higher smoothing parameters and lower percentage of observations below the 50% threshold compared to USP to DSP transmission;
  - MSP to DSP transmission exhibits richer dynamics than USP to DSP indirect transmission, yet the γ estimates are more consistent and exhibit lower variance. This is understandable, as MSP to DSP transmission is not influenced by the activities of the refining stage;
- with respect to cross-product comparisons:

- consumer products (ULP and Diesel) exhibit more homogeneous estimates and higher degree of non-linearity than the industry products (RFOs and gasoil) both in ESTAR and LSTAR models;
- LPG and LP estimates are drastically different from their counterparts. In case of LPG it is most likely because it has alternative sources (natural gas). In case of LP it might be due to the fact that this product is being phased out from production and distribution;

- with respect to cross-country comparisons:
  - countries of Iberian and Scandinavian Peninsulas (Spain, Portugal and Finland and Sweden, accordingly) stand out as outliers compared to the mainland EU countries. This could point to the impact of transportation costs or lags on price transmission. Similar claims for price transmission frictions in Singapore were voiced by Delpachitra (2002);
  - estimates for the Eastern European countries differ significantly from those for Western Europe, which could be a sign of differences in time coverage;

5.3 Summary and Conclusions

In this chapter, we analysed dynamics of price transmission in the EU. First, we performed the analysis of long-run elasticities in the price dynamics using both traditional OLS estimates, advocated by Engle & Granger (1987), and LR estimates in the spirit of Stock & Watson (1993). The results give a coherent picture of EU energy markets as a well-linked system characterized by clear differences between products and countries. This makes this study useful for the purpose of cross- country and product comparisons and policy design. The usability of the analysis was confirmed by the review of popular claims of full pass-through of upstream costs to prices downstream. We also analysed the speeds of downstream adjustments to upstream cost changes. The results are consistent across countries and products and indicate widespread differences between motor spirits (ULP and Diesel) and industry fuels (gasoil and RFOs).

In the second part of this chapter we described the research into the presence and nature of the non-linearities in the EU price transmission. As the first study in petroleum transmission across the whole value chain, we analysed the non-linearities using the smooth-transition models and tested for the presence of two types of non-linearities - exponential and logistic.

The results of the testing procedure were found to be internally coherent and consistent with the body of previous research. They indicate the impact of product- and country-specific effects in the creation of non-linearities.

The innovative tests for the nature of non-linearities have proven that a significant part of non-linear adjustment processes are of an exponential nature. This implies that the commonly used SETAR models mis-specify the nature of the adjustment. For the remaining cases, the results of the analysis favours the LSTAR model which is an enhanced, smooth-transition version of the old SETAR models.

Based on the results of tests for the presence and the character of the non-linearities, we estimated the non-linear models for price transmission. The results are surprising in the sense that while the test results support the existing body of literature, the results of the simulation indicate that the degree of welfare-decreasing APT is lower than expected once more complex autoregressive adjustment dynamics are taken into account. This finds support in several applied studies which claimed that although the tests of APT confirm its existence, the actual simulations reveal that APT might be a relatively short-lived phenomenon - which actually is only to be expected given the size of the markets and their inherent volatility which should make the players accustomed to changes. Below we present a short overview of assessment of APT presented in the applied literature.

While there is no consensus on the extent of APT, the studies that did attempt to measure it conclude that however big APT is initially, it disappears fairly quickly. Bacon (1991) concludes that the difference between adjustment to increases and decreases is constrained to one week only. Reilly & Witt (1998) report that 10% increase in crude oil prices causes immediate increase equal to 4.1%, while a corresponding decrease results only in 1.9% fall in retail prices. Given the overall long-run effect of crude oil (5.8%) this effectively means that increases are passed on to customers within one month, while decreases take a couple of weeks longer to trickle downstream. Eltony (1998) reports similar estimates both for the UK and the US. Borenstein et al. (1997) estimate the APT to be around ten cent four to six weeks after one dollar price change in terminal, but it is not statistically significant after four weeks. The pattern for the crude - retail asymmetry is similar. Balke et al. (1998) report that given a 1% increase and similar decrease in crude oil prices, the differences in response of wholesale gasoline to those changes is just .35% and persists only for two weeks. For retail markets they find that the difference reaches only .2%, i.e. 6 cents per gallon in monetary terms. Brown & Yucel (2000) conclude that given the negligible effects of APT and the fact that no study confirms that it directly results from market power abuse, policies to suppress non-linearities might reduce efficiency and have undesirable outcomes. Energy Information Agency (1999) reports that the majority of adjustments in the USA take place under eight weeks and the asymmetry in responses is usually less than 15%-20%. Asplund et al. (2000) indicate that APT from FEX is negligible, while that from upstream prices is scarcely visible - the adjustment for decreases is completed after eight weeks, while that for increases in only four weeks. Bremmer & Christ (2002) state that:

> one has to wonder whether the difference (*between responses to upstream increases and decreases*) is economically significant.

Similarly, Galeotti et al. (2003) conclude:

> when we translate differences in adjustment speeds into time periods there do not appear to exist sizeable differences between upward and downward deviations from equilibrium.

In the same spirit, Johnson (2002, p. 47) concludes that:

> "asymmetric responses in the retail fuel margin, although present, are short lived".

Bettendorf et al. (2003) estimate that if a customer purchases 7 litres of motor spirit, a 1 Euro-cent per liter increase in spot prices costs that customer 0.4 cent more over the adjustment period that 1 Euro-cent per liter decrease. The authors conclude that this indicates that APT is not significant. Driffield et al. (2003) estimate that when petrol prices are above equilibrium a 1% increase in the price of crude oil causes petrol prices to rise by 0.0095% while if petrol prices are below equilibrium, a 1% increase in the price of crude oil causes a 0.0182% increase in the price of petrol. This difference, although small, is statistically significant. Wlazlowski (2003*a*) estimates that adjustment to negative (margin decreasing) disequilibria is faster than to negative disequilibria (38% and 18% per month respectively), which results in APT of several weeks. Contin et al. (2004) report that in Spain the full adjustment to upstream price decrease is completed three weeks later after that for increases. The difference in prices never exceeds 40 Euro-cents. Chen et al. (2005) report that APT is insignificant after four weeks and even before that time its value is lower than 2 cents per week. Deltas (2004) reports that within one month 70-80% of price increases is passed on to customers while within the same time only 54-63% of decreases is passed downstream. Verlinda (2006) reports that APT varies between countries of different characteristics so that no single measure of non-linearities can be obtained. However, in the pooled sample the asymmetry in the response to a 1 dollar per gallon change varies from -10 to 20 cents over a period of several weeks. To date, this seems to be the highest estimate of APT.

Although the above estimates are constrained to ULP and cover only a handful of countries (most significantly USA), the results of the simulations confirm that asymmetries for other markets are fairly similar. Therefore, we can conclude that the non-linearities in price transmission seem to be fairly short-lived and less pronounced than feared.

Chapter 6

Further Analysis

In this chapter we tackle some remaining aspects of APT analysis which were not addressed in chapters 4 - 5. We start by analysing the price transmission mechanism in the multinational setting (section 6.1). The idea is to check for the consistency of the results and the signs of cross-country dynamics resulting from the so-called "fuel tourism". Given the multi-billion welfare transfer caused by this phenomenon, this topic deserves in-depth research using the innovative multi-tier, multi-product and multi-country dataset. In the second part of this chapter we review explanations of the APT phenomena presented in the literature in the light of the results obtained. The analysis presented here is based on Wlazlowski et al. (2007*a*).

6.1 Cross-country Dynamics

6.1.1 Introduction

Motivation

Past research into APT described in chapter 3 has focused on the time dimension of price transmission and assumed that the disequilibria are eliminated internally and without cross-border effects. However, some previous studies (including Indejehagopian & Simon (2000), Bremmer & Christ (2002) and Ye et al. (2005)) acknowledge that the cross-country dimension might be useful in explaining price behaviour.

In this section we address some of the issues related to the geographical dimension of price transmission. We build upon the existing literature on "fuel tourism", i.e. cross-country purchases of petroleum products (mainly motor spirits). While we do not attempt to build a comprehensive model of price transmission that includes the geographical effects, we want to analyse the basic relationship between prices in different countries.

Due to the fact that every EU country enjoys discretion over taxation of petroleum products, "fuel tourism" is a EU-wide phenomenon - see European Parliament (2003).[1] This, combined with the fact that it might imply a significant drain on budget revenues in high-petroleum-tax countries - the Financial Times (February 16, 2007) reports the European Commission estimates that "fuel tourism" cost Germany GBP 1.3 billion in lost tax on Diesel fuel alone - make it a common topic in the news.

The "fuel tourism" phenomena is not constrained to countries sharing significant borders - the case in point is the UK and Ireland. Although the border between those countries is confined to a thinly populated areas of Northern Ireland Fitz, Bergin, Conefrey, Diffney, Duffy, Kearney, Lyons, Malaguzzi, Mayor & Tol (2008, Box 5.4, p. 110) estimate that:

> (...) in 2005 between 5 and 9 per cent of total petrol sales in Ireland were consumed abroad. The figure for diesel is 15 to 20 per cent.

Similarly, Tax Strategy Group (2003, p. 14) claims that:

> While the relative strength of the Euro has narrowed the differential with fuel prices in the North, there is still a considerable incentive for so called fuel tourism, i.e. purchases by Northern residents in this State.

Given the above, it is hardly surprising that the issue of decreased energy tax revenues due to adverse pricing dynamics receives significant political attention - as indicated by the House of Commons Report (2001). Laszlo Kovacs, European Union tax commissioner, claims that "fuel tourism" costs some national exchequers hundreds of millions of Euro a year and causes damages to the environment as truckers go out of their way to find discount Diesel - the Financial Times (February 16, 2007).

In this section, we analyse cross-country dynamics in the EU petroleum markets using a multi-product and multi-country framework. The purpose is to check for possible differences between level of prices in the EU countries and the impact these differences have on price transmission, particularly from the point of view of asymmetric price transmission. This is done in two stages, with the first involving an analysis of cross-country linkages and focused on testing for the existence of the "fuel tourism" phenomena and the second focused on its impacts on asymmetries (rigidities) in price transmission. By doing so, this chapter represents an attempt to link two strands of literature: the one on cross-national price dynamics (summarised below) and the other on asymmetric price transmission (described in chapter 3).

[1] Directive 2003/96/EC.

Literature on Cross-Country Dynamics

Journalists like to paint the romantic picture of drivers travelling to neighbouring low-tax countries in order to tank-up and avoid high taxation levied at home - see for example the Financial Times (February 16, 2007). This picture tends to be accepted by politicians and even environmentalists. For example, the European Parliament (2002) deemed it important enough to vote on local harmonisation of petroleum taxation,[2] while the Expert Group on the UN Framework Convention on Climate Change (1997) claims that such a trade might be even responsible for increased pollution and CO_2 emission in the low-tax EU countries.

For North America, Slade (1992) reports a shift in demand from Canada to USA that followed a reversal in price differentials between those two countries. Slade (1992, p. 263) claims that the resulting "fuel tourism" was so significant that it resulted in a price war and local market disruptions in *both* countries.

The importance of "fuel tourism" for the EU might increase due to sustained cross-national differences in taxation of petroleum products (see Newbery (2001) for details) and decreasing barriers to movements within the EU, mainly due to removal of or reduction in passport and custom controls (see Williams (1996) for an overview of 1995 Schengen accord and similar policies).

Rietveld, Bruinsma & van Vuuren (2001) analyse the consequences of spatial distribution of fuel taxes, and shifts between the Netherlands and Germany. The results of the drivers' survey indicate that approximately 30% of the Dutch drivers fuel in Germany which confirms the view that "fuel tourism" is indeed widespread.

Bentzen (2003) analyses retail petroleum price convergence in 20 OECD countries over the 1978-2002 period with the help of standard time-series techniques (existence of common trends using DF tests). The results indicate that there is very little or no support for the notion of price convergence either in nominal or purchasing-power-parity-adjusted prices. No other analysis of cross-border purchases is reported.

Michaelis (2004) analyses the incentives for "fuel tourism" and shows that even comparably small price differences induce an increase in *perceived* profitability of cross-border purchases which could potentially be utility-decreasing. The author concludes that it is necessary for drivers to learn the complete private costs of purchasing the fuel abroad. Unfortunately, the analysis is not backed-up by estimation and relies mainly on simulations based on price differentials.

Dreher & Krieger (2007) analyse the prices of petroleum, Diesel, gasoil and fuel oils in

[2] Updates to Directives 92/81/EEC and 92/82/EEC.

the old EU-15 countries over the period 1994-2005. Using univariate and panel techniques they show consumer price arbitrage (i.e. arbitrage for retail tax-inclusive prices) to be weaker than producer price arbitrage (i.e. arbitrage for retail prices net of taxes). This is hardly surprising as the latter requires both tax convergence and realisation of arbitrage opportunities by the drivers while the former does not depend on synchronisation of taxes. The results do not focus on the pattern of the adjustment or on whether the adjustment differs between high and low-price countries.

Banfi, Filippini & Hunt (2005) analyse "fuel travels" to Switzerland from Germany, France and Italy. Based on the estimates of the panel demand model, they argue that as long as price differentials persist, the foreign drivers cannot be easily convinced to stop fuelling in Switzerland. The simulations indicate that from 1985 to 1992 "fuel tourism" accounted for about 15% of overall petrol sales in the three neighbouring regions of Switzerland, falling to about 7% between 1992 and 1997.

6.1.2 Empirical Analysis

The cross-country dynamics are analysed using the same dataset as the one used in the two previous chapters, with the addition of data on tax-inclusive, pump prices of all products, translated to the common denominator using local currency to USD exchange rates. The all inclusive prices are used to establish in which countries the end users face higher prices and thus should be more likely to engage in "fuel tourism". Tables A.73 - A.84 present the yearly averaged all-inclusive prices expressed in USD.

Based on the geographical data, summarized in Table A.1, we analyse 71 cases when one country bordered another, thus giving rise to possible "fuel tourism".[3]

Cross-country Links

The simplest way of analysing the cross-country dynamics would be to use the VECM model as given by (4.4). A significant drawback of this testing framework is that cross-country effects cannot be readily tested, unless some restrictions are placed on other parts of the model. As an example consider a situation when one is interested in analysing the pricing system in the two-country framework, and testing whether the retail prices in the respective countries affect each other. In such a setting, the standard solution for testing the null hypothesis of no effect of foreign retail prices on domestic retail prices would

[3]A possible drawback of this dataset is the lack of data on non-EU countries bordering EU states (mainly Switzerland and the FSU countries). Furthermore,

involve using:

$$B(\mathcal{L})\mathbf{z}_t^* = \mathbf{z}_t^* - \Phi_1 \mathbf{z}_{t-1}^* - \ldots - \Phi_p \mathbf{z}_{t-p}^* = \epsilon_t \tag{6.1}$$

where:

- $\mathbf{z}_t^* = (ln(y_t^{(Product,Country)}), ln(y_t^{(Product,Country^*)}), ln(x), ln(ex^{Country}), ln(ex^{Country^*}))'$ is the column vector of the variables (by country, its neighbours, and by product);

- $Country^*$ stands for countries bordering the country analysed;

and testing linear restrictions on (6.1) in the form of a vector with zero values for the foreign prices and ones otherwise - $(1, 0, 1, 1, 1)'$. Unfortunately, this specification restricts all other effects (such as the marginal impacts of crude oil and the exchange rate) to be of equal magnitude, which is implausible.

In this section we deal with a situation similar to the example presented above, as we are interested in establishing whether disequilibria in prices abroad could affect prices at home. In particular, we want to verify the anecdotal evidence about the potential impact of high petrol prices in one country on cross-border purchases.

The reasoning is that if a bordering country has constantly higher prices, a certain portion of users from that country regularly purchases petrol abroad (i.e. in home country) and this is reflected via aggregated demand in the home country's prices. This portion of total demand is assumed to be constant and cannot be distinguished from domestic demand based on aggregated data. However, this demand is likely to increase when prices of products abroad increase.

In order to test for the presence of such a pattern and overcome the restrictions of the VAR framework described above, we estimate the auxiliary ECM model of the following form:

$$\Delta ln(y_t^{(j,k)}) = \pi^{(j,k)}\hat{\epsilon}_{t-1}^{(j,k)} + \sum_{k^*=1}^{n^*} \pi^{(j,k^*)}\hat{\epsilon}_{t-1}^{(j,k^*)} + \sum_{i=0}^{p} \iota_i^{(j,k)} \Delta ln(ex_{t-i}^k) + \sum_{i=0}^{q} \kappa_i^{(j,k)} \Delta ln(x_{t-i}) + \nu_t \tag{6.2}$$

where:

- k^* describes the neighbourhood of the country k, i.e. other countries from the sample that border country k, n^* denotes the number of these countries;

- $\hat{\epsilon}_{t-1}^{(j,k)}$ are lagged residuals from the level equation $\hat{\epsilon}_t^{(j,k)} = ln(y_t^{(j,k)}) - \hat{\alpha}_{(j,k)} - \hat{\beta}_{(j,k)} ln(x) - \hat{\gamma}_{(j,k)} ln(ex^k)$ for the country k and product j;

- $\hat{\epsilon}_{t-1}^{(j,k^*)}$ are lagged residuals from the level equations $\hat{\epsilon^*}_t = ln(y_t^{(j,k^*)}) - \hat{\alpha}_{(k^*,j)} -$

$\hat{\beta}_{(k^*,j)} ln(x) - \hat{\gamma}_{(k^*,j)} ln(ex^{k^*})$ for all the countries that border country k, i.e. k^* and product j.

In the setting described above, the focus is on the $\pi^{(j,k)}$ and $\pi^{(j,k^*)}$ coefficients. In the traditional one-product setting, the $\pi^{(j,k)}$ coefficient represent the adjustment of the system towards the long-run equilibrium after a disequilibrium occurred. In the setting given by (6.2), the $\pi^{(j,k^*)}$ coefficients show the response of the local prices (via change in the local disequilibrium) to disequilibria in neighbouring countries. If the coefficients are positive it means that local downstream prices and disequilibria increase when disequilibria in the neighbourhood are positive, i.e. when the actual prices are above their long-run equilibrium levels. Intuitively, this could lead to an increase in individual cross-border purchases, thus resulting in the "fuel tourism" and increase in demand in low-price/tax country.[4]

Asymmetries in Price Transmission

We also implemented cross-country disequilibrium feedback mechanism into (5.2) so that the LHS variables would include residuals from the neighbouring countries, lagged by one period.

This analysis is performed only for markets for which data on neighbour's prices were available, by inclusion of lagged residuals from neighbouring countries, so that (5.2) in traditional STAR testing framework becomes:

$$\begin{aligned} \Delta\hat{\epsilon}_t &= \zeta_0 + \zeta_1' * \mathbf{X_t} + \zeta_2' * (\mathbf{X_t} * \hat{\epsilon}_{t-d}) + \zeta_3' * (\mathbf{X_t} * \hat{\epsilon}^2_{t-d}) + \zeta_4' * (\mathbf{X_t} * \hat{\epsilon}^3_{t-d}) \\ &\quad + \zeta_5' * (\mathbf{X_t} * \hat{\epsilon}^4_{t-d}) + \nu_t \end{aligned} \tag{6.3}$$

where $\mathbf{X_t} = (\hat{\epsilon}_{t-1}, \hat{\epsilon}^*_{t-1}, \Delta\hat{\epsilon}_{t-1}, \cdots, \Delta\hat{\epsilon}_{t-p})$, and $\hat{\epsilon}^*_{t-1}$ denotes residuals from the LR pricing equation in neighbouring countries.

The model above allowed us to test whether the inclusion of neighbour's dynamics affects the results of the non-linearity tests, reported in 5.2.1.

[4]Obviously, this can occur only when *after-tax* prices in a neighbouring country are higher than in the home country so that such a trade is profitable for most users. The tax portion of the retail price is irrelevant for some users (via VAT reimbursement), but the majority of buyers consider only fully-loaded prices.

Table 6.1: Non-Linearities in Price Transmission (Cross-Country Effects)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	× / ×	× / ×	× / ×	/	E / L	/	/
BE	L / E	× / L	L / E	× / E	× / L	E / E	L / L
CY	- / -	- / -	- / -	/	/	- / -	/
CZ	× / -	- / -	× / ×	- / L	- / -	- / -	- / -
DE	E / ×	L / E	× / ×	- / -	L / L	/	× / ×
DK	E / ×	× / ×	L / E	/	× / ×	/	× / ×
EE	- / -	- / -	- / -	- / -	/	/	/
ES	× / ×	× / ×	L / E	× / -	× / ×	× / ×	× / ×
FI	× / E	× / E	E / E	/	E / L	/	/
FR	E / L	× / ×	L / L	× / ×	× / ×	- / -	E / ×
GB	E / E	× / ×	L / ×	/	- / -	× / ×	- / -
GR	- / -	- / -	- / -	/	- / -	- / -	- / -
HU	- / ×	× / L	- / ×	- / -	× / ×	/	/
IE	E / E	× / L	E / ×	/	/	- / -	- / -
IT	L / ×	L / ×	L / L	- / -	× / E	× / ×	× / L
LT	× / ×	- / ×	× / L	- / ×	× / ×	- / ×	/
LU	E / L	L / E	E / E	× / L	L / L	- / -	L / E
LV	- / -	× / -	- / -	- / -	/	/	- / -
MT	- / -	- / -	- / -	/	/	- / -	- / -
NL	E / L	× / ×	E / ×	- / -	E / E	/	- / -
PL	× / ×	E / ×	× / ×	- / -	- / -	× / ×	/
PT	L / E	E / E	- / -	- / -	E / E	- / -	× / ×
SE	L / L	× / ×	E / L	/	E / L	/	/
SI	× / ×	E / ×	- / ×	- / E	- / -	/	/
SK	- / ×	- / ×	- / -	- / -	- / -	- / -	- / -

Notes: For each country-product pair, the first symbol refers to USP to DSP transmission and the second one to MSP to DSP transmission. Symbols used: L - LSTAR, E - ESTAR, × - linear cointegration, – no cointegration or data on prices in neighbouring countries not available.

6.1.3 Discussion of Results

Cross-Country Links

Tables A.85 and A.86 present the results of the estimation of ECM model given by equation (6.2) with the p and q parameters set equal to 4 (one month coverage). To facilitate the analysis of the results, the headlines of the tables include comparisons of tax-inclusive prices expressed in USD, averaged over the entire sample. The aggregate information should be analysed in conjunction with year-by-year data presented in Tables A.73 - A.84, as on some occasions changes in taxation could affect the relative prices.[5]

Cross-tier comparisons of the results reveal consistent values and signs of the estimates of cross-country dynamics. This pattern of $\pi^{(j,k^*)}$ values suggests that:

- when neighbours' prices are higher than home prices the coefficients of interest are positive, i.e. home prices increase whenever neighbours' prices are above their equilibrium values (i.e. are even higher than usual);

- when neighbours' prices are lower than home prices the coefficients of interest are zero, i.e. home prices are not affected.

As an example of the former conclusion, consider first the model for ULP petrol in Austria. The mean tax-inclusive prices in Austria over the sample period are amongst the lowest in the region (lower than in Italy and Germany). The results of estimation of (6.2) indicate that when prices of the product are 1% below their long-run values (1% disequilibrium), the adjustment equals .09%. Accordingly, when a similar disequilibrium exists in Germany, Austrian prices increase by .07%.[6]

While the former conclusion is self-explanatory via the supply-demand relationship, the latter one requires some interpretation. Basically, the results obtained show that local buyers who can do it are already buying abroad and when prices abroad increase even further they do not change that pattern. This is in line with the results obtained by Rietveld et al. (2001) and Michaelis (2004).

The results also confirm the conclusions presented in the qualitative study by Rietveld et al. (2001) - in both countries bordering the Netherlands (Germany and Belgium) the results of estimation of (6.2) for both motor spirits (Diesel and ULP) show that when

[5]For example, in 1994 tax-inclusive USD-denominated ULP prices were lower in Germany than in Belgium. This was reversed in 1995.

[6]Please note that while the *average* prices over the sample size are lower in Austria than in Germany, in the years 1995-1998 Germany enjoyed actually lower prices. This offers an interesting opportunity for time analysis in the spirit of Slade (1992).

Dutch prices increase (i.e. they are even more expensive, the disequilibrium is positive), the German and Belgian prices increase via the supply and demand link.

Unfortunately, as no detailed data are available, we cannot establish whether the discovered patterns might result from other market events, such as shared transportation bottlenecks, interruptions of refining activities, etc. However, it is unlikely that those random phenomena could cause persistent cross-country dynamics found in the data.

Asymmetries in Price Transmission

Table 6.1 summarizes the results of the analysis for USP to DSP and MSP to DSP transmissions. Compared with results for one-country analysis the inclusion of cross-country dynamics results in:

- with respect to cross-tier links - a more balanced distribution of the non-linearities - once cross-country effects are taken into account, the non linearities tend to be found in both indirect USP to DSP *and* MSP to DSP transmissions;
- with respect to products - higher degree of non-linearities for consumer products - mainly ULP, Diesel and gasoil;
- with respect to countries - higher degree of non-linearities for low-cost countries - most notably new EU-10 countries and Luxembourg.

The detailed results are presented in Table 6.1. Generally, the results should be seen as a confirmation of the one-country analysis. In particular, the addition of cross-country effects causes the results of USP to DSP and MSP to DSP to become more uniform. The most likely explanation is that cross-country data introduce some cross-tier information lost in the one-country setting.

The patterns visible in the results support the notion that the drivers in high-tax countries tend to travel to neighbouring low-tax countries and enjoy the price differentials, thus contributing to the demand abroad, as specified by Rietveld et al. (2001) and Michaelis (2004). The intensity of the fuel travels seems to increase whenever prices in home country are above their long-run equilibrium levels, thus resulting in extra incentives to fill up abroad. This needs to be verified with the use of information on the volume of trade and commuting, but such data are unfortunately not available for all EU countries. In particular, we confirm the claims made by the Financial Times (February 16, 2007) as Luxembourg is found to be significantly affected by the positive motor spirit price disequilibria in the neighbouring countries. The results for other products which are less likely to be subjected to "fuel tourism" are less clear-cut. For example, the existence of the France-Germany relationship for heating oil found by Indejchagopian & Simon (2000) is not confirmed. This might be due to the fact that the sample includes also Belgium and Italy or might reflect that heating oil purchases rarely involve cross-border purchases.

Despite the reservations described above, the results of the analysis have potentially wide-ranging implications. In particular, "fuel tourism" has to be taken into account when discussing benefits from fuel-tax harmonisation within the EU. If drivers are likely to travel abroad, the EU-wide harmonisation might be the only viable option to be employed for the sake of environment and prevention of tax-base erosion. Partial attempts that do not account for geographical features of the EU borders might not necessarily be successful. It is important to stress that the link between price differentials and disequilibrium restoration discussed above might not be the only source of price dynamics. An alternative mechanism might be related to organized, high volume smuggling. Despite the efforts of the EU governments and enforcement agencies, the problem of smuggling remains significant. Continuing the example of Ireland and the UK, in the words of the Northern Ireland Affairs Committee (1999):

> There is no doubt that the differential in fuel prices (...) has serious consequences for fuel suppliers and road hauliers. It is also a wider problem in that, besides distorting trading patterns, it appears to have become a means of funding for paramilitaries and racketeers.

The Swedish Environmental Protection Agency (2000) extends the example to the new EU-10 countries:

> (...) this problem is argued (...) to be of particular importance in relation to EU Enlargement as well, as smuggling and tax evasion in relation to fuel are already very widespread in many Central and Eastern European countries.

Although smuggling can potentially have significant impact on the issue analysed in this section, we cannot assess the extent to which it is reflected in our results. This, however, does not change the basic policy recommendation resulting from our work - EU-wide harmonisation of petroleum taxation can significantly reduce cross-country fuel purchases, both legal and illegal.

6.2 Explaining the Presence of APT

As discussed in chapter 1, standard economic models of market behaviour (perfect competition, oligopoly and monopoly, etc.) do not explain the presence of non-linearities in price transmission. Over the years, APT researchers have proposed several casual explanations of the non-linearity phenomena found in the price series, but their applicability for the purposes of this analysis is limited for several reasons. Firstly, they do not offer a comprehensive picture of market pricing but were rather prepared to explain a particular set of results obtained for a particular product, market level and data frequency. Accordingly, those casual explanations disregard issues of smooth transition between pricing regimes or the presence of more than one type of transition between pricing regimes, instead focusing either on SETAR-type asymmetry or unspecified asymmetry proxied by the non-linear ECMs. Secondly, the lack of a uniform framework and reliance on numerous, situation-specific assumptions often leads to conflicting predictions and makes assessing relative merits of different explanations impossible.

In this section we describe the most common explanations of the APT phenomenon. We focus on their applicability to petroleum markets and whether they are consistent with the results of this analysis. In the second part of this section we present some attempts to distinguish between conflicting explanations of APT. Since this study does not attempt to answer what causes non-linearities in the data, we only present explanations which have been offered in the existing literature, assess their applicability to pricing of petroleum products and discuss whether their predictions find support in the results of this analysis.

6.2.1 Abuse of Market Power

The most popular explanations of APT link its presence with some form of abuses of market power. This link is often used to justify the launch of formal inquiries into petroleum pricing or the introduction of pricing controls designed to curb the possible welfare transfer to the perpetrators. Below, we discuss various strands of the literature on market power abuse that might shed some light on whether it could facilitate APT.

Regardless of whether the abuse of market power is governed by a formal cartel agreement or occurs as a result of tacit collusion, obtaining artificially increased margins is a punishable offence under the laws governing most market economies. In the EU, each member state can punish anti-competitive agreements according to Article 81 of the EC Treaty - Motta (2004).[7]

[7]For an extensive overview of the theory of collusion see Tirole (1992*b*), Green & Porter (1984) and

Given the gravity of the offence, it is obvious that colluding companies would obstruct identification of their deeds. This, combined with lack of a clear definition of relevant market and abuse in the presence of collective dominance, makes verification of market power as a source of APT difficult, not only for economists but also for practitioners. Kováč, Putzová & Zemplinerová (2005) report a case from the Paris Court of Appeal, which overruled the guilty verdict in a case of petrol retailers who shared information about the prices charged. The appeal verdict stated that although the companies exchanged the information on retail prices, this information did not restrain their autonomy to set their prices (although from the economist's point of view, such information sharing clearly facilitates non-competitive pricing or tacit collusion).

Because the collusive profits obtained by participants are assumed to remain stable (in the absence of external shocks), collusion should not result in APT unless (i) participants decide to disguise their actions as APT or (ii) non-linear pricing results from imperfections in monitoring or maintaining the collusive agreement.

By definition, under the assumption of perfect monitoring and faultless monitoring, the margins of participants remain unchanged as long as the collusive agreement is stable. Once the agreement is broken and companies that adhere to it punish the "cheater", a sudden drop of the price occurs. This can lead to a reverse "rockets and feather phenomenon", with prices falling faster than they rise.

The situation described above does not find support in the data used as both retail and mid-stream prices exhibit constant variance. Furthermore, Kolmogorov-Smirnov (KS) tests do not reject the null hypothesis that absolute values of price increases and decreases come from the same distribution - see Eckert (2002, p. 56) and Eckert (2003, p. 155) for a formal discussion.[8] Furthermore, the non-linear patterns found in the data (short-run adjustment measures in ESTAR and LSTAR models) do not indicate the presence of a reversed "rockets and feathers" phenomenon.

Accordingly, it is unlikely that companies could manage to disguise their collusive pricing practices as APT. Apart from obvious difficulties with coordinating responses to upstream changes, given the size of petroleum markets and the fact that they consist of numerous companies operating at every distribution tier, such a complex collusion would require a truly epic conspiracy.

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the references therein. For a discussion focused on petroleum markets see Driffield (1999), Driffield & Ioannidis (2000) (for the UK), Slade (1987), Borenstein & Shephard (1996) and Borenstein et al. (1997) for the Northern America.

[8]In section 4.1.2 we discuss this issue in greater detail. The results of the KS tests are summarised in table A.70. Following convention used in the code for KS test available in GNU R - Ihaka & Gentleman (1996) - the last column in Table A.70 presents the complements to the p-value for the test (that is 1-p-value for the test).

Once the assumptions of perfect information are dropped, additional forms of APT can emerge from collusive behaviour. As an example consider a closed, colluding market for homogeneous products sold by firms which have no knowledge of quantities supplied to the market by other firms and have to deduce the total supply to the market from the market prices they observe. In such a situation, in order to maintain collusion the participants must disregard small price changes (as these might result from random demand shocks) and react only to significant drops in sales which indicate that someone exceeds assigned quotas. Thus, the equilibrium behaviour involves (i) a cooperative phase in which all firms produce their shares of agreed output and (ii) a punishment phase - when prices fall below the threshold value, companies assume that a member of the agreement exceeded assigned quota so they should retaliate and quickly restore the equilibrium levels of supply and prices. This could lead to APT in which positive and/or small negative shocks to margins are left unchecked, but significant negative disequilibria are eliminated fast. While the sluggish response to price changes does find support in the results obtained (significant presence of ESTAR models), the asymmetric nature of answers to positive and negative price shocks is not supported by the results of this analysis. In addition to the estimation results presented in Table A.71, the scatter plots of $\Delta\epsilon_t$ against ϵ_{t-1} presented in Figure A.87 (together with OLS regression fit and LOWESS non-parametric smooth lines as proposed by Cleveland (1979) and Cleveland & Devlin (1988)) do not support the notion of faster response to negative disequilibria.

Eckert (2002) also deems this explanation unfit for petroleum markets as (i) players can easily observe others' pricing[9] and (ii) market disruptions are relatively frequent and are not followed by periods of stable prices as should be expected from the market ruled by an agreement.

If the market demand is allowed to change substantially (which by itself is questionable, as market data presented in chapter 1 suggest stable demand), the collusive story offers another way of modelling APT. Rotemberg & Saloner (1991) indicate that apart from the actual punishment, firms might choose to lower prices also at times of reductions in collusive profits (e.g. following low demand), simply to remove the incentive to renege on the agreement. In such a setting, assuming random shocks to demand, the highest sustainable margins would be at times of high demand after which the demand is expected to decline. At other times, the agreement is defended by lowering margins. Haltiwanger & Harrington Jr (1991) replace the stochastic demand shocks with a dynamically changing path of demand which leads to a model in which maintaining collusion depends on the

[9]Such data unfortunately are either not available to researchers or priced out of their reach.

predicted changes in demand. With demand increasing, expected profits increase and so does the incentive to sustain collusive prices. Therefore, the highest margins should occur in periods when demand is expected to increase. Unfortunately, without detailed, high-frequency data on consumption patterns, this explanation cannot be tested directly. Furthermore, the assumption of significant random shocks to demand is questionable, as market demand is fairly stable and shocks can be met by adjustments in inventories. Obviously, shocks to small and/or isolated markets could still result in APT in a manner described above, but those situations cannot be analysed using aggregate data of the kind used in this work. Regardless of the remoteness of the market, the applicability of this explanation still relies on the inability of players to monitor / predict market sales, which might be questionable as several market consultancies (including Platt's) offer such analyses. Furthermore, this analysis does not cover how markets perceive the prices and what are the expectations regarding their changes.

Borenstein & Shephard (1996) recast models by Rotemberg & Saloner (1991) and Haltiwanger & Harrington Jr (1991) in terms of dynamic changes of marginal costs rather than demand. Therefore, when upstream costs are expected to increase, players expect lower collusive profits, thus lower costs of punishments and might be more likely to cheat on the agreement. This in turn leads to lower collusive margins now. Therefore, expected changes in costs have *negative* impact on current margins.

Green & Porter (1984) present a "trigger" model of tacit collusion. This model involves a repeated interaction in Cournot quantity competition under the assumption that above a certain price market players act as monopolists, and when market price drops below the threshold, they revert to Cournot equilibrium - which corresponds to the punishment phase. An analytical representation of this model is provided by Tirole (1992*a*, p. 264). Borenstein et al. (1997) develop this model further and explain that prices are sticky downwards because when input prices fall, old selling prices offer a natural focal point for oligopolistic players to coordinate. Companies price at this point and realize extra profits until an adverse demand shock forces prices downwards. Conversely, input price increases invalidate old reference prices, as the margins are squeezed. Brown & Yucel (2000) present a similar explanation in which firms are unaware of upstream prices other players pay and decide to postpone cutting the margins at times of falling upstream prices, so as to signal to their fellow conspirators that they adhere to the agreement. This follows the discussion of the importance of trust in maintaining collusion - Tirole (1992*a*).

Unfortunately, models assuming a focal price suffer from arbitrary assumptions. Firstly, the theory does not specify how sellers coordinate on a particular price. Borenstein et al.

(1997) claim that the price charged before an upstream price decrease is a natural focal point for coordination, but it is not the only equilibrium possible in the model. Secondly, even if one focal or collusive price is informally established, since players cannot enforce it, as soon as the coordination breaks down, downstream prices should return to the competitive levels. Radchenko (2005*b*) points out that this revision should bring downstream prices to the competitive level similarly to the retaliation phase in collusion. A possible solution is presented by Lewis (2004) who points out that the breakdown of a collusive agreement need not result in an instantaneous downward revision of prices to competitive levels, as long as the collusion agreements are only local. However, given spatial and economic integration of the markets, it is difficult to expect that local station managers would engage in this practice. Furthermore, most prices are set in a country-wide campaign with a minimum cross-country variance - Asplund et al. (2000).

Slade (1989) and Slade (1992) analyse sudden price changes that occurred in Vancouver, Canada in the summer of 1983. Both studies interpret the visible patterns as signs of price wars triggered by unanticipated demand shocks without inference from upstream prices. In both papers, the author reports the evidence of tacit collusion in which rivals pay attention to who initiates price change and what is the direction of this change. In particular, the responses to increases initiated by the major firm(s) are faster than to decreases, with the opposite being true for independent sellers. This is attributed to the fact that stations form a tacit collusion in which one of the rules enforcing the agreement is that majors signal that the price wars are over by initiating large price increases.

Verlinda (2006) analyses the degree of APT in wholesale-retail price transmission in California, US. The author attempts to quantify the effect that individual station's characteristics (in particular spatial features that affect local market power) have on short- and long-run changes in prices. This is done by analysing the cumulative response functions from the Bayesian non-linear estimation of (2.17) with station-specific pricing coefficients (αs, βs and γs). The most important finding is that stations with competitors in close proximity exhibit a *lower* degree of APT, which suggests that local market power affects asymmetry. However, some of the other results reported are counter-intuitive and at odds with the explanations provided. In particular, stations located near other stations (so that competitors' prices would be visible to the naked eye, thus facilitating collusion) do *not* exhibit greater APT. Furthermore, stations located near shopping centers are said to exhibit a smaller degree of APT, although they have a greater number of clients. Similarly, stations situated in high-income areas and those with a higher number of pumps also do not exhibit greater APT, although according to the theory they should enjoy a greater market power.

Assessment

Although the link between abuse of market power and presence of APT attracts great attention, according to Verlinda (2006, p. 7) "the evidence in support of market power effect on pricing asymmetry has been sparse". This is mainly because of limited data availability. Since market power is established at the station level, it could be detected only by utilizing station-level data. Unfortunately, such data are not readily available, not even for the well-research US market - Verlinda (2006, p. 8). For other commodities, for which the data are easier to obtain, Peltzman (2000) finds signs of APT in diverse US industries, independently of their organization and number of companies they have.

Furthermore, a number of stylised facts suggests that collusive behaviour is not likely to occur in petroleum markets, so it cannot result in APT. Firstly, collusion is less profitable and more difficult to sustain in markets with a higher number of players. This effectively limits the scope for its presence in the petroleum sector to upstream markets disconnected from the internationally integrated energy hubs. Secondly, collusion cannot be sustained without significant entry barriers. This limits the potential scope for collusion to remote markets relying on government protection. Thirdly, collusion is more difficult to sustain in industries heterogeneous with respect to firm size and cost structures. Given the structure of the industry outlined in section 1.3, this makes collusion less likely to be responsible for the non-linear patterns found in the data used.

Last but not least, collusion results in a peculiar form of APT, usually with two distinct pricing regimes and a sudden switch between them. Our results suggest a more gradual picture of regime switch in price transmission and the presence of at least two pricing regimes.

Given the above, explanations of APT related to collusion find little or no application to petroleum markets.

6.2.2 Explanations Related to Search Costs

While collusion-related explanations focus on the impact which market supply has on prices, search cost explanations are concerned with the demand side of price transmission. Generally, they link APT with costs the buyers face in the process of purchasing petroleum products. Given how markets are organized, search costs should be significant only at the retail level - Borenstein et al. (1997). The applicability of this explanation to various products is a little bit more complicated. In a recent paper, Kaufmann & Laskowski (2005) point out that while motor spirits are purchased mainly by individuals, for which search costs might be significant, heating oil is purchased less frequently and in larger quantities, which should reduce the cost of search per purchase. Unfortunately, the absolute majority of applied studies focus on motor spirits (see Table 3.3) and does not analyse cross-product differences. Therefore, the question of whether explanations related to search costs apply to all the products in the same way remains unanswered.

Standard Search Theory

In its standard version, search theory links the presence of APT to a short-term market power the sellers enjoy because buyers faced with higher prices cannot tell whether those prices reflect common market-wide trends or a station-specific shock. Since searching is costly, some of them decide not to do it, which gives sellers opportunities to exploit their short-term market power. Following this line of reasoning, Marvel (1976) points out that tourists do not search for cheaper motor spirit on the way as possible costs of obtaining low price might be high (no knowledge of local conditions) and possible gains are only occasional.

Given that the "signal extraction problem" is exacerbated by higher volatility of prices, whenever buyers know that common price shocks that sellers face had intensified, they are less likely to search for cheap petrol which results in *higher* APT. Conversely, when volatility is low, buyers are likely to interpret the high prices they encounter at the station as station-specific and search further, thus decreasing APT.

Simple scatter plots of 3 week rolling standard deviation of downstream prices and disequilibrium (a change in the standard margin), summarized in Figure A.89, do not indicate that higher volatility results in higher margins (as proxied by positive residuals).

Search Theory with Bayesian Updating

Benabou & Gertner (1993) introduce an element of learning to the standard search model by allowing the buyers to compare benefits and costs of searching for cheaper products, which might result in an *increased* amount of search at times of increasing prices. Following this approach, Johnson (2002) explains APT as a result of changes of the amount of search undertaken by buyers. The idea is that at times of rising prices, buyers search more (if search costs allow) which puts extra demand on sellers who linger with high prices and causes fast price adjustment. Conversely, when prices fall, the demand is lower and there is no incentive for higher-charging sellers to lower prices.

It is important to add that the above applies only to situations when the search costs are low. When they are high, no search might be undertaken after the upstream price change and each firm will be able to charge the monopoly price to their existing clients. When the search costs are moderate, there might still be an equilibrium without search, where high pricing firms rely on buyers' *reservation condition* to prevent search.[10] With sufficiently low search costs, buyers confronted with higher prices decide to search and a reservation price strategy is established.

The prediction of the model that are relevant to the analysis of APT are related to the effects of inflationary uncertainty. When input costs are volatile, the perception of buyers change and they update their view of the price distribution. Such increases in volatility can lead to:

- an *increase* in the conditional variance of costs / price distribution, which increases profits from searching (greater disparity of prices means more bargains). This is the **variance effect**, which always forces increases in the amount of search and lowers sellers' market power;

- an *increase* in the value of search, as buyers confronted with high price charged by their current sellers believe that search might result in significant savings (if the high price is due to idiosyncratic factors specific to their current seller), together with a *lower* probability of search, as buyers believe that they are less likely to find such an attractive offer (because the high price might be due to industry-wide factors). This is the **correlation effect**, which can increase or decrease the amount of search depending on the changes in the probability and amount of search.

This explanation has several drawbacks. Firstly, the model hinges upon the "reservation price" condition. This assumption is easily invalidated both by frequent changes of prices on petroleum markets (especially upstream) and the presence of transportation costs. The simplest possible example is that driving around to compare other offers is likely to make them unattractive as it involves fuel consumption and thus extra expenditure. Brown & Yucel (2000) indicate that price differentials between US retailers are very small - a couple of US cents at most. Similarly, Hosken et al. (2007) report that the standard deviation of prices charged by 272 stations around Washington DC equals only 11 cents. Given the maximum feasible retail purchase determined by the tank size (50 litres)

[10] Reservation condition is a property of the search function that allows customers who rejected offered price x and decided to search further but found only less attractive offers ($y > x$) to *return* to the first seller and still buy at x. This might facilitate the second equilibrium if search costs are asymmetric (searching from first to second seller is costly, but the return is not) and significant compared to $y - x$.

and the frequency of re-fueling with motor spirits (once a week or less) this gives potential saving fluctuating from one to five dollars a week. For other fuels, the price dispersion and average purchases might be greater, but lower frequency of purchases and more developed market organization (for example, developed and experienced selling staff) might as well overcome this and result in lower relative search costs. Benabou & Gertner (1993, p. 74) defend their results by assuming that the search might still result in APT when sellers' costs are not too correlated - but this assumption is again questionable as in petroleum markets all players face the same or very similar upstream costs.

Interestingly, an experimental study by Deck & Wilson (2004) shows that while there are differences in pricing between small isolated regions in which search costs should be greater and central regions with more stations, prices in isolated regions (although higher) react symmetrically to cost increases and decreases, while central prices exhibit APT. Clemenz & Gugler (2006) support some of those findings by analysing the relationship between station density and pricing and conclude that there is no significant relationship between concentration measures and prices.

Reference Price Search

Lewis (2004) presents a variation of the search model in which buyers form their expectations based on *past* prices which are used as a reference point (hence the name) during the search. When customers observe prices lower than their reference price, they perceive it as low and do not search further. Accordingly, at times of decreasing prices the amount of search is lower, which results in higher profits and temporary market power for the sellers. The APT results from the fact that prices respond to cost only when cost is near or above last period's price. This usually happens following large increases in marginal costs. This casual explanation does not find support in the data used - figures presented in Panel A.90 indicate that downstream prices respond both to upstream and downstream prices, and that the increases in upstream costs (marked in red) involve increases in downstream costs (see direction of the arrows).[11]

Other Search Models

Cabral & Fishman (2006) develop a costly search model in which buyers deduce sellers' costs from the prices they charge and understand that cost changes are positively correlated across sellers. In such a setting, when buyers face a small increase in prices charged

[11] In order to account for the impact of exchange rate, the upstream cost changes were presented as a sum of logarithms, i.e. product of crude oil changes and appropriate USD-home currency exchange rate. This assumes equal impact of those two factors.

by their "old" supplier, they deduce that it is a sign of common industry shock and accept it as searching for lower prices is costly and might not result in a bargain. As a result sellers might increase prices by a little, without losing their customers. Conversely, at times of small decreases in the upstream costs, sellers choose not to decrease their prices so as to avoid sending their customers a signal that search might be profitable.

For large price changes, Cabral & Fishman (2006) predict that decreases would discourage search, as customers believe that other sellers also decrease their prices and search might not be successful. In contrast, potential costs savings after large price increases might surpass search costs, thus inducing search and moderate or full price increases (depending on the value of search costs).

This model has several verifiable predictions, in particular that cost changes and price changes have higher correlation for positive cost changes compared to those for negative changes and that price decreases are less frequent than price increases. However, the model is based on assumptions that are at odds with the nature of petroleum markets. In particular, it does not address the impact of inflation or significant and constant variability of prices which should make buyers accustomed to price changes. Cabral & Fishman (2006, p. 12) seem to acknowledge that by stating:

> (...) for oil products, buyers are better aware of cost variations. In the model used, this would imply the absence of stickiness due to search costs.

Furthermore, it does not account for the opposite direction of variance and correlation effects, whose interaction could cause consumers to search more at times of significant price decreases.

6.2.3 Other Explanations

Accounting Principles

Frey & Manera (2007) link non-linearities in price transmission to the accounting principle used by the sellers. They point that when a historical criterion (FIFO) is adopted to price goods from the inventories, the firms do not adjust their outputs immediately when costs change, but wait until the stocks of inputs bought at the old price are depleted. When instead a replacement cost criterion (LIFO) is applied, firms adjust their prices very rapidly in response to changes in input costs. In such a setting, the accounting convention chosen by a firm affects the speed of adjustment, creating ESTAR-type non-linearity.

McLeay & Jaafar (2004) analyse LIFO/FIFO adoption in the EU Member States and report that firms generally prefer FIFO and the average cost method to the LIFO convention (46%, 44% and 10% of firm-years, accordingly). Furthermore, while the proportion of firms reporting only FIFO or only the average cost method increases, LIFO was commonly phased out since the late 1990s, most likely in anticipation of its prohibition by International Accounting Standard Board in 2003 - the IASB (2003). Therefore, it is highly unlikely that the accounting principles could be responsible for the LSTAR type non-linearities found in the data used. Conversely, they could cause the delays in price transmission, analogous to those predicted by the ESTAR models.

Market Perception

Pindyck (2001) and Radchenko (2005*a*) link APT with perception of market changes, i.e. whether sellers treat them as a temporary fad or a sign of a permanent market change. This might lead to APT as inventory and production dynamics are all related via market-clearing mechanisms of two markets - for the commodity itself and for the necessary storage.

As an example consider how an exogenous shock and related increase in demand might be perceived by the market. If it is perceived as temporary, the optimum reaction of the market would be to temporarily push up the prices and use up a portion of the inventories. Resulting price increases would be instantaneous and reversed only once the agents replenish their stocks. Conversely, a shock deemed persistent would result in an increased demand for storage and the market response would not involve decreasing inventories. At the same time, the net demand also would increase as the opportunity cost of manufacturing increases.

Radchenko (2005*a*) analyses the impact of market perception in the transmission between weekly prices of US crude oil and generic gasoline (inclusive of taxation) over the period March 1991 - February 2003. For that purpose he utilizes a Markov switching model with probability given by (2.1) and regimes i and j interpreted as one for long and short term shocks which are modelled by (2.15) restricted so that only the effects of upstream prices (crudes) vary between regimes. This leads to a system in which *all* regimes are assumed to exhibit APT, regardless of the true properties of price transmission. The results of Bayesian estimation indicate the presence of APT in both regimes, which is not surprising, given that the modelling exercise is designed this way. An interesting finding is that the majority (97%) of price changes are viewed as transitory and short-lived by the market and only the remaining 3% have a long-run impact on the downstream price.

The modelling exercise has several drawbacks. Apart from the fact that it assumes that non-linearities are present in both regimes, the price of storage is proxied by a difference between spot and future prices - Pindyck (2001). This is questionable, as the volume of trading in oil greatly surpasses the trade in spot and future markets - see section 4.2.1. Unfortunately, based on the data available we cannot assess the applicability of this explanation.

An interesting variation of this model is briefly discussed in Asplund et al. (2000) (see section 3.1). The author argues that since spot prices expressed in USD are more volatile than USD to local-currency exchange rate, they are a more significant source of uncertainty than upstream prices denominated in USD. Therefore, sellers expect spot prices to revert and postpone price adjustments. Conversely, a less volatile exchange rate is less likely to revert, so that firms pass on the changes to end customers faster. This results in APT in FEX but not upstream prices. Unfortunately, this explanation can only be analysed for the SR changes (LR disequilibria by definition are expressed in the same currency as downstream prices).

Inventory Adjustment

Borenstein & Shepard (2002) note that US refiners hold inventories of motor spirits equal to *ca.* 25 days of sale to ensure frictionless refining operations. Furthermore, because of transportation lags and technicalities (such as the inability to use pipelines at less than 100% of their capacity) their distribution centres hold inventories equal to several days of sales.[12] Given the size of those inventories and the per-unit price of stored products, it is obvious that their creation and management is costly.

Reagan & Weitzman (1982) develop a model in which a profit-maximising firm uses inventory to mitigate the effects of unanticipated changes in demand. In this model, costs of creating inventories act as a floor below which it is irrational to sell at times of adverse demand shocks. In such a setting, a profit-maximising firm facing lower demand starts depleting their inventories and cutting production, instead of lowering prices of their current output. Hence, an adverse demand shock has a small effect on prices. Conversely, an increase in demand results in sharp price increases as production lags and finite inventories constrain sellers' reactions. As a result, increases in demand are dampened through higher prices, while decreases are met through lower supply. This results in the LSTAR-type of welfare decreasing APT.

Kaufmann & Laskowski (2005) investigate whether a mis-specified model which does

[12]Since 1972, the EU expects that each of its member states holds inventories equal to at least 90-days of domestic consumptions. While some of the new members who joined in 2005 fail to do so, they steadily increase their supply - Balmaceda (2002). While the composition of those reserves varies, their presence shows that there is a significant non-zero lower threshold beyond which inventories cannot fall.

not account for quantity responses to adverse demand shocks might over-estimate the APT and lead to rejection of the true SPT hypothesis. The author finds that the variables designed to capture the quantity responses are not statistically significant at 5%, which does not support the inventory adjustment explanation. The lack of the link also finds support in other studies. Johnson (2002) points out that most of the retail stations are supplied once a week or even daily so should not have significant costs of inventory adjustments. Vásquez (2005) points out that given the stock rotation, inventory adjustment could be responsible for APT at the manufacturing level but not at the retailing level. The author also predicts that refineries might create APT indirectly - by delaying price decreases at times of lower crude oil prices so as to recover margins squeezed by the costly adjustment of production at times of increasing oil prices, or directly - by adjusting the value of their stock. While the former is possible, the latter would be against the generally accepted accounting procedures and thus illegal (see discussion on market power).

Unfortunately, direct tests of this explanation cannot be performed due to lack of storage and production data. Even for the US market, which enjoys well-organized reporting programmes, there is no "reliable and comprehensive data on output and inventories" - Borenstein & Shepard (2002, p. 120).

Customer Loyalty

Klemperer (1987) develops a model in which switching costs create incentives for sellers to price their goods in anticipation of future conditions. Those switching costs are assumed to include learning costs, transaction costs and costs resulting from previous participation in various loyalty programmes (such as repeat-purchase discounts). The last group of costs is increasingly important for motor fuels as all the major chains introduce loyalty schemes - see Dowling & Uncles (1997) for a discussion.

Those costs effectively decrease the elasticity of demand firms face. The higher the switching costs, the more customers are locked-in with their current seller, the lower the elasticity of demand and the fewer *new* customers can be attracted by a price cut. Accordingly, firms face smaller incentives to lower prices. The author also notes that the presence of switching costs *facilitates* tacit collusion, as they decrease incentives of players to increase the sales above the agreed quota. The resulting equilibrium may be similar to the collusive solution in an otherwise identical market with no switching costs - Klemperer (1987, p. 377).

The switching costs explanation seems to be readily applicable to petroleum markets as various loyalty programmes are commonly introduced by many retailers. However, this ability to realize future profits depends on being able to charge *higher* prices in the future. For petroleum products, this is possible only if switching costs were very significant. This assumption, however, is questionable, as products offered by sellers are homogeneous and loyalty programmes are fairly similar across the sellers and generally have small and short-lived power over the buyers. Furthermore, this explanation applies only to the retail tier, and unfortunately cannot be analysed using aggregated data used in this dissertation. As such, it cannot be used to explain the patterns of non-linearities found in the results obtained.

Price Cycles

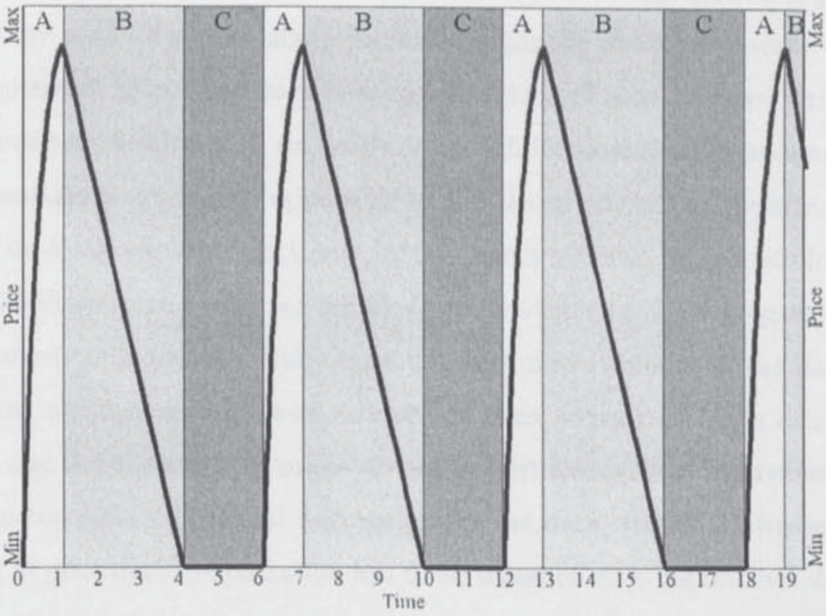
A significant strand of literature is concerned not with explaining the reasons for APT, but rather showing how other economic phenomena - price cycles - could be mistaken for APT. The research into this possibility was initiated by Eckert (2002) and his finding that non-linear patterns in the transmission between weekly series of retail and wholesale petrol prices in Canada might be in fact price cycles resulting from the battles over market share (so-called Edgeworth Cycles) predicted by Maskin & Tirole (1988).

As an example of how Edgeworth cycles could be generated consider a close market occupied by two equal-sized players, manufacturing homogeneous goods using the same cost function and involved in an infinite game played by setting prices. Maskin & Tirole (1988) show that the equilibrium in such a setting involves a repeated three-phased cycle, which starts with both players undercutting each other to get / preserve market share (B in Figure 6.2.3) up to the point when prices reach marginal costs and in the resulting "war of attrition" both have to choose between increasing prices and waiting for the other one to do that (C in Figure 6.2.3). Sooner or later, one realises that it is more profitable to sacrifice immediate margins and increases its price. Finally, a rapid "relenting phase" completes the cycle (denoted as A in Figure 6.2.3).

The interesting feature of Edgeworth cycles is that the relenting phase (and thus the "apparent" APT - "rocket" phase) might occur in the absence of any shocks to upstream prices - simply as the result of competitive behaviour. This is the defining feature of the cyclic behaviour - and one that is at odds with traditional understanding of APT. Given the relative lengths of all phases, according to the Edgeworth story, prices are almost always going down, and the sharp increases are accidental rather than common.

A clear limitation of the original model by Maskin & Tirole (1988) is that both firms are supposed to be of an equal size, so when they charge the same price on the grid they split the market equally. Eckert (2003) and Eckert & West (2004) relax this assumption

Figure 6.1: Illustration of the Edgeworth Cycles.



and find no significant changes in the nature of price cycles. Noel (2007*b*) allows for a greater penetration of small firms and finds that this increases the prevalence of cycles and shortens the undercutting phase. Eckert & West (2004) find that firms have more incentives to undercut prices (which results in lower rigidity of prices) when they have cost incentives to increase volume.

Noel (2007*a*) focuses on how to remove the compounding effect of Edgeworth cycles from the retail-level price data so that price transmission studies could distinguish between the two. The author argues that since the upstream price shocks can postpone or expedite Edgeworth cycles, there is a need to distinguish between *apparent* APT and *true* APT. To reliably establish the presence of APT, he suggests nesting APT models into those for Edgeworth cycles. This boils down to a change of perspective in PT modelling. The standard models assume that in the absence of a shock today, the price would stay at the last period's level. However, when downstream prices are allowed to move without the changes upstream, solely because of the existing Edgeworth cycles, the correct reasoning is that in the absence of shocks, the correct price would be that resulting from the Edgeworth cycle. Up to date this remains the only study that allows for APT and Edgeworth cycles to co-exist in the pricing behaviour and does not treat them as mutually exclusive.

The current research focuses on the presence of Edgeworth cycles in local markets - usually at the level of a city or neighbourhood. This is motivated by the fact that pricing decisions of players are in a constant interaction, which can work only in a constrained environment. Castanias & Johnson (1993) claim that if markets are segregated, a number of cycles could independently coexist provided that there is no room for arbitrage. Those cycles in principle could result in APT at the higher level of aggregation (e.g. countries) but only if they were all synchronized. However, since the shocks can occur without any change in upstream prices but only because of actions of local competitors, the cycles display an inherent tendency to de-synchronize. Unfortunately, the assumption about segregated markets is not readily applicable to petroleum markets where arbitrage opportunities can be easily exploited, not only by customers but also by independent retailers. Therefore, the Edgeworth cycles are not likely to be visible in the aggregated data.

The presence of Edgeworth cycles does not find much support in the data used. In particular, the average upwards and downwards runs present in DSPs and MSPs (see Tables A.17 and A.18) show that prices do not exhibit the cyclical behaviour. Since this might be a consequence of spatial aggregation of the data, the final assessment on the applicability of price cycles explanation has to be based on city/region-level data (see the discussion in the last chapter).

Parameter Stability

Cramon-Taubadel & Meyer (2001) claim that the signs of APT found in the data might in fact indicate a presence of structural changes in price transmission which are mis-labelled by the traditional APT estimation techniques. The authors review three earlier models used for APT testing, i.e. ECM model allowing for LR APT through Wolfram-type split of lagged residuals (2.14) and TAR and M-TAR models (2.32) with respect to the impact that structural changes in the LR parameters (pass-through estimates) have on the results of the APT tests. The results of their Monte Carlo experiments show that size of the APT tests (probability of rejecting the true null of SPT), surpass the traditional 5%. The intuitive explanation for that phenomenon is that structural changes affect the residuals in the LR equation in a way similar to autocorrelation (consistent over / under-stating of true disequilibrium), which resembles the signs of APT, such as persistent disequilibria. While the power comparisons do not cover the smooth-transition models, one can expect that while not being immune to this issue, the smooth transition between models might be less susceptible to mis-interpreting structural changes as signs of APT.

Hosken et al. (2007) analyse the behaviour of retail filling stations in the vicinity of Washington DC. They find that indeed the market behaviour of stations is a subject to frequent changes - some of the stations choose to change their typical pricing position towards the market from year to year, sometimes dramatically - Hosken et al. (2007, p. 7). Those changes of pricing position might be an inherent feature of petroleum markets, responsible for changes in pricing parameters (structural change), mis-identified by some as APT.

Menu Costs

Another explanation of APT is concerned with the costs of the pricing process. If changing the current price involves incurring significant costs, sellers are more likely to do so when other costs (upstream prices) increase, rather than when they decrease (which might result in LSTAR-type asymmetry). Although this is not directly discussed in the literature, it is obvious that the price change might also occur for significant price decreases - as failure to meet such changes could result in a lost market share.

Davis & Hamilton (2004) analyse the pricing decisions made by nine ULP wholesalers in the Philadelphia metropolitan area with the aim of empirically testing the menu cost model proposed by Dixit (1991). According to the model tested, the absolute size of the gap between current and target price should determine the probability of the change. However, the analysis of the data reveal that the menu cost model is not consistent with the asymmetric answer to positive and negative price gaps, identified with the use of an atheoretical logit specification and autoregressive conditional duration model. In particular, when the actual price is below or above the target price by a small amount, a price increase is more likely to occur than a price decrease. In contrast, when the absolute gap is large, decreases are more probable than increases. The probability of adjustment for positive and negative price gaps is presented in Figure 6.2. The authors

Figure 6.2: Probability of DSP Changes as a Function of Disequilibrium

Aston University

Illustration removed for copyright restrictions

Source: Davis & Hamilton (2004).

conclude that pricing decisions are driven by strategic considerations about customers' and competitors' reactions rather than by explicit menu costs. This view finds some support in the literature - a number of researchers claim that menu costs are insignificant or even zero - Eckert (2002) and Noel (2007*b*), but Slade (1998) points out that costs related to small price changes might actually involve costs of losing the reputation gained by holding the prices stable (see below).

Davis (2007) revisits this topic but with the focuses on four retail stations located in Newburgh, New York, USA. Micro-data indicate that stations change their prices on 8%-13% of the days, which is in contrast to earlier studies - in particular Asplund et al. (2000), who find that prices are reviewed daily.[13] The core analysis employs a dynamic structural menu cost model estimated by logit and the autoregressive hazard rate methods which compare the costs and benefits of adjusting the prices. This includes a comparison of actual prices and prices assumed to appear in the absence of menu costs.[14] The author estimates two coefficients affecting the probability of changing the price - maximum deviation between actual and equilibrium price and the standard deviation of the equilibrium price series. The results are found to hinge on the way the problem of missing observations in the sample was tackled. When missing prices are assumed to be the same as last day's prices, the menu costs are significantly different from zero and equal to .8% - 1.9% of production costs, which suggests a minimum change of approximately 10-20 cents.[15] When no assumption about missing prices is made, menu costs are lower (well below 1% of production costs) or even insignificant.

The author also analyses the probability of price changes using the same framework as that employed previously by Davis & Hamilton (2004) to analyse wholesale pricing. The results indicate that retailers are more likely to increase their prices than to reduce them for almost every price gap, which contrasts with Davis & Hamilton (2004) who find that wholesalers are more likely to increase than decrease price. Furthermore, the retailers are also more likely to make large decreases than large increases.[16] The results indicate that a menu-cost model describes the data fairly well, but again not completely. The authors conclude that the visible SETAR style asymmetry should be explained by theories other

[13]This might be due to the fact that the US sample includes only independent retailers, while Asplund et al. (2000) use prices charged by a vertically integrated company - Shell.

[14]The latter series was assumed to equal to a sum of costs, taxation and average markup. Such a calculation indirectly assumes a full-pass through - which although not formally tested might be applicable, given the economic proximity of the analysed tiers and the fact that the analysed stations are not a part of vertically integrated company.

[15]Surprisingly some of the price changes that companies actually introduced are lower than 20 cents, which casts doubts on the reliability of the results.

[16]Effectively, Davis (2007) finds the probability function to be a mirror version of the one found in Davis & Hamilton (2004) - see Figure 6.2.

than menu costs, most likely those related to search costs. Unfortunately, the problem of missing data introduces a significant uncertainty about credibility of results.

Slade (1998) combines the determinants of sluggish adjustment visible on the demand and supply sides. This is implemented with the help of a costly adjustment model in which the decision to adjust the prices is based on costs of changing the price (both fixed *and* variable) and profits from such a decision (which include change in turnover and reputation of the seller). This notion of reputation which a seller enjoys through habit formation of some buyers, product awareness and brand loyalty that arises through the repeated use constitutes a novelty that suits the stylised facts of the petroleum market. It recognizes that by charging consistently below the market average, sellers establish a loyal base of buyers which increases demand. While the model cannot be readily applied to petroleum markets (it deals with saltine crackers sold by four chain stores in one US city), it points to the fact that menu costs might also include other significant elements - such as the risk of losing reputation.

Ray, Chen, Bergen & Levy (2006) show that when retailers face costs of adjusting prices, their suppliers upstream see a region of inelastic demand where small price changes do not translate into appropriate downstream responses. As a result, small wholesale increases are more profitable as sellers do not risk losing customers, while small upstream decreases are less profitable, because they will not create lower retail prices. For larger changes, the asymmetric behaviour disappears as costs of price changes are compensated by higher margins. This can result in ESTAR-type non-linearities.

Consumers' Behaviour

Brown & Yucel (2000) point out that if consumers accelerate their purchases in anticipation of further increases when prices are rising (or are expected to) this might LSTAR-type positive cause APT. The extent of APT could be further increased if customers are afraid of running out of petrol and thus accelerate the rate at which they purchase it. Unfortunately, this explanation does not find support in real life - in Europe, panic and queues at filling stations have not been common since the second oil shock of 1979.

6.2.4 Distinguishing the Causes

Search Models and Collusion

Lewis (2004) attempts to distinguish between his version of search model (reference price model) and two other explanations of APT presented in Borenstein et al. (1997), i.e.

focal price collusion and the Benabout & Gertner search model. To assess their relative applicability, the author attempts to verify their predictions regarding the following issues:

- when do companies enjoy high profits?
- how quickly do prices respond to upstream changes in periods of high margins?
- how quickly do prices respond downwards and is the decline uniform across players?

With respect to the first question, both reference price and focal price models predict a negative relationship between profit margins and prices, while the Benabou & Gertner model predicts higher margins when prices are rising and falling than when the prices are stable. With respect to the second question, both focal price and reference search models predict that the prices are responsive only when margins are low, while the Benabou & Gertner model assumes that the prices would respond in the same manner at all times. For the last question, both the reference search and Benabou & Gertner models predict gradual and unified responses, while the focal price model predicts an uncoordinated reaction of market players.

The dataset used in this exercise comprises a sample of weekly prices charged from January 2000 to December 2001 by 420 gas stations in the San Diego, US area. The wholesale prices are proxied by spot prices in the Los Angeles area. The empirical attempt to distinguish between the models heavily relies on a number of questionable assumptions. Most importantly, although the LR impact of wholesale prices on retail prices was found to equal only .48, the author imposed the assumption of full pass-through and proxied the margins with the straightforward difference between wholesale and retail prices, which might be disputed.

By measuring the average margins in periods when retail prices changed by less or more than one cent, the author finds that margins are high when prices are falling, which contradicts the Benabou & Gertner models. The effect of margin size on adjustment speed is analysed under the assumption of full-pass through by estimation of (2.12) split into two models using the residuals from the LR equation to distinguish between high and low margin periods ($\epsilon_{t-1} > 0$, and $\epsilon_{t-1} < 0$, respectively). The results indicate that the price response is more vivid during times of low margins compared to times of high margins. The APT analysis is performed in a similar manner, by estimation of (2.13) split for low and high margin times. Unfortunately, no tests for the presence of non-linearities, justifying application of what effectively was a SETAR model, is presented.

APT vs Cyclicality

Using city-level data, Noel (2007*b*) develops a framework that combines Edgeworth cycles with APT-related upwards / downwards stickiness and "traditional" perfect-competition pricing and the effect of infiltration of Small & Medium Enterprises (SME). This is done using a Markov-switching regression that covers (i) relenting and (ii) undercutting phases of the Edgeworth Cycle; (iii) normal pricing sub-regime (similar to the perfect-competition outcome) and (iv) sticky pricing sub-regime.

The results of the basic estimation (i.e. without variables related to SME penetration) indicate that:

- in both cyclical phases, the upstream prices do not affect downstream prices in a statistically significant way (as opposed to the third phase);
- the market is more likely to switch from "sharp increases" to "undercutting" phase than to stay in that phase or return to non-cyclical pricing phase;
- the market is more likely to stay in the undercutting phase, rather than switch to undercutting or non-cyclical phases;
- once in the non-cyclical regime, the market is most likely to continue the same way.

The results also indicate differences between the two cyclical phases - in particular, the average duration of the undercutting phase is twice as long as that of a relenting phase and the average weekly increase is almost twice as large as the average weekly price cut. When penetration of SME is taken into account:

- the probability of switching from undercutting to relenting phase decreases with the size of the margin;
- SME penetration increases the prevalence of the cycles and decreases the duration of the undercutting phases;
- increases in the demand determinants (as measured by driving-age population size per retail outlet) are positively correlated with the prevalence of cycles. Market size proxies are also negatively correlated with the duration of the undercutting phase - so that greater markets have less asymmetric cycles;
- increases in the supply density factors (as measured by a number of stations per square mile) are positively correlated with the prevalence of cycles.

Costly adjustment vs Menu Costs

Borenstein & Shepard (2002) develop a formal model in which costly adjustment of inventory stock and production level implies lagged responses of wholesale prices in response to crude oil price changes. This also predicts that futures for end products do not fully adjust to crude oil price changes that occur close to expiration date.

The reasoning is that although costly adjustment modifies the market clearing price, its presence does not affect the market clearing process - demand still equals supply. Conversely, imperfect information models involve non-price allocation, as the equilibrium price does not clear the market.

Thus, for markets with many competing and well-informed traders with no or few long-term contracts, stickiness of clearing prices relative to the long-run costs of production might indicate the presence of costly adjustment and lack of menu costs. For example, consider falling crude oil prices. If production / inventory adjustment is negligible and stickiness results from menu costs and other market frictions, refiners' marginal costs are below the transaction price so that they would increase production, which (given that the prices are sticky) would result in excessive supply that would end up fully and immediately decreasing prices in the futures market. Conversely, if menu costs do not exist and the market price stickiness is caused by costly adjustment, the futures market will also be sticky.

The core analysis is done using NYMEC daily prices for New York futures of light sweet crude and ULP covering the period December 1985 - January 1995. The model used is a univariate version of (2.62) which unfortunately disregards LR relationship between series and thus is incorrectly specified - as discussed in Cramon-Taubadel (1998) and Geweke (2004).

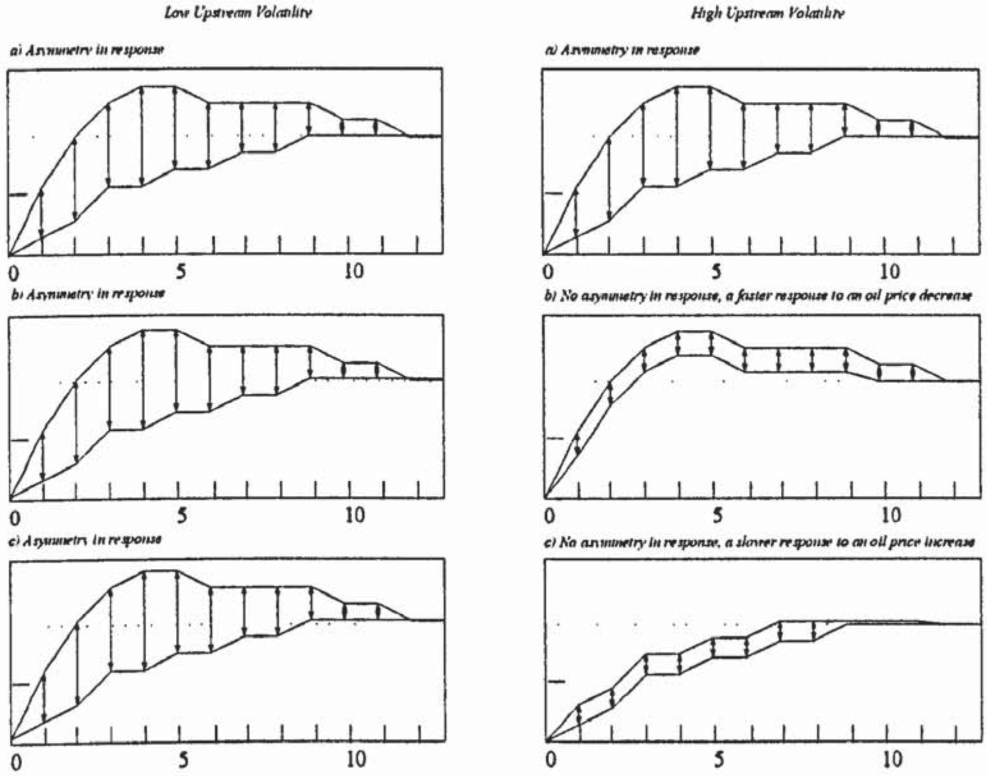
Search Costs vs Oligopolistic Coordination

Radchenko (2005*b*) analyses the effect of volatility in crude oil prices on the degree of APT. The author uses weekly, de-seasonalised data on WTI crude oil and US retail prices (including taxes) to find that the degree of asymmetry declines with increasing upstream volatility, which supports the negative correlation between input price volatility and the degree of APT discussed in Peltzman (2000) and explanations of APT that focus on the oligopolistic coordination.

The modelling framework applied by Radchenko (2005*b*) is based on the fact that three competing explanations of APT - oligopolistic coordination theory and search theory (in standard format and with Bayesian updating) differ with respect to the expected impact of price volatility on the degree of APT.

According to the standard search theory, volatile USPs create a signal-extraction problem for customers and discourage them from searching, which in turn decreases the degree of competition. Such temporary market power given to sellers might result in sellers lowering prices *slower* and increasing them *faster*. This situation (an increase in the degree of APT or sustained level of APT after increases in volatility) is depicted in panel a) of Figure 6.3.

Figure 6.3: Upstream Volatility and APT



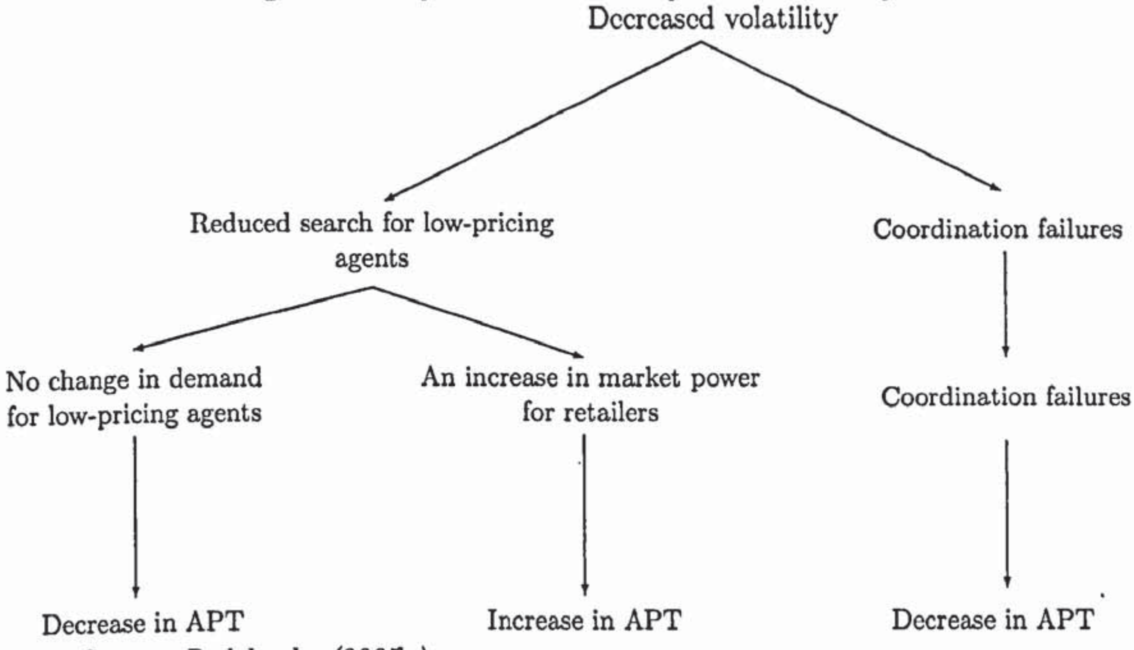
Source: Radchenko (2005b).

The oligopolistic coordination theory predicts that increased upstream volatility makes coordination of collusion difficult, which causes prices to decrease faster in response to a upstream decrease and thus results in a *decrease* in the degree of APT. This situation is depicted in panel b) of Figure 6.3.

According to the Bayesian learning version of search theory, increased upstream volatility might either encourage or discourage agents to search, depending on the cost of search (i.e. relative strength of correlation and variance effects). If one assumes that the correlation effect dominates the variance effect, higher upstream volatility should discourage agents from searching. In such a situation, at times of lower volatility, stations which charge less relative to the rest of the market face higher demand and are forced to increase their prices faster, thus increasing APT. Conversely, with higher upstream volatility and lower search, the adjustment to increases in USPs should be slower. This situation is depicted in panel c) of Figure 6.3.

This rather convoluted reasoning is best illustrated by Figure 6.4. The bottom line is that results indicating a neutral or positive relationship between upstream volatility and that the degree of APT favours standard search theory, while results indicating a negative relationship are ambiguous. To distinguish between Bayesian learning search theory and oligopolistic coordination one has to test whether the lower degree of APT occurs because of slower adjustment to increases in USPs (Bayesian explanation) or due to faster adjustment to decreases in USPs (coordination theory).

Figure 6.4: Impact of Increased Upstream Volatility



Source: Radchenko (2005b).

The estimation of the impact of volatility on APT is done with the help of (2.63). The lag structure reflects the assumption that volatility affects the degree of APT contemporaneously, while APT affects volatility only with a lag. Volatility is proxied by rolling standard deviations and estimated standard deviations $\hat{\sigma}_t$ from the Bayesian estimation of a GARCH(1,1) univariate version of (2.63). The degree of APT is proxied by (i) cumulative responses calculated as in Borenstein et al. (1997) (2.18 and 2.19) and (ii) impulse functions from estimation of (2.62). The second set of tools is obviously incorrect as proven by Cramon-Taubadel (1998).[17]

[17]This is confirmed by the fact that the proxies calculated in this way are *negatively* correlated with

The results indicate that volatility does affect the degree of APT and the decreased APT results from faster adjustment to decreases in USPs. However, this should be treated with caution, as several issues apply to the assumptions made, the data used and the estimation procedure applied in the study.

Firstly, one has to remember that the entire reasoning presented in the article hinges upon the assumption that in the Bayesian search model, higher upstream volatility *reduces* search. If the opposite was the case, it would be impossible to distinguish between Bayesian learning theory and oligopolistic coordination. This means that in the search model the correlation effect is stronger than the variance effect, and this implies that the search costs **are high to begin with** - which can be questioned given how often people compare the prices of petrol.

Secondly, the data cover only the extreme tiers in transmission (crude oil and retail) and it completely disregards issues of lagged responses and different impact of APT at different transmission tiers (raised *inter alia* by Borenstein et al. (1997)). Furthermore, the retail data include taxes (which is by itself unusual in the literature).

Various Explanations

Wlazlowski (2003*b*) attempts to distinguish between commonly proposed explanations of APT (including menu costs, search costs, tacit collusion and adjustment costs) by splitting variables capturing the APT in (2.13) according to behaviour of exogenous variables D^l_j chosen to mirror the proposed explanations of APT. This results in:

$$\begin{aligned} \Delta y_t = \;& \textstyle\sum_{j=0}^{m^+} \beta_j^+ (\Delta x_{t-j})^+ + \sum_{j=0}^{m^+} \beta_j^+ D^l_j (\Delta x_{t-j})^+ + \sum_{i=0}^{m} \beta_i (\Delta x_{t-i}) \\ & \textstyle\sum_{j=0}^{n^+} \beta_j^+ (\Delta ex_{t-j})^+ + \sum_{j=0}^{n^+} \beta_j^+ D^l_j (\Delta ex_{t-j})^+ + \sum_{i=0}^{n} \beta_i (\Delta ex_{t-i}) + \\ & + \gamma ECM_{t-1} + \epsilon_t \end{aligned} \tag{6.4}$$

Whenever the dummy variable D^l_j is found to be significant it is interpreted as a sign of support for the theory according to which the variable was set. While innovative, this explanation suffers from arbitrary assumptions about linkages between data (which governs D^l_j) and economic theories they are supposed to proxy. The results that do not suffer from arbitrary assumptions indicate that:

- at times of stable downstream prices the degree of APT in crude oil price transmission is significantly lower - which supports the costly search theory and retailers' short-run market power it implies;

those based on Borenstein et al. (1997) and exhibit a completely different pattern of changes over time - Radchenko (2005*b*, p. 724).

- at times of stable downstream prices the degree of APT in the exchange rate transmission is not significantly different from that at times of volatile downstream prices;

- at times of volatile margins and input prices the degree of APT is lower.

Search Theory vs Production Lags

Kaufmann & Laskowski (2005) analyse two out of three explanations provided by Borenstein et al. (1997), i.e. production / inventory lags and classical version of the search theory by analysing transmission for two distinctively different products (ULP and gasoil) and relating the identified discrepancies in the results to differences in characteristics of those two products.

The first explanation is analysed in the spirit of Reagan & Weitzman (1982) (see section 6.2.3 for details) and the authors conclude that since the introduction of variables aimed at capturing quantity responses to adverse demand changes the results of SPT tests, production lags and inventory adjustments might be responsible for the presence of APT. Unfortunately, this explanation does not find support in their empirical results as some of the specifications of gasoil transmission that account for inventory and production proxies exhibit signs of non-linearities.

For the second explanation, the authors report that the search process in the case of ULP is transitory and its cost is low while purchases of gasoil are less frequent and some buyers are committed to one seller (e.g. the one who installed the central heating system). Based only on those stylised facts, the authors conclude that the contractual relationship between sellers and buyers best explains differences between findings for ULP and gasoil. In principle this could be true, but this explanation is not convincing given that on other occasions the authors admit that the degree of APT is actually lower for gasoil - Kaufmann & Laskowski (2005, p. 1595). Last but not least, the results of APT tests for ULP and gasoil are very similar, and do not offer support for the claim that the non-linearities present in transmission for those two products are fundamentally different. Therefore, the results about relative merits of explanations based on search theory and production / inventory lags are not conclusive.

6.3 Summary and Conclusions

The analysis summarized in this chapter focuses on several aspects of APT that are neglected in the literature. In particular we analysed the notion of "petrol tourism" and found that the cross-country dynamics support this notion. Furthermore, the inclusion of cross-country linkages did not affect the patterns of non-linearities found previously.

In the second part of this chapter we reviewed the explanations of non-linearities presented in the literature. From all explanations presented, the majority do not find straightforward application to the EU petroleum markets. In particular, the prediction of market power abuse theories do not find support in the results obtained, while their assumptions are at odds with the nature of petroleum industry. Similarly, the search theories find little support for their predictions (in the standard case and for reference price search) or are based on questionable assumptions (Bayesian learning). Other search models (like the one by Cabral & Fishman (2006)) need to be more refined and precise to be readily applicable to petroleum markets. A much simpler assessment can be performed for explanations based on accounting principles and customers' behaviour, which can be rejected as their predictions do not find support in industry statistics.

The explanations that find some support in the results of estimation include menu costs, customer loyalty, costly adjustment and market perception of price changes. The two theories that interpret APT as a sign of other economic phenomena (Edgeworth cycles and inherent parameter instability) cannot be rejected based on the data used.

Chapter 7

Conclusions

This chapter has two aims. Firstly, to summarise the contribution of this research and discuss its limitations and possible extensions. Secondly, to present policy implications resulting from this study.

7.1 Main Contributions and Limitations of the Research

This section describes key findings of this research, its limitations and possible extensions. We start with a discussion of the keys areas for improvement we identified in the existing APT literature. Next, we present the findings related to the long-run relationship between upstream and downstream prices in different national and product markets. We proceed with a discussion of the results of tests for the presence and character of non-linearities and a short overview of other findings related to cross-country dynamics and possible sources of APT. We conclude with a review of limitations and possible extensions of this research.

State of Research

The review of applied APT research reveals several key areas for improvement. Firstly, we note that although energy markets constitute a key element of EU economics, the mechanics of how they work (in particular, impact of diversified quality of feeds and the structure / length of the transmission chain) receive surprisingly little attention from researchers. This can adversely affect reliability of models utilizing oil prices (those used in energy safety, inflation modelling and environmental studies, etc.) or even misunderstanding of market developments (the issues of 2008 100 USD per barrel record and 2007 bottleneck around Cushing, Oklahoma described in section 4.2.1 illustrate the point). Secondly, the analyses are constrained in terms of the products, markets and tiers and suffer from extensive data aggregation or dubious assumptions (e.g. about the pricing functions and tiers, full pass-through). Thirdly, the common estimation techniques rely heavily on harsh assumptions about the shape of non-linearities, nature of regime change, involve computationally burdensome tests for the presence of non-linearities and hinder identification of pricing regime / simulating pricing responses. Furthermore, the issues of price transmission are constrained to upstream-downstream (vertical) linkages. In reality, differences in petroleum taxation give can rise to significant "fuel tourism" and cross-country price linkages that could erode high-taxing governments' taxable base. Last but not least, we find that the applied literature offers only a fragmented picture of possible sources of APT and does not address their relative applicability in a coherent manner.

Based on the results of this review, we analyse the relationship between prices of different petroleum products throughout the EU. Below we describe the key results.

Causality and Endogeneity

For the upstream-downstream linkages, the results obtained confirm that prices downstream depend on the upstream costs, with the transmission chain originating from the crude oil prices. This finding is consistent across all countries, products and tiers. Our results also confirm that among hundreds of different varieties of crudes, Brent and WTI remain the most important ones, despite their decreasing supply. More surprisingly, the Russian crude oil, just as suggested by industry statistics, is found to grow in importance and lead prices in its quality segment. Interestingly, our results indicate that the prices of crude oil from the FSU countries are correlated with the error term, most likely because of remoteness of the supply sources and politically-driven supply shocks which decouple their prices from global markets.

The discovered geographic patterns indicate that EU countries rely to a different extent on different sources of crudes and that local crudes can be endogenous. This needs to be recognized and accounted for in a number of applications, for example inflation modelling.

Cointegration between Series

Following political and economic integration within the European community, petroleum markets display similar patterns with respect to the relationship between upstream and downstream prices. The results indicate integration with international oil markets (reflected by cointegration of USPs and DSPs) and with the pan-European ARA trading hub (reflected by cointegration between MSPs and DSPs). This relationship is strong and consistent across countries for high-volume products (mainly motor spirits), but not necessarily for LPG, which stands out as an exception, most likely because it is also obtained from natural gas so that its prices are not tied solely to crude oil prices. The relationships between prices are also tested using innovative non-linear cointegration tools. The results remain unchanged.

Apart from the analysis of the presence of a long-run relationship between prices, we also analyse the properties of these upstream-downstream price linkages. Our estimates of elasticities present a coherent pan-EU picture indicating that the geographic position and availability of different crudes affect the elasticities of price transmission. Furthermore, we test the common claims of full pass-through in price transmission and find that it does not apply to the case at hand.

Asymmetries in Price Transmission

After ascertaining that upstream and downstream prices are related to each other and the shocks to the system originate upstream, we analyse how this long-run equilibrium relationship is restored following upstream price shocks. This was done with the help of the STAR estimation framework, which allows us to rectify some shortcomings of previously used tools, in particular burdensome testing, unrealistic or harsh assumptions about the regime switch (SETAR) and untraceable regime history (ECM).

Presence of Asymmetries The results of the tests for the presence of non-linearities in price transmission confirm the results obtained by earlier researchers for ULP in the key EU markets (mainly France, Germany, Italy and the UK) but also point to new cases of non-linearities in other EU countries and for other products. The visible pattern of results shows that non-linearities are not constrained to one product or group of countries but rather constitute an inherent feature of petroleum markets.

The findings about the presence of non-linearities significantly broaden the scope of APT studies, showing that non-linearities in price transmission are more common than assumed and deserve more attention from policy-makers and researchers.

Nature of Asymmetries The results of the STAR estimation indicate that transmission between regimes is smooth, rather than abrupt and complete as was assumed previously in SETAR models. This suggests that pricing behaviour is far more complicated than assumed, and that instead of simple low- / high-margin setting, a continuum of regimes governs the pricing process.

Apart from the issues of smooth transition between regimes, this research also sheds some light on the shape of the transition function. The previously used models either assumed simple bivariate responses in two distinct models (SETAR models) or disregarded the issue of regime identification (ECM based models). Our results indicate that a significant portion of transmission chains is characterised by ESTAR-type non-linearities which instead of a simple welfare-decreasing behaviour imply a delayed answer to both margin-increasing and margin-decreasing cost changes.

Based on the estimates of the STAR models, we obtained simulated answers to price adjustments following upstream price increases and decreases. Those simulated responses indicate that in many cases the apparent welfare-decreasing effect is mitigated by the autoregressive portion of the model. The above combined with the analysis of the non-linear estimates and the conclusions from the meta-analysis of the results presented in section 5.3 indicate that non-linearities might be fairly short-lived.

Cross-Country Dynamics

The petroleum products (especially motor spirits) are heavily taxed through the entire EU. However, tax rules and rates are still not harmonized across countries, which gives buyers opportunity to travel abroad and purchase cheaper products. This phenomenon, commonly known as "fuel tourism", is said to result in multi-billion erosion of taxable base and harmful air pollution from increased traffic.

Using the cross-national dataset, we analyse the patterns of cross-country dynamics and find them consistent with the predictions of "fuel tourism" - i.e. price increases in high-cost country increase the demand (and thus prices) for cheaper products sold in the neighbouring countries. This supports the earlier, qualitative studies and expands the coverage of "fuel tourism" studies to more countries and products.

Possible Causes of APT

As mentioned before, there is no single and coherent theoretical framework encompassing non-linearities in petroleum price transmission. Our review of causes for non-linearities presented in the literature, combined with the results of the analysis, indicate that the majority of theories do not find straightforward application to the EU petroleum markets. In particular, the most commonly quoted market power abuse and search cost theories are found to be based on assumptions that are at odds with the nature of the EU petroleum industry, while their predictions find little support in the empirical results. Explanations based on accounting principles and customers' behaviour can be rejected outright as the assumptions they are based on do not find support in industry statistics.

The explanations that find some support in the results of estimation include menu costs, customer loyalty, costly adjustment and market perception of price changes. The two theories that interpret APT as a sign of other economic phenomena (Edgeworth cycles and inherent parameter instability) cannot be assessed based on the data available.

Limitations and Extensions of this Study

Generally, the approach taken in this study is suitable for tackling this problem domain. However, it has to be recognised that all research efforts suffer from limitations and this dissertation is no exception to this rule. This section acknowledges those limitations and sketches opportunities for further research.

As discussed in section 6.2, the research into APT remains mainly empirical and focuses on testing the null of linear transmission envisaged by standard theories, rather than on developing a new framework encompassing non-linearities into the market structure and behaviour of pricing agents. While this is understandable given the herculean effort necessary to replace canonical pricing theories, this *gap in the essential part of economic theory* (to quote Peltzman (2000)) cannot be left unfilled for long. Recent developments utilizing station-level US data (mainly Verlinda (2006), Cabral & Fishman (2006), Noel (2007*b*), Noel (2007*a*) and Davis (2007)) might pave the way for further research, which will develop a coherent theoretical framework for price transmission modelling. At this level of data disaggregation, some qualitative studies based on interviews or surveys could also be conducted to accompany the purely quantitative research done so far.

Our research was not focused on creating such a framework or explaining the presence of APT. Given the resources (mostly time and money) available, achieving such an ambitious goal would not have been possible. Instead, its objective was to test for the presence of APT and gather more information about the mechanics of price transmission - in particular the shape of non-linear answers to margin-increasing and -decreasing cost changes. Nonetheless, the results obtained shed some light on possible sources of APT. In particular, the results show that no single explanation of APT can be used to create a uniform theory of price transmission. Instead, available explanations should be analysed together, so as to allow for both logistic and exponential non-linearities and smooth regime change.

Apart from creating a theoretical framework, research into non-linearities in price transmission could be extended in several ways. Below we briefly discuss author's views on future research. We group the suggestions for future research according to what issues they relate to - (i) data used or (ii) estimation techniques.

Perhaps the easiest way to extend this research is to improve its data coverage. This could be done in several ways, most importantly with respect to tier, product and geographical coverage. In particular, inclusion of the national wholesale tier data, could significantly improve European studies bringing them on a par with those dealing with North America. While obtaining a set of 25 comparable series might be difficult, such data could allow the researchers to compare efficiencies of national markets (accounting for the impact of ARA markets) and impact of FEX (as such data would be expressed in the same currency as retail data).

Accordingly, full product coverage (i.e. inclusion of kerosene prices) could allow the researchers to calculate the overall profitability on refining activities, in the spirit of Denni & Frewer (2006). Although Oil Bulletin databases have placeholders for such data, no consistent retail price data are currently available.[1]

Apart from a broader economic data coverage, the analysis can be extended into non-EU countries (in particular Switzerland), so as to tackle the issue of "fuel tourism" better. Similarly, the data frequency could be increased, in particular to analyse the effects of possible intertemporal aggregation mentioned in section 3.2.2. Wlazlowski et al. (2007c) argue that intertemporal aggregation can affect the results of non-linear estimation.

Apart from a better data coverage, recent developments in estimation techniques could also be used to shed more light on the issue of non-linearities in price transmission. This could be done either by utilizing the stochastic framework based on the work of Hamilton (1989) or by applying the panel approach to estimation.

Rothman & van Dijk (2003) present an interesting avenue into Monte Carlo simulations that could be of some possible use in price transmission analysis. Wlazlowski et al. (2006) show that such a framework has a significant potential, not only to confirm the results of deterministic analysis but also to tackle additional issues - such as the impact of external environment (e.g. changes in taxation) on non-linearities in price transmission. Fok, van Dijk & Franses (2005) offer a multi-level smooth transition model for a panel of time series, which can be used to examine the presence of common non-linear business cycle features across many variables. Implementation of panel techniques is also dependent upon availability of a consistent set of data, described above. With respect to the reliability of the results of non-linearity tests, recent attempts to create a coher-

[1] Interestingly, the 2007 database contains also placeholders for crude oil supply costs - which in principle could replace crude oil prices and solve the issues with transportation costs and variable feed structure.

ent testing framework accounting for non-linearity, structural changes and outliers offer an attractive way to confirm that patterns of non-linearities identified in the data really reflect asymmetries in pricing.

7.2 Policy Implications

Non-Linearities in Price Transmission

The cornerstone of the discussion about policy implications resulting from this research is whether *any* response to non-linearities in price is necessary. This effectively depends on purely normative judgement whether possible welfare transfer upstream from buyers / consumers to sellers should be discouraged. Given that politicians are concerned with opinions voiced by the voters (the majority of whom buy petrol products) it could be assumed that some sort of policy response cannot be avoided. This leads us to the question of what should such a response be.

If non-linearities are treated as market failures, according to Brown & Yucel (2000), the economic policy should respond to them only in a degree to which they could be effectively remedied by the central government. Otherwise, governmental action might obstruct those market processes it is supposed to protect. Given the above, the optimal response to APT should depend on a perceived effect of non-linearities and their extent.

As discussed in chapter 5, although the non-linearities are relatively widespread across markets, tiers and products, they are not uniform. In particular, the LSTAR type non-linearities (which are usually connected with significant welfare transfer) do not dominate the picture. Instead, the ESTAR type non-linearities which differentiate between the size of the disequilibrium and not its sign are found in many cases of price transmission. Accordingly, the picture of price transmission emerging from this research is not particularly alarming. This is supported by the overview of results reported previously in the literature (section 5.3) and by the simulations of the responses to upstream price changes, which suggest that autoregressive elements of pricing models might dampen potential asymmetries and reduce welfare transfer.

The above-described finding has to be combined with the results of the overview of possible causes of APT. As discussed in section 6.2, the probable explanations of APT involve key characteristics of petroleum markets, such as competitive / geographical structure or costs related to the adjustment of prices, stocks or production levels. Since all those elements cannot be adjusted in a matter of weeks (when APT is present), therefore active policies aimed at countering the effects of APT after upstream cost hikes are most likely to be inefficient. Similarly, given the enormous size of energy markets, any automatic administrative controls on pricing (ceilings, price zones, etc.) are likely to result in losses from decreased market efficiency that could outweigh possible gains from lower APT.

Given that, the policy response to APT that could mitigate the adverse effects of both types of non-linearity would have to involve lowering the entry barriers to upstream and downstream parts of the market, deregulation and fostering competition, especially at the distribution stage. According to the common wisdom, this would increase market liquidity and customer choice and lower the adjustment costs. The examples of Germany and Spain quoted by Kirchgassner & Kubler (1992) and Contin et al. (2004) indicate that this might mitigate the adverse effects of non-linearities.

Other Issues

Estimation of the long-run relationship between upstream and downstream prices revealed that EU markets are well integrated within global energy markets. However, cross-country and -product differences between elasticities of price transmission and responses to price shocks still exist. If one assumes that those differences are not a mere reflection of the geography of the EU / relative access to upstream markets and that efficiency of energy markets should be increased, the results obtained indicate that there is significant scope for such action. Again, market integration and removal of barriers to trade combined with regulatory harmonization might be the simplest remedy.

The results of the analysis of upstream markets indicate that prices of Russian crudes remain endogenous towards prices of end products. This needs to be recognized in applied models such as those used for inflation modelling. Similarly, modelling of LPG should account for the fact that this product can be obtained from natural gas and its prices do not necessarily fully follow crude oil prices.

As for the "fuel tourism", the simplest and most effective policy response would be to harmonize the taxation rates so as to remove any incentive for cross-country shopping trips. Some steps towards that goal have already been taken (Directives 92/81/EEC and 92/82/EEC of the European Commission discuss that issue), but a complete harmonization would require the governments of EU member states to relinquish their control in this sensitive area, which might be difficult.

7.3 Final Word

This thesis has advanced the research into APT in the petroleum market in the EU in terms of economic, product and geographical coverage, relaxed assumptions, greater proximity to the true market conditions, superior estimation techniques and theoretical underpinnings of price transmission. It makes some important contributions to the literature, as reflected by the list of publications resulting from it (page 4).

In summary, this study represents an attempt to obtain a comprehensive overview of price transmission in the EU. It tackles previously neglected issues of structure of petroleum supply in the EU, organization of the market and price transmission chain, causality in international and European petroleum markets, long-run relationship between prices and countries. It analyses the presence of non-linearities in the EU and finds that while non-linearities are present across different countries, products and transmission tiers as claimed before, their characteristics are different than previously assumed. This suggests a need for further research, utilizing disaggregated data, perhaps on the station level and within a coherent theoretical framework, that combines various ad hoc explanations currently offered in the literature. We see this study as a step towards such an ambitious goal.

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Appendix A

Data, Results

Table A.1: Geographic Coverage - Neighbouring Countries

	AT	BE	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	SE	SI	SK
AT				√	√								√		√									√	√
BE					√					√							√			√					
CY																									
CZ	√				√																√				√
DE	√	√		√		√				√							√			√	√				
DK					√																				
EE																		√							
ES										√												√			
FI																							√		
FR		√			√			√							√		√								
GB														√											
GR																									
HU	√																							√	√
IE											√														
IT	√									√														√	
LT																		√			√				
LU		√			√					√															
LV							√									√									
MT																									
NL		√			√																				
PL				√	√											√									√
PT								√																	
SE									√																
SI	√												√		√										
SK	√			√									√								√				

Table A.2: Product and Country Coverage

	AT	BE	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	SE	SI	SK
ULP	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Diesel	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Gasoil	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
RFO.1	√	√		√	√	√		√	√	√	√	√	√		√	√	√			√	√	√	√	√	√
RFO.2		√	√	√				√		√	√	√		√	√	√	√		√		√	√			√
LPG.1		√		√	√		√	√		√			√		√	√	√	√		√	√	√		√	√
LP		√		√	√	√		√		√	√	√		√	√		√	√	√	√		√			√

Table A.3: Inputs to the Refineries - Crude Oil Imports

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT	87.09	87.62	87.85	89.73	89.25	88.42	87.70	89.68	89.83	87.75	88.63	88.80
BE	100.61	99.78	99.86	100.19	100.01	99.94	100.18	99.64	99.73	100.02	100.01	99.67
CY	101.10	96.26	105.79	99.62	99.35	100.51	98.47	99.83	99.26	99.79	87.10	
CZ	104.99	101.66	99.29	100.01	102.27	100.08	97.07	98.35	98.56	97.57	96.27	99.87
DE	98.28	97.71	99.08	98.91	100.75	97.47	96.86	98.58	98.01	97.43	98.46	97.90
DK	61:44	55.14	52.13	50.20	60.64	57.43	46.02	38.23	42.24	42.63	46.37	35.21
EE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ES	97.78	99.38	98.90	100.23	99.93	98.71	100.64	100.76	99.95	100.12	98.81	100.06
EU	90.04	89.15	89.13	89.81	90.80	90.02	92.36	93.01	92.66	92.65	93.33	93.00
FI	110.75	81.45	92.58	104.11	100.39	96.48	101.47	100.18	96.91	99.31	101.69	96.28
FR	97.53	97.91	99.57	98.65	98.56	99.03	100.28	99.53	98.94	99.29	98.19	98.78
GB	50.37	47.94	46.74	46.34	45.94	47.46	59.32	63.26	65.57	61.83	66.87	64.29
GR	92.08	103.07	97.57	98.53	100.22	99.23	99.64	98.92	103.45	103.24	108.79	100.52
HU	74.42	72.10	70.57	75.14	79.21	76.90	79.30	76.83	79.25	81.45	84.50	90.95
IE	100.26	100.18	101.22	99.65	99.14	101.11	89.86	99.00	104.59	101.12	96.34	98.85
IT	94.91	93.66	92.50	93.88	94.58	93.25	95.58	94.88	93.61	94.36	94.71	94.91
LT	95.64	99.90	99.46	100.22	99.29	100.64	101.03	97.13	94.75	99.06	100.76	96.92
LV	100.00	200.00	100.00	100.00	100.00	325.00	320.69	172.73	266.67	140.00	75.00	80.00
NL	96.67	95.77	97.01	95.77	95.88	96.67	98.00	97.87	96.04	95.61	97.29	98.58
PL	94.59	96.38	96.09	98.85	95.91	95.83	98.51	97.75	100.88	99.95	95.57	98.61
PT	99.59	100.00	97.47	103.16	98.26	102.90	98.98	101.46	96.51	100.72	100.58	100.43
SE	100.21	100.78	97.19	98.17	99.50	97.62	100.47	98.62	96.39	101.12	97.89	97.82
SI	103.66	96.69	94.40	102.06	94.63	100.78	87.23	0.00	0.00	0.00	0.00	0.00
SK	99.02	104.30	101.69	99.17	99.47	98.47	97.92	98.36	98.77	98.96	102.42	98.35

Notes: Author's calculations based on Eurostat. Other (i) Luxembourg and Malta do not refine crude as they import ready-made products, (ii) Latvia buys and resells to other Baltic countries feed purchased from FSU, (iii) 2005 data for Cyprus not available.

Table A.4: Inputs to the Refineries - FSU Crudes

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT	13.02	21.45	14.37	15.41	24.21	23.34	33.74	23.78	28.85	34.02	42.73	52.18
BE	4.86	8.37	9.34	6.48	9.36	14.13	15.77	15.93	27.19	32.07	40.55	42.02
CY	0.00	0.00	0.00	0.00	0.00	38.70	52.12	38.04	96.29	34.88	41.98	
CZ			92.79	91.29	86.65	87.75	91.47	85.25	80.60	85.76	89.96	94.36
DE	21.46	20.45	25.18	25.34	25.93	30.72	32.99	34.06	36.73	39.07	41.98	41.56
DK	17.98	26.24	14.38	3.63	0.00	1.02	2.62	3.12	0.92	0.00	0.00	0.00
EE												
ES	8.39	8.41	7.78	7.50	8.35	9.65	10.03	10.68	16.27	17.85	16.28	15.76
FI	21.24	18.49	25.35	46.40	45.29	47.07	47.51	53.60	59.49	70.95	81.71	84.25
FR	6.41	7.77	10.18	9.62	6.26	9.31	9.24	11.72	18.02	20.63	22.55	23.34
GR	11.17	12.47	15.59	13.73	5.67	5.24	21.93	30.37	47.78	38.92	28.68	32.54
HU	0.00	0.00	0.00	100.00	99.15	100.00	100.00	100.00	99.84	99.81	98.51	99.85
IE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IT	21.91	15.40	11.76	11.22	13.40	18.17	19.29	23.54	22.72	24.79	26.82	27.44
LT						98.17	93.47	100.00	100.00	100.00	100.00	100.00
LU												
LV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MT												
NL	4.03	3.65	4.94	4.53	2.27	5.46	7.48	11.85	15.96	22.38	28.31	28.43
PL						87.67	97.11	98.62	98.17	98.60	99.23	98.68
PT	2.98	6.12	4.81	6.57	5.08	4.13	2.48	10.05	5.11	11.63	18.02	6.34
SE	7.18	8.65	9.23	8.75	11.08	11.96	6.68	5.68	20.07	19.91	26.40	36.07
SI						0.00	37.40					
SK								99.00	99.33	99.30	97.92	100.00
UK	3.43	3.10	4.28	5.58	5.38	1.77	4.77	5.94	7.59	9.10	14.16	10.09

Table A.5: Inputs to the Refineries - OPEC Crudes

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT	78.07	71.71	74.15	74.82	70.25	67.24	61.83	61.12	53.73	52.58	49.80	41.03
BE	52.37	52.84	44.46	44.47	48.67	34.49	36.76	36.31	33.67	40.10	35.48	35.31
CY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CZ						10.08	8.53	13.83	5.94	4.51	6.00	5.12
DE	37.44	33.45	30.28	30.79	29.10	27.71	27.53	21.94	19.59	19.23	20.01	22.75
DK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE												
ES	53.75	61.88	63.87	62.29	63.02	58.59	61.95	39.44	52.50	50.93	53.01	51.47
FI	2.12	0.00	0.00	0.90	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FR	59.73	54.79	49.94	48.12	54.63	51.44	46.60	39.68	37.51	40.91	40.99	40.37
GR	83.08	75.02	74.65	85.26	93.90	93.89	78.07	69.63	50.67	59.11	71.11	67.46
HU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.76	0.00
IT	60.28	67.33	69.76	72.78	70.46	64.79	65.81	59.03	55.14	60.80	60.65	62.89
LT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LU												
LV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MT												
NL	70.83	61.67	56.12	57.40	60.29	56.85	50.96	47.66	38.87	38.25	39.69	43.38
PL						2.95	0.00	0.00	0.00	0.00	0.00	0.00
PT	80.57	78.92	73.65	72.25	66.03	62.58	67.15	60.19	57.50	52.47	59.43	62.97
SE	33.42	28.64	24.08	22.81	24.69	20.15	18.82	26.85	17.42	19.52	12.51	9.08
SI						0.00	34.15					
SK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UK	26.84	24.74	21.76	16.07	17.95	10.54	8.29	7.50	8.63	10.28	8.02	10.22

Table A.6: Inputs to the Refineries - North-Sea Crudes

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	3.50	1.49
BE	39.70	36.12	44.67	46.70	37.48	48.41	44.85	44.59	36.55	24.43	17.62	16.05
CY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CZ					2.89	2.17	0.00	0.00	3.24	0.00	0.00	0.00
DE	34.22	38.86	38.39	38.38	38.25	33.37	30.62	34.51	32.21	31.82	31.60	28.46
DK	82.02	73.76	85.62	96.33	100.00	98.90	70.05	96.55	99.08	100.00	100.00	100.00
EE												
ES	6.23	7.95	6.76	8.36	6.11	7.21	3.98	3.96	3.48	6.06	6.65	5.82
FI	70.16	74.61	59.81	40.92	33.37	31.13	30.68	26.04	16.77	10.18	5.43	5.75
FR	24.79	29.69	33.50	35.16	32.41	33.97	36.32	35.62	31.64	29.35	28.63	24.39
GR	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IE	100.00	100.00	100.00	100.00	100.00	98.73	100.00	94.96	100.00	97.42	97.24	100.00
IT	1.87	2.34	2.59	3.96	4.90	6.18	4.95	3.95	7.10	5.65	3.92	3.71
LT						1.83	6.53	0.00	0.00	0.00	0.00	0.00
LU												
LV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MT												
NL	22.96	31.10	36.11	34.55	30.98	32.14	36.91	35.46	34.89	31.98	25.40	18.77
PL						4.42	2.63	0.00	0.73	0.00	0.76	1.21
PT	6.51	6.78	5.43	8.72	13.13	20.66	12.64	10.13	12.66	13.32	8.12	3.78
SE						57.44	48.88	55.06	46.56	42.34	32.43	29.07
SI	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
SK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UK	55.36	64.28	65.54	71.94	71.02	65.40	65.85	57.10	56.67	67.05	71.20	71.58

Table A.7: Inputs to the Refineries - US Crudes

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
CZ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EE												
ES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LU												
LV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MT												
NL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SI	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
SK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UK						0.00	0.00	0.00	0.16	0.09	0.00	0.00

Table A.8: Imports of Processed Petroleum Products - FSU Countries

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00
BE	0.05	0.04	0.05	0.04	0.06	0.08	0.07	0.09	0.09	0.07	0.06	0.08
CY	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.06	0.47	0.42	0.03	0.10
CZ			0.04	0.05	0.04	0.04	0.02	0.01	0.02	0.01	0.01	0.02
DE	0.06	0.06	0.06	0.09	0.08	0.07	0.07	0.08	0.07	0.11	0.09	0.07
DK	0.10	0.15	0.17	0.14	0.23	0.17	0.15	0.16	0.18	0.27	0.22	0.20
EE						1.13	0.84	0.85	0.94	0.95	0.89	0.93
ES	0.05	0.10	0.11	0.07	0.06	0.10	0.13	0.14	0.15	0.18	0.18	0.22
FI	0.76	0.68	0.62	0.68	0.52	0.55	0.55	0.56	0.52	0.53	0.55	0.58
FR	0.03	0.08	0.16	0.10	0.12	0.17	0.18	0.19	0.16	0.20	0.27	0.27
GR	0.12	0.27	0.42	0.38	0.60	0.33	0.32	0.47	0.49	0.46	0.42	0.43
HU				0.21	0.25	0.24	0.14	0.28	0.40	0.35	0.48	0.34
IE	0.02	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IT	0.08	0.08	0.07	0.04	0.08	0.06	0.06	0.08	0.12	0.05	0.05	0.06
LT						0.82	0.85	0.88	0.76	0.83	0.94	0.89
LU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LV						0.78	0.84	0.64	0.64	0.69	0.91	0.92
MT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NL	0.13	0.18	0.24	0.29	0.26	0.25	0.27	0.24	0.34	0.28	0.25	0.27
PL						0.31	0.35	0.27	0.45	0.57	0.61	0.51
PT	0.00	0.05	0.07	0.03	0.02	0.05	0.05	0.02	0.03	0.04	0.06	0.01
SE						0.10	0.13	0.15	0.17	0.16	0.14	0.13
SI						0.00	0.00	0.00	0.00	0.01	0.01	0.02
SK								0.00	0.00	0.07	0.07	0.05
UK	0.03	0.05	0.08	0.14	0.17	0.13	0.10	0.07	0.09	0.07	0.20	0.15

Table A.9: Imports of Processed Petroleum Products - OPEC Countries

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BE	0.02	0.03	0.02	0.01	0.02	0.01	0.01	0.01	0.04	0.02	0.00	0.01
CY	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.04	0.03	0.03	0.01	0.01
CZ						0.00	0.00	0.00	0.00	0.00	0.00	0.00
DE	0.20	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01
DK	0.07	0.03	0.25	0.27	0.25	0.25	0.23	0.27	0.21	0.06	0.09	0.10
EE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ES	0.29	0.34	0.30	0.26	0.30	0.13	0.29	0.19	0.20	0.18	0.16	0.15
FI	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.02	0.00	0.00	0.00	0.00
FR	0.18	0.11	0.15	0.16	0.12	0.17	0.14	0.15	0.14	0.12	0.10	0.12
GR	0.46	0.07	0.02	0.04	0.00	0.18	0.15	0.14	0.09	0.11	0.11	0.25
HU						0.00	0.00	0.00	0.00	0.00	0.00	0.00
IE	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
IT	0.26	0.25	0.21	0.28	0.31	0.40	0.50	0.37	0.42	0.43	0.45	0.41
LT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NL	0.12	0.15	0.08	0.10	0.09	0.08	0.06	0.04	0.04	0.04	0.04	0.04
PL						0.00	0.00	0.00	0.00	0.00	0.00	0.00
PT	0.19	0.12	0.10	0.03	0.06	0.02	0.03	0.12	0.14	0.13	0.07	0.03
SE	0.03	0.02	0.05	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.02
SI	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UK	0.08	0.05	0.06	0.14	0.17	0.12	0.21	0.26	0.18	0.19	0.36	0.23

Table A.10: Imports of Processed Petroleum Products - Norway and the UK

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BE	0.09	0.10	0.12	0.17	0.13	0.11	0.13	0.11	0.10	0.07	0.04	0.05
CY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.02	0.01	0.00	0.06
CZ					0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DE	0.10	0.07	0.07	0.09	0.05	0.04	0.06	0.06	0.06	0.05	0.05	0.06
DK	0.13	0.07	0.09	0.09	0.11	0.12	0.12	0.13	0.16	0.14	0.13	0.13
EE						0.01	0.01	0.02	0.02	0.01	0.01	0.02
ES	0.05	0.07	0.07	0.04	0.06	0.09	0.06	0.05	0.08	0.09	0.09	0.06
FI	0.03	0.07	0.11	0.06	0.10	0.15	0.16	0.11	0.16	0.17	0.15	0.13
FR	0.24	0.25	0.16	0.20	0.17	0.16	0.15	0.10	0.12	0.12	0.09	0.10
GR	0.01	0.02	0.00	0.00	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00
HU						0.00	0.01	0.00	0.00	0.00	0.00	0.00
IE	0.78	1.00	0.75	0.65	0.93	0.95	0.91	0.88	0.92	0.90	0.92	0.90
IT	0.18	0.15	0.17	0.19	0.16	0.10	0.09	0.11	0.09	0.09	0.05	0.05
LT						0.02	0.00	0.00	0.03	0.04	0.00	0.00
LU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LV						0.09	0.02	0.02	0.02	0.03	0.03	0.04
MT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NL	0.12	0.15	0.11	0.16	0.14	0.13	0.14	0.11	0.12	0.12	0.12	0.11
PL						0.03	0.05	0.02	0.03	0.05	0.03	0.03
PT	0.15	0.16	0.16	0.29	0.29	0.23	0.14	0.18	0.20	0.15	0.18	0.19
SE	0.26	0.23	0.18	0.23	0.23	0.22	0.19	0.26	0.41	0.43	0.41	0.41
SI						0.00	0.00	0.00	0.00	0.00	0.01	0.00
SK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UK	0.14	0.16	0.16	0.00	0.14	0.16	0.15	0.03	0.01	0.03	0.08	0.09

Table A.11: Imports of Processed Petroleum Products - the USA

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BE	0.03	0.02	0.03	0.03	0.02	0.03	0.05	0.03	0.03	0.03	0.01	0.02
CY	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.10	0.00	0.00	0.00
CZ						0.00	0.00	0.00	0.00	0.00	0.00	0.00
DE	0.03	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.01
DK	0.06	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.05	0.05
EE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ES	0.09	0.16	0.19	0.23	0.18	0.13	0.14	0.15	0.14	0.12	0.14	0.10
FI	0.02	0.01	0.01	0.02	0.06	0.03	0.04	0.05	0.06	0.03	0.03	0.03
FR	0.03	0.03	0.02	0.06	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.03
GR	0.03	0.08	0.08	0.12	0.05	0.04	0.09	0.08	0.07	0.06	0.04	0.05
HU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IE	0.08	0.00	0.02	0.31	0.02	0.00	0.00	0.00	0.04	0.03	0.04	0.05
IT	0.07	0.12	0.08	0.08	0.10	0.09	0.11	0.10	0.11	0.16	0.17	0.16
LT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LU	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LV						0.00	0.00	0.00	0.01	0.02	0.00	0.01
MT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NL	0.05	0.05	0.04	0.06	0.04	0.04	0.06	0.06	0.06	0.04	0.04	0.04
PL						0.00	0.00	0.00	0.00	0.02	0.01	0.03
PT	0.00	0.01	0.03	0.07	0.05	0.07	0.10	0.04	0.01	0.03	0.01	0.14
SE	0.04	0.02	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01
SI						0.00	0.00	0.00	0.00	0.00	0.00	0.01
SK	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UK	0.08	0.08	0.09	0.11	0.07	0.05	0.05	0.00	0.02	0.01	0.06	0.04

Table A.12: Yearly Consumption of ULP

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT	2483	2391	2217	2136	2130	2048	1979	1998	2141	2201	2133	2074
BE	1842	1946	2029	2011	2085	2050	2247	2185	2082	2016	1931	1760
CY										154	239	305
CZ										2100	2092	2053
DE	27935	28497	29185	29859	30376	30304	28875	27913	27194	25777	25183	23430
DK	1856	1913	1929	1975	2031	2016	1984	1938	1953	1953	1935	1876
EE										279	377	294
ES	2032	2283	3154	3645	4286	4823	5415	7289	8206	8040	7714	7260
FI	2035	1953	1832	1874	1837	1850	1785	1810	1840	1782	1884	1879
FR	7579	7864	8391	8906	8891	8530	12250	12047	11695	10803	10217	9583
GB	13201	13656	14789	15963	17158	18750	21300	20932	20502	19078	18993	18106
GR	745	893	1107	1311	1516	1737	2042	2336	3543	3685	3763	3918
HU										1432	1472	1462
IE	483	585	712	868	1105	1297	1352	1530	1583	1617	1625	1711
IT	5528	7318	8084	8646	10158	9584	10496	12333	14692	14615	14350	13347
LT										363	344	339
LU	411	408	436	477	486	556	580	571	556	567	549	501
LV										322		
NL	3129	3398	3845	4136	4097	4134	4023	4110	4169	4187	4158	3804
PL										4235	4300	4024
PT	548	678	804	919	1096	1697	2090	1995	2023	1991	1927	1804
SE	4150	4263	4203	4129	4019	3964	3946	3970	4041	4104	4130	4091
SI										678	658	657
SK										671	617	628

Table A.13: Yearly Consumption of DIESEL

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT				3147	3542	3890	4261	4675	5174	5693	5935	6268
BE	3979	4000	4218	4493		4922	5192	4939	5232	5799		6195
CY												341
CZ										2991	3258	3703
DE	25796	26197	23429	21298	22059	23385	24907	25497	25626	27995	28969	28532
DK	1932	2047	2053	2111	2125	2233	2293	2372	2262		2231	2343
EE												
ES	10421	8700	9090	12059	12130	13233	14119	15084	16140	17420	18613	23216
FI	1486	1463	1507	1600	1674	1748	1787	1825	1863	1886	1995	2013
FR	21387	22274	23124	24141	25243	26757	27134	28667	29770	29900	30484	31023
GB	12777	13311	14375	14975	15142	15187	15377	16417	17028	17208	18789	19464
GR	1978	2323	2453	2513	2655	2530				2520	2554	2597
HU										2136	2201	2475
IE	829	851	884	924	1036	1141	1656	1273	1854	1836	2077	2251
IT	16182	16692	15465	15783	16831	17489	17955	20744	21367	23826	24386	25117
LT										549	614	828
LU	616	569	597	656	702	803	995	1074	1153	1334	1645	1836
LV												
NL	4159	4298	4662	4827	4758	5284	5416	5521	5730	5949	6155	6257
PL										6847	6633	6645
PT	2190	2360	2480	2450	2590	2600	2900	3480	4120	4120	4320	4420
SE	2009	1945	1945	2069	2262		1025	1243	1359	1277	1667	1836
SI										556		
SK											1014	1101

Table A.14: Yearly Consumption of GASOIL

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT	2094	3388	2451	2049	1894	1857	1603	1966	1768	1976	1691	1863
BE	5468	5669	6481	6490	6735	5828	5417	6222	5423	5538	6040	5587
CY										556	438	199
CZ										179	347	140
DE	35932	34900	40939	41175	39902	34883	31921	35080	31549	27991	25447	24465
DK	2104	2048	2144	1919	1844	1726	1466	1456	1434	1811	1552	1430
EE										511	602	166
ES	6190	9486	10055	7411	9366	9927	10875	11831	11639	12626	13451	10134
FI	2176	2355	2344	2411	2462	2437	2149	2364	2280	2295	2188	2051
FR	17461	18531	19146	18086	18070	18408	17747	18632	17089	17928	17711	17488
GB	8094	7795	8276	8054	8007	7653	7727	7009	6333	6238	6614	7150
GR	2566	2721	3283	2784	3581	3638	3961	4542	4768	5281	4943	4877
HU										172	133	361
IE	1180	1273	1324	1383	1556	1710	1370	1911	1302	1506	1266	1338
IT	7537	7743	8398	7939	7791	7703	7711	6026	6002	4630	5651	5856
LT										129	160	
LU	326	334	368	370	380	360	308	341	311	302	319	301
LV										535	636	677
NL	1779	1601	1828	1599	1582	1452	1246	1136	1150	1211	1187	1198
PL										1347	2000	2301
PT	941	795	842	1136	1421	1650	1890	1792	1191	1267	1314	1149
SE	3359	3337	3741	2835	2797	3050	4877	3676	3884	3893	3322	2972
SI										672	812	1380
SK												14

Table A.15: Yearly Consumption of LP

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT												
BE	1001	888	712	526	427	346						
CY										98		
CZ												
DE	2332	1648	811	43		27	25	22	20			18
DK												
EE												
ES	7130	6595	5947	5334	4732	4115	3119		13			
FI												
FR	7591	6297	6606	5729	5686	4442	83	25	23	22	22	27
GB	9698	8133	7366	6325	4726	2847	53	61	54	51	48	76
GR	1954	1958	1833	1728	1640	1478	1221	1049				
HU												
IE	510	453	385	305	201	112	28					
IT	11443	10256	9194	8608	7886	6900	4802	2937				
LT												
LU	133	106	84	65	55							
LV												342
NL	783	626										
PL												
PT	1281	1204	1127	1000	944							
SE												
SI												
SK												

Table A.16: Yearly Consumption of RFO

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
AT	1847	2068	1710	1831	1816	1588	1298	1375	1070	1274	1150	1069
BE	2268	1976	1945	1777	1953	1938	1577	1744	936	2110		
CY										1062	1103	1175
CZ										484	525	499
DE	7538	7758	6935	5791	5804	4990	6360	6921	6864	6654	6307	6044
DK	1118	836	923	640	718	557	435	510	615	744	619	572
EE												
ES	7618	8824	6052	5827	6368	7402	6735	6765	7733	6876	6476	6383
FI	1517	1234	1435	1633	1619	1627	1479	1578	1747	1647	1611	1457
FR	4572	4859	4974	4550	5056	4804	3677	3473	3046	3185	3065	3210
GB	9239	7924	6854	4527	3887	2209	1870	2203	2121	2267	2835	3234
GR	2565	2943	2985	3029	3093	2997	3001	2757	2701	2642	2614	2641
HU										626	335	188
IE	1368	1287	1257	1480	1762	2049	1744	1604	1492	1028	1278	1279
IT	27271	28279	27906	26456	24151	20508	18420	17814	19828	16597	14516	11552
LT										277	233	191
LU	209	98	82	42								
LV										125	158	78
NL	369	365	318	130	91	86		95			59	29
PL										1083	1625	1347
PT	3228	3891	3038	3156	4058	3942	3260	3310	3593	2391	2233	2829
SE	2428	2440	3939	1797	2022	2195	1173	1044	1597	1725	1497	1186
SI										58	53	
SK												

Table A.17: DSP - Summary Statistics

	$x_t^{(AT,ULP)}$	$x_t^{(AT,DIESEL)}$	$x_t^{(AT,HO)}$	$x_t^{(AT,RFO-1)}$	$x_t^{(AT,RFO-2)}$	$x_t^{(AT,LPG-1)}$	$x_t^{(AT,LP)}$	$x_t^{(AT,KEROSENE)}$	$x_t^{(AT,LPG-2)}$
#	538.00	538.00	538.00	538.00	0.00	0.00	0.00	0.00	0.00
min	3109.30	2828.40	1656.03	920.00					
$q^{.25}$	3794.80	3496.10	2586.10	1300.00					
$\bar{x}$	4204.80	4130.70	3209.30	1770.00					
$q^{.25}$	4832.70	4662.80	3732.93	2156.24					
max	7669.44	7726.55	7101.83	3990.49					
γ_2	4.50	4.13	4.27	3.99					
γ_1	1.12	1.15	1.10	0.97					
	$\Delta x_t^{(AT,ULP)}$	$\Delta x_t^{(AT,DIESEL)}$	$\Delta x_t^{(AT,HO)}$	$\Delta x_t^{(AT,RFO-1)}$	$\Delta x_t^{(AT,RFO-2)}$	$\Delta x_t^{(AT,LPG-1)}$	$\Delta x_t^{(AT,LP)}$	$\Delta x_t^{(AT,KEROSENE)}$	$\Delta x_t^{(AT,LPG-2)}$
#	537.00	537.00	537.00	537.00	0.00	0.00	0.00	0.00	0.00
min	−341.60	−441.70	−466.70	−509.13					
$q^{.25}$	−41.70	−41.70	−30.40	0.00					
$\bar{x}$	0.00	0.00	0.00	0.00					
$q^{.25}$	45.82	57.24	40.74	0.00					
max	550.41	441.70	639.85	412.81					
γ_2	6.53	5.76	7.68	18.29					
γ_1	0.68	0.30	0.39	−0.41					
	$x_t^{(BE,ULP)}$	$x_t^{(BE,DIESEL)}$	$x_t^{(BE,HO)}$	$x_t^{(BE,RFO-1)}$	$x_t^{(BE,RFO-2)}$	$x_t^{(BE,LPG-1)}$	$x_t^{(BE,LP)}$	$x_t^{(BE,KEROSENE)}$	$x_t^{(BE,LPG-2)}$
#	586.00	586.00	586.00	584.00	78.00	293.00	439.00	0.00	0.00
min	7309.00	7308.00	4384.00	2615.00	4853.00	10201.56	7438.00		
$q^{.25}$	8941.00	8881.00	5888.00	3763.00	5550.00	11435.15	8716.00		
$\bar{x}$	10918.02	10912.14	7938.00	5150.20	5957.00	12302.06	9917.00		
$q^{.25}$	13290.79	13300.00	10326.00	6310.17	6421.31	13468.69	13692.17		
max	22438.67	23467.74	20073.54	11363.75	7194.22	17436.11	19507.00		
γ_2	3.62	4.00	4.30	3.53	2.41	3.61	2.64		
γ_1	0.92	1.14	1.22	0.84	0.18	0.91	0.93		
	$\Delta x_t^{(BE,ULP)}$	$\Delta x_t^{(BE,DIESEL)}$	$\Delta x_t^{(BE,HO)}$	$\Delta x_t^{(BE,RFO-1)}$	$\Delta x_t^{(BE,RFO-2)}$	$\Delta x_t^{(BE,LPG-1)}$	$\Delta x_t^{(BE,LP)}$	$\Delta x_t^{(BE,KEROSENE)}$	$\Delta x_t^{(BE,LPG-2)}$
#	585.00	585.00	585.00	583.00	77.00	292.00	438.00	0.00	0.00
min	−3044.86	−1911.30	−2025.06	−942.34	−1590.20	−1066.99	−3265.00		
$q^{.25}$	−165.00	−166.60	−17.35	0.00	0.00	0.00	−50.00		
$\bar{x}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
$q^{.25}$	247.00	216.63	66.00	20.50	0.00	0.00	75.00		
max	2353.43	2177.95	3297.00	1289.26	620.43	1337.72	2909.00		
γ_2	6.21	5.78	12.26	6.56	18.82	5.69	12.43		
γ_1	−0.19	0.20	0.41	−0.16	−2.75	0.30	−0.60		
	$x_t^{(CY,ULP)}$	$x_t^{(CY,DIESEL)}$	$x_t^{(CY,HO)}$	$x_t^{(CY,RFO-1)}$	$x_t^{(CY,RFO-2)}$	$x_t^{(CY,LPG-1)}$	$x_t^{(CY,LP)}$	$x_t^{(CY,KEROSENE)}$	$x_t^{(CY,LPG-2)}$
#	82.00	82.00	82.00	0.00	82.00	0.00	0.00	0.00	0.00
min	197.37	190.91	173.52		130.37				
$q^{.25}$	223.83	230.83	213.52		148.61				
$\bar{x}$	236.11	251.37	235.13		164.39				
$q^{.25}$	261.02	290.37	267.40		188.64				
max	321.66	323.87	302.49		212.47				
γ_2	3.14	2.07	2.34		2.20				

	$\Delta x_t^{(CY,ULP)}$	$\Delta x_t^{(CY,DIESEL)}$	$\Delta x_t^{(CY,HO)}$	$\Delta x_t^{(CY,RFO-1)}$	$\Delta x_t^{(CY,RFO-2)}$	$\Delta x_t^{(CY,LPG-1)}$	$\Delta x_t^{(CY,LP)}$	$\Delta x_t^{(CY,KEROSENE)}$	$\Delta x_t^{(CY,LPG-2)}$
γ_1	0.84	0.25	0.18		0.59				
#	81.00	81.00	81.00	0.00	81.00	0.00	0.00	0.00	0.00
min	−26.70	−17.76	−21.81		−17.06				
$q^{.25}$	−0.00	−0.21	0.00		0.00				
$\overline{x}$	0.00	0.00	0.00		0.00				
$q^{.25}$	2.25	3.13	2.43		0.50				
max	45.22	27.13	40.96		35.66				
γ_2	10.41	7.50	14.13		23.01				
γ_1	1.34	0.96	1.86		3.13				

	$x_t^{(CZ,ULP)}$	$x_t^{(CZ,DIESEL)}$	$x_t^{(CZ,HO)}$	$x_t^{(CZ,RFO-1)}$	$x_t^{(CZ,RFO-2)}$	$x_t^{(CZ,LPG-1)}$	$x_t^{(CZ,LP)}$	$x_t^{(CZ,KEROSENE)}$	$x_t^{(CZ,LPG-2)}$
#	82.00	82.00	48.00	82.00	82.00	82.00	82.00	0.00	0.00
min	8623.00	10588.66	10386.00	4235.00	3480.00	8646.00	8487.00		
$q^{.25}$	11052.44	11125.00	11492.27	4665.00	4008.00	9136.00	10635.00		
$\overline{x}$	11449.92	12086.50	13045.79	4853.00	4299.00	9482.77	10967.72		
$q^{.25}$	12205.38	14031.51	13935.19	5050.00	4620.00	10136.64	11760.00		
max	16415.46	16007.00	15218.00	6911.00	6126.00	11027.39	15654.00		
γ_2	3.45	1.92	1.82	4.48	4.57	2.16	3.49		
γ_1	0.66	0.54	−0.15	1.57	1.31	0.55	0.78		

	$\Delta x_t^{(CZ,ULP)}$	$\Delta x_t^{(CZ,DIESEL)}$	$\Delta x_t^{(CZ,HO)}$	$\Delta x_t^{(CZ,RFO-1)}$	$\Delta x_t^{(CZ,RFO-2)}$	$\Delta x_t^{(CZ,LPG-1)}$	$\Delta x_t^{(CZ,LP)}$	$\Delta x_t^{(CZ,KEROSENE)}$	$\Delta x_t^{(CZ,LPG-2)}$
#	81.00	81.00	47.00	81.00	81.00	81.00	81.00	0.00	0.00
min	−622.69	−341.57	−651.00	−687.00	−552.00	−336.52	−646.00		
$q^{.25}$	−141.20	−109.00	−208.00	−69.00	−64.00	−34.45	−133.00		
$\overline{x}$	−13.00	−19.00	45.60	9.00	5.00	0.00	−12.00		
$q^{.25}$	68.84	76.34	219.23	127.00	99.00	49.00	63.50		
max	2111.55	1144.00	911.40	468.00	772.00	593.49	1843.46		
γ_2	11.65	6.48	2.75	4.27	5.19	9.58	9.60		
γ_1	2.31	1.75	0.31	−0.29	0.37	1.79	2.05		

	$x_t^{(DE,ULP)}$	$x_t^{(DE,DIESEL)}$	$x_t^{(DE,HO)}$	$x_t^{(DE,RFO-1)}$	$x_t^{(DE,RFO-2)}$	$x_t^{(DE,LPG-1)}$	$x_t^{(DE,LP)}$	$x_t^{(DE,KEROSENE)}$	$x_t^{(DE,LPG-2)}$
#	586.00	586.00	586.00	586.00	0.00	70.00	135.00	0.00	0.00
min	321.00	292.00	239.00	136.00		660.48	350.00		
$q^{.25}$	395.00	381.00	310.00	179.00		697.96	379.00		
$\overline{x}$	496.00	497.00	431.35	246.50		702.24	392.00		
$q^{.25}$	595.16	595.55	524.36	300.71		709.34	414.50		
max	1104.01	1062.78	1045.00	533.22		786.73	477.00		
γ_2	4.00	3.75	4.27	3.65		3.85	2.83		
γ_1	0.97	1.04	1.17	0.85		0.92	0.87		

	$\Delta x_t^{(DE,ULP)}$	$\Delta x_t^{(DE,DIESEL)}$	$\Delta x_t^{(DE,HO)}$	$\Delta x_t^{(DE,RFO-1)}$	$\Delta x_t^{(DE,RFO-2)}$	$\Delta x_t^{(DE,LPG-1)}$	$\Delta x_t^{(DE,LP)}$	$\Delta x_t^{(DE,KEROSENE)}$	$\Delta x_t^{(DE,LPG-2)}$
#	585.00	585.00	585.00	585.00	0.00	69.00	134.00	0.00	0.00
min	−84.32	−81.75	−95.80	−73.00		−26.56	−26.00		
$q^{.25}$	−13.00	−12.50	−7.00	−3.00		0.00	−11.00		
$\overline{x}$	1.00	0.20	0.00	0.00		0.00	3.00		
$q^{.25}$	13.00	13.00	8.40	3.00		1.76	11.00		
max	201.00	91.90	86.90	73.57		22.77	37.00		
γ_2	11.03	4.64	7.71	17.42		9.20	2.29		

γ_1	0.88	0.05	0.16	0.25		0.12	0.19		
	$x_t^{(DK,ULP)}$	$x_t^{(DK,DIESEL)}$	$x_t^{(DK,HO)}$	$x_t^{(DK,RFO-1)}$	$x_t^{(DK,RFO-2)}$	$x_t^{(DK,LPG-1)}$	$x_t^{(DK,LP)}$	$x_t^{(DK,KEROSENE)}$	$x_t^{(DK,LPG-2)}$
#	586.00	586.00	586.00	586.00	0.00	0.00	97.00	0.00	0.00
min	1366.00	1238.00	1180.00	505.00			1447.00		
$q^{.25}$	1748.00	1588.00	1520.00	740.00			1575.00		
$\overline{x}$	2122.00	1918.00	1872.00	1025.00			1622.00		
$q^{.25}$	2570.00	2434.00	2283.20	1325.00			1703.00		
max	4706.00	4142.00	4376.80	2435.00			1838.00		
γ_2	3.69	3.60	4.37	3.50			2.16		
γ_1	0.83	1.03	1.30	0.89			−0.00		
	$\Delta x_t^{(DK,ULP)}$	$\Delta x_t^{(DK,DIESEL)}$	$\Delta x_t^{(DK,HO)}$	$\Delta x_t^{(DK,RFO-1)}$	$\Delta x_t^{(DK,RFO-2)}$	$\Delta x_t^{(DK,LPG-1)}$	$\Delta x_t^{(DK,LP)}$	$\Delta x_t^{(DK,KEROSENE)}$	$\Delta x_t^{(DK,LPG-2)}$
#	585.00	585.00	585.00	585.00	0.00	0.00	96.00	0.00	0.00
min	−744.00	−368.00	−344.00	−320.00			−120.00		
$q^{.25}$	−40.00	−40.00	−32.00	0.00			−28.50		
$\overline{x}$	0.00	0.00	0.00	0.00			0.00		
$q^{.25}$	40.00	48.00	48.00	30.00			24.00		
max	1024.00	504.00	328.00	250.00			153.00		
γ_2	24.54	6.64	5.34	8.75			4.03		
γ_1	0.85	−0.16	−0.32	−0.45			0.12		
	$x_t^{(EE,ULP)}$	$x_t^{(EE,DIESEL)}$	$x_t^{(EE,HO)}$	$x_t^{(EE,RFO-1)}$	$x_t^{(EE,RFO-2)}$	$x_t^{(EE,LPG-1)}$	$x_t^{(EE,LP)}$	$x_t^{(EE,KEROSENE)}$	$x_t^{(EE,LPG-2)}$
#	81.00	81.00	81.00	0.00	0.00	81.00	0.00	0.00	0.00
min	4432.20	4634.58	3923.00			3769.00			
$q^{.25}$	4906.78	5143.05	4834.24			4470.00			
$\overline{x}$	5245.76	6092.20	5427.46			4802.00			
$q^{.25}$	6297.00	7095.00	5748.00			4886.71			
max	8100.00	8126.00	7248.00			5734.00			
γ_2	2.84	1.85	2.39			3.48			
γ_1	0.91	0.18	0.25			0.61			
	$\Delta x_t^{(EE,ULP)}$	$\Delta x_t^{(EE,DIESEL)}$	$\Delta x_t^{(EE,HO)}$	$\Delta x_t^{(EE,RFO-1)}$	$\Delta x_t^{(EE,RFO-2)}$	$\Delta x_t^{(EE,LPG-1)}$	$\Delta x_t^{(EE,LP)}$	$\Delta x_t^{(EE,KEROSENE)}$	$\Delta x_t^{(EE,LPG-2)}$
#	80.00	80.00	80.00	0.00	0.00	80.00	0.00	0.00	0.00
min	−623.00	−834.00	−616.00			−84.71			
$q^{.25}$	−25.41	−26.21	−37.85			0.00			
$\overline{x}$	0.00	0.00	0.00			0.00			
$q^{.25}$	84.75	139.80	84.74			0.00			
max	1017.00	389.83	581.47			701.00			
γ_2	10.06	6.99	7.38			27.15			
γ_1	0.66	−1.26	0.33			4.77			
	$x_t^{(ES,ULP)}$	$x_t^{(ES,DIESEL)}$	$x_t^{(ES,HO)}$	$x_t^{(ES,RFO-1)}$	$x_t^{(ES,RFO-2)}$	$x_t^{(ES,LPG-1)}$	$x_t^{(ES,LP)}$	$x_t^{(ES,KEROSENE)}$	$x_t^{(ES,LPG-2)}$
#	586.00	586.00	586.00	536.00	441.00	290.00	586.00	0.00	0.00
min	28965.00	26436.00	19926.00	17011.00	12741.00	49692.84	29464.00		
$q^{.25}$	36241.00	32278.00	24547.00	21719.00	17034.00	53287.00	35694.00		
$\overline{x}$	44404.00	44186.00	35548.37	32619.14	19979.00	55567.93	44456.00		
$q^{.25}$	54679.43	54410.00	43634.00	36621.44	27949.00	60923.90	58288.34		
max	90659.24	90799.17	80144.81	60611.09	37643.00	79234.68	97902.69		
γ_2	3.40	3.31	3.52	2.89	2.09	3.23	3.10		

γ_1	0.85	0.90	0.96	0.58	0.60	1.15	0.81		
	$\Delta x_t^{(ES,ULP)}$	$\Delta x_t^{(ES,DIESEL)}$	$\Delta x_t^{(ES,HO)}$	$\Delta x_t^{(ES,RFO-1)}$	$\Delta x_t^{(ES,RFO-2)}$	$\Delta x_t^{(ES,LPG-1)}$	$\Delta x_t^{(ES,LP)}$	$\Delta x_t^{(ES,KEROSENE)}$	$\Delta x_t^{(ES,LPG-2)}$
#	585.00	585.00	585.00	535.00	440.00	289.00	585.00	0.00	0.00
min	−6769.00	−5276.00	−10444.00	−6875.07	−4503.00	−2677.00	−7344.00		
$q^{.25}$	−256.00	−380.00	−445.00	−405.50	−298.50	0.00	−253.00		
$\bar{x}$	6.00	9.00	25.00	5.00	19.98	0.00	16.00		
$q^{.25}$	435.00	434.00	633.93	454.12	402.50	0.00	412.80		
max	7748.26	5469.11	5785.24	7324.31	2705.00	4302.74	7499.68		
γ_2	11.41	7.22	14.49	13.32	8.64	16.57	12.06		
γ_1	0.22	0.28	−1.12	0.38	−0.73	2.28	0.20		
	$x_t^{(FI,ULP)}$	$x_t^{(FI,DIESEL)}$	$x_t^{(FI,HO)}$	$x_t^{(FI,RFO-1)}$	$x_t^{(FI,RFO-2)}$	$x_t^{(FI,LPG-1)}$	$x_t^{(FI,LP)}$	$x_t^{(FI,KEROSENE)}$	$x_t^{(FI,LPG-2)}$
#	538.00	538.00	538.00	538.00	0.00	0.00	0.00	0.00	0.00
min	885.31	1122.89	683.79	475.32					
$q^{.25}$	1343.51	1401.61	1024.44	734.34					
$\bar{x}$	1746.73	1768.32	1313.57	1089.65					
$q^{.25}$	2068.10	2147.35	1591.79	1355.96					
max	3358.96	3420.68	2980.18	3244.79					
γ_2	3.05	2.95	4.11	4.54					
γ_1	0.53	0.68	1.15	0.99					
	$\Delta x_t^{(FI,ULP)}$	$\Delta x_t^{(FI,DIESEL)}$	$\Delta x_t^{(FI,HO)}$	$\Delta x_t^{(FI,RFO-1)}$	$\Delta x_t^{(FI,RFO-2)}$	$\Delta x_t^{(FI,LPG-1)}$	$\Delta x_t^{(FI,LP)}$	$\Delta x_t^{(FI,KEROSENE)}$	$\Delta x_t^{(FI,LPG-2)}$
#	537.00	537.00	537.00	537.00	0.00	0.00	0.00	0.00	0.00
min	−655.74	−345.08	−261.61	−932.13					
$q^{.25}$	−31.97	−32.78	−22.13	−11.48					
$\bar{x}$	0.00	0.00	0.00	0.00					
$q^{.25}$	34.43	41.80	36.89	15.57					
max	583.61	322.13	252.94	1120.85					
γ_2	14.99	6.32	5.87	63.70					
γ_1	0.59	−0.10	−0.47	1.44					
	$x_t^{(FR,ULP)}$	$x_t^{(FR,DIESEL)}$	$x_t^{(FR,HO)}$	$x_t^{(FR,RFO-1)}$	$x_t^{(FR,RFO-2)}$	$x_t^{(FR,LPG-1)}$	$x_t^{(FR,LP)}$	$x_t^{(FR,KEROSENE)}$	$x_t^{(FR,LPG-2)}$
#	586.00	586.00	586.00	584.00	580.00	294.00	586.00	0.00	0.00
min	960.00	910.00	990.00	483.00	433.00	2117.43	920.00		
$q^{.25}$	1170.00	1150.00	1220.00	705.00	636.00	2373.80	1100.00		
$\bar{x}$	1523.57	1569.46	1548.81	934.16	880.43	2490.44	1632.86		
$q^{.25}$	1944.23	1932.55	1932.11	1179.09	1081.05	2759.38	2071.44		
max	3423.71	3432.39	3442.87	2054.68	1898.64	3377.17	3781.42		
γ_2	3.07	3.43	3.92	3.21	3.23	2.87	3.25		
γ_1	0.78	0.98	1.14	0.76	0.74	0.78	0.81		
	$\Delta x_t^{(FR,ULP)}$	$\Delta x_t^{(FR,DIESEL)}$	$\Delta x_t^{(FR,HO)}$	$\Delta x_t^{(FR,RFO-1)}$	$\Delta x_t^{(FR,RFO-2)}$	$\Delta x_t^{(FR,LPG-1)}$	$\Delta x_t^{(FR,LP)}$	$\Delta x_t^{(FR,KEROSENE)}$	$\Delta x_t^{(FR,LPG-2)}$
#	585.00	585.00	585.00	583.00	579.00	293.00	585.00	0.00	0.00
min	−300.56	−272.75	−269.13	−293.24	−232.07	−123.70	−224.69		
$q^{.25}$	−10.00	−12.06	−13.64	−18.15	−15.00	0.00	−10.00		
$\bar{x}$	0.00	0.00	0.00	0.37	0.83	0.00	0.00		
$q^{.25}$	20.00	17.93	20.00	20.00	21.23	0.06	20.00		
max	487.99	193.17	238.06	212.88	204.84	203.75	583.63		
γ_2	19.99	8.24	9.11	10.56	10.28	11.46	30.39		

γ_1	0.90	−0.23	−0.05	−0.32	−0.49	0.89	2.10		
	$x_t^{(GB,ULP)}$	$x_t^{(GB,DIESEL)}$	$x_t^{(GB,HO)}$	$x_t^{(GB,RFO-1)}$	$x_t^{(GB,RFO-2)}$	$x_t^{(GB,LPG-1)}$	$x_t^{(GB,LP)}$	$x_t^{(GB,KEROSENE)}$	$x_t^{(GB,LPG-2)}$
#	586.00	586.00	586.00	155.00	429.00	0.00	282.00	0.00	0.00
min	93.30	91.60	73.90	98.24	50.22		98.71		
$q^{.25}$	137.78	143.73	108.88	115.10	64.12		124.79		
$\overline{x}$	158.49	176.94	136.41	122.00	75.18		137.58		
$q^{.25}$	192.70	203.64	161.18	144.68	91.62		148.60		
max	338.14	362.08	328.63	226.59	127.96		163.55		
γ_2	4.64	4.42	5.26	3.85	2.44		2.43		
γ_1	1.15	1.05	1.45	1.40	0.51		−0.43		
	$\Delta x_t^{(GB,ULP)}$	$\Delta x_t^{(GB,DIESEL)}$	$\Delta x_t^{(GB,HO)}$	$\Delta x_t^{(GB,RFO-1)}$	$\Delta x_t^{(GB,RFO-2)}$	$\Delta x_t^{(GB,LPG-1)}$	$\Delta x_t^{(GB,LP)}$	$\Delta x_t^{(GB,KEROSENE)}$	$\Delta x_t^{(GB,LPG-2)}$
#	585.00	585.00	585.00	154.00	428.00	0.00	281.00	0.00	0.00
min	−20.97	−14.42	−26.19	−27.13	−12.62		−19.83		
$q^{.25}$	−1.41	−1.42	−1.91	−2.87	−0.82		−1.30		
$\overline{x}$	−0.53	−0.54	0.00	0.35	0.08		−0.72		
$q^{.25}$	1.39	0.96	2.56	3.21	1.18		0.24		
max	25.18	28.88	19.54	24.21	10.32		17.40		
γ_2	8.07	8.95	6.93	6.38	7.63		11.40		
γ_1	0.55	1.27	−0.20	0.32	−0.16		1.43		
	$x_t^{(GR,ULP)}$	$x_t^{(GR,DIESEL)}$	$x_t^{(GR,HO)}$	$x_t^{(GR,RFO-1)}$	$x_t^{(GR,RFO-2)}$	$x_t^{(GR,LPG-1)}$	$x_t^{(GR,LP)}$	$x_t^{(GR,KEROSENE)}$	$x_t^{(GR,LPG-2)}$
#	586.00	586.00	586.00	527.00	586.00	0.00	586.00	0.00	0.00
min	46559.00	41611.00	35271.00	28604.00	20140.00		42450.00		
$q^{.25}$	66920.00	52182.00	45259.00	37645.50	31957.00		63696.00		
$\overline{x}$	94500.00	87638.93	72977.50	61800.00	51602.00		92186.50		
$q^{.25}$	119779.00	102865.61	99186.00	71427.64	64026.93		118792.26		
max	199515.94	197982.57	197982.57	109360.30	100521.25		201798.96		
γ_2	2.25	3.21	3.37	2.35	2.54		2.30		
γ_1	0.44	0.92	0.95	0.36	0.51		0.47		
	$\Delta x_t^{(GR,ULP)}$	$\Delta x_t^{(GR,DIESEL)}$	$\Delta x_t^{(GR,HO)}$	$\Delta x_t^{(GR,RFO-1)}$	$\Delta x_t^{(GR,RFO-2)}$	$\Delta x_t^{(GR,LPG-1)}$	$\Delta x_t^{(GR,LP)}$	$\Delta x_t^{(GR,KEROSENE)}$	$\Delta x_t^{(GR,LPG-2)}$
#	585.00	585.00	585.00	526.00	585.00	0.00	585.00	0.00	0.00
min	−19344.38	−11858.10	−38930.69	−12597.00	−16587.00		−13033.69		
$q^{.25}$	−892.00	−892.00	−1050.00	−692.00	−511.12		−807.58		
$\overline{x}$	111.00	159.00	140.00	2.70	0.00		100.00		
$q^{.25}$	1436.00	1597.00	1703.75	990.00	851.88		1386.00		
max	19126.30	12243.15	24554.45	10482.68	10222.50		14519.36		
γ_2	8.89	6.52	20.95	9.11	17.38		7.05		
γ_1	−0.16	−0.33	−1.33	0.07	−0.92		−0.13		
	$x_t^{(HU,ULP)}$	$x_t^{(HU,DIESEL)}$	$x_t^{(HU,HO)}$	$x_t^{(HU,RFO-1)}$	$x_t^{(HU,RFO-2)}$	$x_t^{(HU,LPG-1)}$	$x_t^{(HU,LP)}$	$x_t^{(HU,KEROSENE)}$	$x_t^{(HU,LPG-2)}$
#	82.00	82.00	82.00	82.00	0.00	82.00	0.00	0.00	0.00
min	77523.82	87247.28	87247.28	34075.00		85502.95			
$q^{.25}$	92187.70	96758.55	96758.55	43580.00		88625.64			
$\overline{x}$	97763.68	105961.05	105961.05	48091.50		90727.89			
$q^{.25}$	107657.18	121854.84	121854.84	62195.00		91799.18			
max	126844.30	133052.63	133052.63	72975.00		106754.30			
γ_2	2.62	1.86	1.86	1.92		3.51			

γ_1	0.49	0.31	0.31	0.48		1.22			
	$\Delta x_t^{(HU,ULP)}$	$\Delta x_t^{(HU,DIESEL)}$	$\Delta x_t^{(HU,HO)}$	$\Delta x_t^{(HU,RFO-1)}$	$\Delta x_t^{(HU,RFO-2)}$	$\Delta x_t^{(HU,LPG-1)}$	$\Delta x_t^{(HU,LP)}$	$\Delta x_t^{(HU,KEROSENE)}$	$\Delta x_t^{(HU,LPG-2)}$
#	81.00	81.00	81.00	81.00	0.00	81.00	0.00	0.00	0.00
min	−8252.40	−6391.74	−6391.74	−8724.00		−8393.27			
$q^{.25}$	−218.09	−280.23	−280.23	−1899.00		−119.34			
$\overline{x}$	−1.95	−2.59	−2.59	202.00		−28.03			
$q^{.25}$	1516.71	2349.25	2349.25	2500.00		74.39			
max	7620.03	6007.77	6007.77	12798.00		9061.75			
γ_2	4.61	3.01	3.01	3.70		17.12			
γ_1	−0.24	0.01	0.01	0.30		1.24			
	$x_t^{(IE,ULP)}$	$x_t^{(IE,DIESEL)}$	$x_t^{(IE,HO)}$	$x_t^{(IE,RFO-1)}$	$x_t^{(IE,RFO-2)}$	$x_t^{(IE,LPG-1)}$	$x_t^{(IE,LP)}$	$x_t^{(IE,KEROSENE)}$	$x_t^{(IE,LPG-2)}$
#	586.00	586.00	586.00	0.00	586.00	0.00	362.00	0.00	0.00
min	159.60	173.11	99.68		75.12		175.88		
$q^{.25}$	192.04	206.93	127.07		97.69		200.18		
$\overline{x}$	227.37	241.70	237.12		141.35		210.76		
$q^{.25}$	263.84	286.33	271.45		192.46		233.49		
max	424.61	451.48	478.96		312.62		359.06		
γ_2	4.12	4.53	2.41		2.48		4.16		
γ_1	1.04	1.22	0.58		0.58		1.56		
	$\Delta x_t^{(IE,ULP)}$	$\Delta x_t^{(IE,DIESEL)}$	$\Delta x_t^{(IE,HO)}$	$\Delta x_t^{(IE,RFO-1)}$	$\Delta x_t^{(IE,RFO-2)}$	$\Delta x_t^{(IE,LPG-1)}$	$\Delta x_t^{(IE,LP)}$	$\Delta x_t^{(IE,KEROSENE)}$	$\Delta x_t^{(IE,LPG-2)}$
#	585.00	585.00	585.00	0.00	585.00	0.00	361.00	0.00	0.00
min	−76.67	−125.00	−63.66		−56.58		−23.14		
$q^{.25}$	0.00	0.00	0.00		0.00		0.00		
$\overline{x}$	0.00	0.00	0.00		0.00		0.00		
$q^{.25}$	0.00	0.00	0.91		0.16		0.00		
max	61.19	72.73	61.08		43.75		47.93		
γ_2	34.96	96.94	32.49		36.51		44.48		
γ_1	−0.17	−3.55	0.42		−0.86		4.59		
	$x_t^{(IT,ULP)}$	$x_t^{(IT,DIESEL)}$	$x_t^{(IT,HO)}$	$x_t^{(IT,RFO-1)}$	$x_t^{(IT,RFO-2)}$	$x_t^{(IT,LPG-1)}$	$x_t^{(IT,LP)}$	$x_t^{(IT,KEROSENE)}$	$x_t^{(IT,LPG-2)}$
#	586.00	586.00	586.00	584.00	390.00	295.00	379.00	0.00	0.00
min	390640.00	348330.00	337599.00	161360.00	150190.00	501435.84	371710.00		
$q^{.25}$	463750.00	413870.00	373540.00	222270.00	190000.00	543936.07	436840.00		
$\overline{x}$	563762.00	565962.04	528141.48	283770.50	212730.00	575614.35	476750.00		
$q^{.25}$	692514.00	665941.34	615935.33	375708.32	311101.46	592334.04	565371.00		
max	1066652.42	1165789.44	1073990.88	661836.45	438374.18	725404.19	812038.00		
γ_2	2.65	3.56	3.45	3.61	2.04	3.60	2.90		
γ_1	0.63	0.98	0.98	0.94	0.58	0.73	1.10		
	$\Delta x_t^{(IT,ULP)}$	$\Delta x_t^{(IT,DIESEL)}$	$\Delta x_t^{(IT,HO)}$	$\Delta x_t^{(IT,RFO-1)}$	$\Delta x_t^{(IT,RFO-2)}$	$\Delta x_t^{(IT,LPG-1)}$	$\Delta x_t^{(IT,LP)}$	$\Delta x_t^{(IT,KEROSENE)}$	$\Delta x_t^{(IT,LPG-2)}$
#	585.00	585.00	585.00	583.00	389.00	294.00	378.00	0.00	0.00
min	−65349.11	−65852.54	−78333.33	−72919.93	−68181.82	−27282.04	−56670.00		
$q^{.25}$	−3340.00	−2846.32	−3360.00	−3640.00	−2730.00	0.00	−2520.00		
$\overline{x}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
$q^{.25}$	5111.75	4550.23	6602.68	5286.02	3636.36	1462.00	4200.00		
max	78147.86	77721.88	59211.14	59733.93	50909.09	37215.11	44160.00		
γ_2	12.32	12.29	8.57	9.36	13.88	14.42	10.95		

γ_1	0.36	0.36	−0.47	0.09	−0.88	0.48	−0.27		
	$x_t^{(LT,ULP)}$	$x_t^{(LT,DIESEL)}$	$x_t^{(LT,HO)}$	$x_t^{(LT,RFO-1)}$	$x_t^{(LT,RFO-2)}$	$x_t^{(LT,LPG-1)}$	$x_t^{(LT,LP)}$	$x_t^{(LT,KEROSENE)}$	$x_t^{(LT,LPG-2)}$
#	82.00	82.00	82.00	82.00	82.00	82.00	0.00	0.00	0.00
min	1050.76	1133.20	813.00	473.00	286.00	750.66			
$q^{.25}$	1271.00	1249.31	1016.73	680.00	433.00	834.56			
$\overline{x}$	1328.71	1402.46	1167.76	722.00	507.00	947.23			
$q^{.25}$	1459.56	1632.16	1385.29	846.00	660.46	1033.13			
max	1793.70	1887.47	1656.48	1287.00	778.56	1230.30			
γ_2	3.29	1.95	2.09	4.24	1.93	2.19			
γ_1	0.73	0.35	0.29	0.76	0.14	0.38			
	$\Delta x_t^{(LT,ULP)}$	$\Delta x_t^{(LT,DIESEL)}$	$\Delta x_t^{(LT,HO)}$	$\Delta x_t^{(LT,RFO-1)}$	$\Delta x_t^{(LT,RFO-2)}$	$\Delta x_t^{(LT,LPG-1)}$	$\Delta x_t^{(LT,LP)}$	$\Delta x_t^{(LT,KEROSENE)}$	$\Delta x_t^{(LT,LPG-2)}$
#	81.00	81.00	81.00	81.00	81.00	81.00	0.00	0.00	0.00
min	−108.12	−71.34	−108.48	−272.00	−134.00	−83.45			
$q^{.25}$	−17.83	−20.00	−27.00	−52.00	−7.64	−1.69			
$\overline{x}$	3.00	5.72	6.78	0.00	0.00	0.85			
$q^{.25}$	29.92	30.51	42.48	42.00	16.39	11.89			
max	156.27	91.40	159.32	410.00	137.00	90.36			
γ_2	4.54	2.52	3.29	3.75	7.51	6.31			
γ_1	−0.04	−0.07	−0.04	0.39	−0.08	0.18			
	$x_t^{(LU,ULP)}$	$x_t^{(LU,DIESEL)}$	$x_t^{(LU,HO)}$	$x_t^{(LU,RFO-1)}$	$x_t^{(LU,RFO-2)}$	$x_t^{(LU,LPG-1)}$	$x_t^{(LU,LP)}$	$x_t^{(LU,KEROSENE)}$	$x_t^{(LU,LPG-2)}$
#	586.00	586.00	586.00	521.00	267.00	294.00	259.00	0.00	0.00
min	7690.00	6930.00	5680.00	3361.00	2888.00	9770.00	7890.00		
$q^{.25}$	8940.00	7800.00	7020.00	4419.00	3597.00	10874.02	8320.00		
$\overline{x}$	11425.00	10917.99	9152.72	5917.00	4070.00	11826.05	8760.00		
$q^{.25}$	13986.25	12930.00	11490.00	6634.70	4291.00	13193.57	9720.00		
max	25769.53	23007.86	21170.38	10115.00	4959.00	17000.44	11110.00		
γ_2	3.35	3.57	3.85	2.25	2.52	3.23	2.28		
γ_1	0.79	0.98	1.09	0.26	−0.18	0.82	0.56		
	$\Delta x_t^{(LU,ULP)}$	$\Delta x_t^{(LU,DIESEL)}$	$\Delta x_t^{(LU,HO)}$	$\Delta x_t^{(LU,RFO-1)}$	$\Delta x_t^{(LU,RFO-2)}$	$\Delta x_t^{(LU,LPG-1)}$	$\Delta x_t^{(LU,LP)}$	$\Delta x_t^{(LU,KEROSENE)}$	$\Delta x_t^{(LU,LPG-2)}$
#	585.00	585.00	585.00	520.00	266.00	293.00	258.00	0.00	0.00
min	−2876.23	−2384.09	−2380.05	−1875.00	−741.00	−1827.40	−610.00		
$q^{.25}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
$\overline{x}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
$q^{.25}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
max	4703.82	1750.75	1839.50	1563.00	755.00	1714.45	790.00		
γ_2	22.99	8.99	9.58	24.98	14.91	11.40	10.82		
γ_1	1.07	−0.22	−0.11	−0.73	−0.45	−0.35	1.12		
	$x_t^{(LV,ULP)}$	$x_t^{(LV,DIESEL)}$	$x_t^{(LV,HO)}$	$x_t^{(LV,RFO-1)}$	$x_t^{(LV,RFO-2)}$	$x_t^{(LV,LPG-1)}$	$x_t^{(LV,LP)}$	$x_t^{(LV,KEROSENE)}$	$x_t^{(LV,LPG-2)}$
#	77.00	77.00	77.00	0.00	0.00	77.00	77.00	0.00	0.00
min	219.20	207.10	207.10			118.10	141.88		
$q^{.25}$	234.47	250.41	257.93			151.97	187.64		
$\overline{x}$	256.51	279.97	279.97			153.44	197.88		
$q^{.25}$	297.83	326.68	326.68			160.44	220.69		
max	396.98	368.20	368.20			221.24	318.58		
γ_2	3.33	1.85	1.87			3.70	4.25		

γ_1	0.96	0.04	−0.02			0.98	1.06		
	$\Delta x_t^{(LV,ULP)}$	$\Delta x_t^{(LV,DIESEL)}$	$\Delta x_t^{(LV,HO)}$	$\Delta x_t^{(LV,RFO-1)}$	$\Delta x_t^{(LV,RFO-2)}$	$\Delta x_t^{(LV,LPG-1)}$	$\Delta x_t^{(LV,LP)}$	$\Delta x_t^{(LV,KEROSENE)}$	$\Delta x_t^{(LV,LPG-2)}$
#	76.00	76.00	76.00	0.00	0.00	76.00	76.00	0.00	0.00
min	−33.05	−27.12	−27.12			−8.48	−56.00		
$q^{.25}$	−2.54	−0.85	−0.43			0.00	−1.27		
$\overline{x}$	0.00	0.00	0.00			0.00	0.00		
$q^{.25}$	4.24	4.24	4.66			0.42	3.81		
max	78.81	22.88	22.88			16.95	80.93		
γ_2	23.68	5.10	5.32			6.25	12.72		
γ_1	3.13	0.09	−0.17			1.33	0.97		
	$x_t^{(MT,ULP)}$	$x_t^{(MT,DIESEL)}$	$x_t^{(MT,HO)}$	$x_t^{(MT,RFO-1)}$	$x_t^{(MT,RFO-2)}$	$x_t^{(MT,LPG-1)}$	$x_t^{(MT,LP)}$	$x_t^{(MT,KEROSENE)}$	$x_t^{(MT,LPG-2)}$
#	52.00	52.00	52.00	0.00	79.00	0.00	52.00	0.00	0.00
min	174.63	140.36	94.00		69.84		179.05		
$q^{.25}$	174.63	140.36	94.00		69.84		179.05		
$\overline{x}$	184.80	186.13	110.00		69.84		189.22		
$q^{.25}$	194.12	198.84	154.00		90.50		198.54		
max	195.81	205.62	175.00		145.00		200.24		
γ_2	1.67	1.47	1.46		5.83		1.68		
γ_1	−0.35	−0.35	0.43		2.00		−0.34		
	$\Delta x_t^{(MT,ULP)}$	$\Delta x_t^{(MT,DIESEL)}$	$\Delta x_t^{(MT,HO)}$	$\Delta x_t^{(MT,RFO-1)}$	$\Delta x_t^{(MT,RFO-2)}$	$\Delta x_t^{(MT,LPG-1)}$	$\Delta x_t^{(MT,LP)}$	$\Delta x_t^{(MT,KEROSENE)}$	$\Delta x_t^{(MT,LPG-2)}$
#	51.00	51.00	51.00	0.00	78.00	0.00	51.00	0.00	0.00
min	−11.01	0.00	0.00		0.00		−11.02		
$q^{.25}$	0.00	0.00	0.00		0.00		0.00		
$\overline{x}$	0.00	0.00	0.00		0.00		0.00		
$q^{.25}$	0.00	0.00	0.00		0.00		0.00		
max	19.49	24.58	44.00		36.50		19.49		
γ_2	28.08	17.30	27.82		35.30		28.19		
γ_1	3.39	3.91	4.92		5.62		3.40		
	$x_t^{(NL,ULP)}$	$x_t^{(NL,DIESEL)}$	$x_t^{(NL,HO)}$	$x_t^{(NL,RFO-1)}$	$x_t^{(NL,RFO-2)}$	$x_t^{(NL,LPG-1)}$	$x_t^{(NL,LP)}$	$x_t^{(NL,KEROSENE)}$	$x_t^{(NL,LPG-2)}$
#	586.00	586.00	586.00	586.00	0.00	295.00	295.00	0.00	0.00
min	447.00	419.00	354.00	208.00		568.00	754.00		
$q^{.25}$	537.00	480.00	417.00	273.00		643.65	892.50		
$\overline{x}$	661.45	626.82	581.84	363.00		692.65	949.80		
$q^{.25}$	806.56	766.89	705.19	431.93		759.80	1065.09		
max	1360.68	1261.71	1286.37	707.39		968.57	1524.97		
γ_2	3.12	3.31	3.48	3.43		3.44	4.24		
γ_1	0.75	0.89	0.98	0.78		0.88	1.03		
	$\Delta x_t^{(NL,ULP)}$	$\Delta x_t^{(NL,DIESEL)}$	$\Delta x_t^{(NL,HO)}$	$\Delta x_t^{(NL,RFO-1)}$	$\Delta x_t^{(NL,RFO-2)}$	$\Delta x_t^{(NL,LPG-1)}$	$\Delta x_t^{(NL,LP)}$	$\Delta x_t^{(NL,KEROSENE)}$	$\Delta x_t^{(NL,LPG-2)}$
#	585.00	585.00	585.00	585.00	0.00	294.00	294.00	0.00	0.00
min	−109.13	−107.00	−122.00	−130.00		−156.85	−95.75		
$q^{.25}$	−9.00	−8.00	−8.00	0.00		−6.61	−17.00		
$\overline{x}$	0.00	0.00	0.00	0.00		0.00	0.00		
$q^{.25}$	11.02	11.00	10.00	0.00		7.71	18.95		
max	174.07	105.56	142.58	72.96		157.44	188.35		
γ_2	9.94	7.06	9.78	26.93		30.78	7.00		

γ_1	0.38	−0.29	−0.46	−1.84		0.07	0.51		
	$x_t^{(PL,ULP)}$	$x_t^{(PL,DIESEL)}$	$x_t^{(PL,HO)}$	$x_t^{(PL,RFO-1)}$	$x_t^{(PL,RFO-2)}$	$x_t^{(PL,LPG-1)}$	$x_t^{(PL,LP)}$	$x_t^{(PL,KEROSENE)}$	$x_t^{(PL,LPG-2)}$
#	82.00	82.00	82.00	82.00	82.00	82.00	0.00	0.00	0.00
min	1282.00	1430.00	1124.00	583.00	485.00	927.00			
$q^{.25}$	1587.00	1563.00	1250.00	734.00	627.00	989.00			
$\overline{x}$	1615.00	1744.00	1428.00	786.00	703.50	1077.00			
$q^{.25}$	1764.00	1929.00	1644.00	920.00	781.00	1220.00			
max	2161.00	2086.00	1967.00	1166.00	969.00	1367.00			
γ_2	3.22	1.85	1.95	2.57	2.12	2.03			
γ_1	0.67	0.24	0.31	0.73	0.17	0.50			
	$\Delta x_t^{(PL,ULP)}$	$\Delta x_t^{(PL,DIESEL)}$	$\Delta x_t^{(PL,HO)}$	$\Delta x_t^{(PL,RFO-1)}$	$\Delta x_t^{(PL,RFO-2)}$	$\Delta x_t^{(PL,LPG-1)}$	$\Delta x_t^{(PL,LP)}$	$\Delta x_t^{(PL,KEROSENE)}$	$\Delta x_t^{(PL,LPG-2)}$
#	81.00	81.00	81.00	81.00	81.00	81.00	0.00	0.00	0.00
min	−163.00	−101.00	−160.00	−94.00	−114.00	−86.00			
$q^{.25}$	−10.00	−15.00	−32.00	−10.00	−25.00	−8.00			
$\overline{x}$	0.00	1.00	5.00	4.00	1.00	3.00			
$q^{.25}$	21.00	22.00	50.00	29.00	24.00	18.00			
max	123.00	63.00	133.00	95.00	124.00	87.00			
γ_2	6.73	4.48	2.82	3.02	3.67	5.41			
γ_1	−0.25	−0.22	−0.40	−0.07	0.19	−0.20			
	$x_t^{(PT,ULP)}$	$x_t^{(PT,DIESEL)}$	$x_t^{(PT,HO)}$	$x_t^{(PT,RFO-1)}$	$x_t^{(PT,RFO-2)}$	$x_t^{(PT,LPG-1)}$	$x_t^{(PT,LP)}$	$x_t^{(PT,KEROSENE)}$	$x_t^{(PT,LPG-2)}$
#	586.00	586.00	296.00	534.00	443.00	188.00	295.00	0.00	0.00
min	37607.00	34817.00	44820.00	23690.00	15580.00	65557.61	43905.56		
$q^{.25}$	44924.00	40862.00	49286.00	26548.00	20393.00	67361.95	72288.80		
$\overline{x}$	56276.30	46291.00	59342.67	42837.26	22625.00	70681.93	84870.00		
$q^{.25}$	76397.68	61811.00	69378.80	49920.02	41500.00	78582.93	100974.00		
max	107055.38	111285.55	110190.92	73187.96	54768.00	90224.92	120551.83		
γ_2	2.23	4.27	3.54	1.92	1.89	2.26	2.40		
γ_1	0.76	1.24	1.08	0.27	0.75	0.81	−0.08		
	$\Delta x_t^{(PT,ULP)}$	$\Delta x_t^{(PT,DIESEL)}$	$\Delta x_t^{(PT,HO)}$	$\Delta x_t^{(PT,RFO-1)}$	$\Delta x_t^{(PT,RFO-2)}$	$\Delta x_t^{(PT,LPG-1)}$	$\Delta x_t^{(PT,LP)}$	$\Delta x_t^{(PT,KEROSENE)}$	$\Delta x_t^{(PT,LPG-2)}$
#	585.00	585.00	295.00	533.00	442.00	187.00	294.00	0.00	0.00
min	−27265.55	−9823.62	−11627.96	−7618.32	−7589.00	−5595.45	−41098.81		
$q^{.25}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
$\overline{x}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
$q^{.25}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
max	14533.00	13123.00	9254.74	6054.00	8360.00	5012.05	15838.08		
γ_2	64.26	35.71	16.89	16.64	27.33	9.30	72.08		
γ_1	−3.69	1.95	0.02	−0.13	0.38	−0.10	−5.36		
	$x_t^{(SE,ULP)}$	$x_t^{(SE,DIESEL)}$	$x_t^{(SE,HO)}$	$x_t^{(SE,RFO-1)}$	$x_t^{(SE,RFO-2)}$	$x_t^{(SE,LPG-1)}$	$x_t^{(SE,LP)}$	$x_t^{(SE,KEROSENE)}$	$x_t^{(SE,LPG-2)}$
#	538.00	538.00	538.00	538.00	0.00	0.00	0.00	0.00	0.00
min	1762.00	1788.00	1219.00	605.00					
$q^{.25}$	2138.00	2392.00	1632.00	1020.00					
$\overline{x}$	2570.00	2802.00	2230.00	1674.00					
$q^{.25}$	3032.00	3185.00	2571.00	2034.00					
max	4928.00	5291.00	4963.00	3812.00					
γ_2	3.72	4.44	4.52	2.47					

γ_1	0.93	1.10	1.18	0.43					

	$\Delta x_t^{(SE,ULP)}$	$\Delta x_t^{(SE,DIESEL)}$	$\Delta x_t^{(SE,HO)}$	$\Delta x_t^{(SE,RFO-1)}$	$\Delta x_t^{(SE,RFO-2)}$	$\Delta x_t^{(SE,LPG-1)}$	$\Delta x_t^{(SE,LP)}$	$\Delta x_t^{(SE,KEROSENE)}$	$\Delta x_t^{(SE,LPG-2)}$
#	537.00	537.00	537.00	537.00	0.00	0.00	0.00	0.00	0.00
min	−432.00	−705.00	−637.00	−710.00					
$q^{.25}$	−48.00	0.00	0.00	0.00					
$\overline{x}$	0.00	0.00	0.00	0.00					
$q^{.25}$	56.00	48.00	0.00	0.00					
max	408.00	524.00	366.00	489.00					
γ_2	5.32	11.11	20.38	23.76					
γ_1	−0.04	−1.21	−1.33	−1.99					

	$x_t^{(SI,ULP)}$	$x_t^{(SI,DIESEL)}$	$x_t^{(SI,HO)}$	$x_t^{(SI,RFO-1)}$	$x_t^{(SI,RFO-2)}$	$x_t^{(SI,LPG-1)}$	$x_t^{(SI,LP)}$	$x_t^{(SI,KEROSENE)}$	$x_t^{(SI,LPG-2)}$
#	82.00	82.00	82.00	82.00	0.00	81.00	0.00	0.00	0.00
min	66409.00	71974.00	66299.00	46950.00		71420.00			
$q^{.25}$	79641.00	85898.00	77365.00	49450.00		71420.00			
$\overline{x}$	85899.00	94681.00	86356.00	51130.00		82809.16			
$q^{.25}$	97134.00	111940.00	103038.00	59055.00		89689.00			
max	125468.00	127190.00	116955.00	77834.00		93920.00			
γ_2	2.98	1.92	1.99	3.15		1.40			
γ_1	0.78	0.25	0.42	1.11		0.07			

	$\Delta x_t^{(SI,ULP)}$	$\Delta x_t^{(SI,DIESEL)}$	$\Delta x_t^{(SI,HO)}$	$\Delta x_t^{(SI,RFO-1)}$	$\Delta x_t^{(SI,RFO-2)}$	$\Delta x_t^{(SI,LPG-1)}$	$\Delta x_t^{(SI,LP)}$	$\Delta x_t^{(SI,KEROSENE)}$	$\Delta x_t^{(SI,LPG-2)}$
#	81.00	81.00	81.00	81.00	0.00	80.00	0.00	0.00	0.00
min	−16167.00	−15250.00	−12583.00	−3794.00		−14166.66			
$q^{.25}$	0.00	0.00	0.00	0.00		0.00			
$\overline{x}$	0.00	0.00	0.00	0.00		0.00			
$q^{.25}$	667.00	1000.00	1500.33	0.00		0.00			
max	13417.00	10033.00	10166.00	9825.00		22500.00			
γ_2	7.60	7.53	6.23	17.89		25.79			
γ_1	−0.79	−0.56	−0.47	3.34		2.56			

	$x_t^{(SK,ULP)}$	$x_t^{(SK,DIESEL)}$	$x_t^{(SK,HO)}$	$x_t^{(SK,RFO-1)}$	$x_t^{(SK,RFO-2)}$	$x_t^{(SK,LPG-1)}$	$x_t^{(SK,LP)}$	$x_t^{(SK,KEROSENE)}$	$x_t^{(SK,LPG-2)}$
#	80.00	80.00	80.00	80.00	80.00	80.00	32.00	0.00	0.00
min	11861.34	13113.45	10774.40	6188.00	6006.00	10340.25	12768.91		
$q^{.25}$	14424.37	14176.47	11020.10	6700.00	6500.00	11113.36	14823.53		
$\overline{x}$	14949.58	15613.45	13149.50	6900.00	6700.00	11596.55	15096.64		
$q^{.25}$	16462.18	17865.55	16316.30	7000.00	6800.00	12583.95	15340.34		
max	19861.34	20373.95	20475.00	8500.00	8300.00	15088.15	15777.31		
γ_2	2.85	2.06	2.09	6.51	6.52	3.31	6.86		
γ_1	0.49	0.44	0.65	2.04	2.05	0.93	−1.80		

	$\Delta x_t^{(SK,ULP)}$	$\Delta x_t^{(SK,DIESEL)}$	$\Delta x_t^{(SK,HO)}$	$\Delta x_t^{(SK,RFO-1)}$	$\Delta x_t^{(SK,RFO-2)}$	$\Delta x_t^{(SK,LPG-1)}$	$\Delta x_t^{(SK,LP)}$	$\Delta x_t^{(SK,KEROSENE)}$	$\Delta x_t^{(SK,LPG-2)}$
#	79.00	79.00	79.00	79.00	79.00	79.00	31.00	0.00	0.00
min	−974.79	−831.93	−1820.00	−200.00	−200.00	−134.45	−815.13		
q^{25}	−71.43	−96.64	0.00	0.00	0.00	−50.42	−218.49		
$\overline{x}$	−8.40	0.00	0.00	0.00	0.00	−8.40	0.00		
$q^{.25}$	163.87	357.14	0.00	0.00	0.00	25.21	25.21		
max	1319.33	1109.24	2356.90	1000.00	1000.00	2109.24	689.08		
γ_2	4.26	2.95	11.03	29.17	29.44	34.11	3.46		

γ_1	0.29	0.10	1.53	4.84	4.85	5.32	−0.24

Table A.18: MSP - Summary Statistics

	$x_t^{(MSP,ULP)}$	$x_t^{(MSP,DO)}$	$x_t^{(MSP,GASOIL)}$	$x_t^{(MSP,RFO.1)}$	$x_t^{(MSP,RFO.2)}$	$x_t^{(MSP,LPG-1)}$	$x_t^{(MSP,LP)}$
#	585.00	560.00	585.00	585.00	585.00	584.00	585.00
min	−122.50	−73.25	−71.50	−31.00	−34.25	−110.00	−92.25
$q^{.25}$	−6.00	−5.69	−4.50	−2.50	−3.75	−6.00	−5.00
$\overline{x}$	1.00	0.75	0.50	0.00	0.50	0.50	0.00
$q^{.75}$	8.00	7.50	6.50	3.50	4.25	9.00	7.00
max	120.25	82.75	52.50	32.00	37.00	88.00	45.50
γ_2	14.08	8.14	8.17	6.10	6.27	9.35	8.24
γ_1	−0.56	−0.41	−0.65	0.12	0.16	−0.26	−0.75
	$\Delta x_t^{(MSP,ULP)}$	$\Delta x_t^{(MSP,DO)}$	$\Delta x_t^{(MSP,GASOIL)}$	$\Delta x_t^{(MSP,RFO.1)}$	$\Delta x_t^{(MSP,RFO.2)}$	$\Delta x_t^{(MSP,LPG-1)}$	$\Delta x_t^{(MSP,LP)}$
#	586.00	561.00	586.00	586.00	586.00	585.00	586.00
min	108.75	93.00	93.25	56.50	48.00	109.00	112.50
$q_{.25}$	172.50	155.75	153.75	96.00	86.25	175.00	177.00
$\overline{x}$	225.75	214.75	203.00	120.38	113.00	230.00	229.00
$q^{.75}$	302.50	265.00	248.38	154.50	141.50	308.50	306.00
max	771.50	655.75	625.75	324.00	288.75	612.00	531.00
γ_2	5.10	4.71	5.35	5.55	4.90	3.54	3.64
γ_1	1.45	1.50	1.63	1.42	1.24	0.96	1.16

Table A.19: USP - Summary Statistics

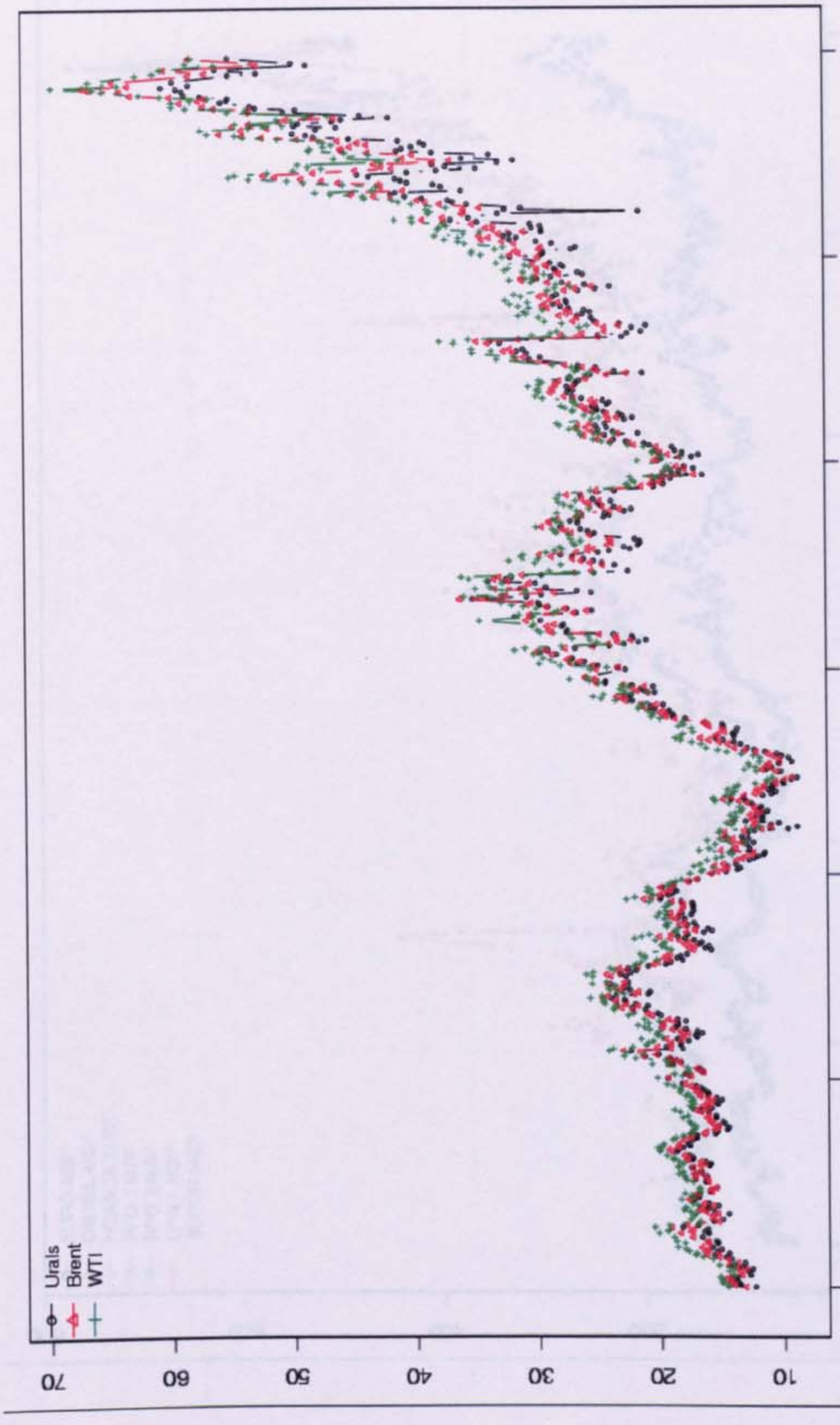
	#	min	$q^{.25}$	$\overline{x}$	$q^{.75}$	max	γ_2	γ_1
$x_t^{(WTISpotPrice)}$	468.00	10.73	20.16	27.35	33.84	69.48	3.69	1.06
$x_t^{(EuropeBrentSpotPrice)}$	468.00	9.20	19.12	25.74	31.30	66.34	3.83	1.09
$x_t^{(EuropeNorwegianEkofiskSpotPrice)}$	468.00	9.55	19.25	25.77	31.32	66.01	3.83	1.09
$x_t^{(CanadianParSpotPrice)}$	468.00	10.06	19.35	27.02	33.41	68.84	3.77	1.09
$x_t^{(CanadaLloydBlendSpotPrice)}$	467.00	5.40	13.07	19.63	25.16	46.79	3.23	0.59
$x_t^{(MexicoIsthmusSpotPrice)}$	468.00	8.78	17.77	24.74	30.57	62.61	3.68	0.99
$x_t^{(MexicoMayaSpotPrice)}$	468.00	5.80	14.59	20.57	25.75	51.08	3.57	0.85
$x_t^{(ColombiaCanoLimonSpotPrice)}$	468.00	8.45	17.73	24.34	30.49	63.05	3.84	1.04
$x_t^{(EcuadorOrienteSpotPrice)}$	468.00	7.90	16.77	23.11	28.34	57.45	4.05	0.92
$x_t^{(AngolaCabindaSpotPrice)}$	468.00	8.95	18.40	25.10	30.49	63.41	3.86	1.05
$x_t^{(CameroonKoleSpotPrice)}$	468.00	8.95	18.35	25.12	30.88	63.79	3.96	1.07
$x_t^{(EgyptSuezBlendSpotPrice)}$	468.00	7.60	16.73	23.12	27.54	58.85	4.04	1.08
$x_t^{(OmanBlendSpotPrice)}$	468.00	9.50	18.27	24.48	29.12	59.79	4.08	1.12
$x_t^{(AustraliaGippslandSpotPrice)}$	468.00	10.25	19.80	26.60	32.78	67.79	3.68	1.07
$x_t^{(MalaysiaTapisSpotPrice)}$	468.00	10.95	21.15	27.15	33.10	70.26	3.88	1.13
$x_t^{(MediterraneanRusianUralsSpotPrice)}$	467.00	8.73	18.23	24.67	29.86	60.90	3.93	1.04
$x_t^{(ChinaDaqingSpotPrice)}$	468.00	9.50	18.67	25.93	31.79	61.78	3.52	0.95
$x_t^{(SaudiArabiaSaudiLightSpotPrice)}$	468.00	9.65	18.33	23.88	28.68	62.10	4.18	1.16
$x_t^{(SaudiArabiaArabMediumSpotPrice)}$	468.00	9.25	17.69	23.34	27.66	59.50	4.24	1.12
$x_t^{(SaudiArabiaSaudiHeavySpotPrice)}$	468.00	8.50	17.16	22.70	26.58	56.75	4.17	1.04
$x_t^{(AsiaMurbanSpotPrice)}$	468.00	9.83	19.30	25.64	30.75	64.19	4.11	1.16
$x_t^{(AsiaDubaiFatehSpotPrice)}$	468.00	9.60	18.10	24.24	28.99	58.64	4.07	1.11
$x_t^{(QatarDukhanSpotPrice)}$	468.00	10.11	18.88	24.96	29.70	63.45	4.18	1.21
$x_t^{(MediterraneanSeriKerirIranLightSpotPrice)}$	468.00	9.45	18.28	24.30	29.41	63.71	4.12	1.14
$x_t^{(MediterraneanSeriKerirIranHeavySpotPrice)}$	468.00	9.20	17.95	23.83	28.55	61.46	4.13	1.09

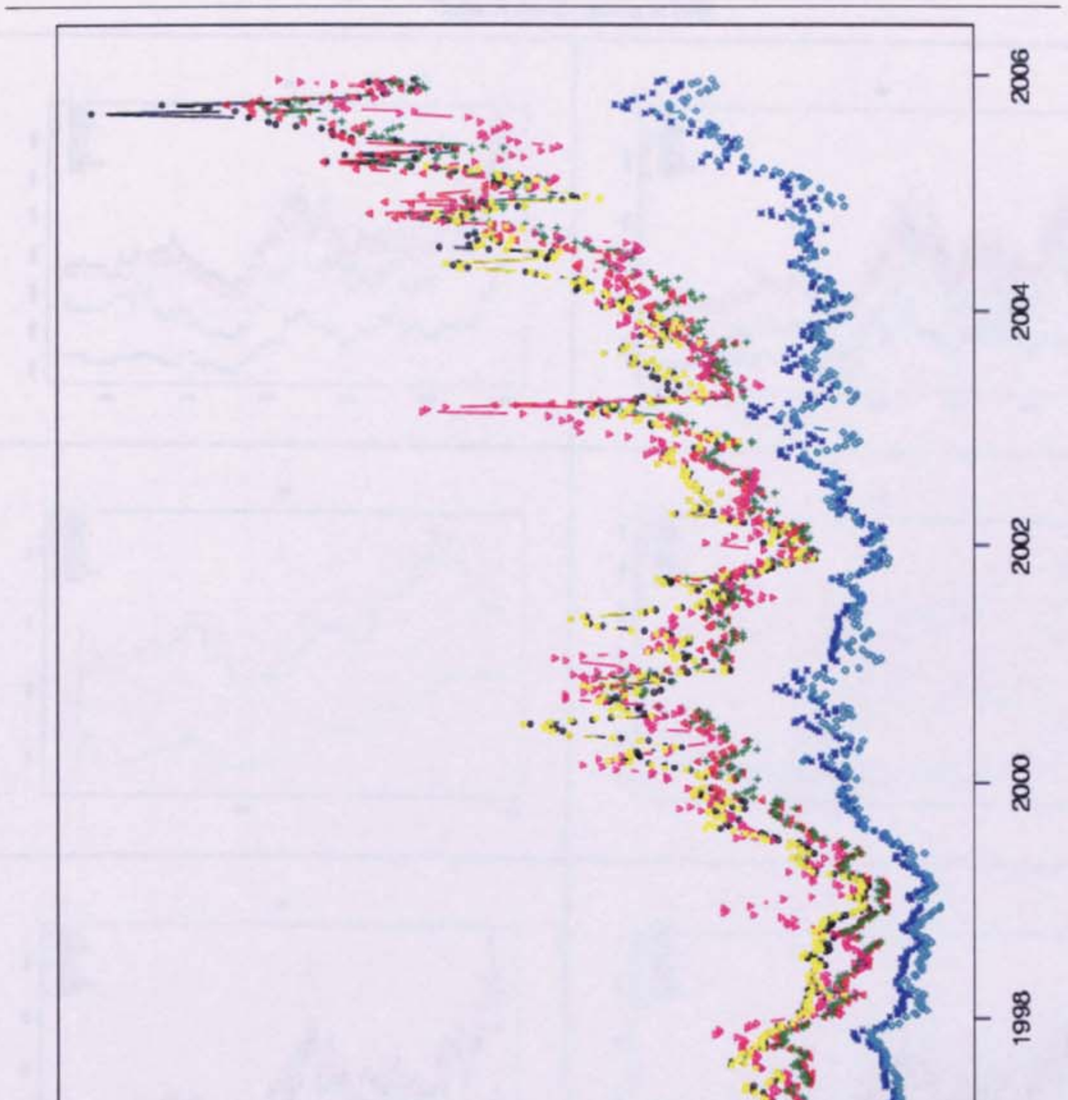
$x_t^{(KuwaitBlendSpotPrice)}$	468.00	9.00	17.65	24.15	28.50	57.37	3.98	1.01
$x_t^{(AlgeriaSaharanBlendSpotPrice)}$	468.00	9.75	19.54	25.96	31.52	66.51	3.85	1.10
$x_t^{(EuropeNigerianBonnyLightSpotPrice)}$	468.00	9.45	19.30	25.86	31.09	68.94	4.05	1.16
$x_t^{(EuropeForcadosSpotPrice)}$	468.00	9.55	19.15	25.74	31.01	68.86	4.05	1.17
$x_t^{(EuropeLibyanEsSiderFOBSpotPrice)}$	468.00	9.65	19.16	25.67	30.95	63.10	3.86	1.06
$x_t^{(IndonesiaMinasSpotPrice)}$	468.00	9.65	18.55	25.92	31.77	64.71	3.67	1.02
$x_t^{(VenezuelaTiaJuanaSpotPrice)}$	468.00	8.85	18.84	24.90	30.84	62.72	3.71	0.99

	#	min	$q^{.25}$	$\overline{x}$	$q^{.75}$	max	γ_2	γ_1
$x_t^{(WTISpotPrice)}$	467.00	−9.38	−0.75	0.06	0.99	6.09	6.86	−0.68
$x_t^{(EuropeBrentSpotPrice)}$	467.00	−5.23	−0.70	0.12	0.85	5.88	4.61	−0.21
$x_t^{(EuropeNorwegianEkofiskSpotPrice)}$	467.00	−5.31	−0.65	0.15	0.81	7.40	5.70	−0.23
$x_t^{(CanadianParSpotPrice)}$	467.00	−6.89	−0.63	0.09	0.88	4.95	5.68	−0.49
$x_t^{(CanadaLloydBlendSpotPrice)}$	465.00	−10.84	−0.67	0.02	0.89	7.20	9.54	−0.83
$x_t^{(MexicoIsthmusSpotPrice)}$	467.00	−6.24	−0.63	0.11	0.91	3.56	5.12	−0.64
$x_t^{(MexicoMayaSpotPrice)}$	467.00	−4.30	−0.59	0.08	0.80	3.52	4.64	−0.57
$x_t^{(ColombiaCanoLimonSpotPrice)}$	467.00	−5.26	−0.65	0.05	0.88	3.68	4.41	−0.49
$x_t^{(EcuadorOrienteSpotPrice)}$	467.00	−6.73	−0.65	0.05	0.90	7.75	7.16	−0.57
$x_t^{(AngolaCabindaSpotPrice)}$	467.00	−4.95	−0.66	0.10	0.80	6.60	5.49	−0.32
$x_t^{(CameroonKoleSpotPrice)}$	467.00	−6.01	−0.65	0.14	0.80	6.60	5.81	−0.38
$x_t^{(EgyptSuezBlendSpotPrice)}$	467.00	−5.75	−0.66	0.15	0.80	5.40	5.01	−0.43
$x_t^{(OmanBlendSpotPrice)}$	467.00	−4.25	−0.54	0.10	0.64	3.15	4.54	−0.33
$x_t^{(AustraliaGippslandSpotPrice)}$	467.00	−6.62	−0.49	0.05	0.65	4.11	6.47	−0.49
$x_t^{(MalaysiaTapisSpotPrice)}$	467.00	−6.87	−0.00	0.00	0.38	4.35	8.40	−0.68
$x_t^{(MediterraneanRusianUralsSpotPrice)}$	465.00	−5.09	−0.71	0.10	0.89	5.38	4.33	−0.26
$x_t^{(ChinaDaqingSpotPrice)}$	467.00	−9.19	−0.50	0.05	0.70	4.76	11.65	−1.10
$x_t^{(SaudiArabiaSaudiLightSpotPrice)}$	467.00	−4.68	−0.57	0.13	0.70	3.66	5.30	−0.58
$x_t^{(SaudiArabiaArabMediumSpotPrice)}$	467.00	−5.01	−0.57	0.13	0.73	4.21	5.57	−0.59

$x_t^{(SaudiArabiaSaudiHeavySpotPrice)}$	467.00	−5.51	−0.57	0.13	0.74	4.36	5.94	−0.68
$x_t^{(AsiaMurbanSpotPrice)}$	467.00	−4.59	−0.50	0.10	0.65	3.97	4.79	−0.37
$x_t^{(AsiaDubaiFatehSpotPrice)}$	467.00	−4.45	−0.53	0.10	0.65	2.99	4.48	−0.39
$x_t^{(QatarDukhanSpotPrice)}$	467.00	−4.09	−0.49	0.10	0.65	3.58	4.56	−0.30
$x_t^{(MediterraneanSeriKerirIranLightSpotPrice)}$	467.00	−5.20	−0.61	0.05	0.75	4.15	4.96	−0.40
$x_t^{(MediterraneanSeriKerirIranHeavySpotPrice)}$	467.00	−5.56	−0.60	0.07	0.75	4.70	5.31	−0.42
$x_t^{(KuwaitBlendSpotPrice)}$	467.00	−4.35	−0.52	0.10	0.66	2.93	4.52	−0.41
$x_t^{(AlgeriaSaharanBlendSpotPrice)}$	467.00	−5.10	−0.68	0.13	0.85	6.56	5.01	−0.28
$x_t^{(EuropeNigerianBonnyLightSpotPrice)}$	467.00	−10.00	−0.70	0.13	0.84	6.95	9.66	−0.69
$x_t^{(EuropeForcadosSpotPrice)}$	467.00	−5.15	−0.65	0.15	0.85	7.30	5.66	−0.23
$x_t^{(EuropeLibyanEsSiderFOBSpotPrice)}$	467.00	−5.07	−0.61	0.15	0.79	6.20	5.05	−0.27
$x_t^{(IndonesiaMinasSpotPrice)}$	467.00	−9.66	−0.49	0.05	0.70	4.81	11.61	−1.02
$x_t^{(VenezuelaTiaJuanaSpotPrice)}$	467.00	−6.24	−0.58	0.00	0.79	3.56	5.37	−0.70

Table A.20: Evolution of USPs and MSPs

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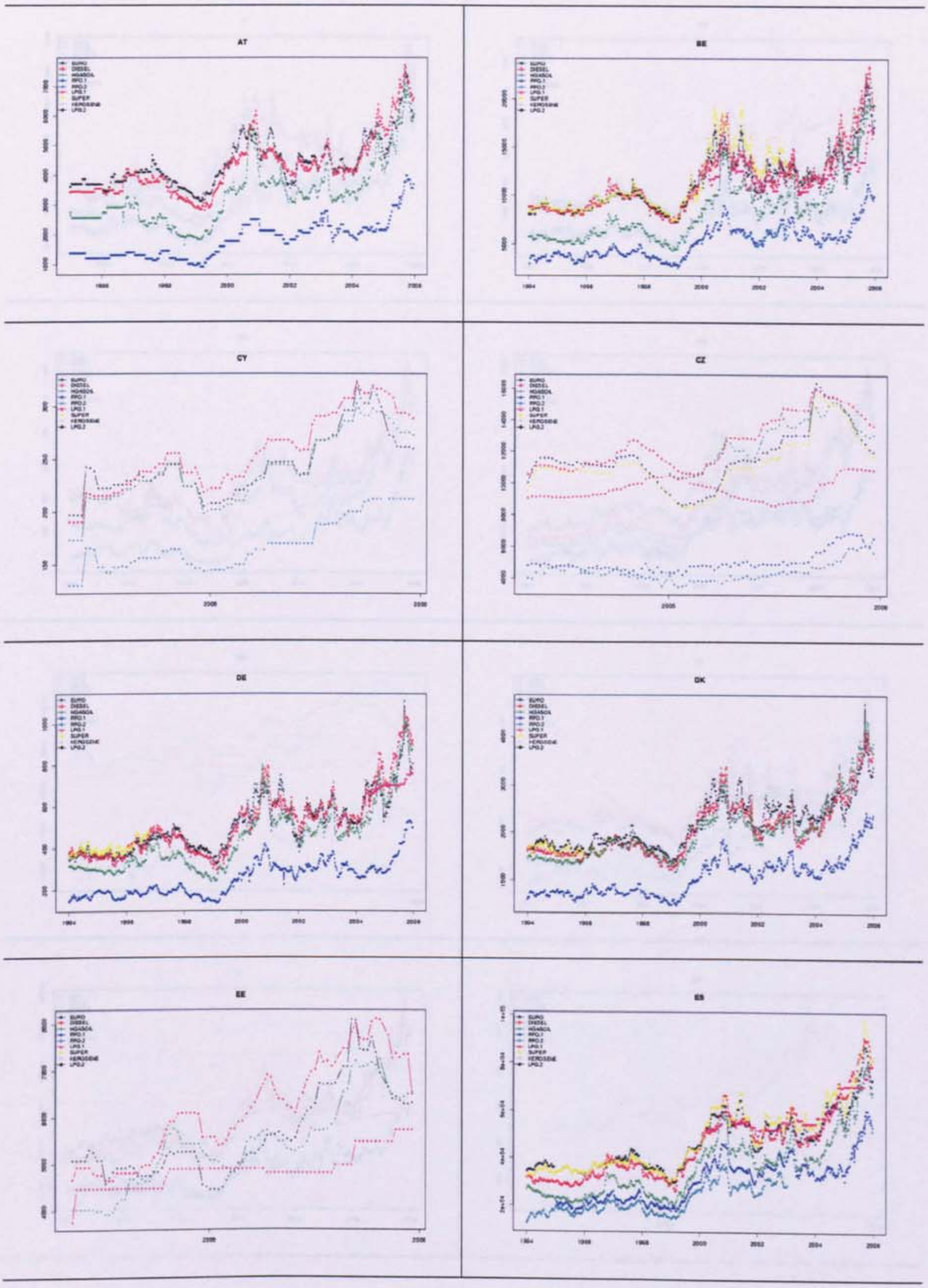
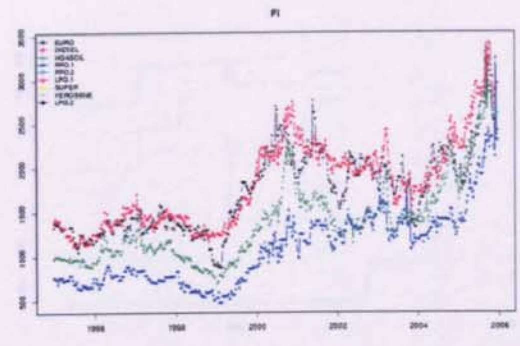
DESEL.MSP
HGASOIL.MSP
RFO.1.MSP
RFO.2.MSP
LPG.1.MSP
SUPER.MSP
200
400
600
800
1994
1996
1998
2000
2002
2004
2006

Table A.21: Evolution of DSP

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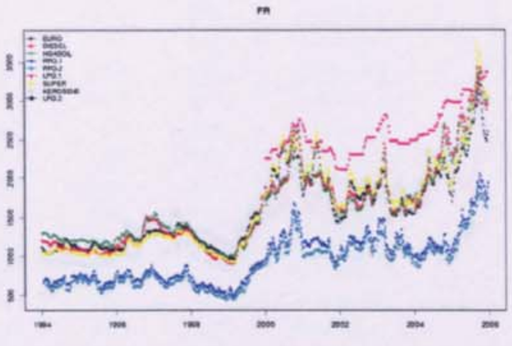
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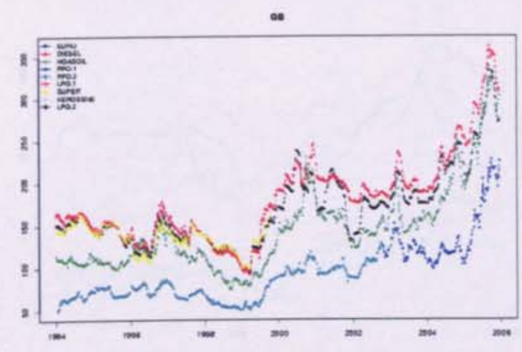
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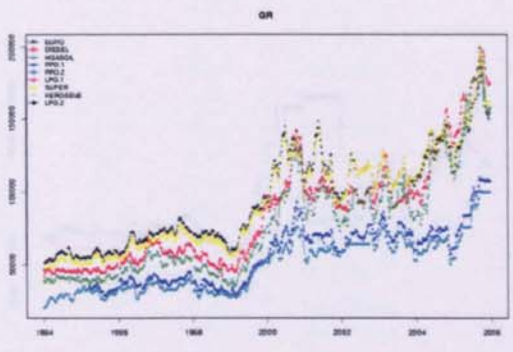
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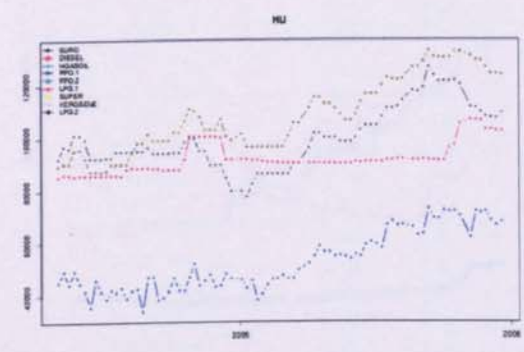
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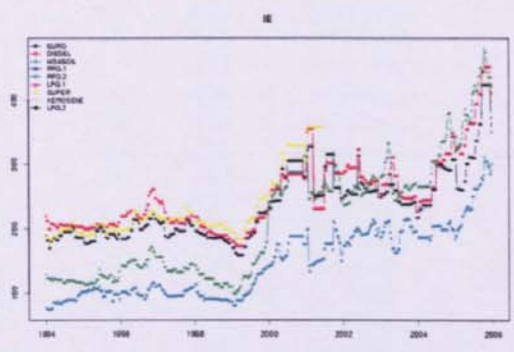
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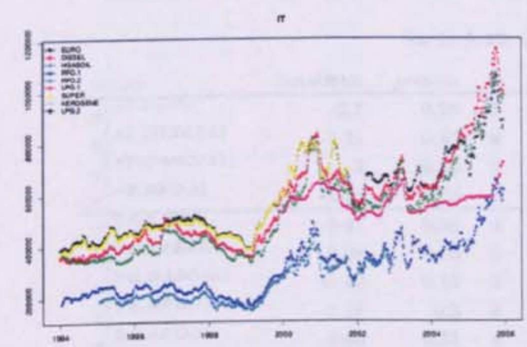
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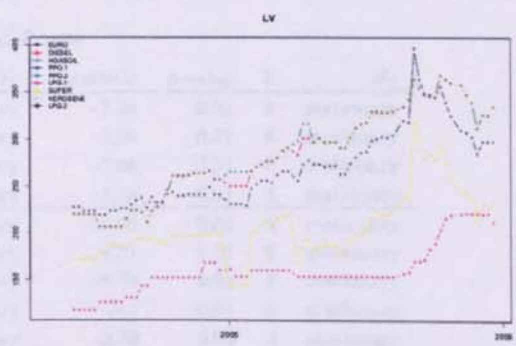
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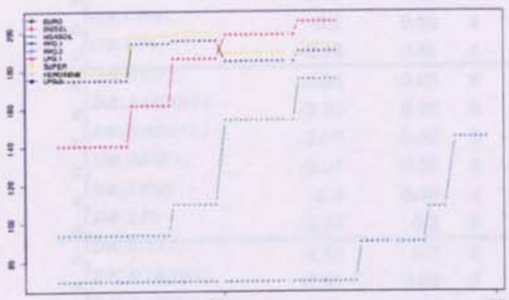
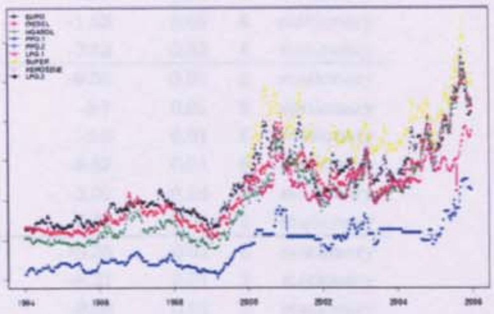
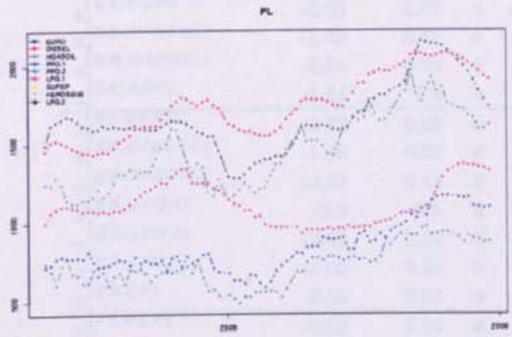
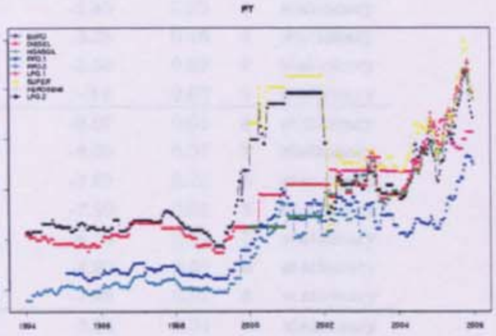








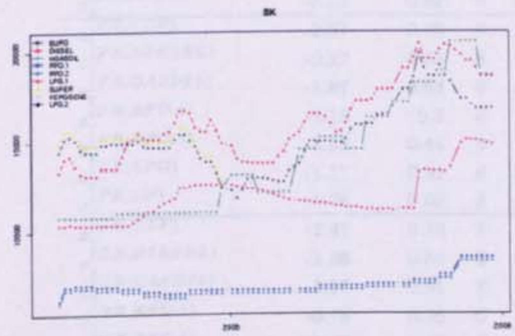


Table A.22: DSPs - ADF tests

Series	t-statistic	p-value	k	H_1	t-statistic	p-value	k	H_1
$x_t^{(AT,ULP)}$	-2.7	0.28	8	stationary	-7.36	0.01	8	stationary
$x_t^{(AT,DIESEL)}$	-2.25	0.47	8	stationary	-7.26	0.01	8	stationary
$x_t^{(AT,GASOIL)}$	-2	0.58	8	stationary	-7.96	0.01	8	stationary
$x_t^{(AT,RFO.1)}$	-1.82	0.66	8	stationary	-7.35	0.01	8	stationary
$x_t^{(BE,ULP)}$	-2.47	0.38	8	stationary	-10.05	0.01	8	stationary
$x_t^{(BE,DIESEL)}$	-2.08	0.55	8	stationary	-8.51	0.01	8	stationary
$x_t^{(BE,GASOIL)}$	-1.42	0.83	8	stationary	-8.73	0.01	8	stationary
$x_t^{(BE,RFO.1)}$	-2.18	0.5	8	stationary	-9.1	0.01	8	stationary
$x_t^{(BE,RFO.2)}$	-2.65	0.31	4	stationary	-3.59	0.04	4	stationary
$x_t^{(BE,LPG)}$	-2.4	0.41	6	stationary	-6.31	0.01	6	stationary
$x_t^{(BE,LP)}$	-2.12	0.53	7	stationary	-8.81	0.01	7	stationary
$x_t^{(CY,ULP)}$	-2.26	0.47	4	stationary	-4	0.01	4	stationary
$x_t^{(CY,DIESEL)}$	-2.1	0.54	4	stationary	-3.81	0.02	4	stationary
$x_t^{(CY,GASOIL)}$	-2.03	0.57	4	stationary	-3.65	0.03	4	stationary
$x_t^{(CY,RFO.2)}$	-2.12	0.53	4	stationary	-5.72	0.01	4	stationary
$x_t^{(CZ,ULP)}$	-2.15	0.51	4	stationary	-2.7	0.29	4	stationary
$x_t^{(CZ,DIESEL)}$	-2.03	0.56	4	stationary	-2.42	0.4	4	stationary

$x_t^{(CZ,GASOIL)}$	-1.21	0.89	3	stationary	-3	0.18	3	stationary
$x_t^{(CZ,RFO.1)}$	-1.85	0.64	4	stationary	-3.65	0.03	4	stationary
$x_t^{(CZ,RFO.2)}$	-0.38	0.98	4	stationary	-3.87	0.02	4	stationary
$x_t^{(CZ,LPG)}$	-2.1	0.53	4	stationary	-1.83	0.64	4	stationary
$x_t^{(CZ,LP)}$	-2.15	0.51	4	stationary	-2.63	0.32	4	stationary
$x_t^{(DE,ULP)}$	-3.24	0.08	8	stationary	-9.58	0.01	8	stationary
$x_t^{(DE,DIESEL)}$	-2.38	0.42	8	stationary	-8.7	0.01	8	stationary
$x_t^{(DE,GASOIL)}$	-2.06	0.55	8	stationary	-8.6	0.01	8	stationary
$x_t^{(DE,RFO.1)}$	-2.07	0.55	8	stationary	-9.82	0.01	8	stationary
$x_t^{(DE,LPG)}$	-0.9	0.95	4	stationary	-3.02	0.16	4	stationary
$x_t^{(DE,LP)}$	-2.67	0.3	5	stationary	-6.21	0.01	5	stationary
$x_t^{(DK,ULP)}$	-2.65	0.3	8	stationary	-10.36	0.01	8	stationary
$x_t^{(DK,DIESEL)}$	-1.81	0.66	8	stationary	-9.31	0.01	8	stationary
$x_t^{(DK,GASOIL)}$	-1.58	0.75	8	stationary	-9.08	0.01	8	stationary
$x_t^{(DK,RFO.1)}$	-1.77	0.68	8	stationary	-9.84	. 0.01	8	stationary
$x_t^{(DK,LP)}$	-3.3	0.08	4	stationary	-5.26	0.01	4	stationary
$x_t^{(EE,ULP)}$	-2.26	0.47	4	stationary	-2.85	0.23	4	stationary
$x_t^{(EE,DIESEL)}$	-1.49	0.78	4	stationary	-2.28	0.46	4	stationary
$x_t^{(EE,GASOIL)}$	-2.76	0.26	4	stationary	-3.96	0.02	4	stationary
$x_t^{(EE,LPG)}$	-1.44	0.8	4	stationary	-3.8	0.02	4	stationary
$x_t^{(ES,ULP)}$	-2.77	0.25	8	stationary	-8.07	0.01	8	stationary
$x_t^{(ES,DIESEL)}$	-1.99	0.58	8	stationary	-8.09	0.01	8	stationary
$x_t^{(ES,GASOIL)}$	-2.39	0.41	8	stationary	-7.82	0.01	8	stationary
$x_t^{(ES,RFO.1)}$	-2.2	0.5	8	stationary	-7.99	0.01	8	stationary
$x_t^{(ES,RFO.2)}$	-2.63	0.31	7	stationary	-8.54	0.01	7	stationary
$x_t^{(ES,LPG)}$	-1.02	0.93	6	stationary	-4.92	0.01	6	stationary
$x_t^{(ES,LP)}$	-2.56	0.34	8	stationary	-7.98	0.01	8	stationary
$x_t^{(FI,ULP)}$	-3.02	0.15	8	stationary	-8.54	0.01	8	stationary
$x_t^{(FI,DIESEL)}$	-1.9	0.62	8	stationary	-8.06	0.01	8	stationary
$x_t^{(FI,GASOIL)}$	-1.84	0.65	8	stationary	-8.35	0.01	8	stationary
$x_t^{(FI,RFO.1)}$	-1.13	0.92	8	stationary	-9.36	0.01	8	stationary
$x_t^{(FR,ULP)}$	-2.37	0.42	8	stationary	-8.51	0.01	8	stationary
$x_t^{(FR,DIESEL)}$	-2.12	0.53	8	stationary	-8	0.01	8	stationary
$x_t^{(FR,GASOIL)}$	-1.87	0.63	8	stationary	-8.02	0.01	8	stationary
$x_t^{(FR,RFO.1)}$	-2.18	0.5	8	stationary	-9.83	0.01	8	stationary
$x_t^{(FR,RFO.2)}$	-2.33	0.44	8	stationary	-9.82	0.01	8	stationary
$x_t^{(FR,LPG)}$	-1.17	0.91	6	stationary	-6.14	0.01	6	stationary
$x_t^{(FR,LP)}$	-1.76	0.68	8	stationary	-8.23	0.01	8	stationary
$x_t^{(GB,ULP)}$	-2.47	0.38	8	stationary	-8.19	0.01	8	stationary
$x_t^{(GB,DIESEL)}$	-1.86	0.64	8	stationary	-8.67	0.01	8	stationary
$x_t^{(GB,GASOIL)}$	-1.17	0.91	8	stationary	-8.19	0.01	8	stationary
$x_t^{(GB,RFO.1)}$	-0.78	0.96	5	stationary	-5.8	0.01	5	stationary
$x_t^{(GB,RFO.2)}$	-1.78	0.67	7	stationary	-7.04	0.01	7	stationary
$x_t^{(GB,LP)}$	-2.2	0.49	6	stationary	-6.19	0.01	6	stationary
$x_t^{(GR,ULP)}$	-2.75	0.26	8	stationary	-9.2	0.01	8	stationary
$x_t^{(GR,DIESEL)}$	-1.96	0.6	8	stationary	-8.15	0.01	8	stationary
$x_t^{(GR,GASOIL)}$	-2.78	0.25	8	stationary	-7.63	0.01	8	stationary
$x_t^{(GR,RFO.1)}$	-2.39	0.41	8	stationary	-8.72	0.01	8	stationary
$x_t^{(GR,RFO.2)}$	-1.98	0.59	8	stationary	-9.42	0.01	8	stationary
$x_t^{(GR,LP)}$	-2.7	0.28	8	stationary	-9.1	0.01	8	stationary
$x_t^{(HU,ULP)}$	-2.38	0.42	4	stationary	-3.82	0.02	4	stationary
$x_t^{(HU,DIESEL)}$	-2.68	0.3	4	stationary	-3.6	0.04	4	stationary
$x_t^{(HU,GASOIL)}$	-2.68	0.3	4	stationary	-3.6	0.04	4	stationary
$x_t^{(HU,RFO.1)}$	-2.89	0.21	4	stationary	-4.8	0.01	4	stationary
$x_t^{(HU,LPG)}$	-2.25	0.47	4	stationary	-3.82	0.02	4	stationary
$x_t^{(IE,ULP)}$	-3.29	0.07	8	stationary	-7.45	0.01	8	stationary
$x_t^{(IE,DIESEL)}$	-2.72	0.27	8	stationary	-9.35	0.01	8	stationary
$x_t^{(IE,GASOIL)}$	-2.24	0.48	8	stationary	-8.38	0.01	8	stationary
$x_t^{(IE,RFO.2)}$	-1.95	0.6	8	stationary	-8.56	0.01	8	stationary
$x_t^{(IE,LP)}$	-0.24	0.99	7	stationary	-7.77	0.01	7	stationary
$x_t^{(IT,ULP)}$	-2.29	0.45	8	stationary	-8	0.01	8	stationary
$x_t^{(IT,DIESEL)}$	-1.35	0.85	8	stationary	-7.54	0.01	8	stationary
$x_t^{(IT,GASOIL)}$	-1.83	0.65	8	stationary	-7.94	0.01	8	stationary
$x_t^{(IT,RFO.1)}$	-1.8	0.66	8	stationary	-10.1	0.01	8	stationary
$x_t^{(IT,RFO.2)}$	-2.6	0.32	7	stationary	-8.55	0.01	7	stationary

$x_t^{(IT,LPG)}$	-1.79	0.66	6	stationary	-5.12	0.01	6	stationary
$x_t^{(IT,LP)}$	-1.75	0.68	7	stationary	-7.07	0.01	7	stationary
$x_t^{(LT,ULP)}$	-2.62	0.32	4	stationary	-3.59	0.04	4	stationary
$x_t^{(LT,DIESEL)}$	-2.97	0.18	4	stationary	-3.72	0.03	4	stationary
$x_t^{(LT,GASOIL)}$	-3.59	0.04	4	stationary	-4.43	0.01	4	stationary
$x_t^{(LT,RFO.1)}$	-3.45	0.05	4	stationary	-4.62	0.01	4	stationary
$x_t^{(LT,RFO.2)}$	-2.07	0.55	4	stationary	-4	0.01	4	stationary
$x_t^{(LT,LPG)}$	-2.1	0.53	4	stationary	-2.59	0.33	4	stationary
$x_t^{(LU,ULP)}$	-2.82	0.23	8	stationary	-8.99	0.01	8	stationary
$x_t^{(LU,DIESEL)}$	-2.17	0.51	8	stationary	-8.14	0.01	8	stationary
$x_t^{(LU,GASOIL)}$	-2.23	0.48	8	stationary	-8.41	0.01	8	stationary
$x_t^{(LU,RFO.1)}$	-2.48	0.37	8	stationary	-8.86	0.01	8	stationary
$x_t^{(LU,RFO.2)}$	-3.17	0.09	6	stationary	-6.38	0.01	6	stationary
$x_t^{(LU,LPG)}$	-2.12	0.53	6	stationary	-6.6	0.01	6	stationary
$x_t^{(LU,LP)}$	-2.07	0.54	6	stationary	-5	0.01	6	stationary
$x_t^{(LV,ULP)}$	-2.11	0.53	4	stationary	-3.29	0.08	4	stationary
$x_t^{(LV,DIESEL)}$	-3.02	0.16	4	stationary	-4.06	0.01	4	stationary
$x_t^{(LV,GASOIL)}$	-2.99	0.17	4	stationary	-4.09	0.01	4	stationary
$x_t^{(LV,LPG)}$	-2.06	0.55	4	stationary	-3.02	0.16	4	stationary
$x_t^{(LV,LP)}$	-2.41	0.41	4	stationary	-3.82	0.02	4	stationary
$x_t^{(MT,ULP)}$	-1.74	0.68	3	stationary	-3.38	0.07	3	stationary
$x_t^{(MT,DIESEL)}$	-1.54	0.76	3	stationary	-4.08	0.01	3	stationary
$x_t^{(MT,GASOIL)}$	-2.37	0.43	3	stationary	-3.83	0.02	3	stationary
$x_t^{(MT,RFO.2)}$	-0.67	0.97	4	stationary	-3.7	0.03	4	stationary
$x_t^{(MT,LP)}$	-1.73	0.68	3	stationary	-3.38	0.07	3	stationary
$x_t^{(NL,ULP)}$	-2.66	0.3	8	stationary	-9.34	0.01	8	stationary
$x_t^{(NL,DIESEL)}$	-2.49	0.37	8	stationary	-8.1	0.01	8	stationary
$x_t^{(NL,GASOIL)}$	-1.94	0.6	8	stationary	-8.22	0.01	8	stationary
$x_t^{(NL,RFO.1)}$	-2.6	0.32	8	stationary	-8.12	0.01	8	stationary
$x_t^{(NL,LPG)}$	-2.43	0.39	6	stationary	-6.5	0.01	6	stationary
$x_t^{(NL,LP)}$	-2.3	0.45	6	stationary	-7.2	0.01	6	stationary
$x_t^{(PL,ULP)}$	-2.21	0.49	4	stationary	-2.64	0.31	4	stationary
$x_t^{(PL,DIESEL)}$	-2.2	0.49	4	stationary	-2.69	0.29	4	stationary
$x_t^{(PL,GASOIL)}$	-2.36	0.43	4	stationary	-3.73	0.03	4	stationary
$x_t^{(PL,RFO.1)}$	-1.9	0.62	4	stationary	-3.3	0.08	4	stationary
$x_t^{(PL,RFO.2)}$	-2.31	0.45	4	stationary	-3.45	0.05	4	stationary
$x_t^{(PL,LPG)}$	-1.61	0.74	4	stationary	-2.44	0.4	4	stationary
$x_t^{(PT,ULP)}$	-2.18	0.5	8	stationary	-7.48	0.01	8	stationary
$x_t^{(PT,DIESEL)}$	-1.33	0.86	8	stationary	-8.41	0.01	8	stationary
$x_t^{(PT,GASOIL)}$	-2.08	0.54	6	stationary	-6.33	0.01	6	stationary
$x_t^{(PT,RFO.1)}$	-2.01	0.58	8	stationary	-7.68	0.01	8	stationary
$x_t^{(PT,RFO.2)}$	-2.04	0.56	7	stationary	-6.3	0.01	7	stationary
$x_t^{(PT,LPG)}$	-2.34	0.43	5	stationary	-4.96	0.01	5	stationary
$x_t^{(PT,LP)}$	-2.57	0.33	6	stationary	-5.47	0.01	6	stationary
$x_t^{(SE,ULP)}$	-3.1	0.11	8	stationary	-9.18	0.01	8	stationary
$x_t^{(SE,DIESEL)}$	-2.59	0.33	8	stationary	-8.72	0.01	8	stationary
$x_t^{(SE,GASOIL)}$	-1.7	0.71	8	stationary	-8.28	0.01	8	stationary
$x_t^{(SE,RFO.1)}$	-2.19	0.5	8	stationary	-7.7	0.01	8	stationary
$x_t^{(SI,ULP)}$	-2.3	0.45	4	stationary	-3.98	0.01	4	stationary
$x_t^{(SI,DIESEL)}$	-2.63	0.32	4	stationary	-4.29	0.01	4	stationary
$x_t^{(SI,GASOIL)}$	-2.6	0.33	4	stationary	-3.9	0.02	4	stationary
$x_t^{(SI,RFO.1)}$	-1.68	0.71	4	stationary	-2.61	0.33	4	stationary
$x_t^{(SI,LPG)}$	-2.34	0.44	4	stationary	-4.2	0.01	4	stationary
$x_t^{(SK,ULP)}$	-1.93	0.6	4	stationary	-3.47	0.05	4	stationary
$x_t^{(SK,DIESEL)}$	-1.9	0.61	4	stationary	-3.3	0.08	4	stationary
$x_t^{(SK,GASOIL)}$	-2.71	0.29	4	stationary	-4.47	0.01	4	stationary
$x_t^{(SK,RFO.1)}$	-0.72	0.96	4	stationary	-4.16	0.01	4	stationary
$x_t^{(SK,RFO.2)}$	-0.71	0.97	4	stationary	-4.16	0.01	4	stationary
$x_t^{(SK,LPG)}$	-1.24	0.89	4	stationary	-3.76	0.03	4	stationary
$x_t^{(SK,LP)}$	0.65	0.99	3	stationary	-2.06	0.55	3	stationary
$x_t^{(Urals)}$	-1.92	0.61	8	stationary	-9.29	0.01	8	stationary
$x_t^{(Brent)}$	-1.84	0.65	8	stationary	-9.06	0.01	8	stationary
$x_t^{(WTI)}$	-1.85	0.64	8	stationary	-8.23	0.01	8	stationary
$x_t^{(MSP,ULP)}$	-2.32	0.44	8	stationary	-9.05	0.01	8	stationary

$x_t^{(MSP,DIESEL)}$	-1.96	0.6	8	stationary	-8.3	0.01	8	stationary
$x_t^{(MSP,GASOIL)}$	-1.86	0.64	8	stationary	-8.16	0.01	8	stationary
$x_t^{(MSP,RFO.1)}$	-2.15	0.51	8	stationary	-9.77	0.01	8	stationary
$x_t^{(MSP,RFO.2)}$	-2.55	0.35	8	stationary	-9.78	0.01	8	stationary
$x_t^{(MSP,LPG)}$	-3.1	0.11	8	stationary	-8.9	0.01	8	stationary
$x_t^{(MSP,LP)}$	-2.26	0.47	8	stationary	-9.46	0.01	8	stationary

Table A.23: USP to MSP Transmission - Cointegration

	Urals	Brent	WTI
ULP	Rejected at 5%	Rejected at 5%	Rejected at 5%
DIESEL	Rejected at 5%	Rejected at 5%	Rejected at 5%
GASOIL	Rejected at 5%	Rejected at 5%	Rejected at 5%
RFO.1	Rejected at 5%	Rejected at 5%	Rejected at 5%
RFO.2	Rejected at 5%	Rejected at 5%	Rejected at 5%
LPG	Rejected at 5%	Rejected at 5%	Rejected at 5%
LP	Rejected at 5%	Rejected at 5%	Rejected at 5%

Table A.27: MSP to DSP Transmission - Cointegration

Country	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Invalid Data	Invalid Data	Invalid Data
BE	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%
CY	Rejected at 5%	Rejected at 5%	Rejected at 5%	Invalid Data	Spurious	Invalid Data	Invalid Data
CZ	Spurious	Spurious	Rejected at 5%	Spurious	Spurious	Spurious	Spurious
DE	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Invalid Data	Spurious	Rejected at 5%
DK	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Invalid Data	Invalid Data	Rejected at 5%
EE	Rejected at 5%	Spurious	Spurious	Invalid Data	Invalid Data	Spurious	Invalid Data
ES	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Spurious	Rejected at 5%
FI	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Invalid Data	Invalid Data	Invalid Data
FR	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Spurious	Rejected at 5%
GB	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Invalid Data	Spurious
GR	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Invalid Data	Rejected at 5%
HU	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Invalid Data	Spurious	Invalid Data
IE	Rejected at 5%	Rejected at 5%	Rejected at 5%	Invalid Data	Rejected at 5%	Invalid Data	Rejected at 5%
IT	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Spurious	Rejected at 5%
LT	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Spurious	Invalid Data
LU	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%
LV	Spurious	Spurious	Spurious	Invalid Data	Invalid Data	Spurious	Spurious
MT	Spurious	Spurious	Spurious	Invalid Data	Spurious	Invalid Data	Spurious
NL	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Invalid Data	Rejected at 5%	Rejected at 5%
PL	Spurious	Spurious	Rejected at 5%	Spurious	Spurious	Spurious	Invalid Data
PT	Rejected at 5%	Rejected at 5%	Spurious	Rejected at 5%	Rejected at 5%	Spurious	Rejected at 5%
SE	Rejected at 5%	Rejected at 5%	Rejected at 5%	Rejected at 5%	Invalid Data	Invalid Data	Invalid Data
SI	Rejected at 5%	Rejected at 5%	Rejected at 5%	Spurious	Invalid Data	Spurious	Invalid Data
SK	Rejected at 5%	Rejected at 5%	Spurious	Spurious	Spurious	Spurious	Spurious

Table A.29: USP to MSP Transmission - Endogeneity

	Urals	Brent	WTI
ULP	Rejected at 5%	Cannot Reject	Cannot Reject
DIESEL	Rejected at 5%	Cannot Reject	Cannot Reject
GASOIL	Rejected at 5%	Cannot Reject	Cannot Reject
RFO.1	Cannot Reject	Cannot Reject	Cannot Reject
RFO.2	Rejected at 5%	Cannot Reject	Cannot Reject
LPG	Cannot Reject	Cannot Reject	Cannot Reject
LP	Rejected at 5%	Cannot Reject	Cannot Reject

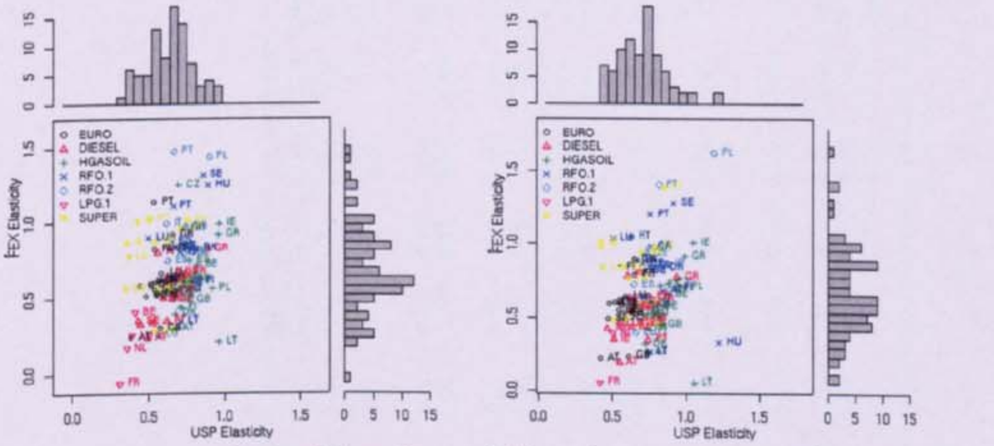
Table A.30: USP to MSP Transmission - Price Elasticity

	Urals	Brent	WTI
ULP	0.9484351	0.9391356	0.9803701
DIESEL	1.0721811	1.0608335	1.1079452
HGASOIL	0.9911975	0.9791649	1.0190878
RFO.1	0.8097441	0.7890079	0.8169433
RFO.2	0.8540944	0.8316210	0.8577817
LPG	0.8483904	0.8292791	0.8627343
LP	0.9022464	0.8925658	0.9309061

Table A.31: MSP to DSP Upstream Price Elasticity Estimation Results

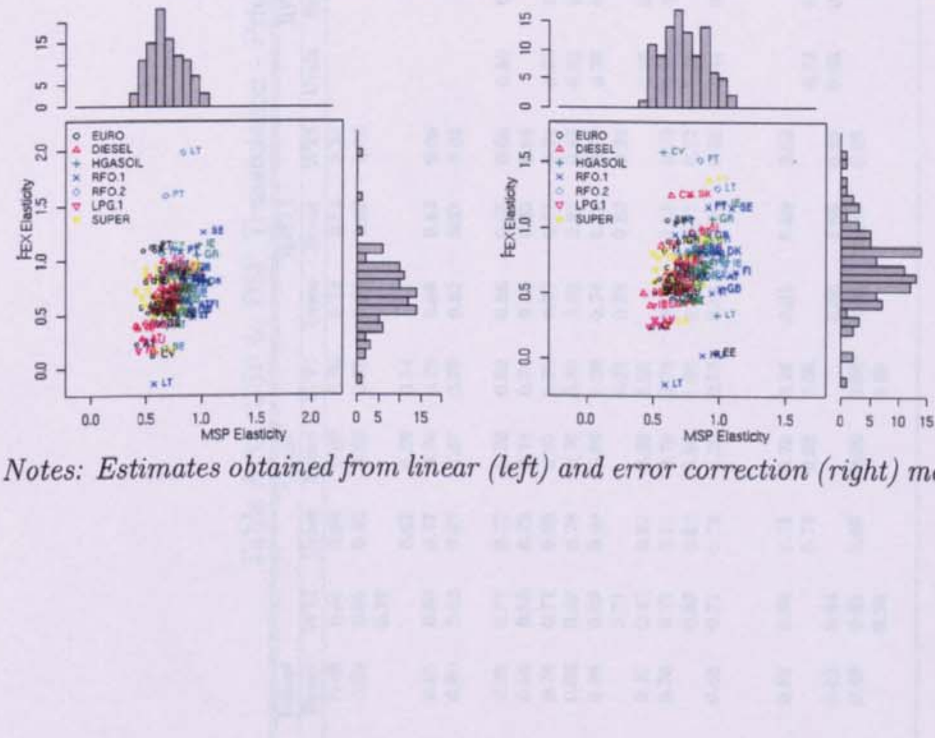
Country	LP	DIESEL	HGASOIL	RFO.1	RFO.2	LPG	LP
AT	0.41	0.47	0.68	0.90			
BE	0.57	0.56	0.83	0.85	0.67	0.49	0.60
CY	0.56	0.69	0.61				
CZ			0.64				
DE	0.59	0.61	0.78	0.84			0.58
DK	0.54	0.58	0.69	0.99			0.48
EE	0.77						
ES	0.58	0.65	0.78	0.80	0.64		0.69
FI	0.57	0.53	0.72	1.00			
FR	0.67	0.71	0.69	0.89	0.87		0.82
GB	0.61	0.63	0.79	0.90	0.69		
GR	0.70	0.83	0.96	0.89	0.87		0.79
HU	0.50	0.63	0.60	0.75			
IE	0.46	0.42	0.97		0.90		0.40
IT	0.59	0.66	0.71	0.92	0.64		0.49
LT	0.56	0.72	0.91	0.57	0.83		
LU	0.62	0.64	0.72	0.66	0.57	0.48	0.46
LV							
MT							
NL	0.60	0.58	0.74	0.74		0.43	0.56
PL			0.92				
PT	0.55	0.58		0.80	0.67		0.50
SE	0.51	0.40	0.66	1.02			
SI	0.63	0.82	0.76				
SK	0.47	0.65					

Figure A.1: Long-Run FEX Elasticity, USP to DSP transmission



Notes: Estimates obtained from linear (left) and error correction (right) models.

Figure A.2: Long-Run FEX Elasticity, MSP to DSP transmission



Notes: Estimates obtained from linear (left) and error correction (right) models.

Table A.32: USP to DSP Transmission - Price Elasticity

Country	ULP			Diesel			Gasoil			RFO.1			RFO.2			LPG.1			LP		
	Urals	Brent	WTI	Urals	Brent	WTI	Urals	Brent	WTI	Urals	Brent	WTI	Urals	Brent	WTI	Urals	Brent	WTI	Urals	Brent	WTI
AT	0.39	0.38	0.40	0.49	0.49	0.51	0.68	0.67	0.70	0.74	0.73	0.76									
BE	0.54	0.53	0.56	0.60	0.59	0.61	0.82	0.82	0.85	0.69	0.67	0.70				0.39	0.41	0.45	0.50	0.54	0.58
CY			0.57	0.58		0.77									0.71						
CZ							0.62	0.69	0.74												
DE	0.56	0.56	0.58	0.66	0.65	0.68	0.77	0.76	0.79	0.68	0.67	0.69							0.51	0.54	0.55
DK	0.52	0.51	0.53	0.61	0.60	0.63	0.67	0.67	0.70	0.82	0.81	0.84								0.35	0.31
EE																					
ES	0.55	0.55	0.57	0.69	0.69	0.72	0.77	0.76	0.80	0.66	0.65	0.68	0.59	0.62	0.66	0.28		0.32	0.64	0.64 ·	0.67
FI	0.54	0.54	0.56	0.56	0.56	0.58	0.72	0.71	0.74	0.84	0.83	0.86									
FR	0.64	0.64	0.67	0.75	0.74	0.77	0.68	0.67	0.70	0.73	0.71	0.74	0.75	0.73	0.76	0.29	0.31	0.34	0.76	0.75	0.79
GB	0.57	0.57	0.60	0.65	0.66	0.69	0.76	0.76	0.80	0.83	0.87	0.93	0.62	0.65	0.68						
GR	0.66	0.65	0.69	0.89	0.88	0.92	0.96	0.96	1.00	0.74	0.73	0.76	0.75	0.74	0.77				0.71	0.71	0.75
HU						0.71			0.71	0.78	0.89	0.99									
IE	0.45	0.45	0.47	0.45	0.45	0.47	0.97	0.96	1.01				0.80	0.79	0.83				0.32	0.35	0.39
IT	0.56	0.56	0.59	0.70	0.70	0.73	0.70	0.70	0.73	0.77	0.75	0.79	0.58	0.61	0.66				0.39	0.43	0.47
LT						0.83	0.82	0.96	1.08	0.60	0.71	0.77	0.73								
LU	0.59	0.58	0.61	0.68	0.68	0.71	0.71	0.70	0.73	0.51	0.50	0.52	0.54	0.56	0.60	0.38	0.39	0.44	0.33	0.36	0.40
LV																					0.66
MT																					
NL	0.56	0.56	0.58	0.62	0.62	0.64	0.74	0.73	0.76	0.61	0.60	0.62				0.33	0.35	0.39	0.53	0.55	0.59
PL							0.74	0.92	1.05				0.73	0.90	1.05						
PT	0.54	0.53	0.56	0.61	0.62	0.64				0.66	0.65	0.69	0.63	0.67	0.72				0.49	0.51	0.56
SE	0.48	0.48	0.50	0.44	0.43	0.45	0.66	0.66	0.68	0.86	0.85	0.89									
SI				0.71		0.94			0.90												
SK																					

Table A.33: USP to MSP Transmission - Foreign Exchange Elasticity

Country	ULP			Diesel			Gasoil			RFO.1			RFO.2			LPG.1			LP		
	Urals	Brent	WTI	Urals	Brent	WTI	Urals	Brent	WTI	Urals	Brent	WTI	Urals	Brent	WTI	Urals	Brent	WTI	Urals	Brent	WTI
AT	0.23	0.24	0.26	0.22	0.24	0.26	0.28	0.30	0.33	0.58	0.60	0.64									
BE	0.55	0.56	0.58	0.49	0.50	0.52	0.70	0.71	0.75	0.82	0.83	0.86				0.33	0.41	0.49	0.93	0.87	0.86
CY			0.86	0.11		0.37									1.18						
CZ							1.03	1.25	1.13												
DE	0.52	0.53	0.55	0.48	0.49	0.52	0.60	0.61	0.65	0.82	0.84	0.87							0.28	0.28	0.28
DK	0.58	0.59	0.62	0.59	0.61	0.64	0.38	0.40	0.43	0.80	0.83	0.86								0.56	0.54
EE																					
ES	0.52	0.53	0.55	0.66	0.67	0.70	0.73	0.75	0.78	0.86	0.87	0.91	0.80	0.74	0.75	−0.19		−0.07	0.59	0.60	0.63
FI	0.81	0.82	0.85	0.78	0.80	0.82	0.42	0.44	0.47	0.59	0.61	0.65									
FR	0.80	0.82	0.85	0.64	0.66	0.70	0.48	0.50	0.54	0.78	0.80	0.84	0.77	0.79	0.83	−0.12	−0.06	−0.01	0.99	1.01	1.05
GB	0.17	0.30	0.39	0.39	0.55	0.64	0.31	0.48	0.60	2.02	2.48	2.59	0.90	0.83	0.91						
GR	0.93	0.92	0.94	0.83	0.82	0.84	0.92	0.92	0.94	0.95	0.96	0.99	0.97	0.97	0.99				0.97	0.96	0.98
HU						0.40			0.40	1.04	1.25	1.28									
IE	0.56	0.58	0.60	0.31	0.33	0.35	0.95	0.99	1.04				0.77	0.80	0.84				0.91	0.86	0.83
IT	0.59	0.61	0.65	0.53	0.56	0.61	0.57	0.61	0.65	0.52	0.56	0.60	1.06	0.99	1.01				1.07	1.00	0.98
LT						0.40	−0.01	0.21	0.23	0.19	0.35	0.38	3.17								
LU	0.65	0.66	0.69	0.63	0.65	0.67	0.54	0.56	0.59	0.89	0.90	0.92	0.32	0.26	0.22	0.18	0.25	0.33	0.79	0.77	0.76
LV																					0.68
MT																					
NL	0.62	0.63	0.65	0.63	0.64	0.66	0.62	0.64	0.67	0.61	0.62	0.65				0.10	0.17	0.24	0.47	0.56	0.63
PL							0.35	0.56	0.66				1.24	1.44	1.56						
PT	1.12	1.14	1.16	0.34	0.35	0.38				1.09	1.11	1.14	1.54	1.47	1.47				0.92	1.02	1.12
SE	0.50	0.52	0.54	0.34	0.35	0.37	0.57	0.59	0.62	1.29	1.31	1.35									
SI				0.12		0.32			0.54												
SK																					

Table A.34: MSP to DSP Foreign Exchange Elasticity Estimation Results

Country	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	0.23	0.28	0.39	0.58			
BE	0.54	0.55	0.82	0.82	0.19	0.40	0.81
CY	0.13	0.92	0.87				
CZ			1.11				
DE	0.52	0.55	0.72	0.82			0.18
DK	0.58	0.66	0.49	0.80			0.60
EE	0.51						
ES	0.52	0.73	0.86	0.85	0.84		0.54
FI	0.81	0.85	0.54	0.58			
FR	0.81	0.73	0.60	0.78	0.71		0.95
GB	0.42	0.63	0.63	0.54	0.94		
GR	0.90	0.87	1.04	0.92	0.92		0.90
HU	0.81	0.74	0.52	0.52			
IE	0.58	0.38	1.14		0.68		0.72
IT	0.61	0.63	0.73	0.48	1.06		0.85
LT	0.68	0.94	0.49	−0.14	1.98		
LU	0.65	0.70	0.65	0.87	0.44	0.26	0.67
LV							
MT							
NL	0.61	0.68	0.73	0.61		0.17	0.49
PL			0.77				
PT	1.12	0.40		1.07	1.59		0.92
SE	0.52	0.40	0.69	1.25			
SI	0.92	0.93	0.75				
SK	1.09	0.99					

Table A.35: USP to DSP Transmission - Upstream Price Elasticity (Conventional LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.49	0.38	0.67		0.73		
BE	0.59	0.53	0.82	0.41	0.67		0.54
CZ			0.69				
DE	0.65	0.56	0.76		0.67		0.54
DK	0.60	0.51	0.67		0.81		0.35
ES	0.69	0.55	0.76		0.65	0.62	0.64
FI	0.56	0.54	0.71		0.83		
FR	0.74	0.64	0.67	0.31	0.71	0.73	0.75
GB	0.66	0.57	0.76		0.87	0.65	
GR	0.88	0.65	0.96		0.73	0.74	0.71
HU					0.89		
IE	0.45	0.45	0.96			0.79	0.35
IT	0.70	0.56	0.70		0.75	0.61	0.43
LT			0.96		0.71		
LU	0.68	0.58	0.70	0.39	0.50	0.56	0.36
NL	0.62	0.56	0.73	0.35	0.60		0.55
PL			0.92			0.90	
PT	0.62	0.53			0.65	0.67	0.51
SE	0.43	0.48	0.66		0.85		

Table A.36: USP to DSP Transmission - Foreign Exchange Elasticity (Conventional LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.24	0.24	0.30		0.60		
BE	0.50	0.56	0.71	0.41	0.83		0.87
CZ			1.25				
DE	0.49	0.53	0.61		0.84		0.28
DK	0.61	0.59	0.40		0.83		0.56
ES	0.67	0.53	0.75		0.87	0.74	0.60
FI	0.80	0.82	0.44		0.61		
FR	0.66	0.82	0.50	−0.06	0.80	0.79	1.01
GB	0.55	0.30	0.48		2.48	0.83	
GR	0.82	0.92	0.92		0.96	0.97	0.96
HU					1.25		
IE	0.33	0.58	0.99			0.80	0.86
IT	0.56	0.61	0.61		0.56	0.99	1.00
LT			0.21		0.35		
LU	0.65	0.66	0.56	0.25	0.90	0.26	0.77
NL	0.64	0.63	0.64	0.17	0.62		0.56
PL			0.56			1.44	
PT	0.35	1.14			1.11	1.47	1.02
SE	0.35	0.52	0.59		1.31		

Table A.37: USP to DSP Transmission - Upstream Price Elasticity (ECM LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.55	0.42	0.74		0.85		
BE	0.63	0.54	0.88	0.56	0.73		0.58
CZ			0.88				
DE	0.69	0.56	0.80		0.70		0.70
DK	0.64	0.52	0.73		0.84		0.61
ES	0.75	0.57	0.82		0.67	0.65	0.67
FI	0.61	0.55	0.76		0.94		
FR	0.79	0.65	0.74	0.42	0.76	0.77	0.79
GB	0.72	0.61	0.83		1.21	0.73	
GR	0.94	0.65	0.99		0.76	0.75	0.70
HU					1.22		
IE	0.51	0.48	1.05			0.88	0.43
IT	0.77	0.57	0.79		0.79	0.63	0.43
LT			1.06		0.75		
LU	0.72	0.59	0.74	0.55	0.51	0.66	0.44
NL	0.65	0.55	0.77	0.50	0.64		0.51
PL			0.99			1.19	
PT	0.74	0.63			0.76	0.82	0.85
SE	0.47	0.47	0.71		0.92		

Table A.38: USP to DSP Transmission - Foreign Exchange Elasticity (ECM LR estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.20	0.22	0.26		0.68		
BE	0.43	0.55	0.66	0.61	0.82		0.84
CZ			0.73				
DE	0.47	0.50	0.57		0.86		0.45
DK	0.56	0.60	0.32		0.83		0.76
ES	0.64	0.53	0.72		0.88	0.72	0.59
FI	0.78	0.84	0.41		0.70		
FR	0.62	0.79	0.43	0.06	0.84	0.84	0.97
GB	0.50	0.24	0.45		3.19	0.93	
GR	0.77	0.90	0.91		0.98	0.97	0.94
HU					0.33		
IE	0.35	0.60	1.01			0.86	1.01
IT	0.46	0.58	0.54		0.58	1.05	0.97
LT			0.05		0.26		
LU	0.59	0.64	0.53	0.46	1.04	0.40	0.84
NL	0.58	0.59	0.60	0.39	0.63		0.48
PL			0.71			1.63	
PT	0.35	1.05			1.20	1.40	1.38
SE	0.42	0.49	0.52		1.28		

Table A.39: MSP to DSP Transmission - Upstream Price Elasticity (Conventional LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.47	0.41	0.68		0.90		
BE	0.56	0.57	0.83	0.49	0.85	0.67	0.60
CY	0.69	0.56	0.61				
CZ			0.64				
DE	0.61	0.59	0.78		0.84		0.58
DK	0.58	0.54	0.69		0.99		0.48
EE		0.77					
ES	0.65	0.58	0.78		0.80	0.64	0.69
FI	0.53	0.57	0.72		1.00		
FR	0.71	0.67	0.69		0.89	0.87	0.82
GB	0.63	0.61	0.79		0.90	0.69	
GR	0.83	0.70	0.96		0.89	0.87	0.79
HU	0.63	0.50	0.60		0.75		
IE	0.42	0.46	0.97			0.90	0.40
IT	0.66	0.59	0.71		0.92	0.64	0.49
LT	0.72	0.56	0.91		0.57	0.83	
LU	0.64	0.62	0.72	0.48	0.66	0.57	0.46
NL	0.58	0.60	0.74	0.43	0.74		0.56
PL			0.92				
PT	0.58	0.55			0.80	0.67	0.50
SE	0.40	0.51	0.66		1.02		
SI	0.82	0.63	0.76				
SK	0.65	0.47					

Table A.40: MSP to DSP Transmission - Foreign Exchange Elasticity (Conventional LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.28	0.23	0.39		0.58		
BE	0.55	0.54	0.82	0.40	0.82	0.19	0.81
CY	0.92	0.13	0.87				
CZ			1.11				
DE	0.55	0.52	0.72		0.82		0.18
DK	0.66	0.58	0.49		0.80		0.60
EE		0.51					
ES	0.73	0.52	0.86		0.85	0.84	0.54
FI	0.85	0.81	0.54		0.58		
FR	0.73	0.81	0.60		0.78	0.71	0.95
GB	0.63	0.42	0.63		0.54	0.94	
GR	0.87	0.90	1.04		0.92	0.92	0.90
HU	0.74	0.81	0.52		0.52		
IE	0.38	0.58	1.14			0.68	0.72
IT	0.63	0.61	0.73		0.48	1.06	0.85
LT	0.94	0.68	0.49		−0.14	1.98	
LU	0.70	0.65	0.65	0.26	0.87	0.44	0.67
NL	0.68	0.61	0.73	0.17	0.61		0.49
PL			0.77				
PT	0.40	1.12			1.07	1.59	0.92
SE	0.40	0.52	0.69		1.25		
SI	0.93	0.92	0.75				
SK	0.99	1.09					

Table A.41: MSP to DSP Transmission - Upstream Price Elasticity (ECM LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.51	0.49	0.74		1.00		
BE	0.59	0.57	0.86	0.51	0.87	0.91	0.66
CY	0.64	0.64	0.58				
CZ			0.76				
DE	0.63	0.60	0.80		0.86		0.62
DK	0.60	0.55	0.73		1.00		0.51
EE		0.98					
ES	0.68	0.61	0.82		0.81	0.68	0.76
FI	0.56	0.58	0.75		1.12		
FR	0.73	0.70	0.73		0.90	0.91	0.89
GB	0.68	0.69	0.83		1.01	0.81	
GR	0.86	0.69	0.95		0.91	0.92	0.77
HU	0.70	0.60	0.67		0.87		
IE	0.48	0.51	1.03			1.05	0.50
IT	0.70	0.61	0.80		0.95	0.68	0.54
LT	0.79	0.62	0.99		0.59	0.99	
LU	0.66	0.63	0.73	0.51	0.67	0.72	0.52
NL	0.59	0.60	0.77	0.47	0.78		0.58
PL			0.95				
PT	0.69	0.67			0.91	0.85	0.92
SE	0.43	0.51	0.69		1.10		
SI	0.87	0.77	0.82				
SK	0.78	0.61					

Table A.42: MSP to DSP Transmission - Foreign Exchange Elasticity (ECM LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.27	0.24	0.43		0.62		
BE	0.51	0.54	0.81	0.40	0.81	0.64	0.77
CY	1.24	0.46	1.57				
CZ			0.79				
DE	0.53	0.50	0.70		0.83		0.27
DK	0.59	0.61	0.42		0.81		0.59
EE		0.04					
ES	0.74	0.52	0.86		0.82	0.80	0.56
FI	0.86	0.83	0.53		0.66		
FR	0.71	0.78	0.57		0.79	0.72	0.90
GB	0.61	0.50	0.62		0.52	0.82	
GR	0.83	0.89	1.06		0.93	0.90	0.90
HU	0.74	0.70	0.45		0.02		
IE	0.40	0.59	1.18			0.72	0.80
IT	0.53	0.59	0.67		0.49	1.05	0.76
LT	0.96	0.89	0.32		−0.21	1.29	
LU	0.67	0.64	0.64	0.29	0.94	0.66	0.68
NL	0.64	0.54	0.71	0.23	0.61		0.53
PL			0.75				
PT	0.41	1.04			1.15	1.51	1.36
SE	0.49	0.51	0.65		1.15		
SI	0.99	0.65	0.93				
SK	1.24	1.06					

Table A.43: USP to MSP Transmission

	OLS	ECM
ULP	0.94	0.93
DIESEL	1.06	1.08
GASOIL	0.98	1.00
RFO.1	0.79	0.82
RFO.2	0.83	0.80
LPG	0.83	0.83
LP	0.89	0.89

Table A.44: USP to DSP Transmission - Tests of Unit USP Elasticity (Conventional LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0	0	0.00		0.00		
BE	0	0	0.00	0	0.00		0
CZ			0.00				
DE	0	0	0.00		0.00		0
DK	0	0	0.00		0.00		0
ES	0	0	0.00		0.00	0.00	0
FI	0	0	0.00		0.00		
FR	0	0	0.00	0	0.00	0.00	0
GB	0	0	0.00		0.00	0.00	
GR	0	0	0.00		0.00	0.00	0
HU					0.11		
IE	0	0	0.00			0.00	0
IT	0	0	0.00		0.00	0.00	0
LT			0.33		0.00		
LU	0	0	0.00	0	0.00	0.00	0
NL	0	0	0.00	0	0.00		0
PL			0.02			0.19	
PT	0	0			0.00	0.00	0
SE	0	0	0.00		0.00		

Table A.45: USP to DSP Transmission - Tests of Unit FEX Elasticity (Conventional LR Estimates)

	DIESEL	ULP	HGASOIL	LPG	RFO.1	RFO.2	LP
AT	0	0	0.00		0.00		
BE	0	0	0.00	0	0.00		0.00
CZ			0.22				
DE	0	0	0.00		0.00		0.00
DK	0	0	0.00		0.00		0.00
ES	0	0	0.00		0.00	0.00	0.00
FI	0	0	0.00		0.00		
FR	0	0	0.00	0	0.00	0.00	0.52
GB	0	0	0.00		0.00	0.08	
GR	0	0	0.00		0.13	0.33	0.08
HU					0.35		
IE	0	0	0.83			0.00	0.00
IT	0	0	0.00		0.00	0.88	0.94
LT			0.00		0.12		
LU	0	0	0.00	0	0.00	0.00	0.00
NL	0	0	0.00	0	0.00		0.00
PL			0.00			0.03	
PT	0	0			0.00	0.00	0.82
SE	0	0	0.00		0.00		

Table A.46: USP to DSP Transmission - Tests of Unit USP Elasticity (ECM LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.00	0	0.00		0.03		
BE	0.00	0	0.01	0.01	0.00		0.00
CZ			0.11				
DE	0.00	0	0.00		0.00		0.00
DK	0.00	0	0.00		0.00		0.08
ES	0.00	0	0.00		0.00	0.00	0.00
FI	0.00	0	0.00		0.37		
FR	0.00	0	0.00	0.00	0.00	0.00	0.00
GB	0.00	0	0.00		0.12	0.08	
GR	0.21	0	0.84		0.00	0.00	0.00
HU					0.10		
IE	0.00	0	0.35			0.15	0.00
IT	0.00	0	0.01		0.00	0.00	0.00
LT			0.27		0.05		
LU	0.00	0	0.00	0.01	0.00	0.00	0.00
NL	0.00	0	0.00	0.01	0.00		0.00
PL			0.86			0.04	
PT	0.00	0			0.00	0.06	0.46
SE	0.00	0	0.00		0.02		

Table A.47: USP to DSP Transmission - Tests of Unit FEX Elasticity (ECM LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.00	0.00	0.00		0.04		
BE	0.00	0.00	0.00	0.08	0.18		0.11
CZ			0.18				
DE	0.00	0.00	0.00		0.33		0.00
DK	0.00	0.00	0.00		0.08		0.21
ES	0.00	0.00	0.00		0.30	0.00	0.00
FI	0.02	0.04	0.00		0.12		
FR	0.00	0.01	0.00	0.00	0.25	0.26	0.74
GB	0.04	0.01	0.00		0.01	0.90	
GR	0.04	0.35	0.45		0.86	0.80	0.64
HU					0.17		
IE	0.00	0.00	0.96			0.54	0.96
IT	0.00	0.00	0.01		0.01	0.72	0.83
LT			0.00		0.18		
LU	0.00	0.00	0.00	0.05	0.82	0.00	0.14
NL	0.00	0.00	0.00	0.02	0.00		0.00
PL			0.10			0.02	
PT	0.00	0.75			0.11	0.02	0.28
SE	0.02	0.00	0.00		0.01		

Table A.48: MSP to DSP Transmission - Tests of Unit MSP Elasticity (Conventional LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0	0	0.00		0.00		
BE	0	0	0.00	0	0.00	0	0
CY	0	0	0.00				
CZ			0.00				
DE	0	0	0.00		0.00		0
DK	0	0	0.00		0.19		0
EE		0					
ES	0	0	0.00		0.00	0	0
FI	0	0	0.00		0.81		
FR	0	0	0.00		0.00	0	0
GB	0	0	0.00		0.00	0	
GR	0	0	0.00		0.00	0	0
HU	0	0	0.00		0.00		
IE	0	0	0.02			0	0
IT	0	0	0.00		0.00	0	0
LT	0	0	0.00		0.00	0	
LU	0	0	0.00	0	0.00	0	0
NL	0	0	0.00	0	0.00		0
PL			0.00				
PT	0	0			0.00	0	0
SE	0	0	0.00		0.34		
SI	0	0	0.00				
SK	0	0					

Table A.49: MSP to DSP Transmission - Tests of Unit FEX Elasticity (Conventional LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.00	0.00	0.00		0.00		
BE	0.00	0.00	0.00	0	0.00	0.00	0.00
CY	0.67	0.00	0.50				
CZ			0.59				
DE	0.00	0.00	0.00		0.00		0.00
DK	0.00	0.00	0.00		0.00		0.00
EE		0.04					
ES	0.00	0.00	0.00		0.00	0.00	0.00
FI	0.00	0.00	0.00		0.00		
FR	0.00	0.00	0.00		0.00	0.00	0.02
GB	0.00	0.00	0.00		0.00	0.48	
GR	0.00	0.00	0.09		0.00	0.00	0.00
HU	0.02	0.08	0.00		0.02		
IE	0.00	0.00	0.00			0.00	0.00
IT	0.00	0.00	0.00		0.00	0.04	0.00
LT	0.72	0.05	0.00		0.01	0.00	
LU	0.00	0.00	0.00	0	0.00	0.00	0.00
NL	0.00	0.00	0.00	0	0.00		0.00
PL			0.00				
PT	0.00	0.00			0.04	0.00	0.39
SE	0.00	0.00	0.00		0.00		
SI	0.72	0.74	0.21				
SK	0.96	0.47					

Table A.50: MSP to DSP Transmission - Tests of Unit MSP Elasticity (ECM LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.00	0.01	0.01		0.97		
BE	0.00	0.00	0.00	0	0.00	0.37	0.00
CY	0.00	0.00	0.00				
CZ			0.00				
DE	0.00	0.00	0.00		0.00		0.05
DK	0.01	0.00	0.00		0.92		0.00
EE		0.78					
ES	0.00	0.00	0.00		0.00	0.00	0.00
FI	0.00	0.00	0.00		0.19		
FR	0.00	0.00	0.00		0.00	0.00	0.04
GB	0.00	0.00	0.00		0.90	0.01	
GR	0.03	0.01	0.34		0.11	0.17	0.03
HU	0.00	0.00	0.00		0.01		
IE	0.00	0.00	0.66			0.49	0.00
IT	0.00	0.00	0.04		0.31	0.00	0.00
LT	0.00	0.00	0.70		0.00	0.89	
LU	0.00	0.00	0.00	0	0.00	0.00	0.00
NL	0.00	0.00	0.00	0	0.00		0.00
PL			0.01				
PT	0.00	0.00			0.19	0.05	0.63
SE	0.00	0.00	0.00		0.18		
SI	0.04	0.00	0.00				
SK	0.00	0.00					

Table A.51: MSP to DSP Transmission - Tests of Unit FEX Elasticity (ECM LR Estimates)

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.00	0.01	0.01		0.00		
BE	0.00	0.00	0.00	0	0.00	0.16	0.06
CY	0.18	0.01	0.01				
CZ			0.00				
DE	0.00	0.00	0.00		0.00		0.06
DK	0.01	0.00	0.00		0.08		0.00
EE		0.01					
ES	0.01	0.00	0.08		0.05	0.00	0.00
FI	0.07	0.01	0.00		0.17		
FR	0.00	0.00	0.00		0.00	0.00	0.34
GB	0.20	0.08	0.00		0.00	0.43	
GR	0.15	0.33	0.64		0.53	0.33	0.59
HU	0.00	0.00	0.00		0.00		
IE	0.00	0.00	0.44			0.13	0.14
IT	0.00	0.00	0.06		0.01	0.63	0.06
LT	0.86	0.39	0.00		0.03	0.52	
LU	0.00	0.00	0.00	0	0.53	0.00	0.01
NL	0.00	0.00	0.00	0	0.00		0.00
PL			0.00				
PT	0.00	0.81			0.27	0.00	0.18
SE	0.03	0.00	0.00		0.42		
SI	0.96	0.15	0.53				
SK	0.03	0.62					

Table A.52: USP to MSP Transmission - Tests of Unit USP Elasticity

	OLS	ECM
ULP	0.0000	0.0264
DIESEL	0.0000	0.0006
GASOIL	0.0029	0.9575
RFO.1	0.0000	0.0040
RFO.2	0.0000	0.0004
LPG	0.0000	0.0152
LP	0.0000	0.0022

Table A.53: USP to MSP Transmission - Upstream Price Adjustment

	Periods
ULP	0.73/4.58
DIESEL	0.89/2.8
GASOIL	0.81/6.67
RFO.1	1.04/4.84
RFO.2	0.75/2.67
LPG	2.2/5.81
LP	0.79/4.65

Notes: Entries denote numbers of weeks necessary for 50% and 90% of disequilibrium to be eliminated.

Table A.54: USP to DSP Transmission - Upstream Price Adjustment

	DIESEL	ULP	HGASOIL	LPG	RFO.1	RFO.2	LP
AT	2.89/21.5	2.05/6.49	1.93/17	NA	6.28/31	NA	NA
BE	1.87/15.75	1.59/4.65	1.7/15	2.79/7.64	1.82/4.85	NA	1.9/12.31
CZ	NA	NA	1.71/10.83	NA	NA	NA	NA
DE	1.88/11.31	1.64/3.54	1.54/12.92	NA	2.43/5.18	NA	2.12/3.4
DK	1.44/7.56	1.25/2.09	1.58/14.1	NA	1.75/9.2	NA	2.41/7.36
ES	3.55/27.5	2.47/10.64	2.7/18.22	NA	3.32/7.32	3.22/6.18	3.33/28.67
FI	4.7/22	1.5/6.84	2.65/14.36	NA	6.79/29.29	NA	NA
FR	2.7/13.62	2.29/5.73	2.22/18.29	5.36/11.07	1.47/9.38	1.54/4.9	2.78/11.56
GB	4.72/22.33	3.4/10.46	3.01/15.83	NA	2.81/15	3.26/22.5	NA
GR	2.82/24	2.08/16	2.19/18.5	NA	2.46/18.38	2.62/17.25	2.34/21
HU	NA	NA	NA	NA	1.44/2.16	NA	NA
IE	9.84/26.3	7.07/15.6	7.81/33.83	NA	NA	12.91/47.4	12.83/35.88
IT	4.53/36.83	2.62/10.3	3.73/29.33	NA	1.86/13.38	1.45/4.24	2.48/6.78
LT	NA	NA	1.89/7.05	NA	57.9/59.22	NA	NA
LU	2.56/15.36	1.93/11.4	2.09/12.58	3/9	2.26/12.14	3.04/7.95	3.97/15.23
NL	1.62/17.44	1.1/4.75	1.72/18.3	3.32/9.5	4.24/15.09	NA	0.92/1.81
PL	NA	NA	0.87/4.91	NA	NA	3.11/9.22	NA
PT	13.43/41.17	10.53/30.25	NA	NA	9.82/34.17	11.36/35.43	7.54/19.29
SE	1.6/3.29	0.92/1.95	3.79/18.36	NA	6.04/15.76	NA	NA

Notes: Entries denote numbers of weeks necessary for 50% and 90% of disequilibrium to be eliminated.

Table A.55: USP to DSP Transmission - FEX Adjustment

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	0.97/1.62	0.74/1.23	0.49/0.88	NA	5.7/30.33	NA	NA
BE	0.59/1.14	0.97/3.19	1.43/2.36	8.99/16.64	1.23/17	NA	5.19/17.77
CZ	NA	NA	9/18.21	NA	NA	NA	NA
DE	1.12/1.56	0.45/0.82	1.34/1.86	NA	7.21/26.33	NA	0.42/9.97
DK	0.52/0.93	1.2/1.7	0.33/0.6	NA	2.03/13.21	NA	0.91/5.52
ES	3.63/25.33	1.31/2.8	1.94/3.39	NA	7.23/19.29	5.66/11.58	1.54/9.33
FI	1.65/18.9	0.86/10.87	0.42/0.75	NA	6.06/28.29	NA	NA
FR	1.58/2.7	1.97/4	0.98/1.74	5.36/11.07	1.5/21.5	1.54/22.25	2.33/7.59
GB	2.17/5.61	1.68/2.23	0.78/3.39	NA	6.04/20.73	14.04/44.33	NA
GR	1.4/16.86	2.48/22.83	1.8/2.58	NA	7.85/26.33	9.75/29	2.55/32.5
HU	NA	NA	NA	NA	67.8/67.96	NA	NA
IE	15.23/31.7	8.51/17.06	6.97/33	NA	NA	15.52/49.6	11.51/34.57
IT	1.83/3.19	2.07/3.57	1.6/8.56	NA	1.34/20.25	6.72/16.79	3.51/8.73
LT	NA	NA	2.61/2.64	NA	57.9/59.22	NA	NA
LU	0.94/3.12	0.88/14.55	1.3/1.94	6.64/15.04	6.91/29.71	6.67/11.58	3.11/10.36
NL	1.25/1.83	1.05/1.8	1.26/4.81	6.14/18.93	6.95/21.45	NA	0.95/1.48
PL	NA	NA	0.54/7.08	NA	NA	1.54/7.69	NA
PT	17.76/45.17	9.61/29.38	NA	NA	12.91/37.17	10.42/34.57	10.17/21.88
SE	0.63/3.3	1.03/1.58	1.33/2.25	NA	5.77/15.44	NA	NA

Notes: Entries denote numbers of weeks necessary for 50% and 90% of disequilibrium to be eliminated.

Table A.56: MSP to DSP Transmission - FEX Adjustment

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	1.09/1.81	0.76/1.3	0.76/1.35	NA	1.1/2.16	NA	NA
BE	1.22/1.79	1.08/6.17	1.4/7.02	0.86/3.07	1.41/7.36	11.24/32.23	2.12/23.88
CY	1.38/2.28	14.47/36.08	2.75/14.62	NA	NA	NA	NA
CZ	NA	NA	1.01/5.17	NA	NA	NA	NA
DE	1.25/1.72	0.46/0.83	1.48/2.76	NA	1.84/12.07	NA	0.26/5.19
DK	0.54/0.98	1.4/12.5	0.44/0.79	NA	1.45/7.6	NA	32.17/76.87
EE	NA	13.89/15.22	NA	NA	NA	NA	NA
ES	4.96/26.43	1.33/2.74	2.04/3.87	NA	2.44/15.22	3.04/11	1.64/19.25
FI	1.81/19.6	0.91/10.77	0.6/9.24	NA	0.86/18.86	NA	NA
FR	1.61/3.16	1.93/12.89	1.12/2.24	NA	1.14/1.72	1.5/8.89	2.51/25
GB	2.6/3.91	3.32/11.71	0.85/3.04	NA	4.04/4.51	7.75/26.56	NA
GR	2.01/27.4	2.3/40	1.93/12.57	NA	1.23/16.5	2.04/15	2.62/49.25
HU	1.86/3.01	1.46/5.84	1.26/2.43	NA	8.75/9.43	NA	NA
IE	12.75/26.5	9.21/20	6.87/41.4	NA	NA	13.24/43.5	10.67/31.38
IT	1.9/3.5	2.23/3.96	1.79/35.75	NA	0.86/1.39	2.85/11.72	2.22/12.83
LT	2.03/4.48	4.62/5.96	0.99/1.17	NA	54.99/55.93	3.86/7.3	NA
LU	1.67/4.34	1.6/10.76	1.49/4.02	2.99/3.58	2.52/14.45	1.58/7.72	2.76/10.46
NL	1.2/1.92	1.01/1.85	1.66/21	1.41/8.72	1.29/10.27	NA	1.37/2.66
PL	NA	NA	65.15/66.08	NA	NA	NA	NA
PT	17.11/45.33	9.53/29.25	NA	NA	10.04/39	8.68/29	10.12/18.91
SE	0.6/3.38	0.97/1.72	1.43/2.74	NA	1.51/17.67	NA	NA
SI	0.75/2.76	1.57/3.26	3.47/5.75	NA	NA	NA	NA
SK	2.86/8.97	3.02/7.66	NA	NA	NA	NA	NA

Notes: Entries denote numbers of weeks necessary for 50% and 90% of disequilibrium to be eliminated.

Table A.57: MSP to DSP Transmission - Upstream Price Adjustment

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	2.35/16.83	1.92/4.37	1.63/3.3	NA	2.98/19.7	NA	NA
BE	1.57/6.88	1.47/2.4	1.37/6.65	1.49/2.97	1.27/7.02	1.63/22.94	1.73/14.75
CY	1.38/2.66	1.31/32.48	1.23/13.06	NA	NA	NA	NA
CZ	NA	NA	1.77/3.09	NA	NA	NA	NA
DE	0.94/5.74	1.65/2.96	1.24/1.99	NA	1.92/4.89	NA	1.96/11.86
DK	1.19/1.84	1.08/1.81	1.38/4.09	NA	1.39/9.2	NA	42.6/76.3
EE	NA	2.53/4.22	NA	NA	NA	NA	NA
ES	2.38/14.29	2.07/8.09	2.36/9.67	NA	2.87/10.5	2.79/6.4	2.94/34.2
FI	1.32/16.9	1.18/4.75	1.23/2.27	NA	6.48/35.33	NA	NA
FR	1.83/6	1.86/4.56	1.66/6.75	NA	1.05/1.83	1.52/10.58	2.45/22.33
GB	3.83/24.33	3.06/12	2.45/7.91	NA	2.18/6.51	3.28/19.89	NA
GR	2.15/28	1.78/3.65	1.84/8.92	NA	2.07/23.5	2.6/24.33	1.88/21.33
HU	1.24/2.53	1.08/2.98	1.26/2.99	NA	3.36/6.11	NA	NA
IE	9.38/23.17	7.8/18.6	4.5/38.4	NA	NA	11.85/42.33	9.79/30.5
IT	3.11/35.4	2.53/13.88	1.96/32.67	NA	1.55/19.57	1.67/5.34	2.43/19.33
LT	2.51/5.91	1.7/3.11	1.64/2.91	NA	54.99/55.93	1.76/3.46	NA
LU	1.89/9.6	1.7/4.4	1.77/3.89	1.74/3.94	2.95/11.23	2.49/5.72	1.85/12.54
NL	1.15/2.12	1/1.9	1.31/16.5	2.09/3.58	2.31/10.42	NA	1.09/1.78
PL	NA	NA	23.14/64.85	NA	NA	NA	NA
PT	11.86/40.33	9.53/29.25	NA	NA	9.3/38.33	9.65/30	8.44/17.62
SE	1.39/1.97	0.98/1.64	2.79/12.07	NA	6.24/24.44	NA	NA
SI	2.92/4.42	2.21/3.29	3.39/4.7	NA	NA	NA	NA
SK	1.65/7.19	1.5/5.11	NA	NA	NA	NA	NA

Notes: Entries denote numbers of weeks necessary for 50% and 90% of disequilibrium to be eliminated.

Table A.58: USP to DSP Transmission - Non-Linear Cointegration Tests (KSS t_{NEC})

	DIESEL	LP	GASOIL	LPG	RFO.1	RFO.2	ULP
AT	-4.55***	-5.07***	-3.91**	NA	-4.94***	NA	NA
BE	-5.11***	-5.35***	-3.68**	-3.55*	-3.63**	-1.66	-3.12
CY	-2.14	-5.46***	-7.01***	NA	NA	-1.97	NA
CZ	-4.7***	-2.4	-2.01	-1.54	-1.53	-1.21	-2.46
DE	-4.06**	-3.46*	-6.58***	-0.92	-3.42*	NA	-3.98**
DK	-5.98***	-4.69***	-6***	NA	-4.9***	NA	-2.7
EE	-2.98	-4.41***	-1.86	-0.78	NA	NA	NA
ES	-4.4***	-4.39***	-5.19***	-2.54	-3.23	-3.75**	-2.97
FI	-5.43***	-4.31***	-8.17***	NA	-5.55***	NA	NA
FR	-7.58***	-5.49***	-7.1***	-5.73***	-4.87***	-4.75***	-4.39***
GB	-4.32***	-3.72**	-5.04***	NA	-1.19	-1.81	-2.43
GR	-2.44	-3.51*	-2.97	NA	-4.37***	-4.89***	-2.84
HU	-1.54	-2.45	-1.54	-1.6	-1.94	NA	NA
IE	-8.03***	-6.77***	-4.86***	NA	NA	-3.81**	-2.41
IT	-3.78**	-4.95***	-3.69**	-5.45***	-5.45***	-4.96***	-2.97
LT	-3.62**	-2.94	-3	-1.89	-0.83	-1.88	NA
LU	-5.93***	-4.07**	-5.36***	-3.41*	-3.91**	-5.07***	-3.29
LV	-0.93	-1.99	-1.22	-3.05	NA	NA	-3.13
MT	-2.93	-2.86	-1.39	NA	NA	-2.06	-2.84
NL	-5.44***	-4.77***	-7***	-5.99***	-3.66**	NA	-3.34*
PL	-4.39***	-2.51	-3.87**	-2.49	-1.87	-5.68***	NA
PT	-5.2***	-4.9***	-1.71	-2.68	-6***	-5.21***	-4.13**
SE	-4.6***	-4.63***	-4.96***	NA	-7.99***	NA	NA
SI	-4.14**	-3.6*	-2.77	-1.76	-1.72	NA	NA
SK	-1.99	-2.29	-1.72	-0.76	-0.98	-0.98	-0.95

Table A.59: MSP to DSP Transmission - Non-Linear Cointegration Tests (KSS t_{NEC})

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	-3.84**	-3.61**	-2.93	NA	-3.26	NA	NA
BE	-2.24	-4.22***	-1.5	-2.97	-4.58***	-2.52	-2.29
CY	-1.71	-6.84***	-1.85	NA	NA	-1.14	NA
CZ	-1.65	-2.24	-0.72	-3.83**	-1.24	-1.71	-2.39
DE	-3.58*	-4.24***	-4.43***	-1.73	-4.65***	NA	-0.48
DK	-2.26	-4.73***	-2.94	NA	-1.26	NA	-1.31
EE	-2.02	-4.13**	0.36	-3.15	NA	NA	NA
ES	-3.92**	-5.9***	-3.41*	-2.05	-3.01	-1.89	-3.62**
FI	-2.89	-2.99	-7.12***	NA	-4.53***	NA	NA
FR	-3.16	-4.3***	-5.5***	-2.99	-1.49	-2.51	-3.55*
GB	-3.7**	-2.6	-6.64***	NA	-3.69**	-2.72	-1.83
GR	-1.21	-2.24	-2.19	NA	-0.11	-1.93	-2.25
HU	-4.01**	-4.88***	-3.37*	-3.72**	-4.02**	NA	NA
IE	-7.17***	-6.71***	-3.05	NA	NA	-7.15***	-1.73
IT	-1.67	-4.54***	-1.63	-3.4*	-1.29	-1.89	-3.67**
LT	-1.83	-2.79	-0.62	-3.68**	-0.33	-2.71	NA
LU	-1.77	-3.44*	-2.92	-2.66	-1.59	-6.21***	-1.91
LV	-2.9	-2.2	-1.62	-1.71	NA	NA	-2.19
MT	-1.96	-1.21	-2	NA	NA	-2.06	-1.16
NL	-3.04	-1.17	-5.21***	-6.78***	-2.51	NA	-1.85
PL	-5.22***	-3.78**	-0.99	-2.69	-2.07	-3.61*	NA
PT	-4.36***	-4.67***	-1.58	-3.02	-4.67***	-4.94***	-5.14***
SE	-4.48***	-3.44*	-3.07	NA	-5.41***	NA	NA
SI	-2.03	-4.9***	-3.12	-4**	-2.14	NA	NA
SK	-2.74	-2.71	-0.93	-1.62	-0.85	-0.84	-0.77

Table A.60: USP to MSP Transmission - Non-Linear Cointegration Tests (KSS t_{NEC})

Products	
DIESEL	-7.53***
ULP	-4.57***
GASOIL	-6.23***
LPG	-7.26***
RFO.1	-3.62**
RFO.2	-4.45***
LP	-3.98**

Table A.61: USP to MSP Transmission - Non-Linear Cointegration Tests (KSS t_{NEG})

Products	
DIESEL	-3.98**
ULP	-4.48***
GASOIL	-5.72***
LPG	-4.14**
RFO.1	-3.19
RFO.2	-3.28
LP	-3.27

Table A.62: USP to MSP Transmission - Non-Linear Cointegration Tests (KSS F_{NEC})

Products	
DIESEL	28.92***
ULP	18.88***
GASOIL	22.1***
LPG	29.02***
RFO.1	9.92
RFO.2	13.97*
LP	15.06**

Table A.63: USP to MSP Transmission - Non-Linear Cointegration Tests (KSS $F^{*}d_{NEC}$)

Products	
DIESEL	19.61***
ULP	12.57
GASOIL	14.74*
LPG	19.33***
RFO.1	6.6
RFO.2	9.36
LP	10.07

Table A.64: USP to DSP Transmission - Non-Linear Cointegration Tests (KSS t_{NEG})

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	-3.53	-4.09**	-3.09	NA	-4.67***	NA	NA
BE	-4.48**	-4.23**	-3.24	-4.59***	-3.4	-3.96**	-1.21
CY	-2.82	-2.8	-3.61	NA	NA	-2.88	NA
CZ	-3.19	-3.23	-1.04	-2.16	-1.25	0.34	-3.41
DE	-4.58***	-4.74***	-4.99***	-2.81	-5.67***	NA	-2.22
DK	-2.8	-4.53***	-4.24**	NA	-4.55***	NA	-2.51
EE	-3.65*	-3.91*	-3.26	-1.03	NA	NA	NA
ES	-4.29**	-4.1**	-4.72***	-2.98	-3.57	-4.77***	-3.75*
FI	-3.83*	-3.42	-5.08***	NA	-6.3***	NA	NA
FR	-4.88***	-5.18***	-5.08***	-3.57	-3.82*	-4.27**	-4.34**
GB	-4.12**	-4.09**	-3.95**	NA	-1.53	-1.62	-1.87
GR	-4.06**	-5.05***	-4.17**	NA	-3.6	-3.87*	-4.85***
HU	-2.69	-2.95	-2.69	-2.88	-3.84*	NA	NA
IE	-5.95***	-5.12***	-4.15**	NA	NA	-3.62	-2.4
IT	-4.29**	-4.61***	-3.2	-3.14	-4**	-4.08**	-3.62
LT	-2.68	-3.55	-1.39	-2.99	-0.99	-2.91	NA
LU	-4.51***	-4.74***	-5.8***	-3.5	-3.86*	-5.18***	-3.97**
LV	-2.17	-2.11	-2.54	-2.18	NA	NA	-2.87
MT	-1.95	-2.61	-1.16	NA	NA	-1.4	-2.59
NL	-4.41**	-3.67*	-3.36	-6.54***	-6.3***	NA	-2.69
PL	-2.53	-3.71*	-2.67	-3.05	-2.64	-4.08**	NA
PT	-4.07**	-3.47	-2.8	-3.2	-4.96***	-3.57	-3.26
SE	-4.31**	-3.53	-5.63***	NA	-6.86***	NA	NA
SI	-3.34	-3.83*	-2.91	-1.18	-2.53	NA	NA
SK	-2.78	-2.99	-2.27	-1	-0.79	-0.79	-1.1

Table A.65: MSP to DSP Transmission - Non-Linear Cointegration Tests (KSS t_{NEG})

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	-3.57	-3.79*	-3.78*	NA	-5.04***	NA	NA
BE	-3.52	-4.34**	-2.16	-5.06***	-4.91***	-3.19	-0.27
CY	-2.94	-1.61	-2.55	NA	NA	-2.98	NA
CZ	-3.11	-3.13	-2.42	-3.53	-1.53	0.13	-1.6
DE	-3.91*	-3.29	-3.06	-3.15	-7.47***	NA	-3.21
DK	-2.32	-2.21	-2.31	NA	-4.18**	NA	-3.3
EE	-1.51	-2.28	-2.2	-1.61	NA	NA	NA
ES	-3.49	-3.72*	-3.07	-3.14	-3.65*	-4.9***	-2.29
FI	-3.8*	-3.13	-5.59***	NA	-5.55***	NA	NA
FR	-4.77***	-5.92***	-3.17	-4.07**	-3.6	-2.69	-1.54
GB	-3.73*	-3.39	-4.24**	NA	-2.98	-4.35**	-1.89
GR	-3.15	-2.91	-2.46	NA	-3.03	-5.2***	-1.71
HU	-2.56	-2.47	-2.92	-2.86	-3.92*	NA	NA
IE	-6.62***	-4.31**	-3.74*	NA	NA	-6.26***	-2.4
IT	-4.53***	-3.96**	-1.62	-3.33	-5.08***	-5.19***	-3.53
LT	-2.47	-2.28	-1.89	-2.8	-1.74	-2.36	NA
LU	-4.96***	-4.97***	-5.51***	-6.36***	-1.94	-6.95***	-3.45
LV	-1.77	-1.91	-2.14	-3.25	NA	NA	-1.79
MT	-2.24	-2.16	-1.65	NA	NA	-1.81	-2.05
NL	-2.87	-1.37	-2.39	-4.99***	-5.52***	NA	-0.84
PL	-2.14	-1.79	-1.39	-2.31	-1.95	-2.27	NA
PT	-4.74***	-4.27**	-2.08	-3.32	-5.28***	-4.22**	-3.48
SE	-3.09	-3.14	-4.18**	NA	-6.36***	NA	NA
SI	-1.9	-2.46	-2.27	-2.73	-2.22	NA	NA
SK	-3.17	-3.12	-1.73	-2.35	-0.47	-1.02	-1.23

Table A.66: USP to DSP Transmission - Non-Linear Cointegration Tests (KSS-F_{NEC})

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	12.2	13.27*	11.92	NA	12.63	NA	NA
BE	20.2***	36.01***	13.46*	8.03	10.73	2.08	13.85*
CY	4.89	14.84*	28.37***	NA	NA	8.43	NA
CZ	13.93*	6	5.05	1.67	1.41	0.78	6.89
DE	17.54**	13.28*	23.13***	1.13	9.99	NA	14.26*
DK	22.74***	23.94***	19.98**	NA	15.05*	NA	4.54
EE	13.99*	9.61	6.38	1.48	NA	NA	NA
ES	12.39	14.08*	17.98**	8.71	10.17	18.79**	8.82
FI	17.56**	19.38**	36.16***	NA	17.47**	NA	NA
FR	33.35***	19.74**	25.23***	21.4***	13*	11.87	15.26*
GB	14.07*	12.44	15.97**	NA	1.38	4.71	3.26
GR	9.03	8.61	10.16	NA	13.66*	13.6*	6.89
HU	11.28	4.6	11.28	2.5	5.55	NA	NA
IE	32.24***	33.91***	13.54*	NA	NA	10.99	11.85
IT	8.71	13.64*	9.6	15.7**	15.4**	14.61*	8.88
LT	17.49**	5.66	5.7	1.81	0.6	1.9	NA
LU	20.15***	12.48	25.04***	6.41	8.78	17.39**	13.46*
LV	1.15	2.75	2.29	4.7	NA	NA	4.91
MT	4.19	4.27	2.94	NA	NA	2.1	4.2
NL	16.17**	13.7*	24.72***	18.02**	13.42*	NA	9.32
PL	9.58	3.24	7.44	3.07	3.61	16.69**	NA
PT	18.36**	18.34**	1.56	3.57	20.53***	20.16***	10.27
SE	10.61	15.25*	15.21*	NA	33.27***	NA	NA
SI	23.81***	12.35	10.41	2.95	2.09	NA	NA
SK	8.04	3.64	1.92	0.84	0.68	0.68	0.42

Table A.67: MSP to DSP Transmission - Non-Linear Cointegration Tests (KSS F_{NEC})

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	9.64	7.39	6.46	NA	9.41	NA	NA
BE	15.56**	21.92***	19.4**	8.2	40.07***	4.13	8.74
CY	8.35	28.38***	17.46**	NA	NA	1.59	NA
CZ	1.8	7.33	11.51	7.59	0.92	2.49	3.52
DE	21.95***	17.68**	19.04**	1.94	17.18**	NA	3.39
DK	3.82	23.14***	7.01	NA	6.31	NA	1.69
EE	4.52	8.57	3.35	5.68	NA	NA	NA
ES	9.19	17.92**	9.1	5.12	6.87	12.29	6.54
FI	13.91*	20.09***	31.23***	NA	10.27	NA	NA
FR	12.93*	11.23	16.49**	5.8	3.55	14.98*	6.65
GB	8.63	12.09	32.58***	NA	7.62	9.08	2.24
GR	3.48	2.99	5.1	NA	5.51	4.89	2.64
HU	10.62	20.31***	13.97*	9.06	16.18**	NA	NA
IE	26.77***	34.69***	6.58	NA	NA	25.55***	17.41**
IT	3.46	10.91	2.74	6.13	1.7	11.38	7
LT	3.18	7.25	0.23	6.74	0.06	6.37	NA
LU	14.29*	17.26**	22.56***	9.93	8.69	24.55***	5.14
LV	4.49	3.4	1.81	7.14	NA	NA	2.59
MT	2.52	0.76	3.32	NA	NA	2.14	0.87
NL	8.09	2.17	13.62*	22.99***	14.7*	NA	3.68
PL	20.51***	12.06	0.56	4.69	3.01	7.04	NA
PT	17.29**	21.25***	1.26	4.58	14.05*	23.48***	15.53**
SE	10.09	11.59	16.43**	NA	14.97*	NA	NA
SI	10.48	16.64**	28.16***	8.46	9.07	NA	NA
SK	7.58	7.96	1.53	4.86	1.79	0.65	0.81

Table A.68: USP to DSP Transmission - Non-Linear Cointegration Tests (KSS F^*_{NEC})

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	8.42	8.9	7.95	NA	8.46	NA	NA
BE	13.45	24.5***	9.34	5.34	7.36	1.6	10.29
CY	4.22	13.7	18.69**	NA	NA	6.76	NA
CZ	9.47	4.2	3.35	1.88	1.15	2.24	4.7
DE	11.76	8.95	15.4*	1.76	6.75	NA	11.37
DK	18.03**	15.99*	14.25	NA	10.1	NA	3.04
EE	9.35	6.33	5.53	6.86	NA	NA	NA
ES	8.25	9.82	12	5.85	7.03	13.02	6.09
FI	11.99	13.19	24.18***	NA	13.45	NA	NA
FR	22.25***	13.25	16.84**	20.33**	8.65	7.91	11.42
GB	9.48	8.3	10.68	NA	0.91	3.17	2.2
GR	7.98	7.15	7.27	NA	13.39	12.72	6.2
HU	9.4	3.03	9.4	2.56	4.44	NA	NA
IE	21.5**	22.75***	9.41	NA	NA	7.33	9.58
IT	6.43	9.89	6.4	11.84	10.26	10.06	6.25
LT	11.71	3.79	3.89	1.54	0.45	1.51	NA
LU	13.94	8.47	16.68*	4.41	6.34	11.96	8.97
LV	1.83	1.92	3.11	3.25	NA	NA	3.45
MT	5.27	4.89	2.58	NA	NA	4.89	4.85
NL	10.84	9.9	16.55*	12.09	9.24	NA	6.27
PL	6.44	2.15	4.91	2.03	2.75	11.08	NA
PT	12.22	12.21	1.04	2.59	14.01	14.69*	6.88
SE	8.77	10.27	10.13	NA	22.24***	NA	NA
SI	16.28*	8.29	7.04	3.15	3.2	NA	NA
SK	7.51	2.39	1.27	4.73	0.72	0.72	0.32

Table A.69: MSP to DSP Transmission - Non-Linear Cointegration Tests (KSS F^*_{NEC})

	DIESEL	ULP	GASOIL	LPG	RFO.1	RFO.2	LP
AT	6.46	4.92	4.46	NA	6.79	NA	NA
BE	10.66	14.6*	14.8*	6.16	26.73***	2.91	6.4
CY	5.49	18.99**	11.62	NA	NA	1.85	NA
CZ	1.22	5.39	8.85	5.08	0.67	4.4	2.32
DE	15.1*	11.77	13.17	1.55	16.21*	NA	2.53
DK	3.04	15.78*	5.63	NA	5.03	NA	1.12
EE	3.27	5.92	2.36	4.13	NA	NA	NA
ES	6.12	12.74	6.23	4.43	6.56	8.17	4.46
FI	9.54	14.15	20.98**	NA	6.98	NA	NA
FR	8.63	9.02	11.53	4.27	2.76	10.02	5.95
GB	5.75	8.14	21.7**	NA	5.23	6.67	1.55
GR	4.28	3.39	5.14	NA	4.64	8.08	5.54
HU	7.92	13.47	11.79	10.11	11.71	NA	NA
IE	18.09**	23.37***	4.53	NA	NA	17.32**	13.11
IT	2.49	7.66	2.75	4.14	2.25	7.58	4.69
LT	2.17	4.95	0.2	4.67	0.16	4.6	NA
LU	10.67	11.5	15.36*	7.95	7.86	17.16**	3.49
LV	3.55	2.24	2.22	4.83	NA	NA	1.85
MT	3.42	1.55	3.56	NA	NA	4.26	1.68
NL	5.81	1.48	11.62	15.31*	10.29	NA	3.01
PL	14.53*	8.34	0.45	3.34	2.56	5.33	NA
PT	11.95	14.39	0.84	3.57	9.94	16.21*	10.46
SE	8.39	7.75	11.3	NA	10.35	NA	NA
SI	7.07	10.93	18.68**	9.35	5.98	NA	NA
SK	6.92	5.36	1.06	7.23	1.22	0.58	3.04

Table A.70: Runs in Data - Results

	$l_{r,up}$	$n_{r,up}$	$l_{r,down}$	$n_{r,down}$	$l_{r,cons}$	$n_{r,const}$	p-value	$\overline{increase}$	# of increases	$\overline{decrease}$	# of decreases	K-S 1-p-value
$x_t^{(AT,ULP)}$	3.15	87.00	3.26	92.00	4.41	41.00	0.00	105.09	189.00	−83.84	208.00	0.00
$x_t^{(AT,DIESEL)}$	3.14	94.00	2.97	99.00	4.02	46.00	0.00	98.30	203.00	−86.12	195.00	0.00
$x_t^{(AT,GASOIL)}$	3.32	84.00	3.22	83.00	4.37	46.00	0.00	108.36	198.00	−98.74	184.00	0.00
$x_t^{(AT,RFO.1)}$	2.31	39.00	2.16	31.00	7.80	66.00	0.00	147.43	52.00	−147.81	36.00	0.00
$x_t^{(BE,ULP)}$	2.73	116.00	2.44	124.00	3.71	75.00	0.00	554.92	203.00	−574.53	179.00	0.00
$x_t^{(BE,DIESEL)}$	2.72	118.00	2.58	120.00	3.59	74.00	0.00	496.66	203.00	−475.39	190.00	0.00
$x_t^{(BE,GASOIL)}$	2.69	109.00	2.51	105.00	3.18	108.00	0.00	395.87	184.00	−372.30	159.00	0.00
$x_t^{(BE,RFO.1)}$	2.42	107.00	2.27	88.00	3.06	154.00	0.00	289.65	152.00	−330.55	112.00	0.00
$x_t^{(BE,RFO.2)}$	2.20	15.00	2.36	11.00	3.15	20.00	0.00	251.64	19.00	−316.70	15.00	0.00
$x_t^{(BE,LPG-1)}$	2.11	44.00	2.19	36.00	3.84	70.00	0.00	595.71	49.00	−558.92	43.00	0.00
$x_t^{(BE,LP)}$	2.57	75.00	2.43	84.00	3.98	66.00	0.00	534.25	118.00	−474.91	123.00	0.00
$x_t^{(CY,ULP)}$	2.63	19.00	3.50	8.00	2.61	18.00	0.60	7.13	31.00	−7.57	21.00	0.00
$x_t^{(CY,DIESEL)}$	2.58	19.00	3.00	11.00	2.42	19.00	0.03	6.65	30.00	−4.25	24.00	0.00
$x_t^{(CY,GASOIL)}$	2.65	20.00	2.90	10.00	2.47	19.00	0.39	6.04	33.00	−5.00	20.00	0.00
$x_t^{(CY,RFO.2)}$	2.35	17.00	2.25	8.00	3.15	20.00	0.00	5.60	23.00	−4.68	10.00	0.00
$x_t^{(CZ,ULP)}$	4.20	10.00	4.78	9.00	2.00	2.00	0.67	325.00	32.00	−179.57	47.00	0.00
$x_t^{(CZ,DIESEL)}$	3.62	13.00	4.00	12.00	2.00	2.00	0.09	250.19	34.00	−120.35	45.00	0.00
$x_t^{(CZ,GASOIL)}$	4.43	7.00	4.00	7.00	2.00	1.00	0.06	313.09	25.00	−255.61	21.00	0.00
$x_t^{(CZ,RFO.1)}$	2.72	25.00	2.48	23.00	2.00	3.00	0.00	151.89	44.00	−144.88	34.00	0.00
$x_t^{(CZ,RFO.2)}$	2.72	25.00	2.13	23.00	2.00	10.00	0.00	154.88	43.00	−178.11	28.00	0.00
$x_t^{(CZ,LPG-1)}$	3.79	14.00	4.10	10.00	2.14	7.00	0.00	103.56	39.00	−65.92	34.00	0.00
$x_t^{(CZ,LP)}$	4.00	11.00	4.56	9.00	2.00	3.00	0.09	305.99	33.00	−175.08	45.00	0.00
$x_t^{(DE,ULP)}$	2.90	158.00	2.73	156.00	2.00	14.00	0.00	17.88	301.00	−18.23	270.00	0.00
$x_t^{(DE,DIESEL)}$	2.88	156.00	2.79	155.00	2.00	13.00	0.00	17.76	294.00	−16.83	278.00	0.00
$x_t^{(DE,GASOIL)}$	3.13	134.00	2.99	139.00	2.05	20.00	0.00	13.59	287.00	−11.99	277.00	0.00
$x_t^{(DE,RFO.1)}$	3.46	107.00	3.44	112.00	2.13	39.00	0.00	7.11	263.00	−5.45	278.00	0.00
$x_t^{(DE,LPG-1)}$	2.24	17.00	2.00	13.00	3.27	15.00	0.03	7.92	21.00	−5.26	13.00	0.00
$x_t^{(DE,LP)}$	2.87	38.00	2.48	40.00	2.00	3.00	0.00	11.25	72.00	−11.81	59.00	0.00
$x_t^{(DK,ULP)}$	2.75	117.00	2.46	127.00	2.71	112.00	0.00	90.30	207.00	−91.18	186.00	0.00
$x_t^{(DK,DIESEL)}$	2.67	130.00	2.45	121.00	2.71	112.00	0.00	82.05	219.00	−90.82	175.00	0.00
$x_t^{(DK,GASOIL)}$	2.67	130.00	2.43	119.00	2.69	116.00	0.00	81.21	219.00	−90.29	170.00	0.00
$x_t^{(DK,RFO.1)}$	2.58	111.00	2.29	104.00	3.06	133.00	0.00	59.13	177.00	−64.89	134.00	0.00
$x_t^{(DK,LP)}$	2.67	15.00	2.24	21.00	2.91	23.00	0.00	54.12	25.00	−58.58	26.00	0.00
$x_t^{(EE,ULP)}$	3.33	15.00	3.00	14.00	3.00	8.00	0.02	150.06	36.00	−148.54	28.00	0.00

$x_t^{(EE,DIESEL)}$	3.50	16.00	2.85	13.00	2.88	8.00	0.01	152.29	40.00	−169.66	25.00	0.00
$x_t^{(EE,GASOIL)}$	4.89	9.00	2.67	15.00	2.78	9.00	0.17	134.01	39.00	−108.33	25.00	0.00
$x_t^{(EE,LPG-1)}$	2.17	6.00	2.00	2.00	10.57	7.00	0.85	292.82	7.00	−42.39	2.00	0.06
$x_t^{(ES,ULP)}$	3.66	115.00	3.23	114.00	2.21	19.00	0.00	691.34	308.00	−683.95	254.00	0.00
$x_t^{(ES,DIESEL)}$	3.86	108.00	3.45	106.00	2.17	12.00	0.00	678.26	311.00	−619.26	260.00	0.00
$x_t^{(ES,GASOIL)}$	3.65	116.00	3.32	113.00	2.15	13.00	0.00	838.17	308.00	−826.79	262.00	0.00
$x_t^{(ES,RFO.1)}$	3.73	99.00	3.61	98.00	2.33	6.00	0.00	732.25	271.00	−649.61	256.00	0.00
$x_t^{(ES,RFO.2)}$	3.86	80.00	3.53	79.00	2.25	8.00	0.00	506.31	230.00	−501.77	200.00	0.00
$x_t^{(ES,LPG-1)}$	2.37	30.00	2.69	16.00	6.56	39.00	0.04	1219.31	41.00	−761.00	27.00	0.00
$x_t^{(ES,LP)}$	3.87	111.00	3.25	110.00	2.13	15.00	0.00	674.04	321.00	−674.02	247.00	0.00
$x_t^{(FI,ULP)}$	2.81	117.00	2.71	121.00	2.66	70.00	0.00	72.24	214.00	−69.44	207.00	0.00
$x_t^{(FI,DIESEL)}$	2.68	129.00	2.66	125.00	2.76	63.00	0.00	67.31	217.00	−62.42	208.00	0.00
$x_t^{(FI,GASOIL)}$	2.73	129.00	2.57	123.00	2.71	69.00	0.00	55.54	226.00	−56.60	193.00	0.00
$x_t^{(FI,RFO.1)}$	2.55	112.00	2.58	103.00	3.24	89.00	0.00	68.26	174.00	−63.36	163.00	0.00
$x_t^{(FR,ULP)}$	3.89	82.00	3.55	102.00	2.43	60.00	0.00	39.73	239.00	−30.79	260.00	0.00
$x_t^{(FR,DIESEL)}$	4.05	82.00	3.49	106.00	2.50	46.00	0.00	38.52	252.00	−30.08	264.00	0.00
$x_t^{(FR,GASOIL)}$	3.71	95.00	3.40	104.00	2.73	44.00	0.00	37.76	259.00	−32.12	250.00	0.00
$x_t^{(FR,RFO.1)}$	3.37	123.00	3.29	121.00	2.00	13.00	0.00	31.02	293.00	−28.21	277.00	0.00
$x_t^{(FR,RFO.2)}$	3.45	120.00	3.27	118.00	2.14	14.00	0.00	27.89	294.00	−26.39	269.00	0.00
$x_t^{(FR,LPG-1)}$	3.03	37.00	3.21	28.00	4.97	39.00	0.00	36.06	75.00	−25.18	63.00	0.00
$x_t^{(FR,LP)}$	3.52	101.00	3.12	119.00	2.31	58.00	0.00	38.76	257.00	−31.37	252.00	0.00
$x_t^{(GB,ULP)}$	3.51	89.00	4.83	93.00	2.00	5.00	0.00	3.97	224.00	−2.15	356.00	0.00
$x_t^{(GB,DIESEL)}$	3.23	91.00	5.10	92.00	2.00	4.00	0.00	4.11	204.00	−1.84	377.00	0.00
$x_t^{(GB,GASOIL)}$	3.39	119.00	3.34	117.00	2.15	20.00	0.00	3.75	288.00	−3.26	274.00	0.00
$x_t^{(GB,RFO.1)}$	3.19	36.00	2.95	37.00	2.00	1.00	0.00	4.89	81.00	−4.10	72.00	−0.00
$x_t^{(GB,RFO.2)}$	3.15	103.00	2.78	105.00	2.00	17.00	0.00	1.66	221.00	−1.56	190.00	0.00
$x_t^{(GB,LP)}$	2.62	47.00	5.08	49.00	2.00	3.00	0.00	4.03	78.00	−1.49	200.00	0.00
$x_t^{(GR,ULP)}$	3.56	119.00	3.02	123.00	2.26	23.00	0.00	2219.99	307.00	−2293.23	249.00	0.00
$x_t^{(GR,DIESEL)}$	3.65	115.00	3.30	111.00	2.21	19.00	0.00	2053.67	307.00	−1948.87	255.00	0.00
$x_t^{(GR,GASOIL)}$	3.56	117.00	3.25	118.00	2.12	17.00	0.00	2551.99	301.00	−2449.14	265.00	0.00
$x_t^{(GR,RFO.1)}$	3.60	102.00	3.23	100.00	2.54	24.00	0.00	1434.84	265.00	−1375.44	224.00	0.00
$x_t^{(GR,RFO.2)}$	3.90	99.00	3.36	97.00	3.85	20.00	0.00	1302.09	287.00	−1285.33	229.00	0.00
$x_t^{(GR,LP)}$	3.68	115.00	3.14	115.00	2.32	22.00	0.00	2082.95	310.00	−2136.84	246.00	0.00
$x_t^{(HU,ULP)}$	3.47	15.00	3.87	15.00		0.00	0.18	1995.79	38.00	−1355.57	43.00	−0.00
$x_t^{(HU,DIESEL)}$	3.25	16.00	3.47	15.00		0.00	0.07	2428.53	36.00	−1180.47	45.00	−0.00
$x_t^{(HU,GASOIL)}$	3.25	16.00	3.47	15.00		0.00	0.07	2428.53	36.00	−1180.47	45.00	−0.00
$x_t^{(HU,RFO.1)}$	2.74	23.00	2.58	24.00	2.00	2.00	0.00	3326.98	41.00	−2984.58	38.00	0.00
$x_t^{(HU,LPG-1)}$	2.67	21.00	3.20	20.00		0.00	0.01	1023.93	35.00	−404.23	46.00	0.00

$x_t^{(IE,ULP)}$	2.08	73.00	2.18	66.00	4.58	119.00	0.00	10.07	79.00	−7.92	80.00	0.00
$x_t^{(IE,DIESEL)}$	2.09	76.00	2.25	67.00	4.35	124.00	0.00	9.06	83.00	−6.51	86.00	0.00
$x_t^{(IE,GASOIL)}$	3.01	85.00	2.71	70.00	3.73	107.00	0.00	5.82	173.00	−5.93	120.00	0.00
$x_t^{(IE,RFO.2)}$	2.52	101.00	2.44	73.00	3.47	131.00	0.00	4.72	156.00	−4.89	105.00	0.00
$x_t^{(IE,LP)}$	2.10	41.00	2.24	37.00	4.51	72.00	0.00	8.11	45.00	−4.48	46.00	0.00
$x_t^{(IT,ULP)}$	4.22	83.00	3.95	81.00	2.60	48.00	0.00	8874.05	269.00	−7900.89	239.00	0.00
$x_t^{(IT,DIESEL)}$	4.38	81.00	3.60	88.00	2.36	59.00	0.00	8511.50	276.00	−7379.73	229.00	0.00
$x_t^{(IT,GASOIL)}$	3.60	110.00	3.36	114.00	2.12	24.00	0.00	9560.62	289.00	−7988.62	269.00	0.00
$x_t^{(IT,RFO.1)}$	3.32	117.00	3.35	117.00	2.13	31.00	0.00	8961.02	272.00	−7252.59	276.00	0.00
$x_t^{(IT,RFO.2)}$	3.01	76.00	3.01	67.00	2.64	61.00	0.00	7575.15	154.00	−7468.10	135.00	0.00
$x_t^{(IT,LPG-1)}$	4.03	39.00	3.45	29.00	2.93	54.00	0.04	4433.23	119.00	−4661.43	71.00	0.00
$x_t^{(IT,LP)}$	3.83	58.00	3.48	56.00	2.62	45.00	0.00	7210.11	164.00	−6128.75	141.00	0.00
$x_t^{(LT,ULP)}$	3.56	16.00	3.00	18.00	2.00	2.00	0.01	33.39	43.00	−30.51	36.00	0.00
$x_t^{(LT,DIESEL)}$	3.87	15.00	3.57	14.00	2.00	1.00	0.14	33.93	43.00	−24.89	37.00	0.00
$x_t^{(LT,GASOIL)}$	4.21	14.00	3.00	16.00	2.00	2.00	0.46	40.06	47.00	−41.97	32.00	0.00
$x_t^{(LT,RFO.1)}$	2.42	19.00	2.14	22.00	2.86	14.00	0.00	128.81	27.00	−129.52	25.00	0.00
$x_t^{(LT,RFO.2)}$	3.50	16.00	3.40	15.00	3.00	2.00	0.36	24.40	40.00	−22.72	37.00	0.00
$x_t^{(LT,LPG-1)}$	5.20	10.00	4.40	10.00	2.50	2.00	0.76	18.52	42.00	−12.91	36.00	0.00
$x_t^{(LU,ULP)}$	2.37	78.00	2.33	69.00	4.13	123.00	0.00	657.30	108.00	−652.36	92.00	0.00
$x_t^{(LU,DIESEL)}$	2.34	79.00	2.26	70.00	4.00	130.00	0.00	598.45	107.00	−589.55	88.00	0.00
$x_t^{(LU,GASOIL)}$	2.36	76.00	2.28	71.00	4.07	127.00	0.00	598.90	104.00	−564.00	91.00	0.00
$x_t^{(LU,RFO.1)}$	2.06	35.00	2.06	31.00	7.55	64.00	0.00	512.75	37.00	−523.22	33.00	0.00
$x_t^{(LU,RFO.2)}$	2.05	19.00	2.07	15.00	7.56	34.00	0.05	335.60	20.00	−364.56	16.00	0.00
$x_t^{(LU,LPG-1)}$	2.17	35.00	2.04	26.00	4.73	60.00	0.00	572.37	41.00	−690.23	27.00	0.00
$x_t^{(LU,LP)}$	2.10	20.00	2.14	22.00	5.95	42.00	0.00	384.55	22.00	−281.20	25.00	0.00
$x_t^{(LV,ULP)}$	2.82	17.00	2.59	17.00	2.33	12.00	0.00	8.93	31.00	−7.66	27.00	0.00
$x_t^{(LV,DIESEL)}$	3.50	12.00	2.92	12.00	3.00	11.00	0.10	8.17	31.00	−6.03	23.00	0.00
$x_t^{(LV,GASOIL)}$	3.67	12.00	3.10	10.00	3.00	11.00	0.35	7.67	33.00	−6.61	21.00	0.00
$x_t^{(LV,LPG-1)}$	2.64	14.00	2.00	7.00	4.00	15.00	0.84	5.56	23.00	−4.16	8.00	0.00
$x_t^{(LV,LP)}$	2.76	17.00	2.31	16.00	3.40	10.00	0.00	10.84	31.00	−13.06	21.00	0.00
$x_t^{(MT,ULP)}$	2.00	3.00	2.00	1.00	11.00	4.00	1.00	8.79	3.00	−11.01	1.00	1.00
$x_t^{(MT,DIESEL)}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$x_t^{(MT,GASOIL)}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$x_t^{(MT,RFO.2)}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$x_t^{(MT,LP)}$	2.00	3.00	2.00	1.00	11.00	4.00	1.00	8.76	3.00	−11.02	1.00	1.00
$x_t^{(NL,ULP)}$	3.06	110.00	2.73	115.00	2.82	87.00	0.00	21.02	227.00	−20.89	200.00	0.00
$x_t^{(NL,DIESEL)}$	3.04	110.00	2.75	113.00	2.82	89.00	0.00	20.15	224.00	−19.62	199.00	0.00
$x_t^{(NL,GASOIL)}$	3.03	110.00	2.81	112.00	2.80	88.00	0.00	20.01	223.00	−18.57	204.00	0.00

$x_t^{(NL,RFO.1)}$	2.55	76.00	2.27	66.00	4.47	110.00	0.00	15.30	118.00	−16.40	84.00	0.00
$x_t^{(NL,LPG-1)}$	3.90	42.00	3.65	40.00	2.43	44.00	0.01	13.70	125.00	−13.74	106.00	0.00
$x_t^{(NL,LP)}$	3.42	57.00	3.05	57.00	2.52	25.00	0.00	26.05	138.00	−27.36	118.00	0.00
$x_t^{(PL,ULP)}$	5.00	10.00	4.25	8.00	2.00	3.00	0.27	30.11	40.00	−25.29	38.00	0.00
$x_t^{(PL,DIESEL)}$	5.20	10.00	4.00	10.00	3.00	1.00	0.76	26.00	42.00	−17.16	37.00	0.00
$x_t^{(PL,GASOIL)}$	3.69	16.00	3.12	16.00	2.00	2.00	0.04	49.58	45.00	−54.74	34.00	0.00
$x_t^{(PL,RFO.1)}$	3.00	22.00	2.57	21.00	2.00	3.00	0.00	30.47	45.00	−30.18	33.00	0.00
$x_t^{(PL,RFO.2)}$	2.67	24.00	2.52	23.00	2.00	5.00	0.00	33.93	41.00	−35.80	35.00	0.00
$x_t^{(PL,LPG-1)}$	3.59	17.00	2.88	16.00	3.00	1.00	0.01	20.17	44.00	−16.09	35.00	0.00
$x_t^{(PT,ULP)}$	2.76	59.00	2.42	52.00	5.55	88.00	0.00	2150.34	104.00	−2200.88	81.00	0.00
$x_t^{(PT,DIESEL)}$	2.83	47.00	2.40	48.00	7.16	69.00	0.00	1847.60	86.00	−1386.09	74.00	0.00
$x_t^{(PT,GASOIL)}$	2.58	33.00	2.43	23.00	5.98	42.00	0.00	2515.77	52.00	−2411.83	33.00	0.00
$x_t^{(PT,RFO.1)}$	2.10	78.00	2.05	64.00	3.89	131.00	0.00	1653.12	86.00	−1454.86	68.00	0.00
$x_t^{(PT,RFO.2)}$	2.03	63.00	2.07	44.00	4.24	101.00	0.00	1457.18	65.00	−1461.45	47.00	0.00
$x_t^{(PT,LPG-1)}$	2.58	12.00	2.29	14.00	7.76	21.00	0.00	2826.69	19.00	−2143.15	18.00	0.00
$x_t^{(PT,LP)}$	3.33	30.00	2.70	27.00	6.31	32.00	0.00	2506.47	70.00	−2816.92	54.00	0.00
$x_t^{(SE,ULP)}$	2.53	118.00	2.46	115.00	2.63	114.00	0.00	107.40	181.00	−105.13	168.00	0.00
$x_t^{(SE,DIESEL)}$	2.47	106.00	2.49	83.00	3.42	106.00	0.00	117.18	156.00	−137.40	124.00	0.00
$x_t^{(SE,GASOIL)}$	2.84	57.00	2.34	62.00	5.72	72.00	0.00	97.22	105.00	−89.77	92.00	0.00
$x_t^{(SE,RFO.1)}$	2.71	65.00	2.45	53.00	6.19	67.00	0.00	100.02	111.00	−124.06	77.00	0.00
$x_t^{(SI,ULP)}$	2.09	22.00	2.08	13.00	2.14	35.00	0.00	4017.58	24.00	−5487.93	14.00	0.00
$x_t^{(SI,DIESEL)}$	2.05	22.00	2.07	15.00	2.08	36.00	0.00	4380.57	23.00	−3799.19	16.00	0.00
$x_t^{(SI,GASOIL)}$	2.04	24.00	2.07	14.00	2.09	35.00	0.00	3819.49	25.00	−3827.62	15.00	0.00
$x_t^{(SI,RFO.1)}$	2.11	9.00	2.00	5.00	5.57	14.00	0.27	3654.60	10.00	−2280.40	5.00	0.00
$x_t^{(SI,LPG-1)}$	2.14	7.00	2.00	9.00	6.80	10.00	1.00	4994.69	8.00	−3779.08	9.00	0.00
$x_t^{(SK,ULP)}$	3.73	11.00	3.93	14.00	2.40	5.00	0.70	375.07	30.00	−212.28	42.00	0.00
$x_t^{(SK,DIESEL)}$	4.00	12.00	3.50	14.00	2.20	5.00	0.19	385.39	36.00	−246.34	35.00	0.00
$x_t^{(SK,GASOIL)}$	2.11	9.00	2.00	4.00	6.25	12.00	0.09	1142.96	10.00	−887.28	4.00	0.00
$x_t^{(SK,RFO.1)}$	2.00	8.00	2.00	4.00	6.55	11.00	1.00	351.50	8.00	−125.00	4.00	0.01
$x_t^{(SK,RFO.2)}$	2.00	8.00	2.00	4.00	6.55	11.00	1.00	349.25	8.00	−125.00	4.00	0.01
$x_t^{(SK,LPG-1)}$	3.45	11.00	3.93	14.00	2.14	7.00	0.00	242.14	27.00	−47.36	44.00	0.00
$x_t^{(SK,LP)}$	2.57	7.00	3.17	6.00	2.25	4.00	0.80	211.61	11.00	−294.12	15.00	0.00

Table A.71: STAR DF ECM Estimation (Brent) - Results

Transition	Product	ζ	c	$< 1/2$	γ_1^L	ψ_1^L	ψ_2^L	ψ_3^L	ψ_4^L
Country	Transition	d	c^{th}	$sd(\hat{u}_t)$	γ^H	ψ_1^H	ψ_2^H	ψ_3^H	ψ_4^H
USP→DSP	ULP	15.004	0.027	0.704	-0.335***	-0.172***			
BE	LSTAR	2	0.205	0.064	-0.204***	0.004			
USP→DSP	ULP	3.212	-0.01	0.312	-0.427				
CY	ESTAR	1	-0.051	0.065	-0.23***				
USP→DSP	ULP	9.401***	-0.029	0.079	0.493*	0.129			
GB	ESTAR	1	-0.091	0.1	-0.091***	0.07			
USP→DSP	ULP	3.148	0.036	0.186	-0.116		0.061		
GR	ESTAR	1	0.18	0.079	-0.124***		-0.173***		
USP→DSP	ULP	2.498+	0.011	0.293	-0.169				
IT	ESTAR	1	0.094	0.057	-0.151***				
USP→DSP	ULP	4.552	-0.061	0.096	-0.022	-0.343			
LU	ESTAR	1	-0.32	0.069	-0.193***	-0.044			
USP→DSP	ULP	1.512***	-0.026	0.477	-0.13*	-0.041			-0.211**
PT	ESTAR	2	-0.068	0.128	-0.08***	0.146**			0.296***
USP→DSP	ULP	1.312***	0.008	0.39	0.819*	-0.116	0.661**		
SI	ESTAR	1	0.084	0.073	-0.542***	0.53***	0.176		
USP→DSP	DIESEL	1.525	0.053	0.306	-0.066	-0.092	0.101		
BE	ESTAR	3	0.287	0.071	-0.183***	-0.306***	-0.187***		
USP→DSP	DIESEL	5.891+	-0.013	0.112	-0.053	-0.495	-0.191	0.084	
DK	ESTAR	2	-0.077	0.068	-0.137***	-0.208***	-0.088*	-0.107**	
USP→DSP	DIESEL	4.276**	-0.001	0.184	-3.244	3.307		-0.238	
EE	ESTAR	2	-0.023	0.081	-0.268***	0.338***		0.261**	
USP→DSP	DIESEL	1.523***	0.025	0.329	-0.031	0.14			0.055
ES	ESTAR	2	0.17	0.077	-0.136***	-0.251***			0.077
USP→DSP	DIESEL	5.823***	-0.004	0.099	2.756**	-0.169			
FI	ESTAR	1	0.032	0.075	-0.156***	-0.101**			
USP→DSP	DIESEL	8.075	-0.042	0.294	-0.184***				-0.008
FR	LSTAR	1	-0.206	0.074	-0.143***				0.084*
USP→DSP	DIESEL	50	0.013	0.589	-0.148***	0.009	-0.121**	-0.016	
GR	LSTAR	2	0.089	0.091	-0.11***	-0.271***	-0.159**	-0.133**	
USP→DSP	DIESEL	3.523	0.007	0.208	-0.079	0.203	0.359		0.171
IE	ESTAR	2	0.052	0.094	-0.093***	0.044	0.002		0.053
USP→DSP	DIESEL	2.049+	0.006	0.32	0.367***	-0.233***	-0.175*	0.005	
LU	ESTAR	1	0.085	0.07	-0.199***	-0.021	-0.025	-0.099*	
USP→DSP	DIESEL	4.376***	-0.036	0.112	0.246	-0.469***	-0.196		
NL	ESTAR	1	-0.189	0.064	-0.148***	-0.109**	-0.056		
USP→DSP	DIESEL	3.223***	0.013	0.191	-0.271	0.743**	0.007		
PT	ESTAR	2	0.074	0.11	-0.079***	0.003	0.089*		
USP→DSP	DIESEL	5+	-0.075	0.274	-0.06**	-0.255**	-0.009	-0.035	
SE	LSTAR	2	-0.226	0.112	-0.086***	-0.067	-0.146***	-0.154***	
USP→DSP	GASOIL	2.016*	0.045	0.312	0.125				
CY	ESTAR	1	0.195	0.066	-0.309***				
USP→DSP	GASOIL	1.716*	-0.074	0.246	-0.144**	-0.278**			
DE	ESTAR	2	-0.365	0.07	-0.146***	-0.114**			
USP→DSP	GASOIL	1.03+	0.012	0.594	-0.126***	-0.304***	-0.091	0.147+	
DK	LSTAR	2	0.093	0.083	-0.064+	-0.202**	-0.07	-0.318+	
USP→DSP	GASOIL	2.002+	0.023	0.666	-0.168***	-0.121+			
ES	LSTAR	1	0.167	0.082	-0.146***	-0.006+			
USP→DSP	GASOIL	3.271	0.003	0.205	-0.499	0.018	-0.072	0.008	
FI	ESTAR	1	0.032	0.079	-0.129***	-0.231***	-0.083	-0.095*	
USP→DSP	GASOIL	1.429	0.02	0.637	-0.074**	-0.307***		-0.11	
FR	LSTAR	1	0.137	0.072	-0.128***	0.123		0.023	
USP→DSP	GASOIL	5.514	0.057	0.773	-0.074***	-0.157***			
IT	LSTAR	1	0.273	0.084	-0.087***	0.139			
USP→DSP	GASOIL	2.86**	0.024	0.207	-0.026	-0.394***	-0.225**	0.039	
LU	ESTAR	1	0.167	0.066	-0.208***	-0.064	-0.047	-0.137***	
USP→DSP	GASOIL	1.562***	-0.004	0.425	0.156	-0.425***	-0.107		
NL	ESTAR	1	0.05	0.071	-0.184***	0.067	-0.035		
USP→DSP	GASOIL	4.479**	-0.016	0.154	0.219		0.165		
SE	ESTAR	2	-0.052	0.08	-0.136***		-0.145***		
USP→DSP	RFO.1	6+	-0.078	0.081	-0.044				
AT	ESTAR	1	-0.23	0.116	-0.09***				
USP→DSP	RFO.1	1.468**	-0.03	0.415	-0.043	0.133			
DE	ESTAR	1	-0.084	0.1	-0.093***	-0.278***			
USP→DSP	RFO.1	2.407***	-0.195	0.077	0.071	0.153	-0.13	-0.016	
FI	ESTAR	1	-0.421	0.135	-0.123***	-0.248***	-0.125**	-0.147***	
USP→DSP	RFO.1	50	0.094	0.753	-0.805***				
LT	LSTAR	1	0.258	0.143	-0.701***				
USP→DSP	RFO.1	3.599***	0.027	0.194	-0.291		-0.104		
NL	ESTAR	1	0.127	0.092	-0.124***		0.103**		
USP→DSP	RFO.1	5.484	0.074	0.098	0.056				-0.034
PT	ESTAR	1	0.212	0.124	-0.07***				-0.07
USP→DSP	RFO.1	3.999	0.006	0.176	-0.209	-0.027			-0.248

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Table A.71 – continued from previous page

Transition Country	Product Transition	ζ d	c c^{th}	$< 1/2$ $sd(\hat{u}_t)$	γ_1^L γ^H	ψ_1^L ψ_1^H	ψ_2^L ψ_2^H	ψ_3^L ψ_3^H	ψ_4^L ψ_4^H
SE	ESTAR	1	0.016	0.112	-0.185***	-0.139***			0.131***
USP→DSP	RFO.2	8+	0.01	0.616	-0.207**				
BE	LSTAR	1	0.117	0.057	-0.301***				
USP→DSP	LPG	13.04***	-0.007	0.066	2.365*	0.554*	0.498	0.56	
NL	ESTAR	1	0.022	0.073	-0.105***	0.191***	-0.13**	0.088	
USP→DSP	LP	11.999	0.037	0.071	-0.443*	-0.324			0.039
BE	ESTAR	1	0.241	0.073	-0.155***	-0.119**			-0.096**
USP→DSP	LP	4.596	0.05	0.862	-0.58***				0.134
DE	LSTAR	1	0.368	0.047	-0.231**				0.076
USP→DSP	LP	50	-0.091	0.17	-0.207***	-0.286***	-0.054	-0.193*	
GR	LSTAR	2	-0.331	0.089	-0.066***	-0.034	-0.126***	-0.041	
USP→DSP	LP	2.854***	-0.036	0.31	-0.337*	0.613***			-0.134
PT	ESTAR	1	-0.155	0.162	-0.093***	0.123**			0.321***
MSP→DSP	ULP	6.497	0.026	0.09	-0.005	0.009	-0.119		
BE	ESTAR	1	0.208	0.05	-0.398***	-0.245***	-0.155***		
MSP→DSP	ULP	2.868+	-0.04	0.203	-0.25	-0.435***	-0.101	-0.032	0.126*
DE	ESTAR	3	-0.276	0.06	-0.229***	-0.311***	-0.271***	-0.134**	-0.151***
MSP→DSP	ULP	5.416*	-0.003	0.105	0.644	-0.675	-0.106		
ES	ESTAR	2	-0.004	0.05	-0.206***	-0.142***	-0.129***		
MSP→DSP	ULP	4.5	0.027	0.625	-0.22***			0.102*	
FI	LSTAR	1	0.125	0.075	-0.254***			0.063	
MSP→DSP	ULP	11.001+	0.017	0.632	-0.202***	-0.065	-0.053		
FR	LSTAR	3	0.131	0.055	-0.288***	-0.104*	-0.22***		
MSP→DSP	ULP	4.981**	0.017	0.127	0.031	0.203	0.088		0.038
LU	ESTAR	1	0.145	0.047	-0.32***	-0.179***	-0.174***		-0.091*
MSP→DSP	ULP	2.495***	0.006	0.265	-0.002				-0.223*
PT	ESTAR	1	0.051	0.131	-0.081***				0.205***
MSP→DSP	DIESEL	2.022+	-0.024	0.268	0.124	-0.568+	-0.551+	-0.336+	-0.193**
BE	ESTAR	1	-0.201	0.056	-0.243***	-0.323***	-0.156***	-0.007	-0.007+
MSP→DSP	DIESEL	1.376***	0.039	0.341	-0.101	-0.542***	-0.178*		
FI	ESTAR	1	0.248	0.064	-0.189***	-0.025	-0.078		
MSP→DSP	DIESEL	7.004	-0.02	0.363	-0.308***	-0.126	-0.001		
FR	LSTAR	3	-0.138	0.05	-0.244***	-0.123	-0.153*		
MSP→DSP	DIESEL	32.359	-0.035	0.345	-0.178***	0.011	-0.353***	-0.051	
GR	LSTAR	4	-0.155	0.072	-0.174***	-0.273***	-0.157***	-0.054	
MSP→DSP	DIESEL	10.788**	0	0.112	-1.747	-0.059			-0.202
IE	ESTAR	1	0.003	0.093	-0.108***	0.104**			0.166***
MSP→DSP	DIESEL	6.412	0.041	0.808	-0.388***	-0.043	-0.04	-0.052	
LU	LSTAR	2	0.307	0.053	-0.12*	-0.241**	-0.317***	-0.076	
MSP→DSP	DIESEL	7.02	-0.013	0.405	-0.234***	-0.412***	-0.199**	-0.13	-0.014
NL	LSTAR	3	-0.096	0.044	-0.08*	-0.392***	-0.343***	-0.082	-0.172***
MSP→DSP	DIESEL	7.001+	0.026	0.095	0.222+				
PT	ESTAR	1	0.127	0.104	-0.073***				
MSP→DSP	DIESEL	1.965+	-0.012	0.458	-0.057**	-0.259***	-0.064+	0.092***	
SE	LSTAR	2	-0.043	0.114	-0.08***	-0.09	-0.152+	-0.258***	
MSP→DSP	DIESEL	13.787	-0.046	0.273	-0.382**	0.272	0.884***		
SI	LSTAR	2	-0.231	0.066	-0.581***	0.363***	0.075		
MSP→DSP	GASOIL	4.009+	-0.037	0.153	-0.43***	-0.01	0.012	-0.025	
BE	ESTAR	1	-0.283	0.054	-0.226***	-0.409***	-0.284***	-0.134***	
MSP→DSP	GASOIL	3.096***	0.025	0.176	-0.516***	0.159	0.158	-0.317**	-0.147
DE	ESTAR	2	0.258	0.042	-0.196***	-0.468***	-0.324***	-0.107*	-0.127***
MSP→DSP	GASOIL	2.713***	-0.022	0.258	0.081	-0.844***	-0.73***	-0.631**	0.014
DK	ESTAR	4	-0.062	0.064	-0.09***	-0.36***	-0.148**	-0.053	-0.12**
MSP→DSP	GASOIL	4.746***	0.036	0.107	-0.541**	0.044	0.269	-0.098	-0.083
ES	ESTAR	2	0.259	0.065	-0.159***	-0.078	-0.206***	-0.069	-0.06
MSP→DSP	GASOIL	3.933***	0.026	0.171	-0.068	-0.399*	0.216		
FI	ESTAR	1	0.201	0.057	-0.252***	-0.161***	-0.111**		
MSP→DSP	GASOIL	6	0.005	0.554	-0.158***	-0.32***	-0.091	-0.023	-0.041
FR	LSTAR	3	0.054	0.05	-0.124***	-0.187***	-0.16**	-0.133*	-0.13**
MSP→DSP	GASOIL	32.447	-0.043	0.325	-0.229***	-0.098	-0.314***		
GR	LSTAR	2	-0.175	0.093	-0.101***	-0.153***	-0.143***		
MSP→DSP	GASOIL	24.153	0.057	0.857	-0.437***		-0.083		
LT	LSTAR	3	0.36	0.053	-0.921***		-0.626*		
MSP→DSP	GASOIL	2.401	-0.02	0.358	-0.182***		-0.099		
SE	LSTAR	1	-0.141	0.07	-0.169***		-0.052		
MSP→DSP	RFO.1	15+	0.069	0.784	-0.081***		-0.22***		
AT	LSTAR	3	0.285	0.096	-0.229***		0.091		
MSP→DSP	RFO.1	7.599+	-0.036	0.197	-0.447***	-0.335***			
BE	LSTAR	1	-0.304	0.043	-0.615***	-0.038			
MSP→DSP	RFO.1	4.793+	0.026	0.694	-0.297***	-0.201***	-0.175***		
DE	LSTAR	1	0.195	0.062	-0.237***	0.034	0.094		
MSP→DSP	RFO.1	8.998+	0.034	0.598	-0.103***	-0.176***			
FI	LSTAR	1	0.098	0.13	-0.118***	-0.263***			
MSP→DSP	RFO.1	10.401*	-0.005	0.117	5.882				0.189
HU	ESTAR	1	-0.003	0.082	-0.708***				0.152
MSP→DSP	RFO.1	50	-0.012	0.452	-0.087**		-0.106	0	

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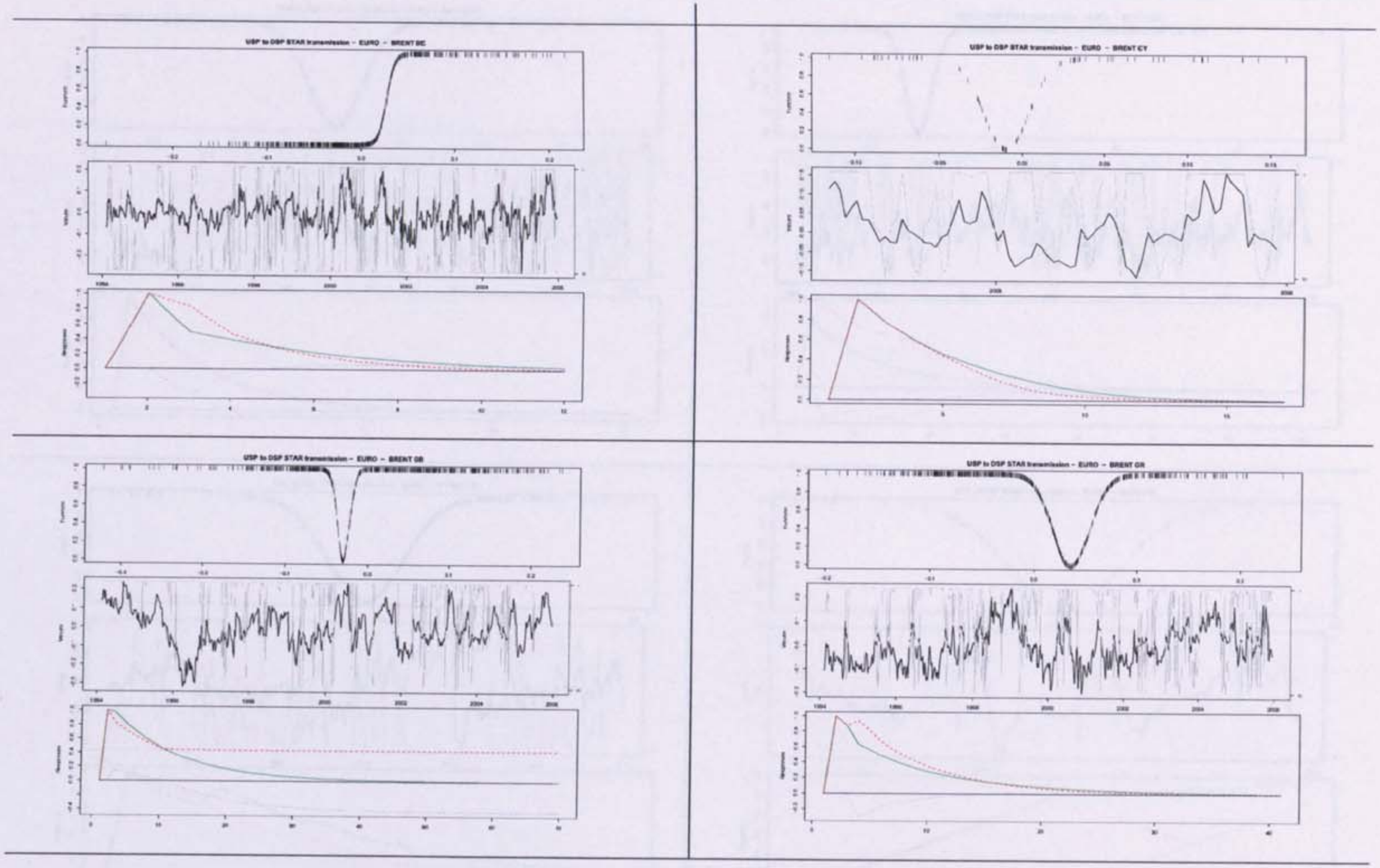
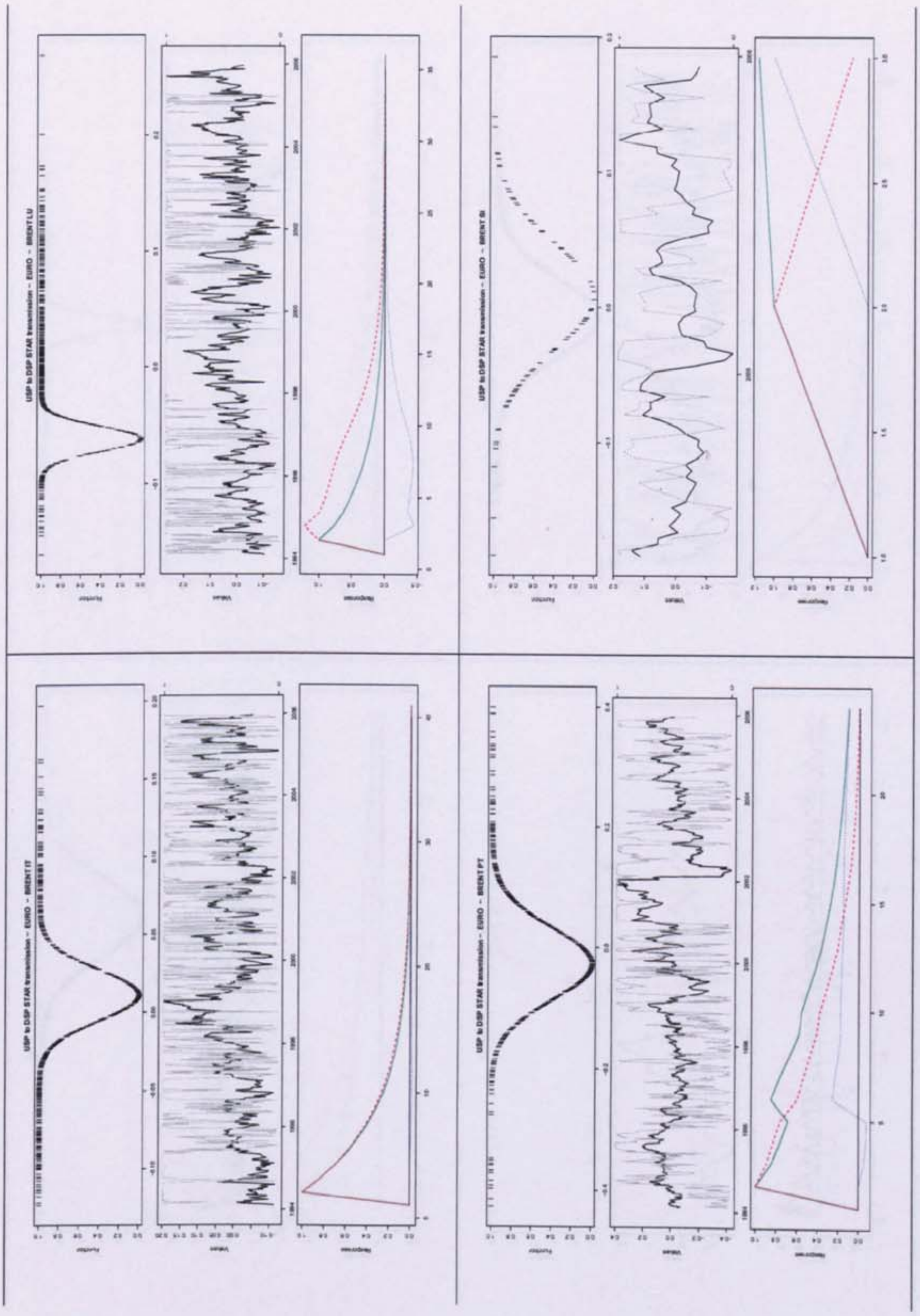
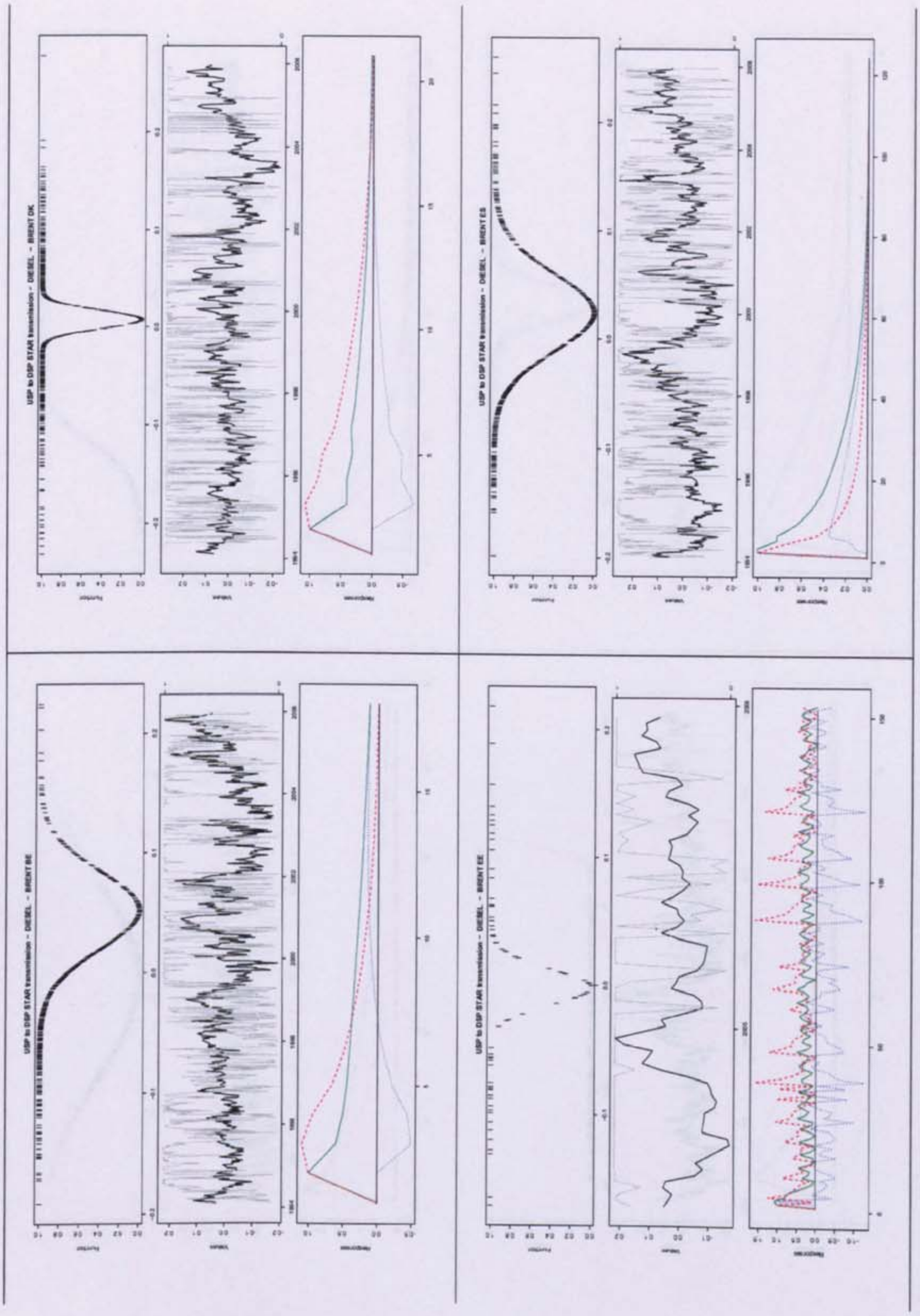
Table A.71 – continued from previous page

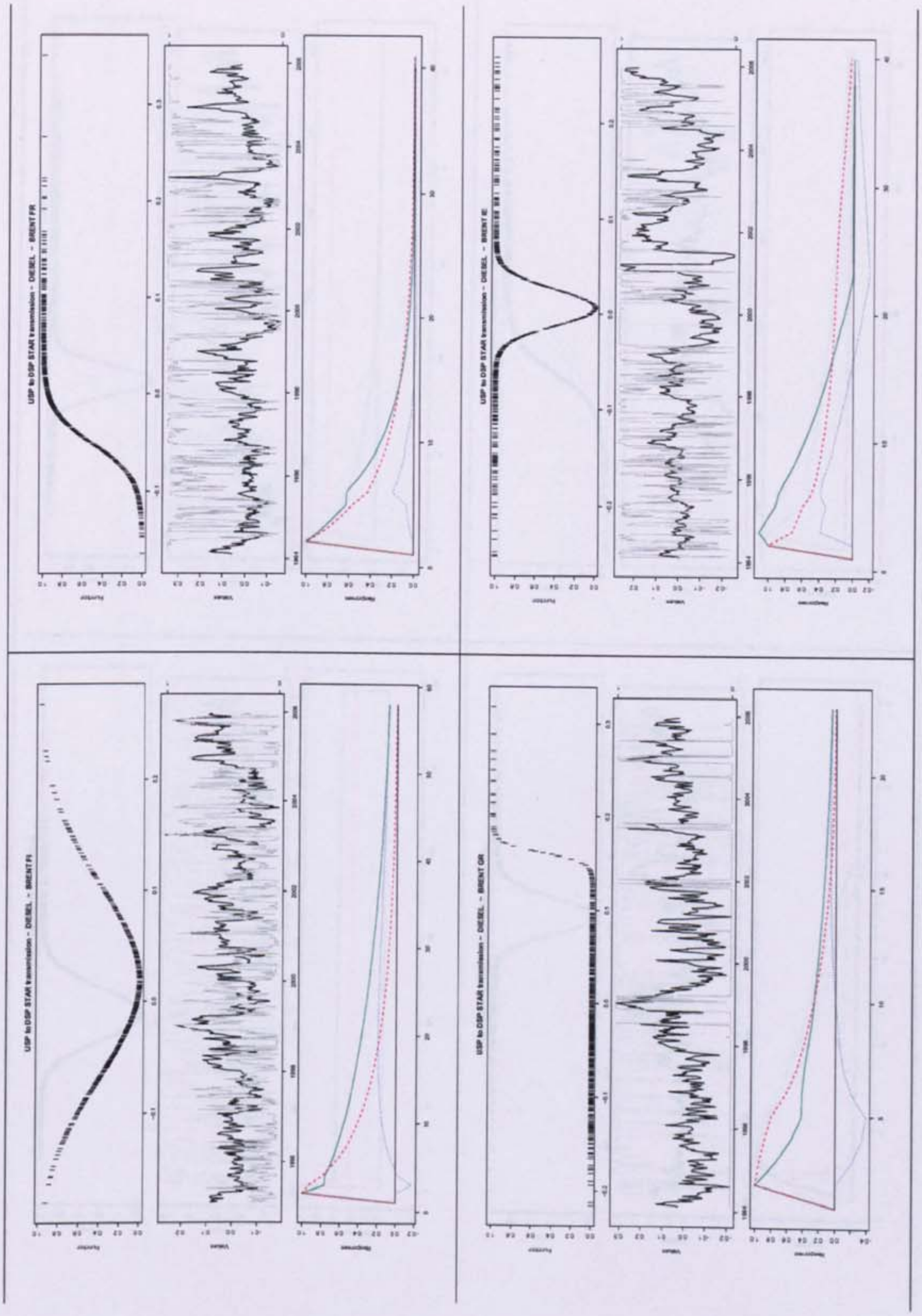
Transition	Product	ζ	c	$< 1/2$	γ_1^L	ψ_1^L	ψ_2^L	ψ_3^L	ψ_4^L
Country	Transition	d	c^{th}	$sd(\hat{u}_t)$	γ^H	ψ_1^H	ψ_2^H	ψ_3^H	ψ_4^H
LU	LSTAR	1	-0.048	0.085	-0.144***		-0.083	-0.126**	
MSP→DSP	RFO.1	3.007**	0.08	0.091	0.026	-0.307*			
NL	ESTAR	1	0.386	0.068	-0.203***	-0.099**			
MSP→DSP	RFO.1	3.55**	-0.009	0.174	-0.149	0.62			
PT	ESTAR	2	-0.005	0.116	-0.096***	0.022			
MSP→DSP	RFO.1	2.021	-0.146	0.152	-0.082	0.111			
SE	ESTAR	1	-0.378	0.132	-0.148***	-0.164			
MSP→DSP	RFO.2	1.493*	-0.063	0.26	-0.312				
BE	ESTAR	1	-0.45	0.054	-0.478***				
MSP→DSP	RFO.2	6.542***	0.003	0.119	2.106	-0.138			
ES	ESTAR	1	0.058	0.065	-0.319***	0.121**			
MSP→DSP	RFO.2	0.995***	0.004	0.537	-0.04		-0.19***	-0.152**	-0.03
GR	ESTAR	2	0.026	0.088	-0.306***		0.064	0.07	-0.098
MSP→DSP	RFO.2	5.075*	0.018	0.117	0.034	-0.302			
IE	ESTAR	2	0.036	0.143	-0.106***	0.116***			
MSP→DSP	RFO.2	2.992^{+}	-0.001	0.294	0.627***		0.07	-0.065^{+}	
LU	ESTAR	1	-0.033	0.078	-0.283***		0.138*	0.212**	
MSP→DSP	LPG	50	-0.006	0.468	-0.046	0.193		0.044	
CZ	LSTAR	2	-0.028	0.057	-0.111**	0.355**		0.461**	
MSP→DSP	LPG	5.215	0.04	0.844	-0.343***	0.43***	0.482***		
HU	LSTAR	3	0.35	0.042	-0.215**	0.071	-0.001		
MSP→DSP	LPG	8.919	-0.03	0.21	-0.141***	-0.104		0.179	
IT	LSTAR	2	-0.289	0.045	-0.064**	0.343***		0.047	
MSP→DSP	LPG	16.001	-0.028	0.215	-0.34***		-0.163		
LU	LSTAR	1	-0.285	0.039	-0.294***		0.181***		
MSP→DSP	LPG	4.115***	0.002	0.183	-1.522	0.118	0.132		
NL	ESTAR	1	0.013	0.042	-0.248***	0.176**	-0.236***		
MSP→DSP	LP	12^{+}	-0.001	0.449	-0.107**	-0.243***	-0.18***		-0.209***
BE	LSTAR	1	-0.051	0.066	-0.22***	-0.409***	-0.179***		-0.018
MSP→DSP	LP	7.791	-0.057	0.277	-0.13***	0.095	-0.29***	-0.069	0.02
GR	LSTAR	1	-0.224	0.089	-0.069**	-0.331***	-0.226***	-0.044	-0.142***
MSP→DSP	LP	15.274	-0.01	0.393	-0.15***		0.056		
IT	LSTAR	3	-0.107	0.044	-0.168***		-0.175**		
MSP→DSP	LP	1.804***	0.001	0.346	0.74*				
LU	ESTAR	1	-0.067	0.042	-0.263***				
MSP→DSP	LP	2.517*	-0.025	0.317	-0.128	0.257			-0.377*
PT	ESTAR	1	-0.032	0.171	-0.088***	0.107			0.368***
USP→MSP	DIESEL	6.096	-0.008	0.103	-0.9	-0.449			
	ESTAR	1	-0.017	0.075	-0.228***	-0.089*			
USP→MSP	LPG	5.44**	0.066	0.112	-0.131	-0.094		0.336**	
	ESTAR	2	0.177	0.179	-0.094***	0.298***		0.06	

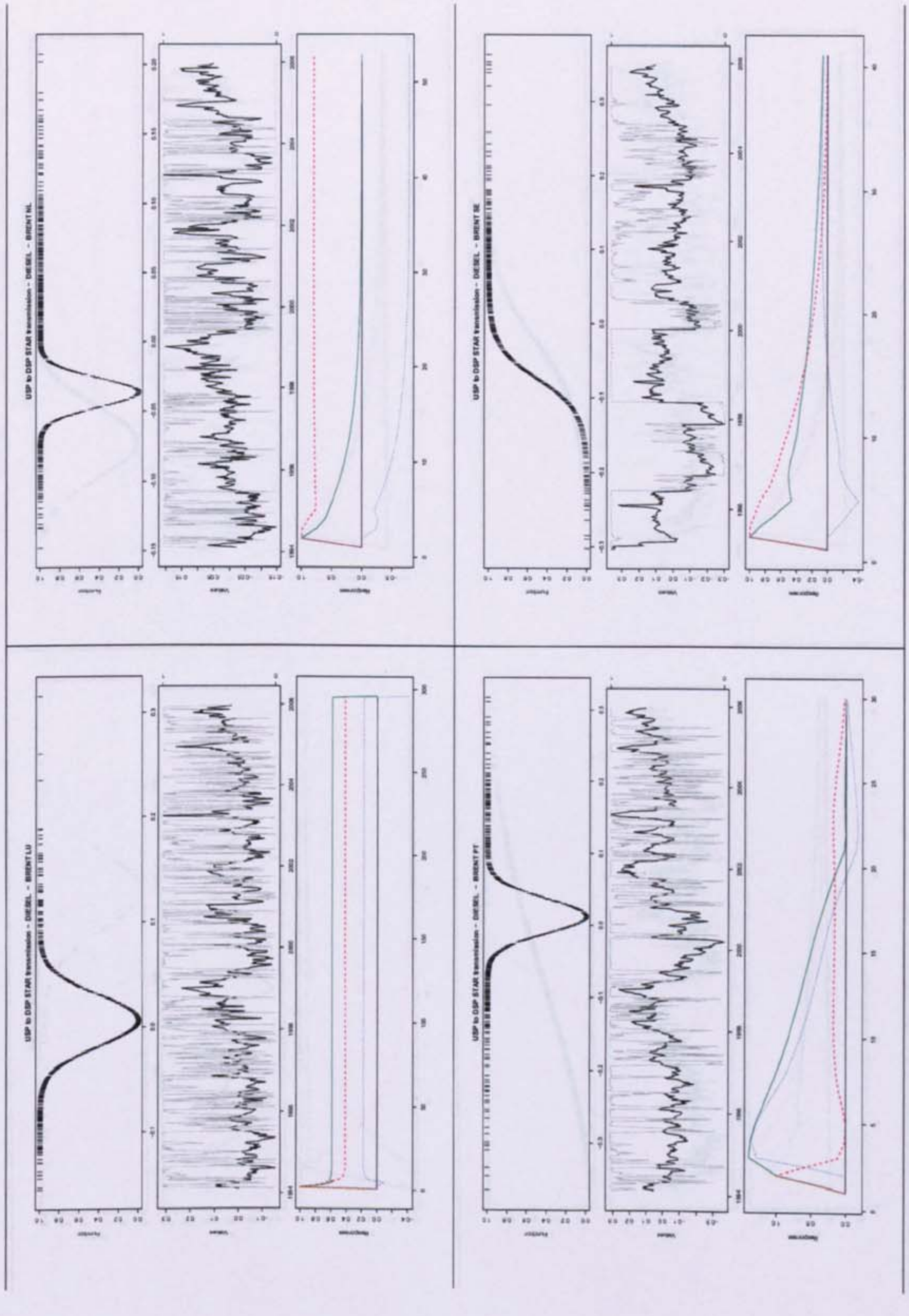
Table A.72: STAR DF ECM Estimation (Brent) - Graphical Overview

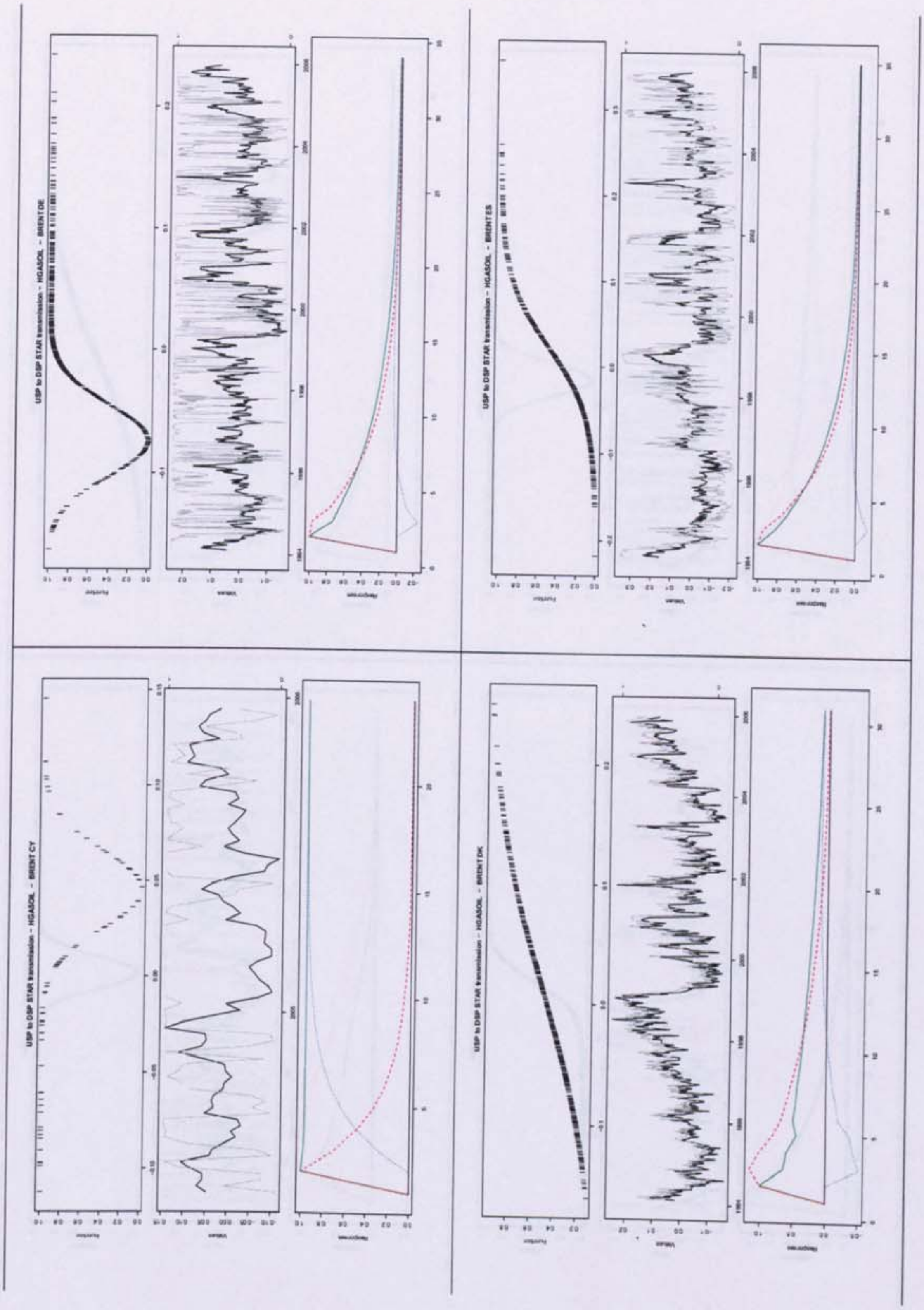


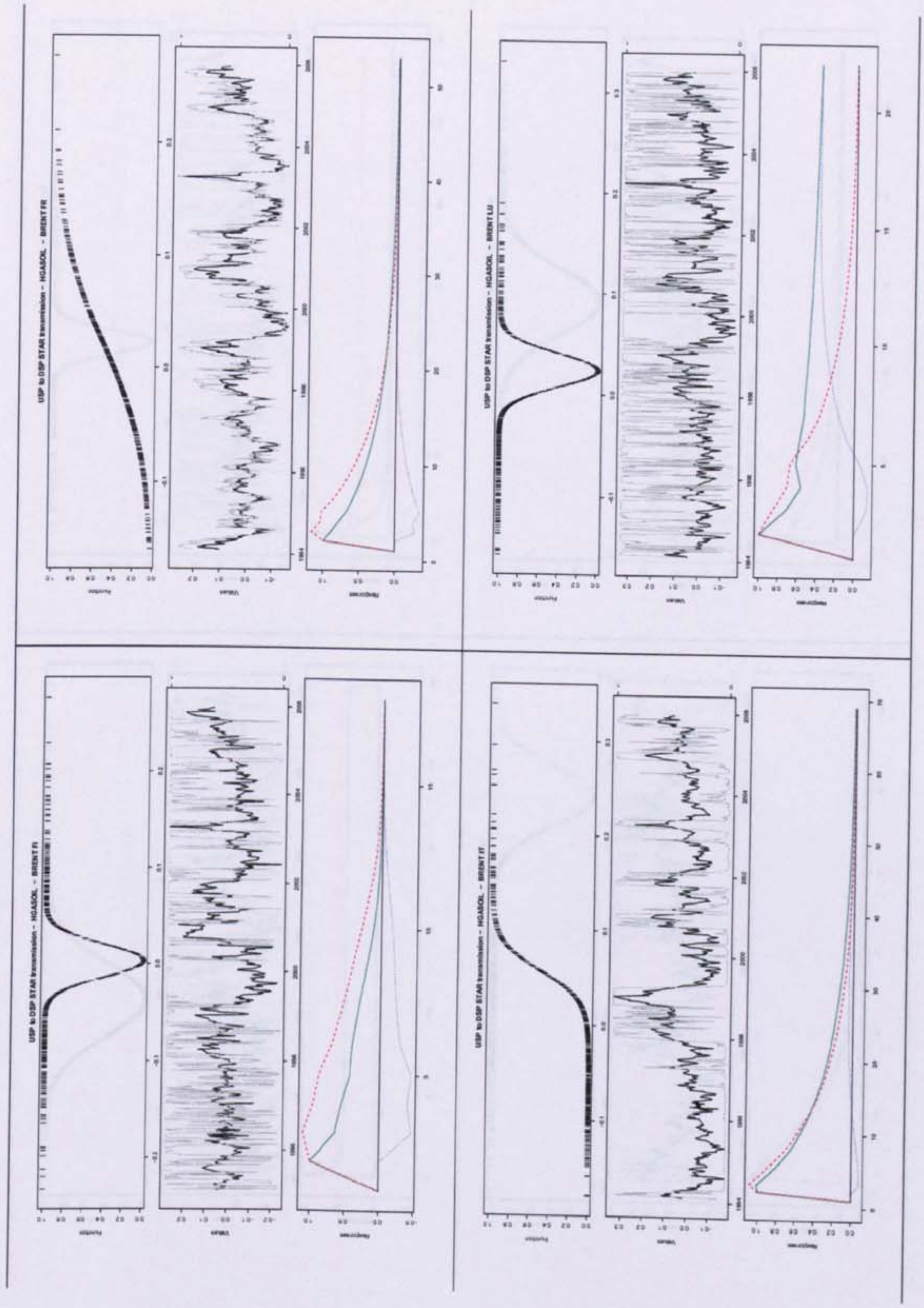

USP to DSP STAR transmission - EURO - BRENT IT
USP to DSP STAR transmission - EURO - BRENT LU
USP to DSP STAR transmission - EURO - BRENT PT
USP to DSP STAR transmission - EURO - BRENT SI

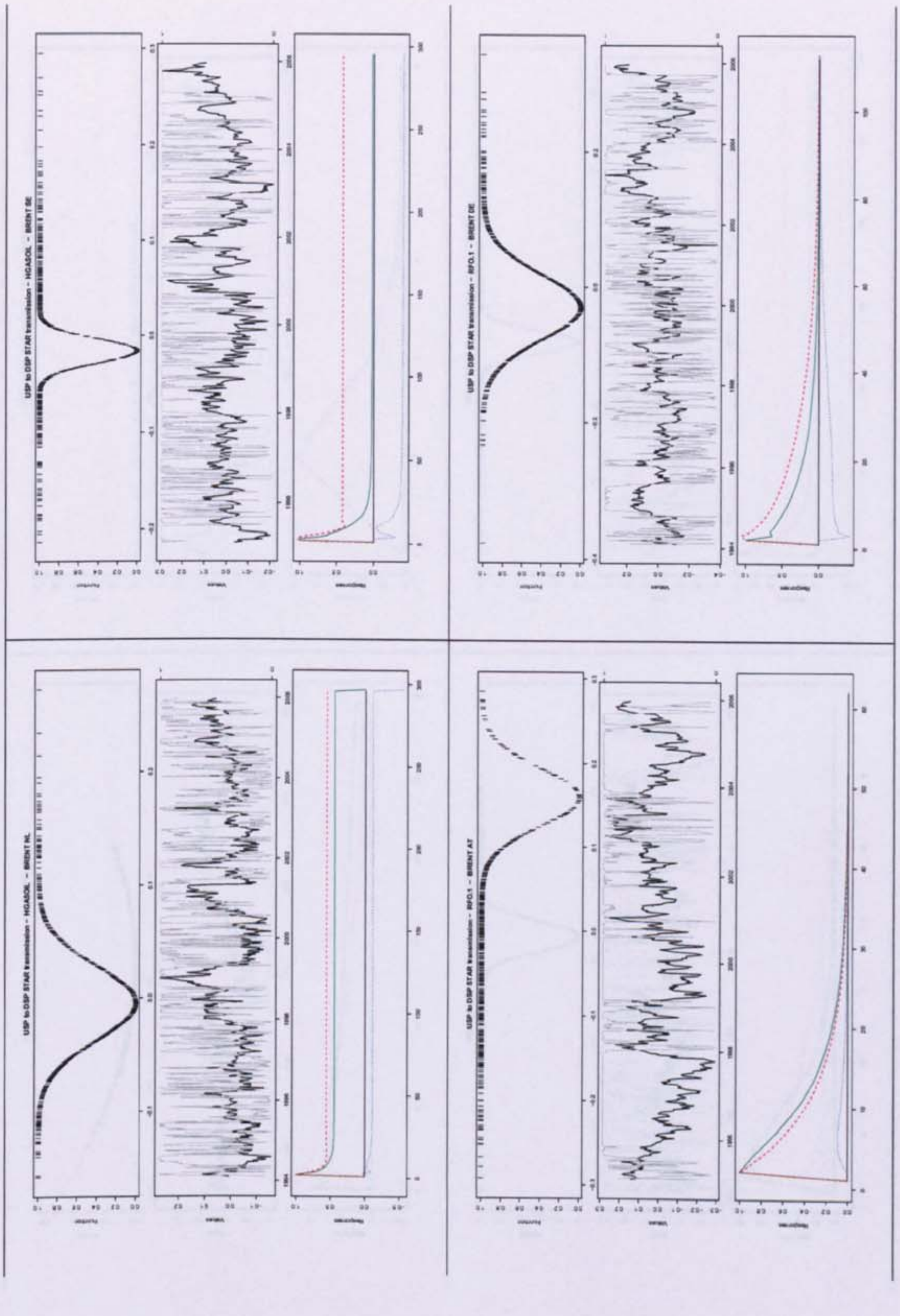

USP to DSP STAR transmission - DIESEL - BRENT DK
USP to DSP STAR transmission - DIESEL - BRENT BE
USP to DSP STAR transmission - DIESEL - BRENT ES
USP to DSP STAR transmission - DIESEL - BRENT EE

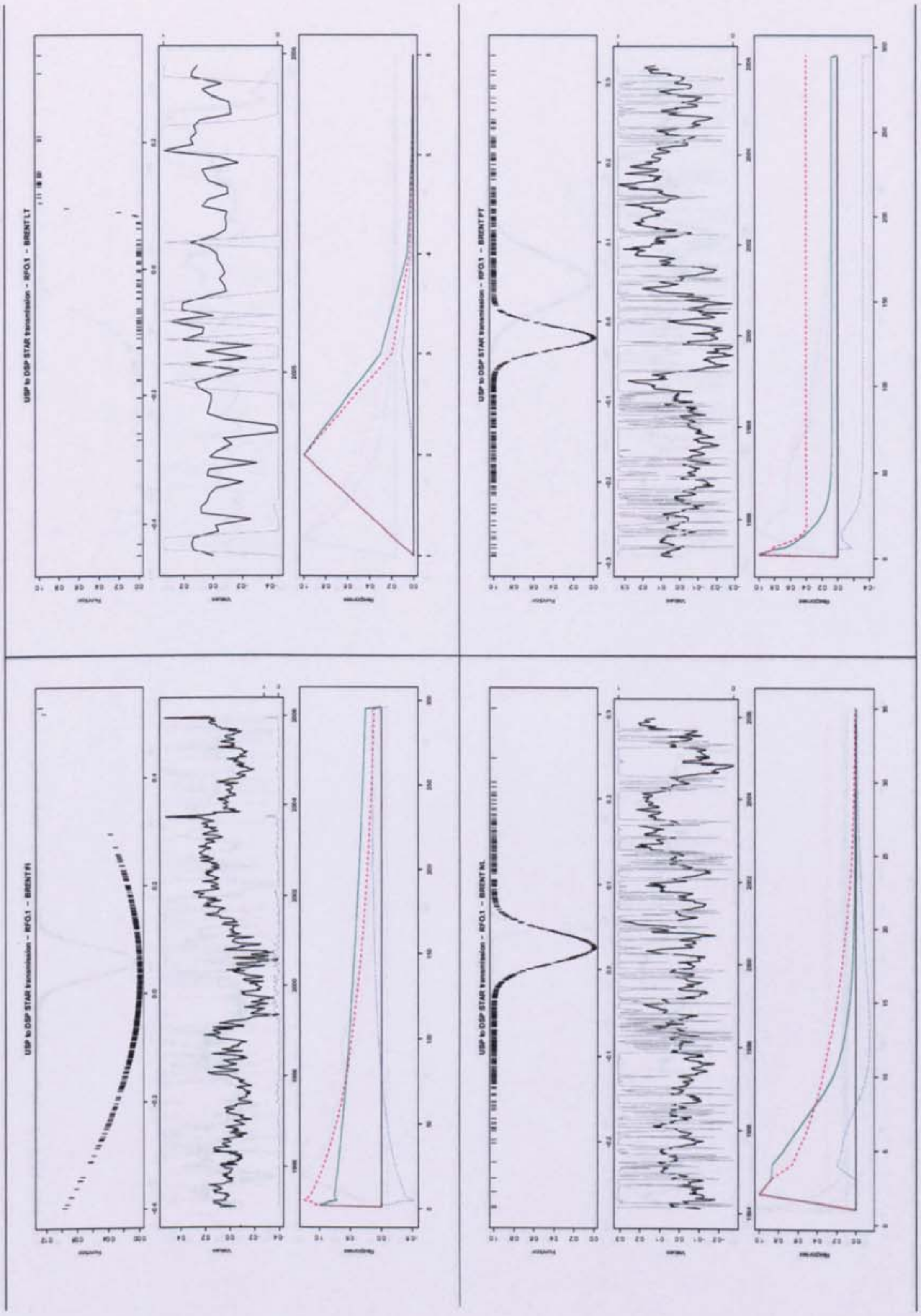

USP to DSP STAR transmission - DIESEL - BRENT FR
USP to DSP STAR transmission - DIESEL - BRENT IE
USP to DSP STAR transmission - DIESEL - BRENT FI
USP to DSP STAR transmission - DIESEL - BRENT GR

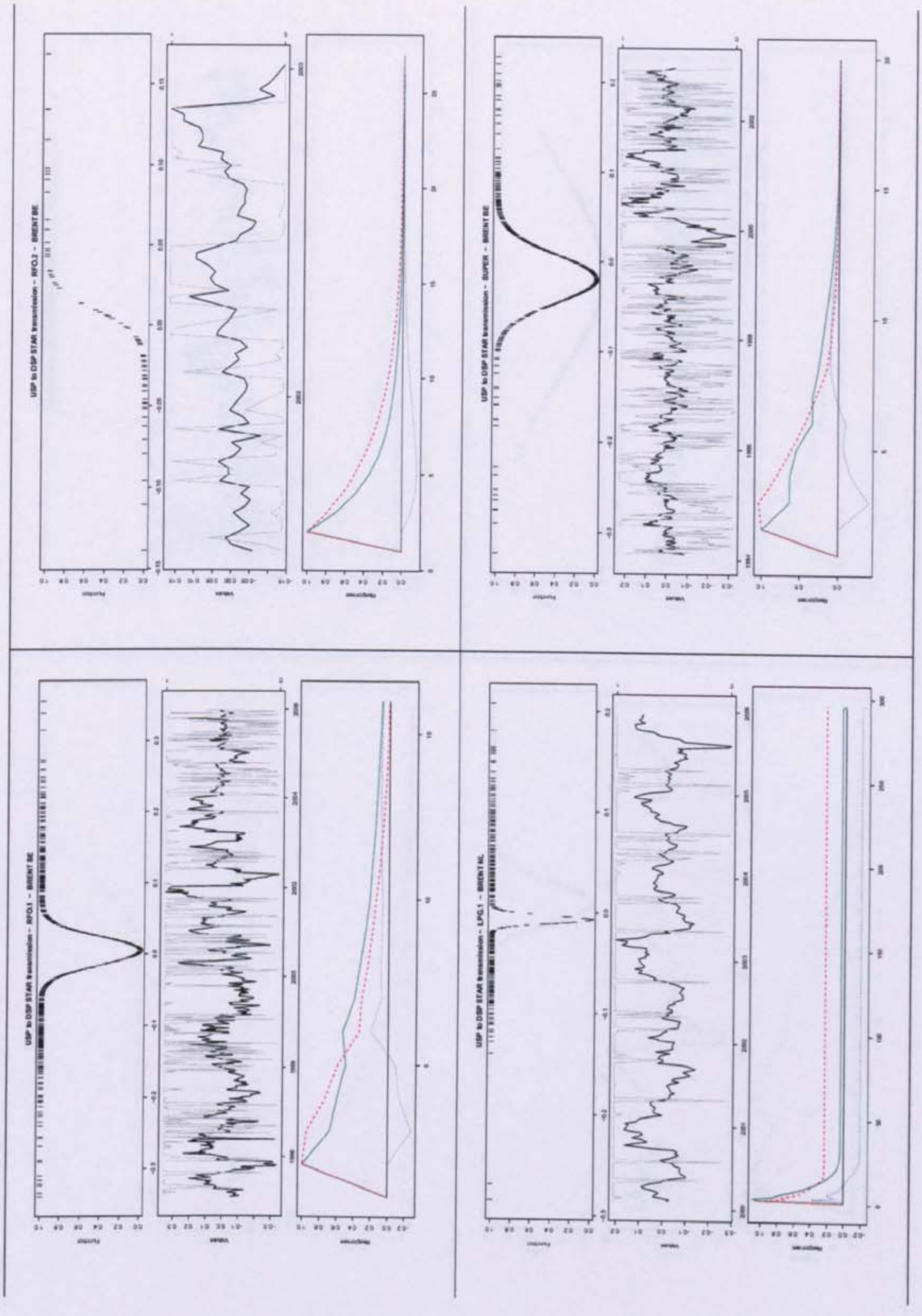

USP to DSP STAR transmission - DIESEL - BRENT NL
USP to DSP STAR transmission - DIESEL - BRENT LU
USP to DSP STAR transmission - DIESEL - BRENT SE
USP to DSP STAR transmission - DIESEL - BRENT PT

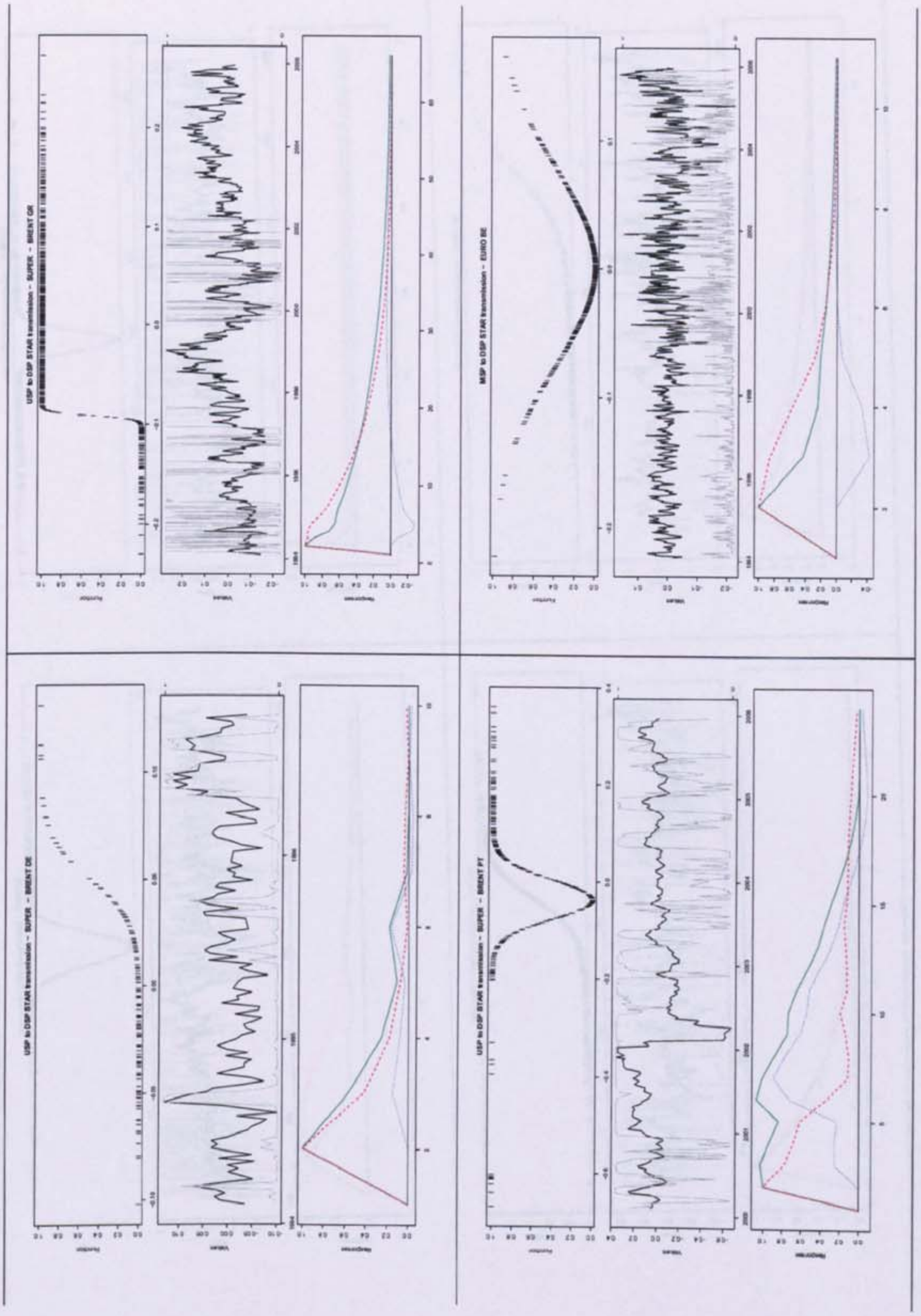

USP to DSP STAR transmission - HGASOIL - BRENT DE
USP to DSP STAR transmission - HGASOIL - BRENT ES
USP to DSP STAR transmission - HGASOIL - BRENT CY
USP to DSP STAR transmission - HGASOIL - BRENT DK

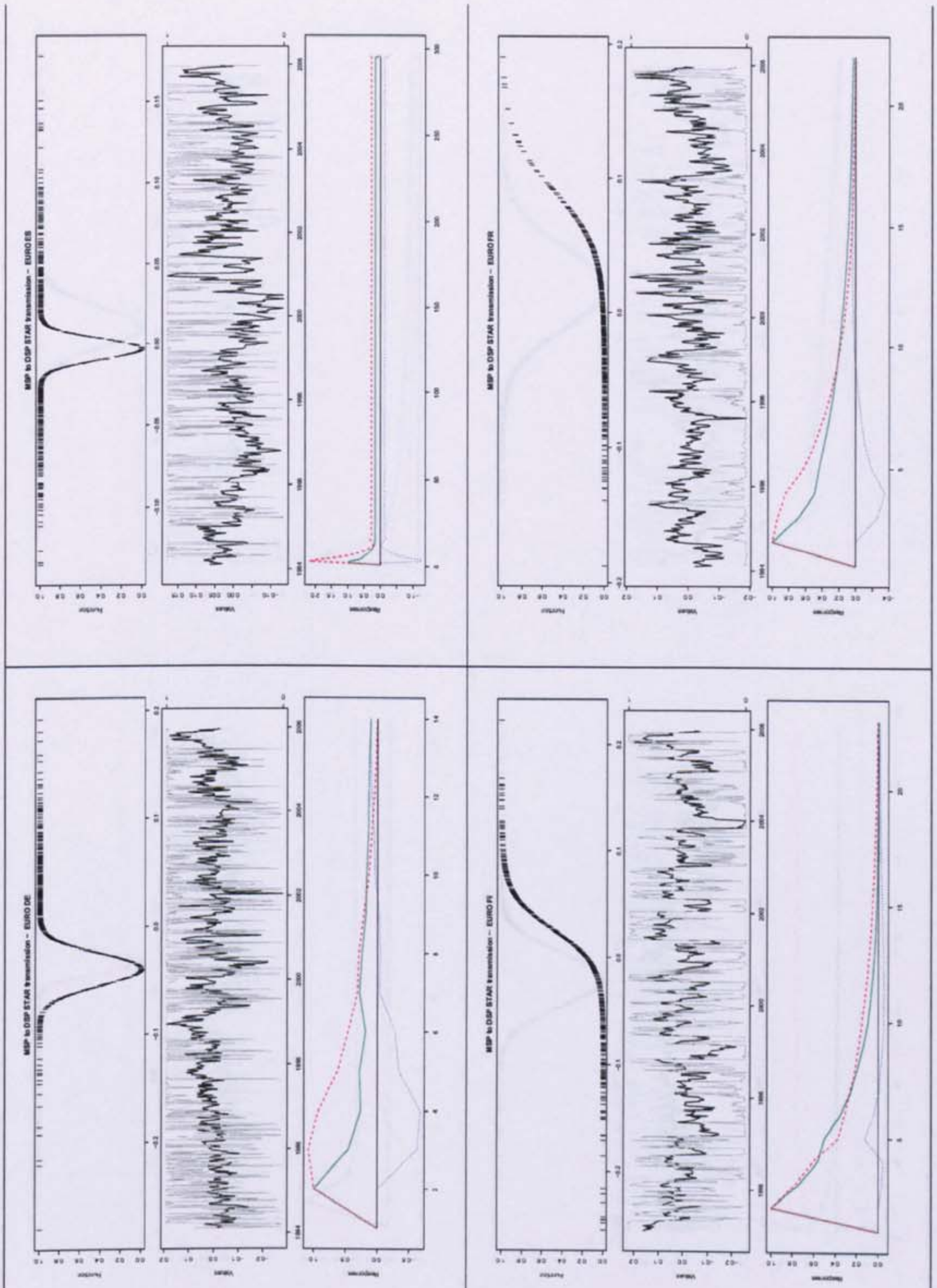

USP to DSP STAR transmission – HGASOIL – BRENT FR
USP to DSP STAR transmission – HGASOIL – BRENT LU
USP to DSP STAR transmission – HGASOIL – BRENT FI
USP to DSP STAR transmission – HGASOIL – BRENT IT

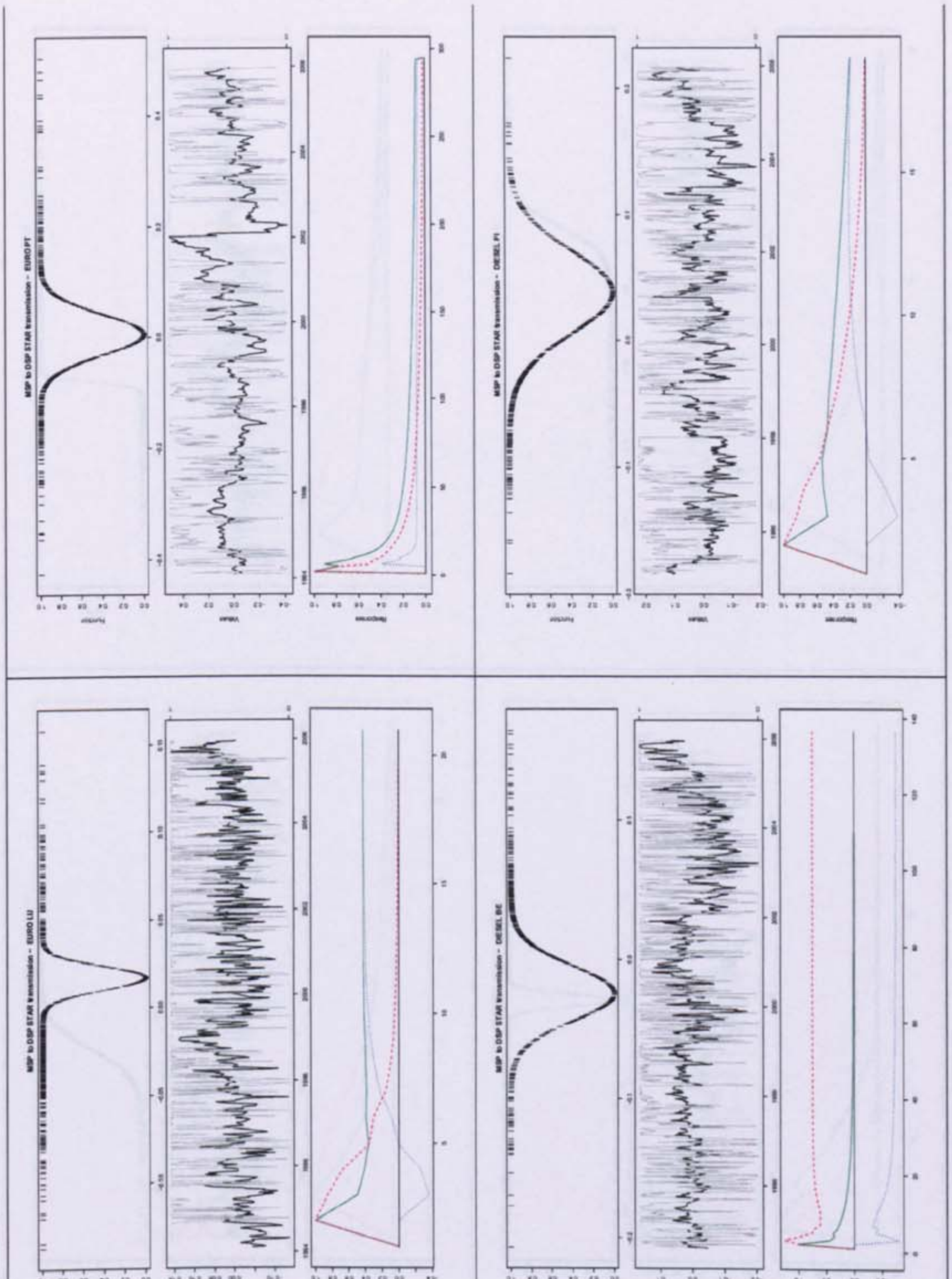


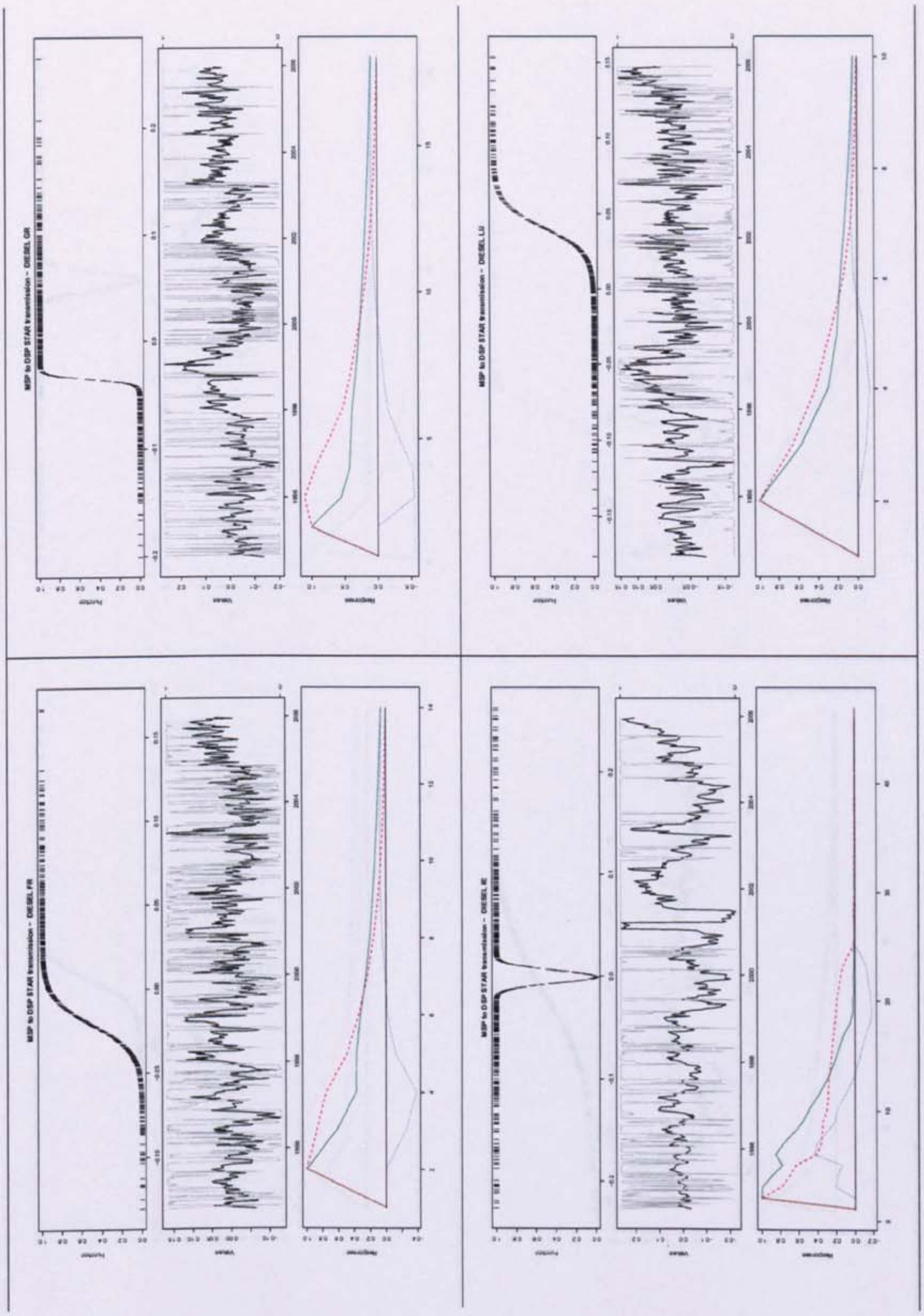

USP to DSP STAR transmission – RFO.1 – BRENT LT
USP to DSP STAR transmission – RFO.1 – BRENT FI
USP to DSP STAR transmission – RFO.1 – BRENT PT
USP to DSP STAR transmission – RFO.1 – BRENT NL

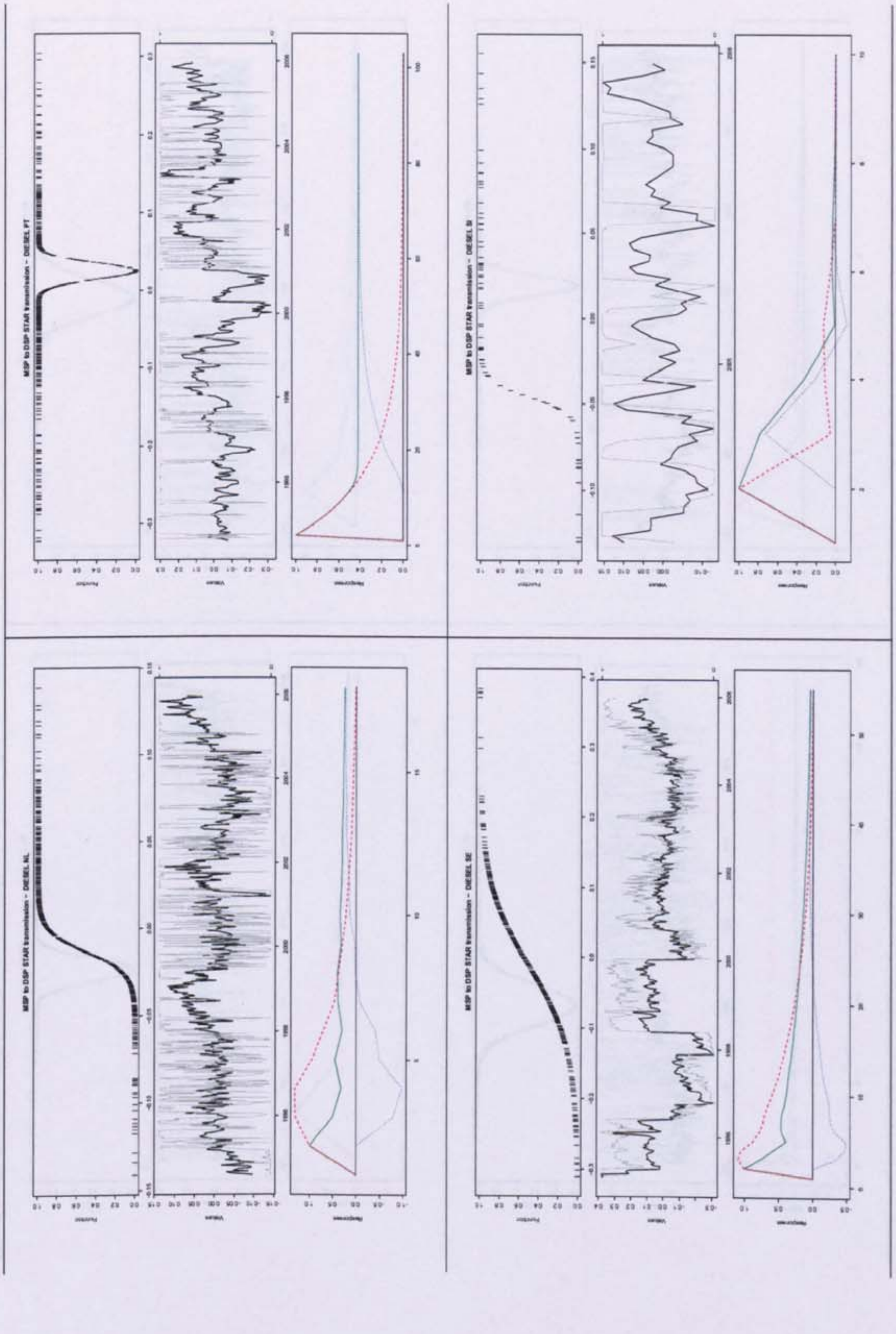

USP to DSP STAR transmission - RFO.2 - BRENT BE
USP to DSP STAR transmission - SUPER - BRENT BE
USP to DSP STAR transmission - RFO.1 - BRENT BE
USP to DSP STAR transmission - LPG.1 - BRENT NL

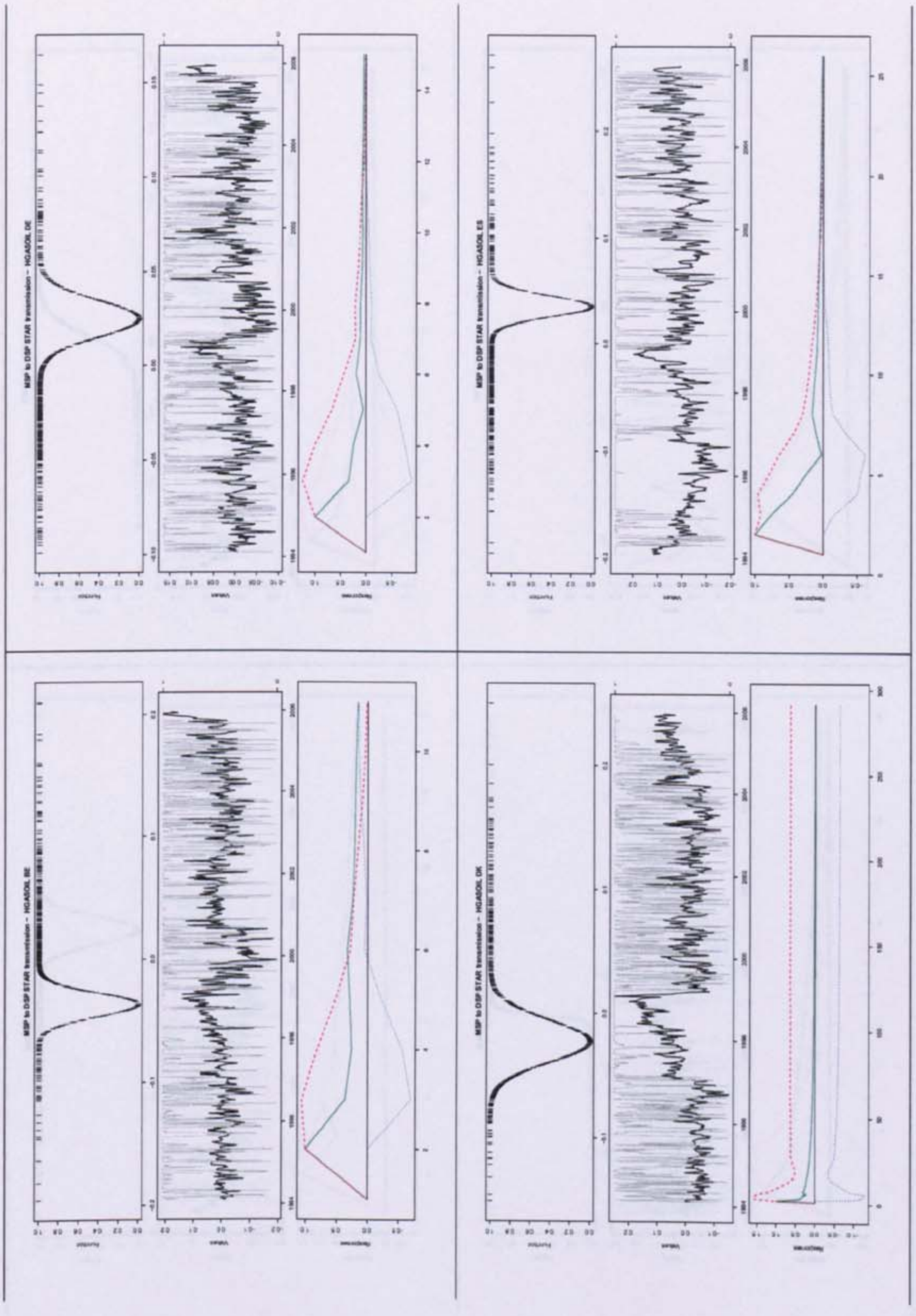

USP to DSP STAR transmission - SUPER - BRENT GR
MSP to DSP STAR transmission - EURO BE
USP to DSP STAR transmission - SUPER - BRENT DE
USP to DSP STAR transmission - SUPER - BRENT PT

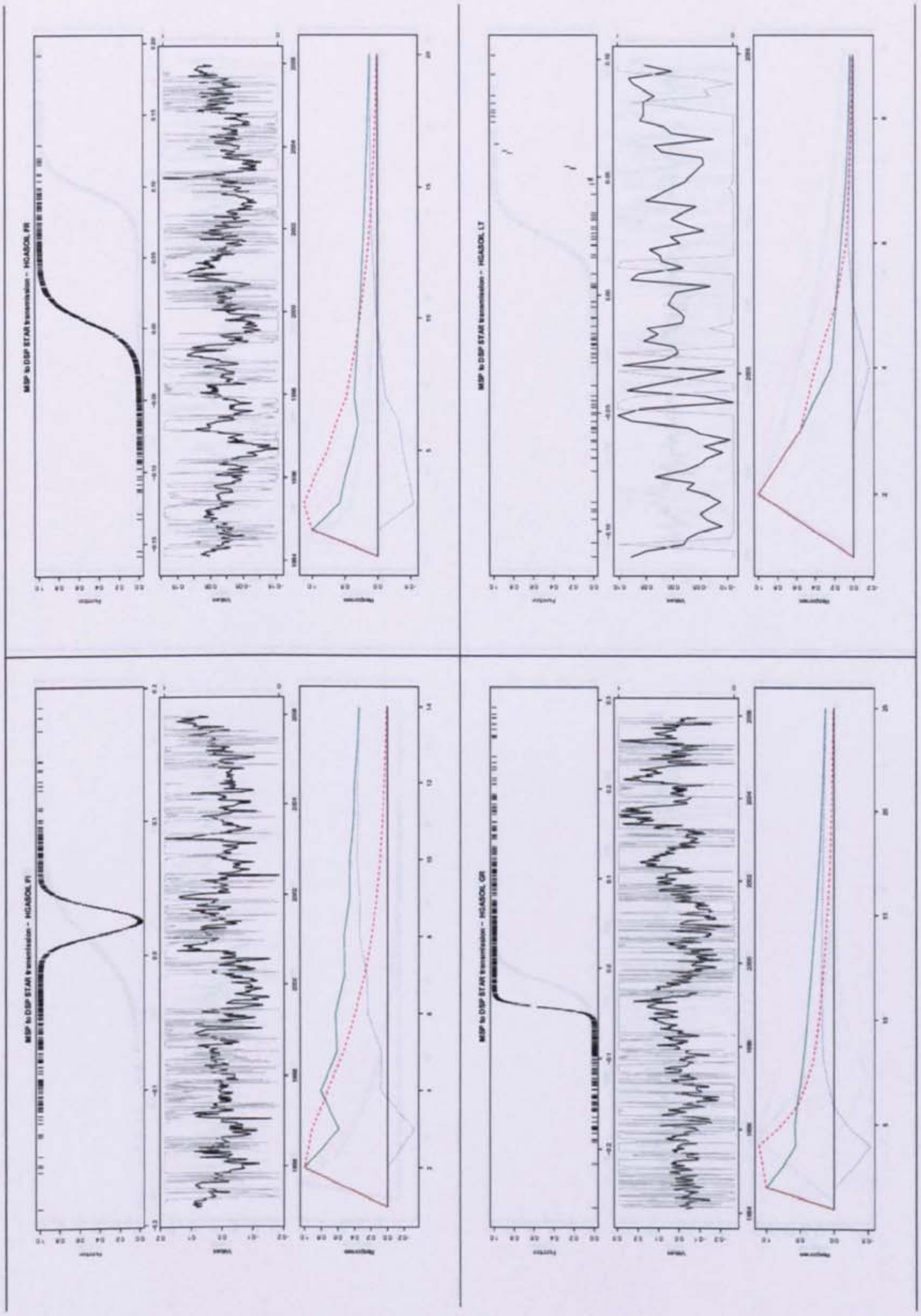

MSP to DSP STAR transmission – EURO ES
MSP to DSP STAR transmission – EURO DE
MSP to DSP STAR transmission – EURO FR
MSP to DSP STAR transmission – EURO FI

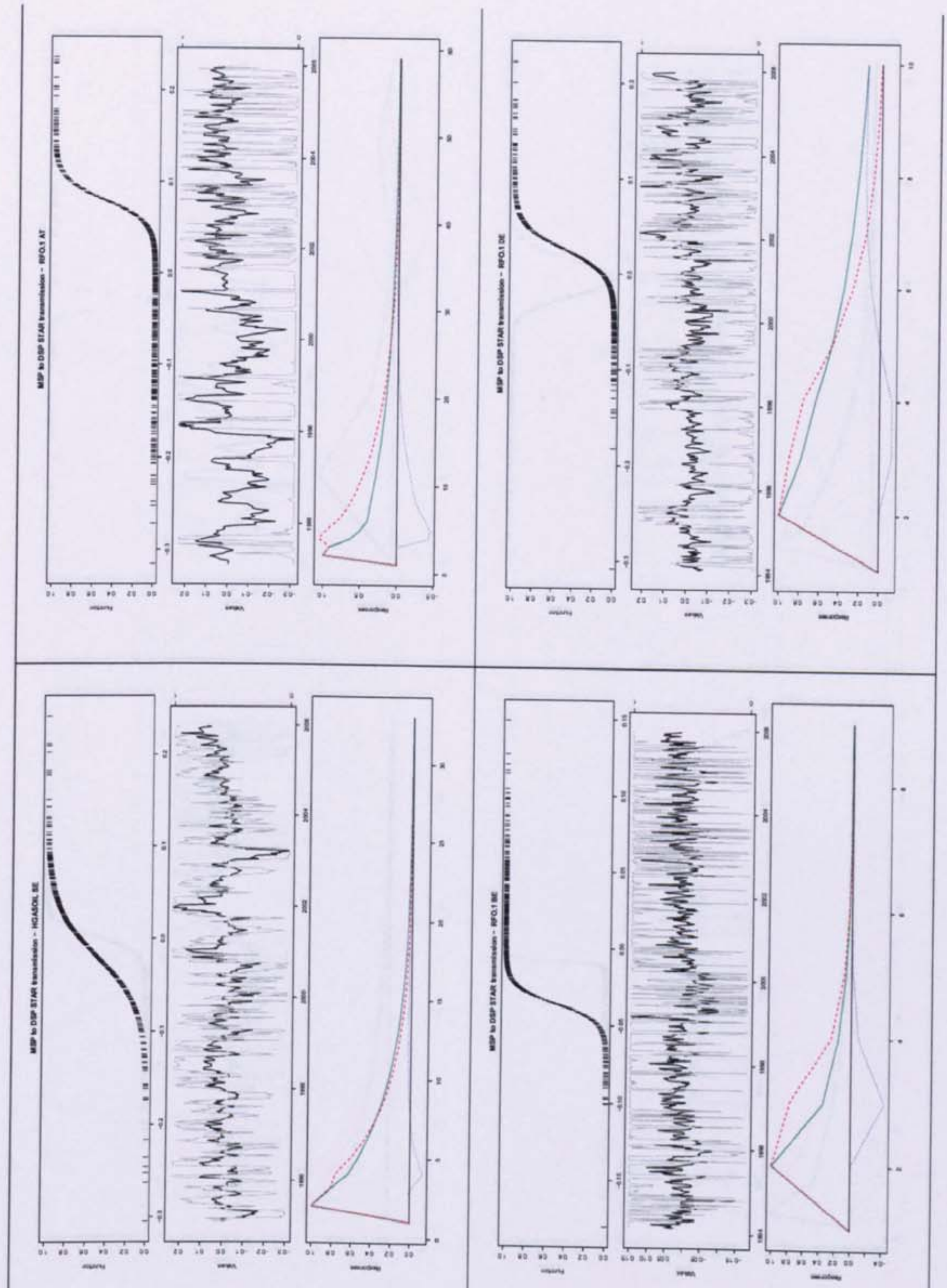

MSP to DSP STAR transmission - EURO PT
MSP to DSP STAR transmission - EURO LU
MSP to DSP STAR transmission - DIESEL FI
MSP to DSP STAR transmission - DIESEL BE

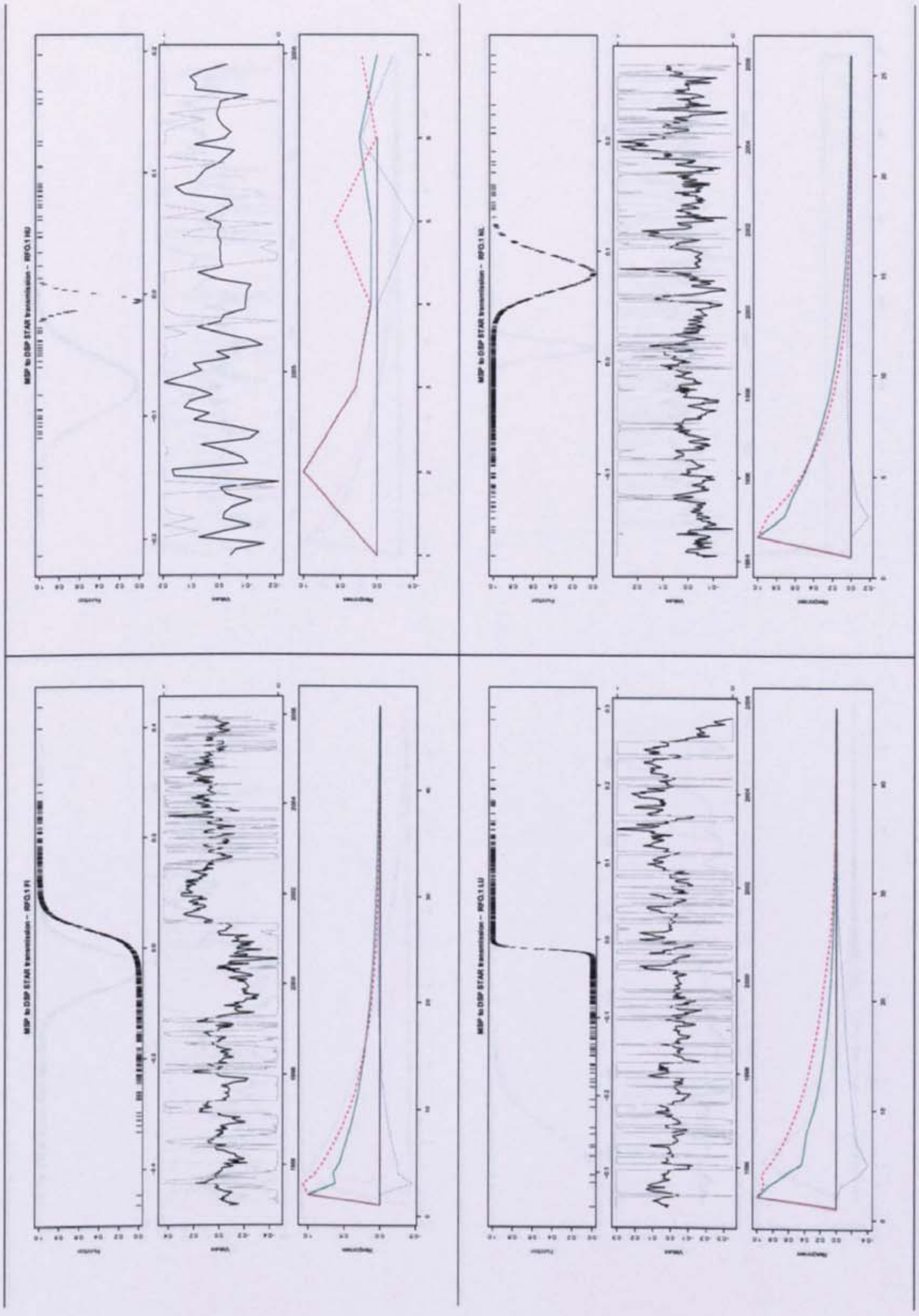

MSP to DSP STAR transmission – DIESEL GR
MSP to DSP STAR transmission – DIESEL FR
MSP to DSP STAR transmission – DIESEL LU
MSP to DSP STAR transmission – DIESEL IE

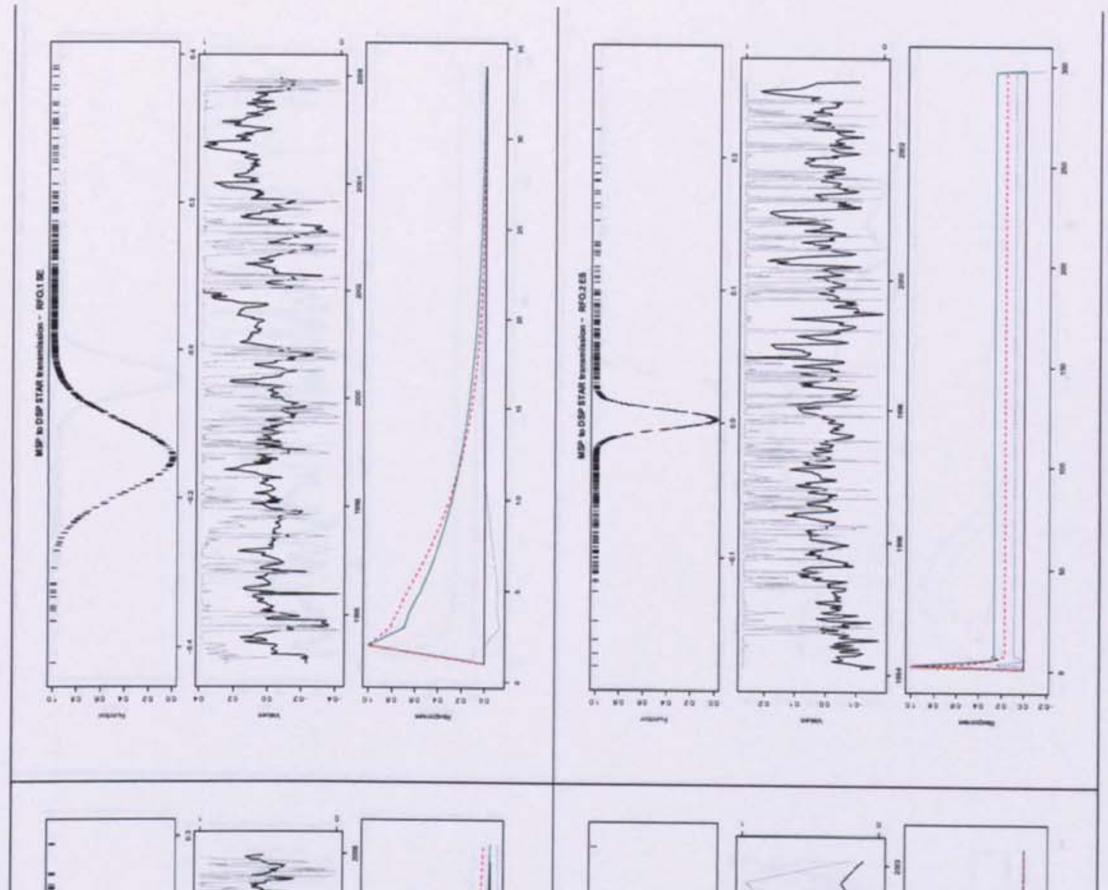

MSP to DSP STAR transmission – DIESEL PT
MSP to DSP STAR transmission – DIESEL NL
MSP to DSP STAR transmission – DIESEL SI
MSP to DSP STAR transmission – DIESEL SE


MSP to DSP STAR transmission – HGASOIL DE
MSP to DSP STAR transmission – HGASOIL ES
MSP to DSP STAR transmission – HGASOIL BE
MSP to DSP STAR transmission – HGASOIL DK

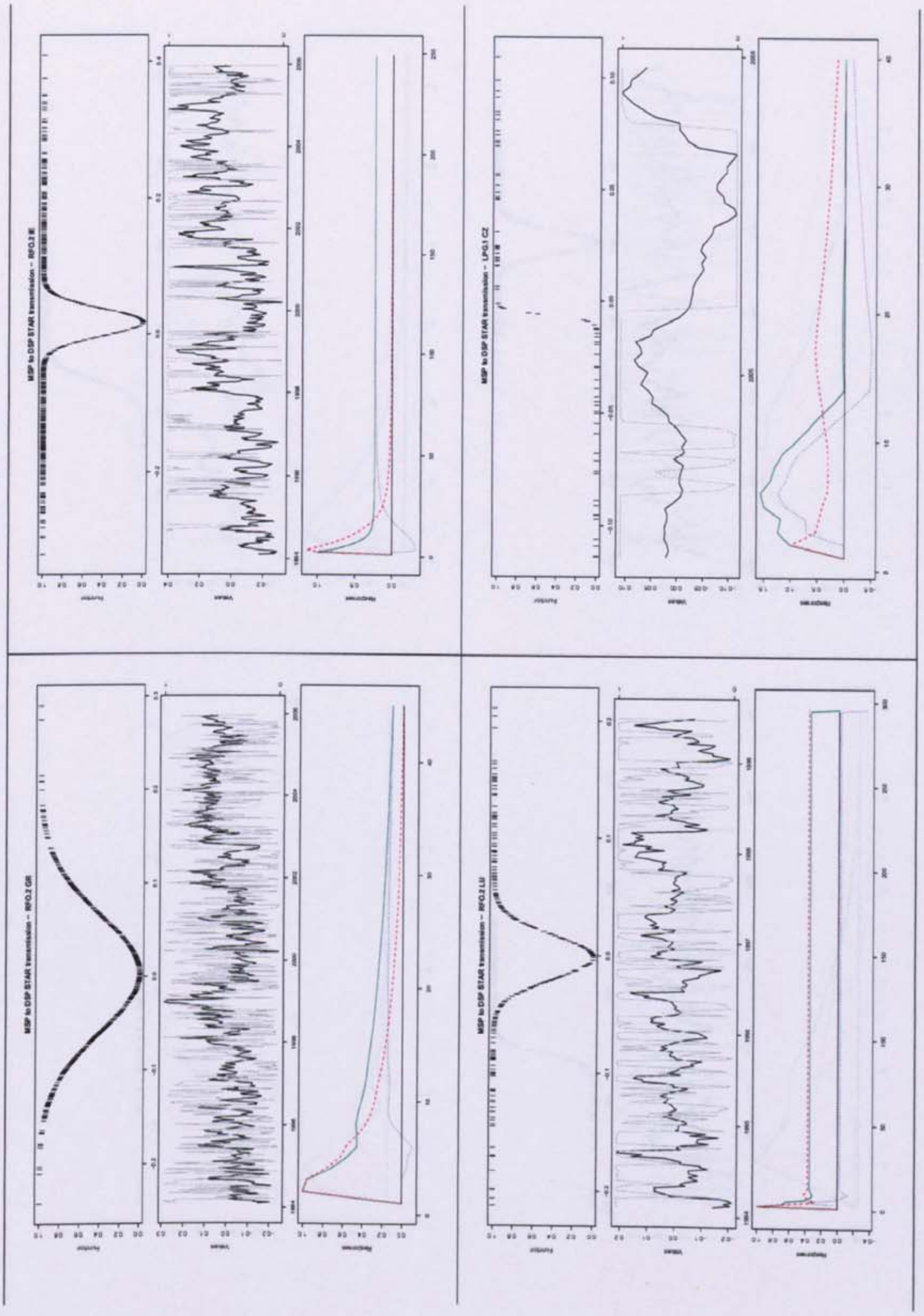

MSP to DSP STAR transmission - HGASOL FR
MSP to DSP STAR transmission - HGASOL FI
MSP to DSP STAR transmission - HGASOL LT
MSP to DSP STAR transmission - HGASOL GR

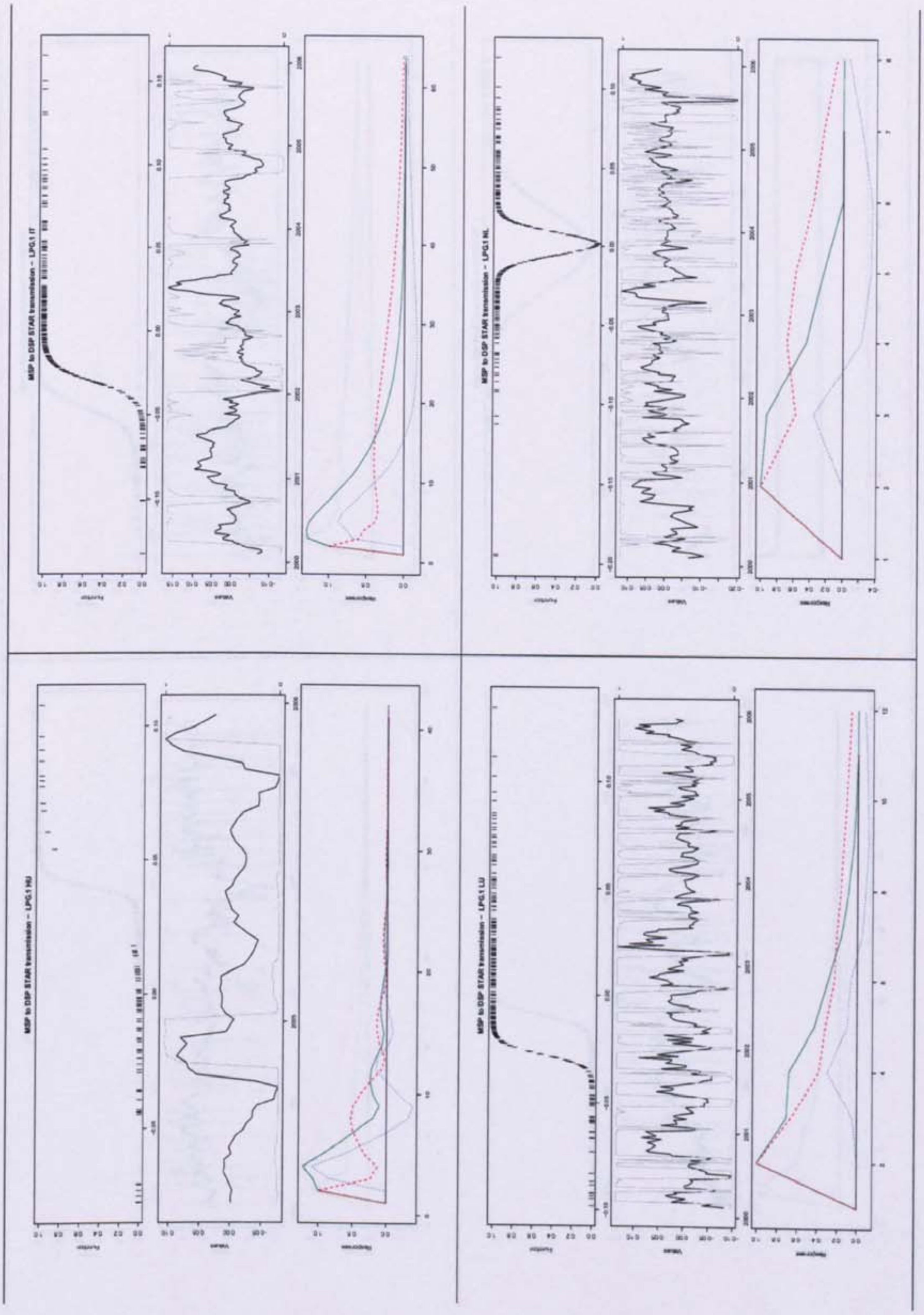

MSP to DSP STAR transmission - RFO.1 AT
MSP to DSP STAR transmission - HGASOIL SE
MSP to DSP STAR transmission - RFO.1 DE
MSP to DSP STAR transmission - RFO.1 SE

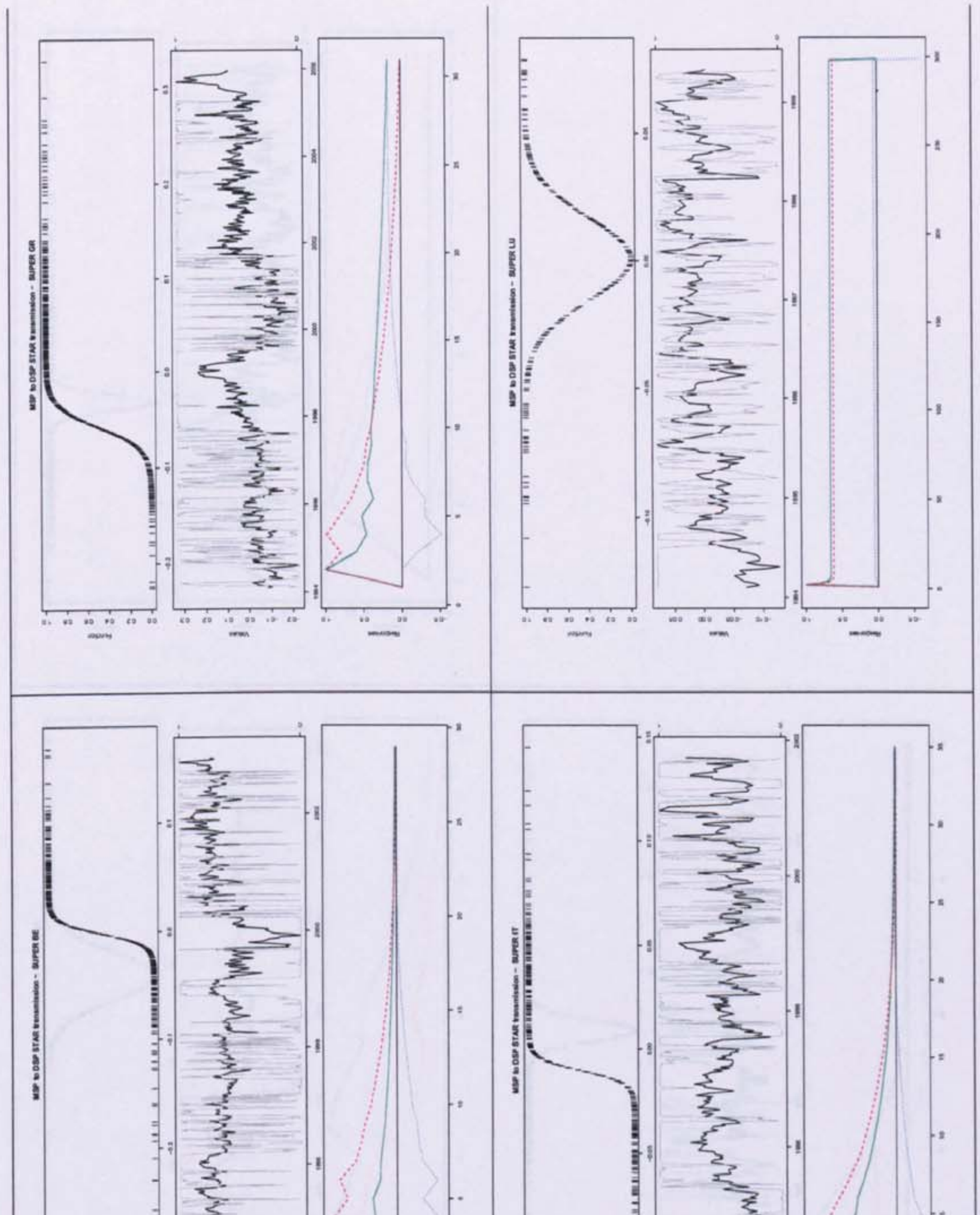

MSP to DSP STAR transmission – RFO.1 HU
MSP to DSP STAR transmission – RFO.1 NL
MSP to DSP STAR transmission – RFO.1 FI
MSP to DSP STAR transmission – RFO.1 LU

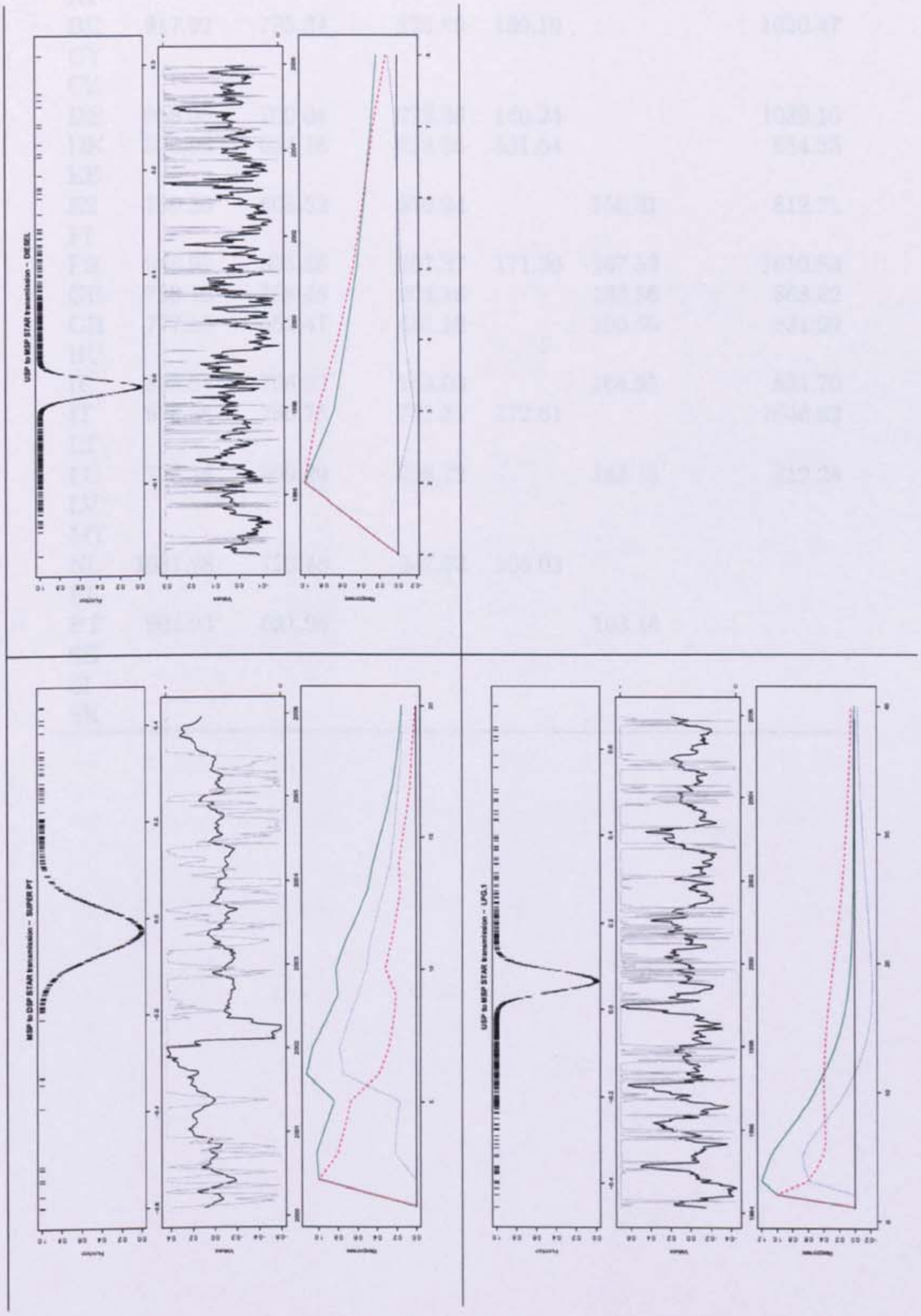


MSP to DSP STAR transmission ~ RFO.1 BE
MSP to DSP STAR transmission ~ RFO.1 PT
MSP to DSP STAR transmission ~ RFO.2 ES
MSP to DSP STAR transmission ~ RFO.2 BE


MSP to DSP STAR transmission – RFO.2 IE
MSP to DSP STAR transmission – RFO.2 GR
MSP to DSP STAR transmission – LPG.1 CZ
MSP to DSP STAR transmission – RFO.2 LU


MSP to DSP STAR transmission – LPG.1 IT
MSP to DSP STAR transmission – LPG.1 HU
MSP to DSP STAR transmission – LPG.1 NL
MSP to DSP STAR transmission – LPG.1 LU


MSP to DSP STAR transmission - SUPER GR
MSP to DSP STAR transmission - SUPER BE
MSP to DSP STAR transmission - SUPER LU
MSP to DSP STAR transmission - SUPER IT



USP to MSP STAR transmission – DIESEL
MSP to DSP STAR transmission – SUPER PT
USP to MSP STAR transmission – LPG.1

Table A.73: 1994 Average Prices

	ULP	DIESEL	HGASOIL	RFO.1	RFO.2	LPG	LP
AT	-						
BE	917.92	735.34	223.69	139.10			1020.47
CY							
CZ							
DE	958.03	700.04	272.30	140.24			1039.16
DK	835.99	697.18	629.56	531.64			854.85
EE							
ES	789.36	608.52	316.94		156.31		812.71
FI							
FR	948.97	695.26	367.37	171.36	167.59		1010.83
GB	788.10	788.48	204.16		138.86		868.82
GR	777.15	552.47	431.10		190.65		831.99
HU							
IE	835.34	796.23	263.03		164.35		891.70
IT	976.88	766.75	761.31	172.61			1046.62
LT							
LU	716.38	599.29	238.72		143.15		812.28
LV							
MT							
NL	1031.28	723.48	347.62	205.03			
PL							
PT	904.93	621.96			163.14		
SE							
SI							
SK							

Table A.74: 1995 Average Prices

	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	1086.18	868.14	422.46	201.43			
BE	1040.21	818.49	236.42	157.54			1153.84
CY							
CZ							
DE	1079.57	781.43	295.12	164.83			1178.08
DK	1032.79	821.34	701.18	599.24			1063.01
EE							
ES	856.46	658.78	322.15	204.53	182.84		904.99
FI	1111.03	808.82	324.45	256.19			
FR	1124.68	770.23	399.64	194.19	190.34		1169.76
GB	849.54	854.40	218.10		164.52		941.37
GR	822.61	605.04	482.21	230.60	217.71		882.56
HU							
IE	901.22	857.51	288.35		205.96		970.35
IT	1050.99	824.69	796.65	184.45	191.25		1123.93
LT							
LU	842.01	679.32	258.71	169.10	171.87		951.50
LV							
MT							
NL	1175.72	818.89	388.47	239.75			
PL							
PT	1026.33	696.41		196.12	179.42		
SE	1058.07	965.60	542.62	486.63			
SI							
SK							

Table A.75: 1996 Average Prices

	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	1078.53	862.88	450.24	203.38			
BE	1109.92	836.41	277.19	169.66			1204.04
CY							
CZ							
DE	1068.64	802.41	331.68	168.54			1165.87
DK	1089.69	827.36	735.40	599.47			
EE							
ES	878.42	711.56	357.04	225.67	198.55		927.72
FI	1186.51	816.03	347.74	266.95			
FR	1165.46	836.77	427.92	206.67	200.75		1213.80
GB	876.47	891.13	254.97		173.93		951.23
GR	854.06	650.54	533.35	251.62	228.40		916.09
HU							
IE	945.75	925.77	344.80		211.12		1017.93
IT	1162.18	925.77	891.57	204.60	210.76		1223.96
LT							
LU	839.33	698.77	285.78	172.02	175.03		943.40
LV							
MT							
NL	1180.10	849.41	441.36	252.45			
PL							
PT	1025.29	721.86		203.90	187.71		
SE	1177.55	968.96	629.14	541.79			
SI							
SK							

Table A.76: 1997 Average Prices

	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	973.20	774.60	357.24	173.41			
BE	1037.60	744.93	254.30	152.74			1122.54
CY							
CZ							
DE	962.25	716.80	296.91	151.29			
DK	987.61	770.89	671.85	541.20			
EE							
ES	793.01	638.22	332.64	201.25	177.99		823.54
FI	1066.16	732.71	340.92	238.50			
FR	1059.79	762.49	396.35	179.39	175.41		1103.83
GB	1010.69	1019.81	254.78		171.46		1097.86
GR	784.67	590.13	485.56	227.74	209.27		838.85
HU							
IE	915.87	879.62	310.89		198.09		1011.26
IT	1074.35	848.61	827.67	179.45	187.48		1127.55
LT							
LU	758.33	626.90	263.32	154.90	156.95		851.59
LV							
MT							
NL	1089.79	770.88	407.56	218.15			
PL							
PT	931.41	658.80		201.04	186.80		
SE	1083.32	875.71	577.12	498.50			
SI							
SK							

Table A.77: 1998 Average Prices

	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	902.81	704.08	301.49	162.08			
BE	964.88	669.61	198.37	121.48			1049.71
CY							
CZ							
DE	904.29	651.49	239.41	128.35			
DK	934.09	699.44	630.01	528.19			
EE							
ES	741.90	591.01	283.88	174.26	146.82		782.00
FI	1043.06	713.15	289.43	210.60			
FR	1022.28	715.18	335.22	146.31	141.80		1066.07
GB	1077.41	1088.58	204.52		151.67		1182.20
GR	699.07	510.56	380.95	189.97	173.56		749.61
HU							
IE	836.96	787.16	258.19		172.01		976.85
IT	1014.60	792.48	776.97	150.13	165.62		1072.46
LT							
LU	705.28	568.22	211.55	128.71	127.72		796.37
LV							
MT							
NL	1063.32	722.32	374.08	190.47			
PL							
PT	893.85	618.34		175.59	161.95		
SE	1021.30	793.32	517.15	463.04			
SI							
SK							

Table A.78: 1999 Average Prices

	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	866.87	676.71	313.74	163.92			
BE	959.90	670.87	213.05	135.88			1031.12
CY							
CZ							
DE	921.16	675.63	275.82	141.86			
DK	1002.69	729.42	629.15	559.53			
EE							
ES	744.50	600.52	303.40	193.24	165.99		787.41
FI	1049.10	717.87	301.42	220.57			
FR	1013.44	728.68	344.97	164.25	151.95		1063.30
GB	1129.09	1148.05	217.13		175.14		1223.67
GR	691.61	556.74	373.35	208.08	198.68		743.69
HU							
IE	801.32	747.67	266.88		186.95		951.03
IT	1017.56	806.32	781.20	172.77	199.59		1064.73
LT							
LU	733.71	575.34	224.14	141.91	120.33		786.09
LV							
MT							
NL	1071.66	736.05	415.71	204.69			
PL							
PT	860.16	589.42		183.08	169.28		
SE	1012.69	801.98	518.01	466.29			
SI							
SK							

Table A.79: 2000 Average Prices

	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	870.22	716.01	410.28	209.39			
BE	964.70	726.06	316.71	196.58		360.16	1009.91
CY							
CZ							
DE	941.53	740.01	373.32	195.54			
DK	1016.43	780.84	690.99	587.94			
EE							
ES	755.83	638.82	388.27	261.64	216.85	377.08	806.12
FI	1046.51	773.10	386.84	279.44			
FR	1010.96	779.81	425.61	232.05	213.67	480.30	1081.10
GB	1217.08	1238.32	316.50		223.27		
GR	717.52	617.54	458.78	272.11	243.52		758.05
HU							
IE	818.77	757.59	412.43		243.95		951.33
IT	998.92	821.13	790.19	232.42	242.36	500.15	1040.51
LT							
LU	764.61	632.89	316.82	198.99		357.28	
LV							
MT							
NL	1072.01	777.92	513.81	254.22		417.48	1143.48
PL							
PT	800.32	558.10		256.68	244.71		837.22
SE	1032.19	816.69	589.59	548.92			
SI							
SK							

Table A.80: 2001 Average Prices

	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	809.53	669.39	371.60	196.19			
BE	901.98	676.11	293.48	170.25	169.54	321.22	961.85
CY							
CZ							
DE	920.45	738.77	341.60	171.24			
DK	975.69	767.68	641.53	546.54			
EE							
ES	722.58	620.61	350.25	230.80	187.63	375.96	773.68
FI	995.60	734.82	363.31	292.01			
FR	926.67	714.39	353.91	203.28	186.53	455.89	1003.18
GB	1090.12	1123.28	281.74		206.52		
GR	673.65	568.71	420.11	248.80	221.18		705.75
HU							
IE	765.08	661.06	397.74		233.25		994.21
IT	942.01	777.23	733.92	198.57	218.41	483.83	994.09
LT							
LU	711.89	588.70	284.83	174.49		317.76	
LV							
MT							
NL	1027.16	734.18	542.28	233.94		388.95	1100.79
PL							
PT	817.35	580.63		272.02	258.36		853.08
SE	907.88	752.75	579.18	575.13			
SI							
SK							

Table A.81: 2002 Average Prices

	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	826.02	678.79	361.37	213.98			
BE	926.23	685.51	273.48	186.06	195.65	327.32	990.72
CY							
CZ							
DE	990.36	793.61	333.13	194.26			
DK	1032.90	783.18	660.64	600.30			
EE							
ES	768.09	650.13	349.12	258.42	213.74	382.36	823.40
FI	1019.31	741.28	344.10	328.48			
FR	958.68	728.85	344.43	226.67	211.54	469.35	1034.63
GB	1101.93	1134.78	269.23	264.28	231.03		
GR	695.92	586.10	441.82	248.66	230.31		741.22
HU							
IE	838.61	759.01	406.27		280.30		
IT	989.43	807.97	787.23	220.23	243.91	491.22	
LT							
LU	730.98	597.51	277.78	190.59		329.93	
LV							
MT							
NL	1078.59	743.46	547.61	247.83		405.86	1154.70
PL							
PT	868.84	637.88		293.48	279.25	437.98	913.00
SE	950.55	781.25	627.90	598.03			
SI							
SK							

Table A.82: 2003 Average Prices

	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	993.74	820.83	444.64	268.65			
BE	1115.49	818.59	336.56	234.02	214.82	397.22	
CY							
CZ							
DE	1231.68	993.80	411.31	241.97			
DK	1234.24	918.38	804.03	718.36			
EE							
ES	920.43	782.95	436.76	312.74	226.97	491.55	998.70
FI	1235.12	906.96	438.52	398.38			
FR	1147.22	895.23	439.54	271.98	249.68	606.19	1237.42
GB	1241.13	1270.65	337.69	305.96			
GR	833.08	718.22	551.49	310.80	282.10		887.89
HU							
IE	982.73	906.37	510.53		338.41		
IT	1194.02	989.86	959.03	287.36	282.45	608.79	
LT							
LU	876.21	720.67	345.01	241.66		412.11	
LV							
MT							
NL	1308.68	897.07	677.34	315.19		488.58	1399.06
PL							
PT	1082.04	801.91	487.93	326.46	281.10	531.00	1145.85
SE	1150.60	943.55	792.43	781.60			
SI							
SK							

Table A.83: 2004 Average Prices

	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	1174.97	1003.32	591.38	318.31			
BE	1335.20	1020.57	448.94	233.78		477.70	
CY	989.52	914.00	879.94		395.14		
CZ	1080.46	1007.07		241.30	224.28	549.97	1061.19
DE	1414.06	1168.40	512.88	243.17		645.93	
DK	1382.98	1096.73	993.83	785.08			
EE	890.55	850.52	480.41			511.76	
ES	1078.63	936.21	537.99	317.89		576.69	1166.35
FI	1412.02	1042.18	547.60	431.17			
FR	1317.28	1096.17	557.55	277.58	258.56	700.72	1417.93
GB	1469.74	1498.46	442.57	329.79			
GR	987.65	890.09	680.39	323.90	293.32		1058.49
HU	1242.45	1143.46	1143.46	311.93		726.40	
IE	1180.13	1092.45	628.03		378.63		
IT	1397.29	1165.29	1127.50	316.86		669.09	
LT	968.93	896.82	458.08	290.59	214.17	479.35	
LU	1122.21	865.60	449.32	236.11		484.56	
LV	899.46	844.84	546.37			480.23	915.22
MT	1096.61	910.93	305.44				1184.01
NL	1552.07	1101.54	825.26	333.33		575.35	1651.92
PL	1082.96	929.15	513.98	259.21	229.01	516.35	
PT	1282.41	976.31	602.50	332.42		621.16	1356.31
SE	1347.91	1122.01	1031.07	950.74			
SI	1060.75	974.20	574.17	388.03		600.60	
SK	1122.27	1092.09	436.29	280.58	273.15	578.65	

Table A.84: 2005 Average Prices

	ULP	DIESEL	GASOIL	RFO.1	RFO.2	LPG	LP
AT	1284.42	1178.03	755.42	423.10			
BE	1519.09	1233.00	627.86	336.25		535.89	
CY	1068.01	1038.18	898.27		469.63		
CZ	1183.94	1160.10	1129.59	287.14	245.15	592.13	1164.92
DE	1518.20	1323.35	679.28	330.18		663.39	
DK	1505.66	1273.66	1189.91	919.75			
EE	990.40	998.06	617.16			557.62	
ES	1186.32	1109.00	687.07	430.88		676.20	1291.35
FI	1512.24	1206.19	715.81	580.48			
FR	1445.93	1272.83	723.44	385.53	360.85	798.71	1577.99
GB	1576.82	1650.37	601.17	468.05			
GR	1091.42	1084.35	857.33	419.19	384.13		1167.20
HU	1306.30	1267.41	1267.41	410.64		749.14	
IE	1302.59	1282.01	782.48		472.39		
IT	1518.15	1377.53	1303.20	419.62		708.46	
LT	1029.78	1023.16	593.66	369.88	279.47	523.03	
LU	1272.68	1046.18	597.55	242.48		533.32	
LV	1014.35	1002.29	690.17			535.03	1051.10
MT	1137.60	1091.47	506.23				1227.87
NL	1682.77	1272.26	1010.66	422.42		631.51	1781.63
PL	1238.45	1142.21	678.35	360.22	309.02	575.85	
PT	1422.49	1161.86	758.44	429.19		684.86	1495.14
SE	1470.66	1342.94	1186.35	1069.04			
SI	1144.45	1130.90	698.25	455.00		633.51	
SK	1195.60	1209.18	635.15	305.09	297.40	639.75	

Table A.85: Results of the Cross-Country Analysis - USP to DSP Transmission

Variable	Coefficient	Standard Error	t-Value	$Pr(\geq \|t\|)$
$\Delta y^{(AT;ULP)} = f(\Delta ex_t^{(AT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(AT;ULP)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(IT)}) \| AT < DE < IT$				
$\epsilon_{t-1}^{(AT)}$	−0.088	0.018	−4.919	0.000
$\epsilon_{t-1}^{(DE)}$	0.072	0.018	4.003	0.000
$\epsilon_{t-1}^{(IT)}$	−0.044	0.024	−1.834	0.067
$\Delta y^{(BE;ULP)} = f(\Delta ex_t^{(BE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(BE;ULP)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| LU < BE < DE < FR < NL$				
$\epsilon_{t-1}^{(BE)}$	−0.488	0.041	−11.954	0.000
$\epsilon_{t-1}^{(DE)}$	−0.024	0.035	−0.679	0.498
$\epsilon_{t-1}^{(FR)}$	0.077	0.050	1.551	0.121
$\epsilon_{t-1}^{(LU)}$	−0.022	0.061	−0.364	0.716
$\epsilon_{t-1}^{(NL)}$	0.298	0.058	5.135	0.000
$\Delta y^{(DE;ULP)} = f(\Delta ex_t^{(DE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(DE;ULP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DK)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| LU < BE < DE < DK < FR < NL$				
$\epsilon_{t-1}^{(DE)}$	−0.361	0.033	−11.054	0.000
$\epsilon_{t-1}^{(BE)}$	0.063	0.042	1.508	0.132
$\epsilon_{t-1}^{(DK)}$	−0.015	0.042	−0.352	0.725
$\epsilon_{t-1}^{(FR)}$	−0.119	0.048	−2.466	0.014
$\epsilon_{t-1}^{(LU)}$	0.076	0.059	1.280	0.201
$\epsilon_{t-1}^{(NL)}$	0.316	0.057	5.575	0.000
$\Delta y^{(DK;ULP)} = f(\Delta ex_t^{(DK)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(DK;ULP)}; \epsilon_{t-1}^{(DE)}) \| DE < DK$				
$\epsilon_{t-1}^{(DK)}$	−0.201	0.029	−6.975	0.000
$\epsilon_{t-1}^{(DE)}$	0.025	0.023	1.077	0.282
$\Delta y^{(ES;ULP)} = f(\Delta ex_t^{(ES)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(ES;ULP)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(PT)}) \| ES < PT < FR$				
$\epsilon_{t-1}^{(ES)}$	−0.083	0.018	−4.550	0.000

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(FR)}$	0.045	0.017	2.692	0.007
$\epsilon_{t-1}^{(PT)}$	−0.017	0.006	−2.569	0.010
$\Delta y^{(FI;ULP)} = f(\Delta ex_t^{(FI)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(FI;ULP)}; \epsilon_{t-1}^{(SE)}) \| SE < FI$				
$\epsilon_{t-1}^{(FI)}$	−0.222	0.028	−7.875	0.000
$\epsilon_{t-1}^{(SE)}$	0.129	0.037	3.457	0.001
$\Delta y^{(FR;ULP)} = f(\Delta ex_t^{(FR)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(FR,ULP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(ES)}; \epsilon_{t-1}^{(IT)}; \epsilon_{t-1}^{(LU)}) \| LU < ES < BE < DE < FR < IT$				
$\epsilon_{t-1}^{(FR)}$	−0.117	0.026	−4.485	0.000
$\epsilon_{t-1}^{(BE)}$	0.026	0.021	1.267	0.206
$\epsilon_{t-1}^{(DE)}$	0.005	0.018	0.293	0.769
$\epsilon_{t-1}^{(ES)}$	−0.039	0.022	−1.752	0.080
$\epsilon_{t-1}^{(IT)}$	−0.093	0.029	−3.169	0.002
$\epsilon_{t-1}^{(LU)}$	0.124	0.029	4.205	0.000
$\Delta y^{(GB;ULP)} = f(\Delta ex_t^{(GB)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(GB;ULP)}; \epsilon_{t-1}^{(IE)}) \| IE < GB$				
$\epsilon_{t-1}^{(GB)}$	−0.033	0.011	−2.965	0.003
$\epsilon_{t-1}^{(IE)}$	−0.056	0.014	−4.023	0.000
$\Delta y^{(IE;ULP)} = f(\Delta ex_t^{(IE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(IE;ULP)}; \epsilon_{t-1}^{(GB)}) \| IE < GB$				
$\epsilon_{t-1}^{(IE)}$	−0.127	0.016	−7.739	0.000
$\epsilon_{t-1}^{(GB)}$	0.043	0.014	3.168	0.002
$\Delta y^{(IT;ULP)} = f(\Delta ex_t^{(IT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(IT;ULP)}; \epsilon_{t-1}^{(FR)}) \| FR < IT$				
$\epsilon_{t-1}^{(IT)}$	−0.079	0.016	−4.823	0.000
$\epsilon_{t-1}^{(FR)}$	0.038	0.014	2.751	0.006
$\Delta y^{(LU;ULP)} = f(\Delta ex_t^{(LU)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(LU;ULP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}) \| LU < BE < DE < FR$				
$\epsilon_{t-1}^{(LU)}$	−0.127	0.032	−3.921	0.000
$\epsilon_{t-1}^{(BE)}$	0.025	0.029	0.869	0.385
$\epsilon_{t-1}^{(DE)}$	0.028	0.025	1.105	0.270

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Variable	Coefficient	Standard Error	t-Value	$\Pr(\geq \|t\|)$
$\epsilon_{t-1}^{(FR)}$	−0.005	0.036	−0.144	0.886
$\Delta y^{(NL;ULP)} = f(\Delta ex_t^{(NL)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(NL;ULP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}) \| BE < DE < NL$				
$\epsilon_{t-1}^{(NL)}$	−0.050	0.024	−2.082	0.038
$\epsilon_{t-1}^{(BE)}$	−0.038	0.022	−1.671	0.095
$\epsilon_{t-1}^{(DE)}$	0.000	0.021	0.015	0.988
$\Delta y^{(PT;ULP)} = f(\Delta ex_t^{(PT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(PT;ULP)}; \epsilon_{t-1}^{(ES)}) \| ES < PT$				
$\epsilon_{t-1}^{(PT)}$	−0.061	0.012	−5.273	0.000
$\epsilon_{t-1}^{(ES)}$	0.049	0.026	1.899	0.058
$\Delta y^{(SE;ULP)} = f(\Delta ex_t^{(SE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(SE;ULP)}; \epsilon_{t-1}^{(FI)}) \| SE < FI$				
$\epsilon_{t-1}^{(SE)}$	−0.126	0.025	−5.141	0.000
$\epsilon_{t-1}^{(FI)}$	0.002	0.019	0.086	0.931
$\Delta y^{(AT;DIESEL)} = f(\Delta ex_t^{(AT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(AT;DIESEL)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(IT)}) \| AT < DE < IT$				
$\epsilon_{t-1}^{(AT)}$	−0.077	0.018	−4.377	0.000
$\epsilon_{t-1}^{(DE)}$	0.041	0.017	2.342	0.020
$\epsilon_{t-1}^{(IT)}$	−0.031	0.016	−1.913	0.056
$\Delta y^{(BE,DIESEL)} = f(\Delta ex_t^{(BE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(BE;DIESEL)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| LU < BE < FR < DE < NL$				
$\epsilon_{t-1}^{(BE)}$	−0.398	0.036	−11.017	0.000
$\epsilon_{t-1}^{(DE)}$	−0.041	0.030	−1.362	0.174
$\epsilon_{t-1}^{(FR)}$	0.164	0.048	3.406	0.001
$\epsilon_{t-1}^{(LU)}$	−0.111	0.052	−2.134	0.033
$\epsilon_{t-1}^{(NL)}$	0.299	0.045	6.664	0.000
$\Delta y^{(DE;DIESEL)} = f(\Delta ex_t^{(DE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(DE;DIESEL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DK)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| LU < BE < FR < DE < NL < DK$				
$\epsilon_{t-1}^{(DE)}$	−0.304	0.032	−9.453	0.000
$\epsilon_{t-1}^{(BE)}$	−0.011	0.043	−0.253	0.800
$\epsilon_{t-1}^{(DK)}$	−0.007	0.035	−0.190	0.850

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(FR)}$	0.037	0.054	0.685	0.494
$\epsilon_{t-1}^{(LU)}$	−0.017	0.057	−0.295	0.768
$\epsilon_{t-1}^{(NL)}$	0.231	0.048	4.768	0.000
$\Delta y^{(DK;DIESEL)} = f(\Delta ex_t^{(DK)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(DK;DIESEL)}; \epsilon_{t-1}^{(DE)}) \| DE < DK$				
$\epsilon_{t-1}^{(DK)}$	−0.130	0.022	−5.812	0.000
$\epsilon_{t-1}^{(DE)}$	−0.024	0.022	−1.096	0.274
$\Delta y^{(ES;DIESEL)} = f(\Delta ex_t^{(ES)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(ES;DIESEL)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(PT)}) \| ES < PT < FR$				
$\epsilon_{t-1}^{(ES)}$	−0.059	0.019	−3.204	0.001
$\epsilon_{t-1}^{(FR)}$	0.043	0.017	2.482	0.013
$\epsilon_{t-1}^{(PT)}$	−0.008	0.011	−0.730	0.466
$\Delta y^{(FI;DIESEL)} = f(\Delta ex_t^{(FI)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(FI;DIESEL)}; \epsilon_{t-1}^{(SE)}) \| FI < SE$				
$\epsilon_{t-1}^{(FI)}$	−0.159	0.023	−6.942	0.00
$\epsilon_{t-1}^{(SE)}$	0.026	0.015	1.755	0.08
$\Delta y^{(FR;DIESEL)} = f(\Delta ex_t^{(FR)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(FR;DIESEL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(ES)}; \epsilon_{t-1}^{(IT)}; \epsilon_{t-1}^{(LU)}) \| LU < ES < BE < FR < DE < IT$				
$\epsilon_{t-1}^{(FR)}$	−0.100	0.028	−3.560	0.000
$\epsilon_{t-1}^{(BE)}$	0.015	0.019	0.765	0.444
$\epsilon_{t-1}^{(DE)}$	0.005	0.017	0.315	0.753
$\epsilon_{t-1}^{(ES)}$	0.011	0.023	0.478	0.633
$\epsilon_{t-1}^{(IT)}$	−0.029	0.024	−1.211	0.227
$\epsilon_{t-1}^{(LU)}$	0.031	0.030	1.021	0.308
$\Delta y^{(GB;DIESEL)} = f(\Delta ex_t^{(GB)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(GB;DIESEL)}; \epsilon_{t-1}^{(IE)}) \| IE < GB$				
$\epsilon_{t-1}^{(GB)}$	−0.048	0.012	−4.011	0.000
$\epsilon_{t-1}^{(IE)}$	−0.025	0.011	−2.196	0.028
$\Delta y^{(IE;DIESEL)} = f(\Delta ex_t^{(IE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(IE;DIESEL)}; \epsilon_{t-1}^{(GB)}) \| IE < GB$				
$\epsilon_{t-1}^{(IE)}$	−0.084	0.014	−5.922	0.000

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(GB)}$	0.026	0.015	1.719	0.086
$\Delta y^{(IT;DIESEL)} = f(\Delta ex_t^{(IT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(IT;DIESEL)}; \epsilon_{t-1}^{(FR)}) \Vert FR < IT$				
$\epsilon_{t-1}^{(IT)}$	−0.044	0.011	−3.844	0.000
$\epsilon_{t-1}^{(FR)}$	0.018	0.013	1.377	0.169
$\Delta y^{(LU;DIESEL)} = f(\Delta ex_t^{(LU)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(LU;DIESEL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}) \Vert LU < BE < FR < DE$				
$\epsilon_{t-1}^{(LU)}$	−0.188	0.031	−6.033	0.000
$\epsilon_{t-1}^{(BE)}$	0.017	0.025	0.655	0.513
$\epsilon_{t-1}^{(DE)}$	0.034	0.023	1.494	0.136
$\epsilon_{t-1}^{(FR)}$	0.052	0.036	1.420	0.156
$\Delta y^{(NL;DIESEL)} = f(\Delta ex_t^{(NL)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(NL;DIESEL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}) \Vert BE < DE < NL$				
$\epsilon_{t-1}^{(NL)}$	−0.116	0.026	−4.480	0.000
$\epsilon_{t-1}^{(BE)}$	0.025	0.024	1.037	0.300
$\epsilon_{t-1}^{(DE)}$	−0.006	0.022	−0.278	0.781
$\Delta y^{(PT;DIESEL)} = f(\Delta ex_t^{(PT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(PT;DIESEL)}; \epsilon_{t-1}^{(ES)}) \Vert ES < PT$				
$\epsilon_{t-1}^{(PT)}$	−0.103	0.012	−8.491	0
$\epsilon_{t-1}^{(ES)}$	0.112	0.017	6.449	0
$\Delta y^{(SE;DIESEL)} = f(\Delta ex_t^{(SE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(SE,DIESEL)}; \epsilon_{t-1}^{(FI)}) \Vert FI < SE$				
$\epsilon_{t-1}^{(SE)}$	−0.068	0.015	−4.446	0.00
$\epsilon_{t-1}^{(FI)}$	0.026	0.025	1.016	0.31
$\Delta y^{(AT;GASOIL)} = f(\Delta ex_t^{(AT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(AT;GASOIL)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(IT)}) \Vert DE < AT < IT$				
$\epsilon_{t-1}^{(AT)}$	−0.107	0.020	−5.368	0.000
$\epsilon_{t-1}^{(DE)}$	0.130	0.036	3.567	0.000
$\epsilon_{t-1}^{(IT)}$	−0.081	0.025	−3.237	0.001
$\Delta y^{(BE;GASOIL)} = f(\Delta ex_t^{(BE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(BE;GASOIL)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \Vert BE < LU < DE < FR < NL$				
$\epsilon_{t-1}^{(BE)}$	−0.374	0.041	−9.165	0.000

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(DE)}$	0.166	0.052	3.166	0.002
$\epsilon_{t-1}^{(FR)}$	0.032	0.047	0.694	0.488
$\epsilon_{t-1}^{(LU)}$	0.048	0.059	0.819	0.413
$\epsilon_{t-1}^{(NL)}$	0.083	0.036	2.323	0.021
$\Delta y^{(CZ;GASOIL)} = f(\Delta ex_t^{(CZ)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(CZ;GASOIL)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(PL)}; \epsilon_{t-1}^{(SK)}) \| DE < AT < SK < PL < CZ$				
$\epsilon_{t-1}^{(CZ)}$	−0.497	0.167	−2.983	0.006
$\epsilon_{t-1}^{(AT)}$	−0.122	0.258	−0.475	0.639
$\epsilon_{t-1}^{(DE)}$	0.038	0.215	0.175	0.862
$\epsilon_{t-1}^{(PL)}$	0.419	0.177	2.364	0.026
$\epsilon_{t-1}^{(SK)}$	−0.166	0.072	−2.298	0.030
$\Delta y^{(DE;GASOIL)} = f(\Delta ex_t^{(DE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(DE;GASOIL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DK)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| BE < LU < DE < FR < NL < DK$				
$\epsilon_{t-1}^{(DE)}$	−0.167	0.040	−4.115	0.000
$\epsilon_{t-1}^{(BE)}$	0.063	0.032	1.951	0.052
$\epsilon_{t-1}^{(DK)}$	0.028	0.025	1.121	0.263
$\epsilon_{t-1}^{(FR)}$	0.006	0.036	0.179	0.858
$\epsilon_{t-1}^{(LU)}$	−0.090	0.047	−1.933	0.054
$\epsilon_{t-1}^{(NL)}$	0.039	0.028	1.362	0.174
$\Delta y^{(DK;GASOIL)} = f(\Delta ex_t^{(DK)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(DK;GASOIL)}; \epsilon_{t-1}^{(DE)}) \| DE < DK$				
$\epsilon_{t-1}^{(DK)}$	−0.110	0.024	−4.54	0.000
$\epsilon_{t-1}^{(DE)}$	0.018	0.029	0.61	0.542
$\Delta y^{(ES;GASOIL)} = f(\Delta ex_t^{(ES)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(ES;GASOIL)}; \epsilon_{t-1}^{(FR)}) \| ES < FR$				
$\epsilon_{t-1}^{(ES)}$	−0.128	0.020	−6.420	0
$\epsilon_{t-1}^{(FR)}$	0.084	0.022	3.749	0
$\Delta y^{(FI;GASOIL)} = f(\Delta ex_t^{(FI)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(FI,GASOIL)}; \epsilon_{t-1}^{(SE)}) \| FI < SE$				
$\epsilon_{t-1}^{(FI)}$	−0.217	0.028	−7.834	0.000

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(SE)}$	0.056	0.028	2.016	0.044
$\Delta y^{(FR;GASOIL)} = f(\Delta ex_t^{(FR)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(FR;GASOIL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(ES)}; \epsilon_{t-1}^{(IT)}; \epsilon_{t-1}^{(LU)}) \Vert BE < LU < DE < ES < FR < IT$				
$\epsilon_{t-1}^{(FR)}$	−0.072	0.026	−2.795	0.005
$\epsilon_{t-1}^{(BE)}$	0.047	0.022	2.151	0.032
$\epsilon_{t-1}^{(DE)}$	0.009	0.027	0.332	0.740
$\epsilon_{t-1}^{(ES)}$	−0.040	0.021	−1.935	0.054
$\epsilon_{t-1}^{(IT)}$	0.038	0.019	1.971	0.049
$\epsilon_{t-1}^{(LU)}$	−0.057	0.031	−1.844	0.066
$\Delta y^{(GB;GASOIL)} = f(\Delta ex_t^{(GB)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(GB,GASOIL)}; \epsilon_{t-1}^{(IE)}) \Vert GB < IE$				
$\epsilon_{t-1}^{(GB)}$	−0.078	0.015	−5.111	0.000
$\epsilon_{t-1}^{(IE)}$	−0.018	0.010	−1.769	0.077
$\Delta y^{(IE;GASOIL)} = f(\Delta ex_t^{(IE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(IE;GASOIL)}; \epsilon_{t-1}^{(GB)}) \Vert GB < IE$				
$\epsilon_{t-1}^{(IE)}$	−0.045	0.010	−4.357	0.000
$\epsilon_{t-1}^{(GB)}$	−0.021	0.017	−1.205	0.229
$\Delta y^{(IT;GASOIL)} = f(\Delta ex_t^{(IT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(IT;GASOIL)}; \epsilon_{t-1}^{(FR)}) \Vert FR < IT$				
$\epsilon_{t-1}^{(IT)}$	−0.022	0.013	−1.634	0.103
$\epsilon_{t-1}^{(FR)}$	−0.031	0.015	−2.027	0.043
$\Delta y^{(LT;GASOIL)} = f(\Delta ex_t^{(LT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(LT;GASOIL)}; \epsilon_{t-1}^{(PL)}) \Vert LT < PL$				
$\epsilon_{t-1}^{(LT)}$	−0.459	0.098	−4.694	0.000
$\epsilon_{t-1}^{(PL)}$	0.265	0.109	2.432	0.018
$\Delta y^{(LU;GASOIL)} = f(\Delta ex_t^{(LU)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(LU;GASOIL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}) \Vert BE < LU < DE < FR$				
$\epsilon_{t-1}^{(LU)}$	−0.353	0.038	−9.302	0.000
$\epsilon_{t-1}^{(BE)}$	0.064	0.030	2.160	0.031
$\epsilon_{t-1}^{(DE)}$	0.121	0.036	3.332	0.001
$\epsilon_{t-1}^{(FR)}$	0.030	0.033	0.927	0.354

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\Delta y^{(NL;GASOIL)} = f(\Delta ex_t^{(NL)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(NL;GASOIL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}) \| BE < DE < NL$				
$\epsilon_{t-1}^{(NL)}$	−0.117	0.026	−4.558	0.000
$\epsilon_{t-1}^{(BE)}$	0.033	0.031	1.042	0.298
$\epsilon_{t-1}^{(DE)}$	−0.014	0.037	−0.391	0.696
$\Delta y^{(SE;GASOIL)} = f(\Delta ex_t^{(SE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(SE;GASOIL)}; \epsilon_{t-1}^{(FI)}) \| FI < SE$				
$\epsilon_{t-1}^{(SE)}$	−0.108	0.018	−5.942	0.000
$\epsilon_{t-1}^{(FI)}$	0.056	0.019	2.903	0.004
$\Delta y^{(AT;RFO.1)} = f(\Delta ex_t^{(AT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(AT;RFO.1)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(IT)}) \| DE < IT < AT$				
$\epsilon_{t-1}^{(AT)}$	−0.140	0.020	−6.876	0.000
$\epsilon_{t-1}^{(DE)}$	0.055	0.025	2.235	0.026
$\epsilon_{t-1}^{(IT)}$	0.082	0.031	2.640	0.009
$\Delta y^{(BE,RFO.1)} = f(\Delta ex_t^{(BE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(BE;RFO.1)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(NL)}) \| BE < DE < FR < NL$				
$\epsilon_{t-1}^{(BE)}$	−0.308	0.036	−8.547	0.000
$\epsilon_{t-1}^{(DE)}$	0.045	0.031	1.427	0.154
$\epsilon_{t-1}^{(FR)}$	0.192	0.035	5.463	0.000
$\epsilon_{t-1}^{(NL)}$	0.022	0.029	0.758	0.449
$\Delta y^{(DE;RFO.1)} = f(\Delta ex_t^{(DE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(DE;RFO.1)}; \epsilon_{t-1}^{(DK)}; \epsilon_{t-1}^{(NL)}) \| DE < NL < DK$				
$\epsilon_{t-1}^{(DE)}$	−0.190	0.026	−7.260	0.00
$\epsilon_{t-1}^{(DK)}$	0.114	0.025	4.494	0.00
$\epsilon_{t-1}^{(NL)}$	0.060	0.026	2.340	0.02
$\Delta y^{(DK;RFO.1)} = f(\Delta ex_t^{(DK)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(DK;RFO.1)}; \epsilon_{t-1}^{(DE)}) \| DE < DK$				
$\epsilon_{t-1}^{(DK)}$	−0.210	0.029	−7.192	0
$\epsilon_{t-1}^{(DE)}$	0.101	0.026	3.815	0
$\Delta y^{(ES;RFO.1)} = f(\Delta ex_t^{(ES)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(ES;RFO.1)}; \epsilon_{t-1}^{(FR)}) \| FR < ES$				
$\epsilon_{t-1}^{(ES)}$	−0.181	0.020	−8.987	0

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(FR)}$	0.152	0.019	7.981	0
$\Delta y^{(FI;RFO.1)} = f(\Delta ex_t^{(FI)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(FI;RFO.1)}; \epsilon_{t-1}^{(SE)}) \| FI < SE$				
$\epsilon_{t-1}^{(FI)}$	−0.132	0.021	−6.212	0.000
$\epsilon_{t-1}^{(SE)}$	0.047	0.026	1.799	0.073
$\Delta y^{(FR;RFO.1)} = f(\Delta ex_t^{(FR)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(FR;RFO.1)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(IT)}) \| BE < DE < FR < IT$				
$\epsilon_{t-1}^{(FR)}$	−0.088	0.039	−2.257	0.024
$\epsilon_{t-1}^{(BE)}$	0.003	0.032	0.095	0.924
$\epsilon_{t-1}^{(DE)}$	0.075	0.028	2.627	0.009
$\epsilon_{t-1}^{(IT)}$	−0.074	0.035	−2.111	0.035
$\Delta y^{(HU;RFO.1)} = f(\Delta ex_t^{(HU)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(HU;RFO.1)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(SI)}) \| AT < HU < SI$				
$\epsilon_{t-1}^{(HU)}$	−0.776	0.124	−6.239	0.000
$\epsilon_{t-1}^{(AT)}$	0.505	0.171	2.962	0.004
$\epsilon_{t-1}^{(SI)}$	0.083	0.195	0.424	0.673
$\Delta y^{(IT;RFO.1)} = f(\Delta ex_t^{(IT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(IT;RFO.1)}; \epsilon_{t-1}^{(FR)}) \| FR < IT$				
$\epsilon_{t-1}^{(IT)}$	−0.168	0.028	−5.935	0
$\epsilon_{t-1}^{(FR)}$	0.113	0.026	4.301	0
$\Delta y^{(LT;RFO.1)} = f(\Delta ex_t^{(LT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(LT,RFO.1)}; \epsilon_{t-1}^{(PL)}) \| PL < LT$				
$\epsilon_{t-1}^{(LT)}$	−0.751	0.125	−6.019	0.00
$\epsilon_{t-1}^{(PL)}$	0.126	0.214	0.586	0.56
$\Delta y^{(LU;RFO.1)} = f(\Delta ex_t^{(LU)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(LU;RFO.1)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}) \| LU < BE < DE < FR$				
$\epsilon_{t-1}^{(LU)}$	−0.137	0.020	−6.705	0.000
$\epsilon_{t-1}^{(BE)}$	0.018	0.035	0.509	0.611
$\epsilon_{t-1}^{(DE)}$	0.024	0.032	0.741	0.459
$\epsilon_{t-1}^{(FR)}$	0.088	0.036	2.428	0.016

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Variable	Coefficient	Standard Error	t-Value	$Pr(\geq \|t\|)$
$\Delta y^{(NL;RFO.1)} = f(\Delta ex_t^{(NL)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(NL;RFO.1)}; \epsilon_{t-1}^{(DE)}) \| DE < NL$				
$\epsilon_{t-1}^{(NL)}$	−0.134	0.021	−6.462	0
$\epsilon_{t-1}^{(DE)}$	0.073	0.018	4.005	0
$\Delta y^{(PT;RFO.1)} = f(\Delta ex_t^{(PT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(PT;RFO.1)}; \epsilon_{t-1}^{(ES)}) \| ES < PT$				
$\epsilon_{t-1}^{(PT)}$	−0.105	0.014	−7.539	0
$\epsilon_{t-1}^{(ES)}$	0.095	0.019	5.052	0
$\Delta y^{(SE;RFO.1)} = f(\Delta ex_t^{(SE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(SE;RFO.1)}; \epsilon_{t-1}^{(FI)}) \| FI < SE$				
$\epsilon_{t-1}^{(SE)}$	−0.144	0.022	−6.644	0.000
$\epsilon_{t-1}^{(FI)}$	0.038	0.021	1.804	0.072
$\Delta y^{(ES;RFO.2)} = f(\Delta ex_t^{(ES)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(ES;RFO.2)}; \epsilon_{t-1}^{(PT)}) \| ES < PT$				
$\epsilon_{t-1}^{(ES)}$	−0.087	0.022	−3.960	0.000
$\epsilon_{t-1}^{(PT)}$	−0.004	0.013	−0.334	0.738
$\Delta y^{(GB;RFO.2)} = f(\Delta ex_t^{(GB)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(GB;RFO.2)}; \epsilon_{t-1}^{(IE)}) \| GB < IE$				
$\epsilon_{t-1}^{(GB)}$	−0.069	0.021	−3.384	0.001
$\epsilon_{t-1}^{(IE)}$	0.028	0.016	1.701	0.090
$\Delta y^{(IT;RFO.2)} = f(\Delta ex_t^{(IT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(IT;RFO.2)}; \epsilon_{t-1}^{(FR)}) \| IT < FR$				
$\epsilon_{t-1}^{(IT)}$	−0.124	0.032	−3.829	0.000
$\epsilon_{t-1}^{(FR)}$	0.071	0.034	2.071	0.039
$\Delta y^{(BE;LPG)} = f(\Delta ex_t^{(BE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(BE;LPG)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| BE < LU < NL < FR$				
$\epsilon_{t-1}^{(BE)}$	−0.234	0.062	−3.805	0.000
$\epsilon_{t-1}^{(FR)}$	−0.058	0.047	−1.240	0.216
$\epsilon_{t-1}^{(LU)}$	0.132	0.064	2.078	0.039
$\epsilon_{t-1}^{(NL)}$	0.072	0.061	1.187	0.236
$\Delta y^{(FR;LPG)} = f(\Delta ex_t^{(FR)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(FR;LPG)}; \epsilon_{t-1}^{(IT)}; \epsilon_{t-1}^{(LU)}) \| LU < IT < FR$				
$\epsilon_{t-1}^{(FR)}$	−0.115	0.023	−4.923	0.000

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(IT)}$	0.000	0.019	−0.026	0.979
$\epsilon_{t-1}^{(LU)}$	0.040	0.012	3.467	0.001
$\Delta y^{(LU;LPG)} = f(\Delta ex_t^{(LU)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(LU;LPG)}; \epsilon_{t-1}^{(FR)}) \| LU < FR$				
$\epsilon_{t-1}^{(LU)}$	−0.052	0.024	−2.173	0.031
$\epsilon_{t-1}^{(FR)}$	−0.018	0.047	−0.381	0.704
$\Delta y^{(BE;LP)} = f(\Delta ex_t^{(BE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(BE;LP)}; \epsilon_{t-1}^{(FR)}) \| BE < FR$				
$\epsilon_{t-1}^{(BE)}$	−0.207	0.034	−6.129	0.000
$\epsilon_{t-1}^{(FR)}$	0.109	0.043	2.536	0.012
$\Delta y^{(DE;LP)} = f(\Delta ex_t^{(DE)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(DE;LP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}) \| LU < BE < DE < FR$				
$\epsilon_{t-1}^{(DE)}$	−0.605	0.092	−6.546	0.000
$\epsilon_{t-1}^{(BE)}$	0.127	0.149	0.855	0.394
$\epsilon_{t-1}^{(FR)}$	0.216	0.184	1.173	0.243
$\epsilon_{t-1}^{(LU)}$	0.170	0.117	1.453	0.149
$\Delta y^{(DK;LP)} = f(\Delta ex_t^{(DK)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(DK;LP)}; \epsilon_{t-1}^{(DE)}) \| DK < DE$				
$\epsilon_{t-1}^{(DK)}$	−0.324	0.087	−3.713	0.000
$\epsilon_{t-1}^{(DE)}$	0.151	0.098	1.538	0.128
$\Delta y^{(ES;LP)} = f(\Delta ex_t^{(ES)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(ES;LP)}; \epsilon_{t-1}^{(FR)}) \| ES < FR$				
$\epsilon_{t-1}^{(ES)}$	−0.070	0.016	−4.299	0.000
$\epsilon_{t-1}^{(FR)}$	0.048	0.017	2.788	0.005
$\Delta y^{(FR;LP)} = f(\Delta ex_t^{(FR)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(FR;LP)}; \epsilon_{t-1}^{(ES)}) \| ES < FR$				
$\epsilon_{t-1}^{(FR)}$	−0.055	0.02	−2.732	0.006
$\epsilon_{t-1}^{(ES)}$	−0.002	0.02	−0.102	0.919
$\Delta y^{(IT;LP)} = f(\Delta ex_t^{(IT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(IT;LP)}; \epsilon_{t-1}^{(FR)}) \| IT < FR$				
$\epsilon_{t-1}^{(IT)}$	−0.029	0.014	−2.087	0.038

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(FR)}$	0.007	0.015	0.508	0.612
$\Delta y^{(LU;LP)} = f(\Delta ex_t^{(LU)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(LU;LP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(FR)}) \| LU < BE < FR$				
$\epsilon_{t-1}^{(LU)}$	−0.110	0.032	−3.452	0.001
$\epsilon_{t-1}^{(BE)}$	0.089	0.043	2.045	0.042
$\epsilon_{t-1}^{(FR)}$	0.004	0.054	0.066	0.948
$\Delta y^{(PT;LP)} = f(\Delta ex_t^{(PT)}; \Delta x_t^{Brent}; \epsilon_{t-1}^{(PT;LP)}; \epsilon_{t-1}^{(ES)}) \| ES < PT$				
$\epsilon_{t-1}^{(PT)}$	−0.069	0.020	−3.489	0.001
$\epsilon_{t-1}^{(ES)}$	0.083	0.061	1.374	0.171

Table A.86: Results of the Cross-Country Analysis - MSP to DSP Transmission

Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\Delta y^{(AT;ULP)} = f(\Delta ex_t^{(AT)}; \Delta MSP; \epsilon_{t-1}^{(AT;ULP)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(IT)}) \| AT < DE < IT$				
$\epsilon_{t-1}^{(AT)}$	−0.077	0.016	−4.741	0.000
$\epsilon_{t-1}^{(DE)}$	0.050	0.016	3.124	0.002
$\epsilon_{t-1}^{(IT)}$	−0.075	0.024	−3.097	0.002
$\Delta y^{(BE;ULP)} = f(\Delta ex_t^{(BE)}; \Delta MSP; \epsilon_{t-1}^{(BE;ULP)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| LU < BE < DE < FR < NL$				
$\epsilon_{t-1}^{(BE)}$	−0.509	0.038	−13.371	0.000
$\epsilon_{t-1}^{(DE)}$	−0.015	0.032	−0.467	0.641
$\epsilon_{t-1}^{(FR)}$	0.169	0.045	3.760	0.000
$\epsilon_{t-1}^{(LU)}$	0.000	0.058	0.006	0.995
$\epsilon_{t-1}^{(NL)}$	0.004	0.059	0.067	0.947
$\Delta y^{(DE;ULP)} = f(\Delta ex_t^{(DE)}; \Delta MSP; \epsilon_{t-1}^{(DE;ULP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DK)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| LU < BE < DE < DK < FR < NL$				
$\epsilon_{t-1}^{(DE)}$	−0.354	0.032	−11.103	0.000

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(BE)}$	0.081	0.041	2.005	0.045
$\epsilon_{t-1}^{(DK)}$	−0.068	0.043	−1.576	0.116
$\epsilon_{t-1}^{(FR)}$	−0.050	0.045	−1.103	0.270
$\epsilon_{t-1}^{(LU)}$	0.133	0.059	2.262	0.024
$\epsilon_{t-1}^{(NL)}$	0.152	0.059	2.577	0.010
$\Delta y^{(DK;ULP)} = f(\Delta ex_t^{(DK)}; \Delta\text{MSP}; \epsilon_{t-1}^{(DK;ULP)}; \epsilon_{t-1}^{(DE)}) \| DE < DK$				
$\epsilon_{t-1}^{(DK)}$	−0.330	0.032	−10.485	0.000
$\epsilon_{t-1}^{(DE)}$	−0.018	0.023	−0.779	0.436
$\Delta y^{(ES;ULP)} = f(\Delta ex_t^{(ES)}; \Delta\text{MSP}; \epsilon_{t-1}^{(ES;ULP)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(PT)}) \| ES < PT < FR$				
$\epsilon_{t-1}^{(ES)}$	−0.093	0.018	−5.261	0.000
$\epsilon_{t-1}^{(FR)}$	0.018	0.018	1.037	0.300
$\epsilon_{t-1}^{(PT)}$	−0.004	0.006	−0.744	0.457
$\Delta y^{(FI;ULP)} = f(\Delta ex_t^{(FI)}; \Delta\text{MSP}; \epsilon_{t-1}^{(FI;ULP)}; \epsilon_{t-1}^{(SE)}) \| SE < FI$				
$\epsilon_{t-1}^{(FI)}$	−0.215	0.027	−7.969	0.000
$\epsilon_{t-1}^{(SE)}$	0.046	0.051	0.902	0.368
$\Delta y^{(FR,ULP)} = f(\Delta ex_t^{(FR)}; \Delta\text{MSP}; \epsilon_{t-1}^{(FR;ULP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(ES)}; \epsilon_{t-1}^{(IT)}; \epsilon_{t-1}^{(LU)}) \| LU < ES < BE < DE < FR < IT$				
$\epsilon_{t-1}^{(FR)}$	−0.071	0.020	−3.463	0.001
$\epsilon_{t-1}^{(BE)}$	0.005	0.017	0.293	0.769
$\epsilon_{t-1}^{(DE)}$	0.000	0.014	0.001	1.000
$\epsilon_{t-1}^{(ES)}$	−0.035	0.018	−1.880	0.061
$\epsilon_{t-1}^{(IT)}$	−0.052	0.022	−2.361	0.019
$\epsilon_{t-1}^{(LU)}$	0.040	0.023	1.743	0.082
$\Delta y^{(GB,ULP)} = f(\Delta ex_t^{(GB)}; \Delta\text{MSP}; \epsilon_{t-1}^{(GB;ULP)}; \epsilon_{t-1}^{(IE)}) \| IE < GB$				
$\epsilon_{t-1}^{(GB)}$	−0.042	0.012	−3.619	0.000
$\epsilon_{t-1}^{(IE)}$	−0.039	0.012	−3.250	0.001
$\Delta y^{(HU;ULP)} = f(\Delta ex_t^{(HU)}; \Delta\text{MSP}; \epsilon_{t-1}^{(HU;ULP)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(SI)}) \| AT < SI < HU$				

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(HU)}$	−0.609	0.121	−5.031	0.000
$\epsilon_{t-1}^{(AT)}$	0.258	0.095	2.724	0.008
$\epsilon_{t-1}^{(SI)}$	0.092	0.056	1.630	0.108
$\Delta y^{(IE;ULP)} = f(\Delta ex_t^{(IE)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(IE;ULP)}; \epsilon_{t-1}^{(GB)}) \| IE < GB$				
$\epsilon_{t-1}^{(IE)}$	−0.127	0.016	−8.038	0.00
$\epsilon_{t-1}^{(GB)}$	0.036	0.015	2.330	0.02
$\Delta y^{(IT;ULP)} = f(\Delta ex_t^{(IT)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(IT;ULP)}; \epsilon_{t-1}^{(FR)}) \| FR < IT$				
$\epsilon_{t-1}^{(IT)}$	−0.081	0.015	−5.226	0.00
$\epsilon_{t-1}^{(FR)}$	0.028	0.014	2.058	0.04
$\Delta y^{(LT;ULP)} = f(\Delta ex_t^{(LT)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(LT;ULP)}; \epsilon_{t-1}^{(PL)}) \| LT < PL$				
$\epsilon_{t-1}^{(LT)}$	−0.289	0.096	−2.999	0.004
$\epsilon_{t-1}^{(PL)}$	−0.027	0.059	−0.466	0.643
$\Delta y^{(LU;ULP)} = f(\Delta ex_t^{(LU)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(LU;ULP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}) \| LU < BE < DE < FR$				
$\epsilon_{t-1}^{(LU)}$	−0.261	0.033	−7.957	0.000
$\epsilon_{t-1}^{(BE)}$	−0.017	0.026	−0.669	0.504
$\epsilon_{t-1}^{(DE)}$	0.022	0.021	1.008	0.314
$\epsilon_{t-1}^{(FR)}$	0.020	0.030	0.665	0.506
$\Delta y^{(NL;ULP)} = f(\Delta ex_t^{(NL)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(NL;ULP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}) \| BE < DE < NL$				
$\epsilon_{t-1}^{(NL)}$	−0.164	0.025	−6.652	0.000
$\epsilon_{t-1}^{(BE)}$	−0.008	0.019	−0.422	0.673
$\epsilon_{t-1}^{(DE)}$	0.024	0.017	1.437	0.151
$\Delta y^{(PT;ULP)} = f(\Delta ex_t^{(PT)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(PT;ULP)}; \epsilon_{t-1}^{(ES)}) \| ES < PT$				
$\epsilon_{t-1}^{(PT)}$	−0.059	0.011	−5.169	0.000
$\epsilon_{t-1}^{(ES)}$	−0.017	0.035	−0.472	0.637
$\Delta y^{(SE;ULP)} = f(\Delta ex_t^{(SE)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(SE;ULP)}; \epsilon_{t-1}^{(FI)}) \| SE < FI$				
$\epsilon_{t-1}^{(SE)}$	−0.259	0.030	−8.649	0.000

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Variable	Coefficient	Standard Error	t-Value	$Pr(\geq \|t\|)$
$\epsilon_{t-1}^{(FI)}$	−0.003	0.016	−0.171	0.864
$\Delta y^{(SI;ULP)} = f(\Delta ex_t^{(SI)}; \Delta MSP; \epsilon_{t-1}^{(SI;ULP)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(HU)}; \epsilon_{t-1}^{(IT)}) \| AT < SI < IT < HU$				
$\epsilon_{t-1}^{(SI)}$	−0.561	0.104	−5.403	0.000
$\epsilon_{t-1}^{(AT)}$	−0.022	0.188	−0.119	0.906
$\epsilon_{t-1}^{(HU)}$	0.573	0.217	2.634	0.011
$\epsilon_{t-1}^{(IT)}$	0.166	0.144	1.155	0.252
$\Delta y^{(SK;ULP)} = f(\Delta ex_t^{(SK)}; \Delta MSP; \epsilon_{t-1}^{(SK;ULP)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(CZ)}; \epsilon_{t-1}^{(HU)}; \epsilon_{t-1}^{(PL)}) \| AT < CZ < SK < PL < HU$				
$\epsilon_{t-1}^{(SK)}$	−0.214	0.119	−1.802	0.077
$\epsilon_{t-1}^{(AT)}$	0.284	0.127	2.230	0.030
$\epsilon_{t-1}^{(CZ)}$	−0.064	0.081	−0.791	0.432
$\epsilon_{t-1}^{(HU)}$	−0.049	0.131	−0.372	0.711
$\epsilon_{t-1}^{(PL)}$	0.050	0.069	0.726	0.471
$\Delta y^{(AT;DIESEL)} = f(\Delta ex_t^{(AT)}; \Delta MSP; \epsilon_{t-1}^{(AT;DIESEL)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(IT)}) \| AT < DE < IT$				
$\epsilon_{t-1}^{(AT)}$	−0.084	0.017	−4.967	0.000
$\epsilon_{t-1}^{(DE)}$	0.034	0.016	2.091	0.037
$\epsilon_{t-1}^{(IT)}$	−0.037	0.017	−2.168	0.031
$\Delta y^{(BE;DIESEL)} = f(\Delta ex_t^{(BE)}; \Delta MSP; \epsilon_{t-1}^{(BE;DIESEL)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| LU < BE < FR < DE < NL$				
$\epsilon_{t-1}^{(BE)}$	−0.370	0.034	−10.882	0.000
$\epsilon_{t-1}^{(DE)}$	−0.032	0.029	−1.126	0.261
$\epsilon_{t-1}^{(FR)}$	0.142	0.060	2.377	0.018
$\epsilon_{t-1}^{(LU)}$	−0.073	0.050	−1.461	0.145
$\epsilon_{t-1}^{(NL)}$	0.231	0.048	4.867	0.000
$\Delta y^{(DE;DIESEL)} = f(\Delta ex_t^{(DE)}; \Delta MSP; \epsilon_{t-1}^{(DE;DIESEL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DK)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| LU < BE < FR < DE < NL < DK$				
$\epsilon_{t-1}^{(DE)}$	−0.292	0.032	−9.243	0.000
$\epsilon_{t-1}^{(BE)}$	0.017	0.042	0.401	0.688
$\epsilon_{t-1}^{(DK)}$	−0.012	0.034	−0.337	0.736

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(FR)}$	−0.042	0.068	−0.625	0.532
$\epsilon_{t-1}^{(LU)}$	0.011	0.055	0.199	0.842
$\epsilon_{t-1}^{(NL)}$	0.168	0.052	3.221	0.001
$\Delta y^{(DK;DIESEL)} = f(\Delta ex_t^{(DK)}; \Delta \text{MSP}; \epsilon_{t-1}^{(DK;DIESEL)}; \epsilon_{t-1}^{(DE)}) \| DE < DK$				
$\epsilon_{t-1}^{(DK)}$	−0.146	0.023	−6.475	0.000
$\epsilon_{t-1}^{(DE)}$	−0.004	0.024	−0.178	0.859
$\Delta y^{(ES;DIESEL)} = f(\Delta ex_t^{(ES)}; \Delta \text{MSP}; \epsilon_{t-1}^{(ES;DIESEL)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(PT)}) \| ES < PT < FR$				
$\epsilon_{t-1}^{(ES)}$	−0.094	0.020	−4.797	0.000
$\epsilon_{t-1}^{(FR)}$	0.073	0.025	2.866	0.004
$\epsilon_{t-1}^{(PT)}$	0.019	0.011	1.797	0.073
$\Delta y^{(FI;DIESEL)} = f(\Delta ex_t^{(FI)}; \Delta \text{MSP}; \epsilon_{t-1}^{(FI;DIESEL)}; \epsilon_{t-1}^{(SE)}) \| FI < SE$				
$\epsilon_{t-1}^{(FI)}$	−0.196	0.026	−7.636	0.000
$\epsilon_{t-1}^{(SE)}$	0.033	0.014	2.323	0.021
$\Delta y^{(FR;DIESEL)} = f(\Delta ex_t^{(FR)}; \Delta \text{MSP}; \epsilon_{t-1}^{(FR;DIESEL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(ES)}; \epsilon_{t-1}^{(IT)}; \epsilon_{t-1}^{(LU)}) \| LU < ES < BE < FR < DE < IT$				
$\epsilon_{t-1}^{(FR)}$	−0.135	0.027	−5.019	0.000
$\epsilon_{t-1}^{(BE)}$	0.010	0.014	0.727	0.468
$\epsilon_{t-1}^{(DE)}$	0.013	0.012	1.010	0.313
$\epsilon_{t-1}^{(ES)}$	0.008	0.018	0.436	0.663
$\epsilon_{t-1}^{(IT)}$	−0.002	0.020	−0.088	0.930
$\epsilon_{t-1}^{(LU)}$	0.007	0.022	0.319	0.750
$\Delta y^{(GB;DIESEL)} = f(\Delta ex_t^{(GB)}; \Delta \text{MSP}; \epsilon_{t-1}^{(GB;DIESEL)}; \epsilon_{t-1}^{(IE)}) \| IE < GB$				
$\epsilon_{t-1}^{(GB)}$	−0.042	0.012	−3.469	0.001
$\epsilon_{t-1}^{(IE)}$	−0.019	0.012	−1.605	0.109
$\Delta y^{(HU;DIESEL)} = f(\Delta ex_t^{(HU)}; \Delta \text{MSP}; \epsilon_{t-1}^{(HU;DIESEL)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(SI)}) \| AT < SI < HU$				
$\epsilon_{t-1}^{(HU)}$	−0.405	0.103	−3.950	0.000
$\epsilon_{t-1}^{(AT)}$	0.082	0.063	1.291	0.201

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(SI)}$	0.113	0.063	1.783	0.079
$\Delta y^{(IE;DIESEL)} = f(\Delta ex_t^{(IE)}; \Delta\text{MSP}; \epsilon_{t-1}^{(IE;DIESEL)}; \epsilon_{t-1}^{(GB)}) \| IE < GB$				
$\epsilon_{t-1}^{(IE)}$	−0.100	0.015	−6.603	0.00
$\epsilon_{t-1}^{(GB)}$	0.017	0.016	1.103	0.27
$\Delta y^{(IT;DIESEL)} = f(\Delta ex_t^{(IT)}; \Delta\text{MSP}; \epsilon_{t-1}^{(IT;DIESEL)}; \epsilon_{t-1}^{(FR)}) \| FR < IT$				
$\epsilon_{t-1}^{(IT)}$	−0.042	0.012	−3.594	0.000
$\epsilon_{t-1}^{(FR)}$	0.021	0.019	1.085	0.279
$\Delta y^{(LT;DIESEL)} = f(\Delta ex_t^{(LT)}; \Delta\text{MSP}; \epsilon_{t-1}^{(LT;DIESEL)}; \epsilon_{t-1}^{(PL)}) \| LT < PL$				
$\epsilon_{t-1}^{(LT)}$	−0.149	0.068	−2.205	0.031
$\epsilon_{t-1}^{(PL)}$	−0.076	0.086	−0.879	0.383
$\Delta y^{(LU;DIESEL)} = f(\Delta ex_t^{(LU)}; \Delta\text{MSP}; \epsilon_{t-1}^{(LU;DIESEL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}) \| LU < BE < FR < DE$				
$\epsilon_{t-1}^{(LU)}$	−0.255	0.032	−7.963	0.000
$\epsilon_{t-1}^{(BE)}$	0.018	0.023	0.772	0.441
$\epsilon_{t-1}^{(DE)}$	0.047	0.020	2.329	0.020
$\epsilon_{t-1}^{(FR)}$	0.082	0.043	1.929	0.054
$\Delta y^{(NL;DIESEL)} = f(\Delta ex_t^{(NL)}; \Delta\text{MSP}; \epsilon_{t-1}^{(NL;DIESEL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}) \| BE < DE < NL$				
$\epsilon_{t-1}^{(NL)}$	−0.217	0.028	−7.820	0.000
$\epsilon_{t-1}^{(BE)}$	0.078	0.022	3.465	0.001
$\epsilon_{t-1}^{(DE)}$	0.013	0.019	0.663	0.508
$\Delta y^{(PT;DIESEL)} = f(\Delta ex_t^{(PT)}; \Delta\text{MSP}; \epsilon_{t-1}^{(PT;DIESEL)}; \epsilon_{t-1}^{(ES)}) \| ES < PT$				
$\epsilon_{t-1}^{(PT)}$	−0.095	0.013	−7.475	0
$\epsilon_{t-1}^{(ES)}$	0.114	0.021	5.302	0
$\Delta y^{(SE;DIESEL)} = f(\Delta ex_t^{(SE)}; \Delta\text{MSP}; \epsilon_{t-1}^{(SE,DIESEL)}; \epsilon_{t-1}^{(FI)}) \| FI < SE$				
$\epsilon_{t-1}^{(SE)}$	−0.073	0.015	−4.772	0.000
$\epsilon_{t-1}^{(FI)}$	0.033	0.028	1.213	0.226
$\Delta y^{(SI;DIESEL)} = f(\Delta ex_t^{(SI)}; \Delta\text{MSP}; \epsilon_{t-1}^{(SI;DIESEL)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(HU)}; \epsilon_{t-1}^{(IT)}) \| AT < IT < SI < HU$				

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(SI)}$	−0.515	0.117	−4.406	0.000
$\epsilon_{t-1}^{(AT)}$	−0.013	0.119	−0.113	0.910
$\epsilon_{t-1}^{(HU)}$	0.329	0.199	1.648	0.104
$\epsilon_{t-1}^{(IT)}$	0.072	0.091	0.786	0.435
$\Delta y^{(SK;DIESEL)} = f(\Delta ex_t^{(SK)}; \Delta\text{MSP}; \epsilon_{t-1}^{(SK;DIESEL)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(CZ)}; \epsilon_{t-1}^{(HU)}; \epsilon_{t-1}^{(PL)}) \Vert AT < PL < CZ < SK < HU$				
$\epsilon_{t-1}^{(SK)}$	−0.412	0.135	−3.058	0.003
$\epsilon_{t-1}^{(AT)}$	0.070	0.081	0.864	0.391
$\epsilon_{t-1}^{(CZ)}$	−0.032	0.072	−0.448	0.656
$\epsilon_{t-1}^{(HU)}$	0.124	0.117	1.056	0.295
$\epsilon_{t-1}^{(PL)}$	0.310	0.119	2.608	0.012
$\Delta y^{(AT;HGASOIL)} = f(\Delta ex_t^{(AT)}; \Delta\text{MSP}; \epsilon_{t-1}^{(AT;HGASOIL)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(IT)}) \Vert DE < AT < IT$				
$\epsilon_{t-1}^{(AT)}$	−0.094	0.018	−5.228	0.000
$\epsilon_{t-1}^{(DE)}$	0.119	0.041	2.872	0.004
$\epsilon_{t-1}^{(IT)}$	−0.066	0.023	−2.909	0.004
$\Delta y^{(BE;HGASOIL)} = f(\Delta ex_t^{(BE)}; \Delta\text{MSP}; \epsilon_{t-1}^{(BE;HGASOIL)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \Vert BE < LU < DE < FR < NL$				
$\epsilon_{t-1}^{(BE)}$	−0.411	0.038	−10.951	0.000
$\epsilon_{t-1}^{(DE)}$	0.092	0.051	1.808	0.071
$\epsilon_{t-1}^{(FR)}$	0.051	0.042	1.208	0.228
$\epsilon_{t-1}^{(LU)}$	0.061	0.049	1.229	0.220
$\epsilon_{t-1}^{(NL)}$	0.049	0.031	1.591	0.112
$\Delta y^{(CZ;HGASOIL)} = f(\Delta ex_t^{(CZ)}; \Delta\text{MSP}; \epsilon_{t-1}^{(CZ;HGASOIL)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(PL)}; \epsilon_{t-1}^{(SK)}) \Vert DE < AT < SK < PL < CZ$				
$\epsilon_{t-1}^{(CZ)}$	−0.382	0.179	−2.139	0.042
$\epsilon_{t-1}^{(AT)}$	−0.177	0.167	−1.062	0.298
$\epsilon_{t-1}^{(DE)}$	0.112	0.124	0.907	0.372
$\epsilon_{t-1}^{(PL)}$	0.173	0.127	1.365	0.183

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(SK)}$	−0.020	0.049	−0.398	0.694
$\Delta y^{(DE;HGASOIL)} = f(\Delta ex_t^{(DE)}; \Delta\text{MSP}; \epsilon_{t-1}^{(DE;HGASOIL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DK)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| BE < LU < DE < FR < NL < DK$				
$\epsilon_{t-1}^{(DE)}$	−0.258	0.034	−7.571	0.000
$\epsilon_{t-1}^{(BE)}$	0.054	0.025	2.113	0.035
$\epsilon_{t-1}^{(DK)}$	−0.003	0.019	−0.154	0.877
$\epsilon_{t-1}^{(FR)}$	0.013	0.029	0.459	0.646
$\epsilon_{t-1}^{(LU)}$	−0.042	0.034	−1.237	0.217
$\epsilon_{t-1}^{(NL)}$	0.028	0.021	1.318	0.188
$\Delta y^{(DK;HGASOIL)} = f(\Delta ex_t^{(DK)}; \Delta\text{MSP}; \epsilon_{t-1}^{(DK;HGASOIL)}; \epsilon_{t-1}^{(DE)}) \| DE < DK$				
$\epsilon_{t-1}^{(DK)}$	−0.123	0.022	−5.579	0.0
$\epsilon_{t-1}^{(DE)}$	−0.026	0.038	−0.675	0.5
$\Delta y^{(ES;HGASOIL)} = f(\Delta ex_t^{(ES)}; \Delta\text{MSP}; \epsilon_{t-1}^{(ES;HGASOIL)}; \epsilon_{t-1}^{(FR)}) \| ES < FR$				
$\epsilon_{t-1}^{(ES)}$	−0.115	0.020	−5.881	0.000
$\epsilon_{t-1}^{(FR)}$	0.048	0.025	1.909	0.057
$\Delta y^{(FI;HGASOIL)} = f(\Delta ex_t^{(FI)}; \Delta\text{MSP}; \epsilon_{t-1}^{(FI;HGASOIL)}; \epsilon_{t-1}^{(SE)}) \| FI < SE$				
$\epsilon_{t-1}^{(FI)}$	−0.319	0.032	−9.975	0.000
$\epsilon_{t-1}^{(SE)}$	0.010	0.027	0.362	0.718
$\Delta y^{(FR;HGASOIL)} = f(\Delta ex_t^{(FR)}; \Delta\text{MSP}; \epsilon_{t-1}^{(FR;HGASOIL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(ES)}; \epsilon_{t-1}^{(IT)}; \epsilon_{t-1}^{(LU)}) \| BE < LU < DE < ES < FR < IT$				
$\epsilon_{t-1}^{(FR)}$	−0.080	0.021	−3.762	0.000
$\epsilon_{t-1}^{(BE)}$	0.041	0.018	2.227	0.026
$\epsilon_{t-1}^{(DE)}$	−0.050	0.025	−2.032	0.043
$\epsilon_{t-1}^{(ES)}$	−0.006	0.018	−0.319	0.750
$\epsilon_{t-1}^{(IT)}$	0.020	0.016	1.225	0.221
$\epsilon_{t-1}^{(LU)}$	−0.033	0.025	−1.363	0.174
$\Delta y^{(GB;HGASOIL)} = f(\Delta ex_t^{(GB)}; \Delta\text{MSP}; \epsilon_{t-1}^{(GB;HGASOIL)}; \epsilon_{t-1}^{(IE)}) \| GB < IE$				
$\epsilon_{t-1}^{(GB)}$	−0.194	0.025	−7.833	0.000

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Variable	Coefficient	Standard Error	t-Value	$Pr(\geq \|t\|)$
$\epsilon_{t-1}^{(IE)}$	−0.008	0.009	−0.902	0.368
$\Delta y^{(HU;HGASOIL)} = f(\Delta ex_t^{(HU)}; \Delta MSP; \epsilon_{t-1}^{(HU;HGASOIL)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(SI)}) \| AT < SI < HU$				
$\epsilon_{t-1}^{(HU)}$	−0.370	0.095	−3.889	0.000
$\epsilon_{t-1}^{(AT)}$	0.044	0.087	0.508	0.613
$\epsilon_{t-1}^{(SI)}$	0.164	0.079	2.082	0.041
$\Delta y^{(IE;HGASOIL)} = f(\Delta ex_t^{(IE)}; \Delta MSP; \epsilon_{t-1}^{(IE;HGASOIL)}; \epsilon_{t-1}^{(GB)}) \| GB < IE$				
$\epsilon_{t-1}^{(IE)}$	−0.039	0.010	−3.826	0.000
$\epsilon_{t-1}^{(GB)}$	−0.017	0.027	−0.621	0.535
$\Delta y^{(IT;HGASOIL)} = f(\Delta ex_t^{(IT)}; \Delta MSP; \epsilon_{t-1}^{(IT;HGASOIL)}; \epsilon_{t-1}^{(FR)}) \| FR < IT$				
$\epsilon_{t-1}^{(IT)}$	−0.018	0.010	−1.840	0.066
$\epsilon_{t-1}^{(FR)}$	−0.037	0.016	−2.393	0.017
$\Delta y^{(LT;HGASOIL)} = f(\Delta ex_t^{(LT)}; \Delta MSP; \epsilon_{t-1}^{(LT;HGASOIL)}; \epsilon_{t-1}^{(PL)}) \| LT < PL$				
$\epsilon_{t-1}^{(LT)}$	−0.433	0.108	−4.011	0.000
$\epsilon_{t-1}^{(PL)}$	0.072	0.151	0.479	0.634
$\Delta y^{(LU;HGASOIL)} = f(\Delta ex_t^{(LU)}; \Delta MSP; \epsilon_{t-1}^{(LU;HGASOIL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}) \| BE < LU < DE < FR$				
$\epsilon_{t-1}^{(LU)}$	−0.351	0.035	−9.968	0.000
$\epsilon_{t-1}^{(BE)}$	0.053	0.027	1.944	0.052
$\epsilon_{t-1}^{(DE)}$	0.051	0.036	1.409	0.159
$\epsilon_{t-1}^{(FR)}$	0.049	0.031	1.586	0.113
$\Delta y^{(NL;HGASOIL)} = f(\Delta ex_t^{(NL)}; \Delta MSP; \epsilon_{t-1}^{(NL;HGASOIL)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}) \| BE < DE < NL$				
$\epsilon_{t-1}^{(NL)}$	−0.138	0.024	−5.813	0.000
$\epsilon_{t-1}^{(BE)}$	0.037	0.029	1.282	0.200
$\epsilon_{t-1}^{(DE)}$	−0.037	0.038	−0.972	0.332
$\Delta y^{(PL;HGASOIL)} = f(\Delta ex_t^{(PL)}; \Delta MSP; \epsilon_{t-1}^{(PL;HGASOIL)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(LT)}) \| DE < LT < PL$				
$\epsilon_{t-1}^{(PL)}$	−0.845	0.149	−5.682	0.000
$\epsilon_{t-1}^{(DE)}$	−0.131	0.111	−1.178	0.243

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Variable	Coefficient	Standard Error	t-Value	$Pr(\geq \|t\|)$
$\epsilon_{t-1}^{(LT)}$	0.112	0.087	1.285	0.204
$\Delta y^{(SE;HGASOIL)} = f(\Delta ex_t^{(SE)}; \Delta MSP; \epsilon_{t-1}^{(SE;HGASOIL)}; \epsilon_{t-1}^{(FI)}) \| FI < SE$				
$\epsilon_{t-1}^{(SE)}$	−0.119	0.020	−5.870	0.000
$\epsilon_{t-1}^{(FI)}$	0.007	0.024	0.278	0.781
$\Delta y^{(SI;HGASOIL)} = f(\Delta ex_t^{(SI)}; \Delta MSP; \epsilon_{t-1}^{(SI;HGASOIL)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(HU)}; \epsilon_{t-1}^{(IT)}) \| AT < SI < IT < HU$				
$\epsilon_{t-1}^{(SI)}$	−0.726	0.134	−5.404	0.000
$\epsilon_{t-1}^{(AT)}$	−0.041	0.182	−0.225	0.823
$\epsilon_{t-1}^{(HU)}$	0.214	0.157	1.360	0.179
$\epsilon_{t-1}^{(IT)}$	0.251	0.169	1.483	0.143
$\Delta y^{(AT;RFO.1)} = f(\Delta ex_t^{(AT)}; \Delta MSP; \epsilon_{t-1}^{(AT;RFO.1)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(IT)}) \| DE < IT < AT$				
$\epsilon_{t-1}^{(AT)}$	−0.12	0.020	−6.000	0.000
$\epsilon_{t-1}^{(DE)}$	0.04	0.029	1.398	0.163
$\epsilon_{t-1}^{(IT)}$	0.06	0.026	2.357	0.019
$\Delta y^{(BE;RFO.1)} = f(\Delta ex_t^{(BE)}; \Delta MSP; \epsilon_{t-1}^{(BE;RFO.1)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(NL)}) \| BE < DE < FR < NL$				
$\epsilon_{t-1}^{(BE)}$	−0.609	0.039	−15.474	0.000
$\epsilon_{t-1}^{(DE)}$	0.026	0.025	1.047	0.296
$\epsilon_{t-1}^{(FR)}$	0.031	0.028	1.106	0.269
$\epsilon_{t-1}^{(NL)}$	0.017	0.021	0.787	0.431
$\Delta y^{(DE;RFO.1)} = f(\Delta ex_t^{(DE)}; \Delta MSP; \epsilon_{t-1}^{(DE;RFO.1)}; \epsilon_{t-1}^{(DK)}; \epsilon_{t-1}^{(NL)}) \| DE < NL < DK$				
$\epsilon_{t-1}^{(DE)}$	−0.237	0.028	−8.518	0.000
$\epsilon_{t-1}^{(DK)}$	0.039	0.023	1.744	0.082
$\epsilon_{t-1}^{(NL)}$	0.037	0.025	1.475	0.141
$\Delta y^{(DK;RFO.1)} = f(\Delta ex_t^{(DK)}; \Delta MSP; \epsilon_{t-1}^{(DK;RFO.1)}; \epsilon_{t-1}^{(DE)}) \| DE < DK$				
$\epsilon_{t-1}^{(DK)}$	−0.183	0.025	−7.199	0.00
$\epsilon_{t-1}^{(DE)}$	0.043	0.031	1.375	0.17
$\Delta y^{(ES;RFO.1)} = f(\Delta ex_t^{(ES)}; \Delta MSP; \epsilon_{t-1}^{(ES;RFO.1)}; \epsilon_{t-1}^{(FR)}) \| FR < ES$				

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(ES)}$	−0.165	0.021	−7.752	0
$\epsilon_{t-1}^{(FR)}$	0.151	0.026	5.770	0
$\Delta y^{(FI;RFO.1)} = f(\Delta ex_t^{(FI)}; \Delta\text{MSP}; \epsilon_{t-1}^{(FI;RFO.1)}; \epsilon_{t-1}^{(SE)}) \| FI < SE$				
$\epsilon_{t-1}^{(FI)}$	−0.143	0.022	−6.517	0.000
$\epsilon_{t-1}^{(SE)}$	0.062	0.022	2.863	0.004
$\Delta y^{(FR;RFO.1)} = f(\Delta ex_t^{(FR)}; \Delta\text{MSP}; \epsilon_{t-1}^{(FR;RFO.1)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(IT)}) \| BE < DE < FR < IT$				
$\epsilon_{t-1}^{(FR)}$	−0.274	0.036	−7.555	0.000
$\epsilon_{t-1}^{(BE)}$	−0.060	0.039	−1.517	0.130
$\epsilon_{t-1}^{(DE)}$	0.031	0.025	1.230	0.219
$\epsilon_{t-1}^{(IT)}$	0.077	0.026	2.967	0.003
$\Delta y^{(HU;RFO.1)} = f(\Delta ex_t^{(HU)}; \Delta\text{MSP}; \epsilon_{t-1}^{(HU;RFO.1)}; \epsilon_{t-1}^{(AT)}; \epsilon_{t-1}^{(SI)}) \| AT < HU < SI$				
$\epsilon_{t-1}^{(HU)}$	−0.730	0.123	−5.937	0.000
$\epsilon_{t-1}^{(AT)}$	0.593	0.286	2.071	0.042
$\epsilon_{t-1}^{(SI)}$	0.108	0.186	0.581	0.563
$\Delta y^{(IT;RFO.1)} = f(\Delta ex_t^{(IT)}; \Delta\text{MSP}; \epsilon_{t-1}^{(IT;RFO.1)}; \epsilon_{t-1}^{(FR)}) \| FR < IT$				
$\epsilon_{t-1}^{(IT)}$	−0.045	0.023	−1.970	0.049
$\epsilon_{t-1}^{(FR)}$	−0.045	0.032	−1.399	0.162
$\Delta y^{(LT;RFO.1)} = f(\Delta ex_t^{(LT)}; \Delta\text{MSP}; \epsilon_{t-1}^{(LT;RFO.1)}; \epsilon_{t-1}^{(PL)}) \| PL < LT$				
$\epsilon_{t-1}^{(LT)}$	−0.779	0.122	−6.366	0.000
$\epsilon_{t-1}^{(PL)}$	−0.332	0.285	−1.164	0.249
$\Delta y^{(LU;RFO.1)} = f(\Delta ex_t^{(LU)}; \Delta\text{MSP}; \epsilon_{t-1}^{(LU;RFO.1)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(DE)}; \epsilon_{t-1}^{(FR)}) \| LU < BE < DE < FR$				
$\epsilon_{t-1}^{(LU)}$	−0.119	0.022	−5.441	0.000
$\epsilon_{t-1}^{(BE)}$	−0.037	0.052	−0.701	0.484
$\epsilon_{t-1}^{(DE)}$	0.028	0.033	0.873	0.383
$\epsilon_{t-1}^{(FR)}$	0.045	0.037	1.240	0.216
$\Delta y^{(NL;RFO.1)} = f(\Delta ex_t^{(NL)}; \Delta\text{MSP}; \epsilon_{t-1}^{(NL;RFO.1)}; \epsilon_{t-1}^{(DE)}) \| DE < NL$				

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Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(NL)}$	−0.139	0.021	−6.607	0.000
$\epsilon_{t-1}^{(DE)}$	0.033	0.023	1.444	0.149
$\Delta y^{(PT;RFO.1)} = f(\Delta ex_t^{(PT)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(PT;RFO.1)}; \epsilon_{t-1}^{(ES)}) \| ES < PT$				
$\epsilon_{t-1}^{(PT)}$	−0.092	0.014	−6.564	0
$\epsilon_{t-1}^{(ES)}$	0.107	0.025	4.312	0
$\Delta y^{(SE;RFO.1)} = f(\Delta ex_t^{(SE)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(SE;RFO.1)}; \epsilon_{t-1}^{(FI)}) \| FI < SE$				
$\epsilon_{t-1}^{(SE)}$	−0.123	0.021	−5.823	0.000
$\epsilon_{t-1}^{(FI)}$	0.020	0.021	0.923	0.356
$\Delta y^{(BE;RFO.2)} = f(\Delta ex_t^{(BE)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(BE;RFO.2)}; \epsilon_{t-1}^{(FR)}) \| BE < FR$				
$\epsilon_{t-1}^{(BE)}$	−0.377	0.110	−3.416	0.001
$\epsilon_{t-1}^{(FR)}$	0.120	0.145	0.834	0.408
$\Delta y^{(ES;RFO.2)} = f(\Delta ex_t^{(ES)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(ES;RFO.2)}; \epsilon_{t-1}^{(PT)}) \| ES < PT$				
$\epsilon_{t-1}^{(ES)}$	−0.187	0.030	−6.320	0.000
$\epsilon_{t-1}^{(PT)}$	0.011	0.012	0.959	0.338
$\Delta y^{(GB;RFO.2)} = f(\Delta ex_t^{(GB)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(GB;RFO.2)}; \epsilon_{t-1}^{(IE)}) \| GB < IE$				
$\epsilon_{t-1}^{(GB)}$	−0.161	0.026	−6.158	0.000
$\epsilon_{t-1}^{(IE)}$	0.040	0.016	2.566	0.011
$\Delta y^{(IT;RFO.2)} = f(\Delta ex_t^{(IT)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(IT;RFO.2)}; \epsilon_{t-1}^{(FR)}) \| IT < FR$				
$\epsilon_{t-1}^{(IT)}$	−0.140	0.030	−4.737	0.000
$\epsilon_{t-1}^{(FR)}$	0.013	0.031	0.433	0.665
$\Delta y^{(LT;RFO.2)} = f(\Delta ex_t^{(LT)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(LT;RFO.2)}; \epsilon_{t-1}^{(PL)}) \| LT < PL$				
$\epsilon_{t-1}^{(LT)}$	−0.474	0.109	−4.328	0.000
$\epsilon_{t-1}^{(PL)}$	−0.090	0.119	−0.761	0.449
$\Delta y^{(BE;LPG)} = f(\Delta ex_t^{(BE)}; \Delta \mathrm{MSP}; \epsilon_{t-1}^{(BE;LPG)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}; \epsilon_{t-1}^{(NL)}) \| BE < LU < NL < FR$				
$\epsilon_{t-1}^{(BE)}$	−0.358	0.052	−6.917	0.000
$\epsilon_{t-1}^{(FR)}$	0.020	0.029	0.671	0.503

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Variable	Coefficient	Standard Error	t-Value	Pr($\geq \|t\|$)
$\epsilon_{t-1}^{(LU)}$	0.067	0.053	1.255	0.211
$\epsilon_{t-1}^{(NL)}$	0.134	0.050	2.693	0.008
$\Delta y^{(LU;LPG)} = f(\Delta ex_t^{(LU)}; \Delta \text{MSP}; \epsilon_{t-1}^{(LU;LPG)}; \epsilon_{t-1}^{(FR)}) \| LU < FR$				
$\epsilon_{t-1}^{(LU)}$	−0.282	0.042	−6.713	0.000
$\epsilon_{t-1}^{(FR)}$	0.044	0.030	1.466	0.144
$\Delta y^{(BE;LP)} = f(\Delta ex_t^{(BE)}; \Delta \text{MSP}; \epsilon_{t-1}^{(BE;LP)}; \epsilon_{t-1}^{(FR)}) \| BE < FR$				
$\epsilon_{t-1}^{(BE)}$	−0.217	0.031	−7.097	0.000
$\epsilon_{t-1}^{(FR)}$	0.139	0.040	3.428	0.001
$\Delta y^{(DE;LP)} = f(\Delta ex_t^{(DE)}; \Delta \text{MSP}; \epsilon_{t-1}^{(DE;LP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(FR)}; \epsilon_{t-1}^{(LU)}) \| LU < BE < DE < FR$				
$\epsilon_{t-1}^{(DE)}$	−0.525	0.086	−6.106	0.000
$\epsilon_{t-1}^{(BE)}$	0.107	0.156	0.684	0.495
$\epsilon_{t-1}^{(FR)}$	0.210	0.194	1.085	0.280
$\epsilon_{t-1}^{(LU)}$	0.235	0.126	1.866	0.065
$\Delta y^{(DK;LP)} = f(\Delta ex_t^{(DK)}; \Delta \text{MSP}; \epsilon_{t-1}^{(DK;LP)}; \epsilon_{t-1}^{(DE)}) \| DK < DE$				
$\epsilon_{t-1}^{(DK)}$	−0.509	0.099	−5.169	0.000
$\epsilon_{t-1}^{(DE)}$	0.114	0.093	1.220	0.226
$\Delta y^{(ES;LP)} = f(\Delta ex_t^{(ES)}; \Delta \text{MSP}; \epsilon_{t-1}^{(ES;LP)}; \epsilon_{t-1}^{(FR)}) \| ES < FR$				
$\epsilon_{t-1}^{(ES)}$	−0.066	0.015	−4.355	0.000
$\epsilon_{t-1}^{(FR)}$	0.038	0.013	2.894	0.004
$\Delta y^{(FR;LP)} = f(\Delta ex_t^{(FR)}; \Delta \text{MSP}; \epsilon_{t-1}^{(FR;LP)}; \epsilon_{t-1}^{(ES)}) \| ES < FR$				
$\epsilon_{t-1}^{(FR)}$	−0.045	0.017	−2.605	0.009
$\epsilon_{t-1}^{(ES)}$	0.012	0.016	0.733	0.464
$\Delta y^{(IT;LP)} = f(\Delta ex_t^{(IT)}; \Delta \text{MSP}; \epsilon_{t-1}^{(IT;LP)}; \epsilon_{t-1}^{(FR)}) \| IT < FR$				
$\epsilon_{t-1}^{(IT)}$	−0.049	0.015	−3.276	0.001
$\epsilon_{t-1}^{(FR)}$	0.010	0.012	0.863	0.389
$\Delta y^{(LU;LP)} = f(\Delta ex_t^{(LU)}; \Delta \text{MSP}; \epsilon_{t-1}^{(LU;LP)}; \epsilon_{t-1}^{(BE)}; \epsilon_{t-1}^{(FR)}) \| LU < BE < FR$				

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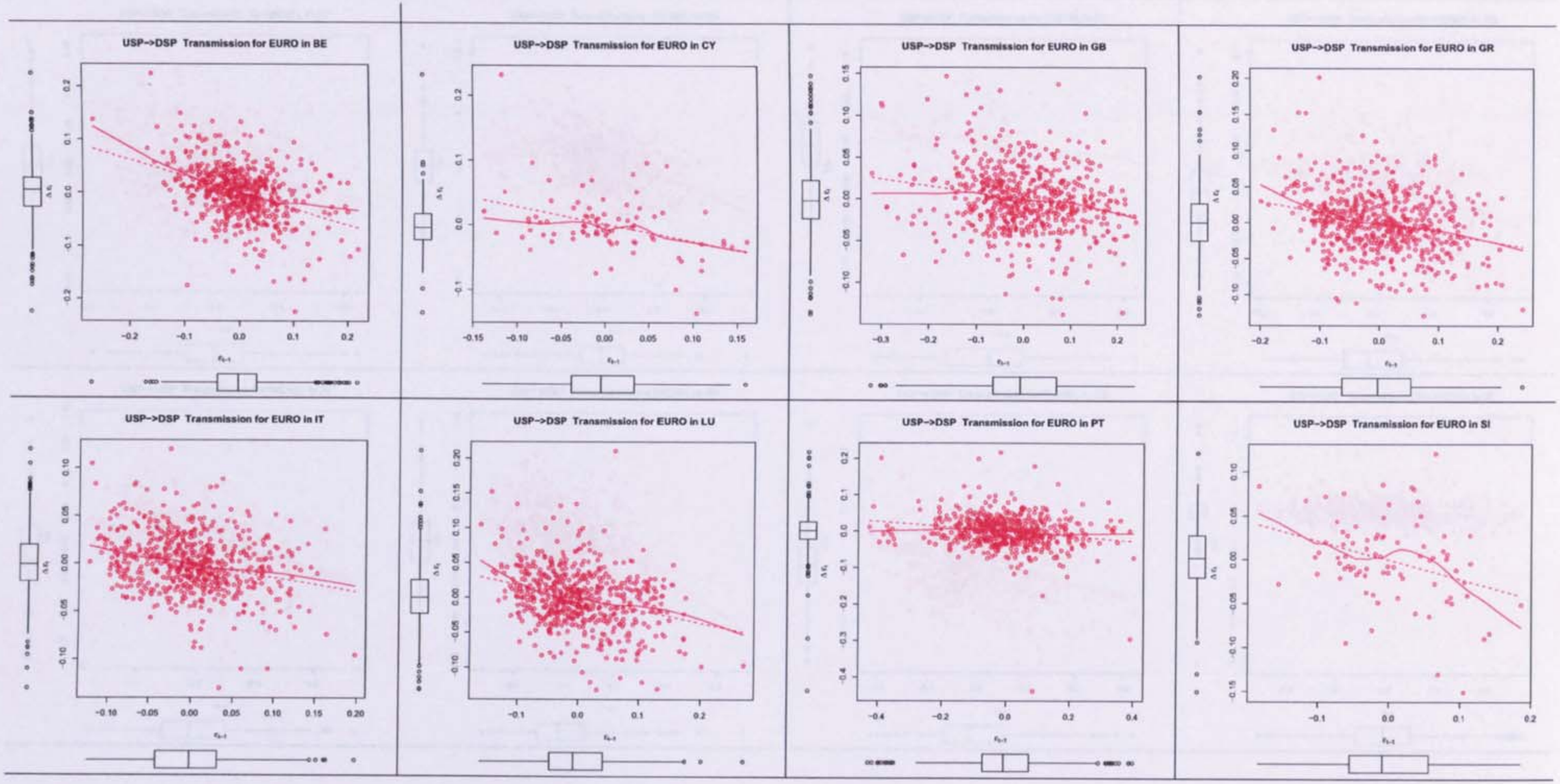
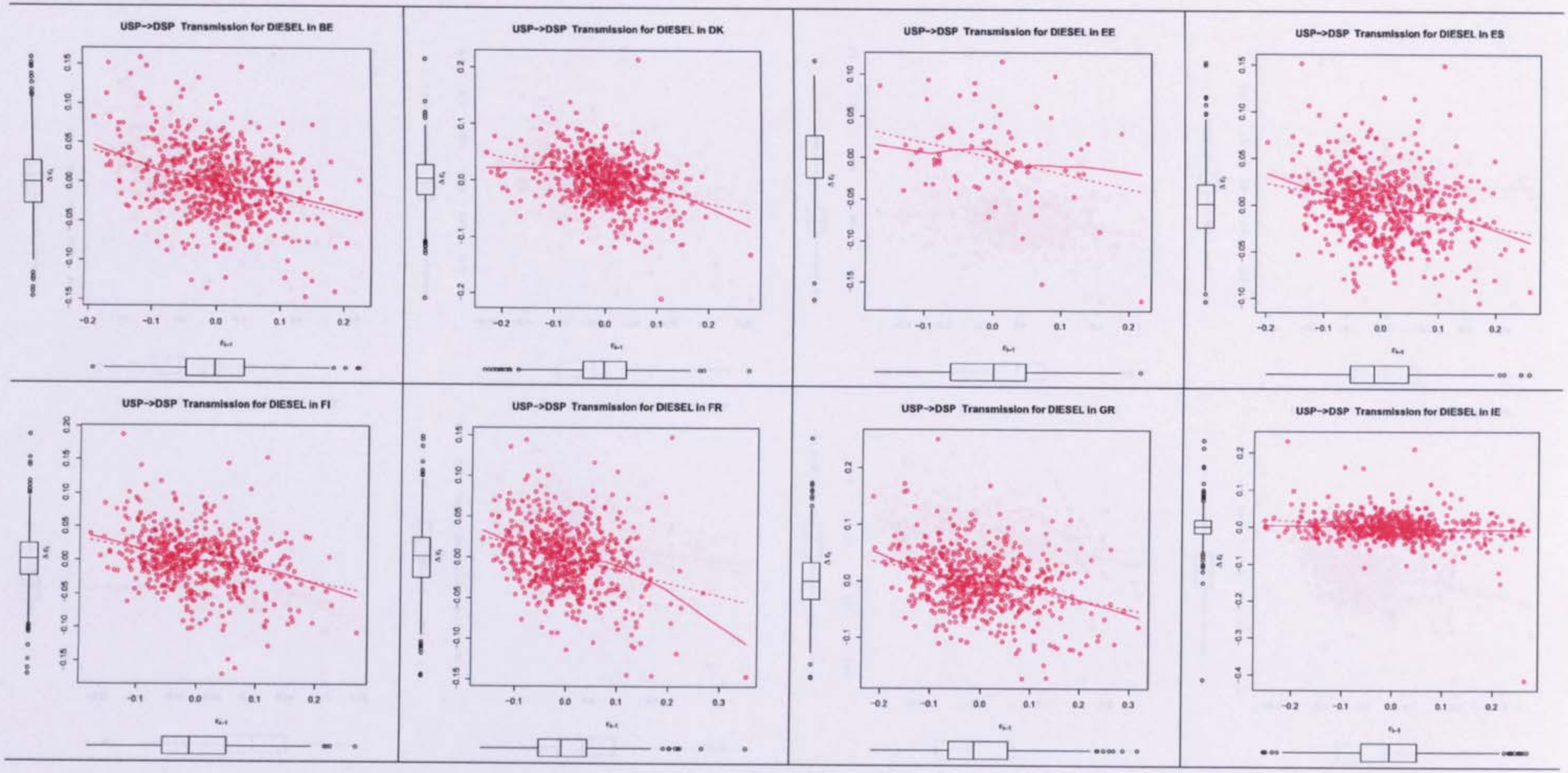
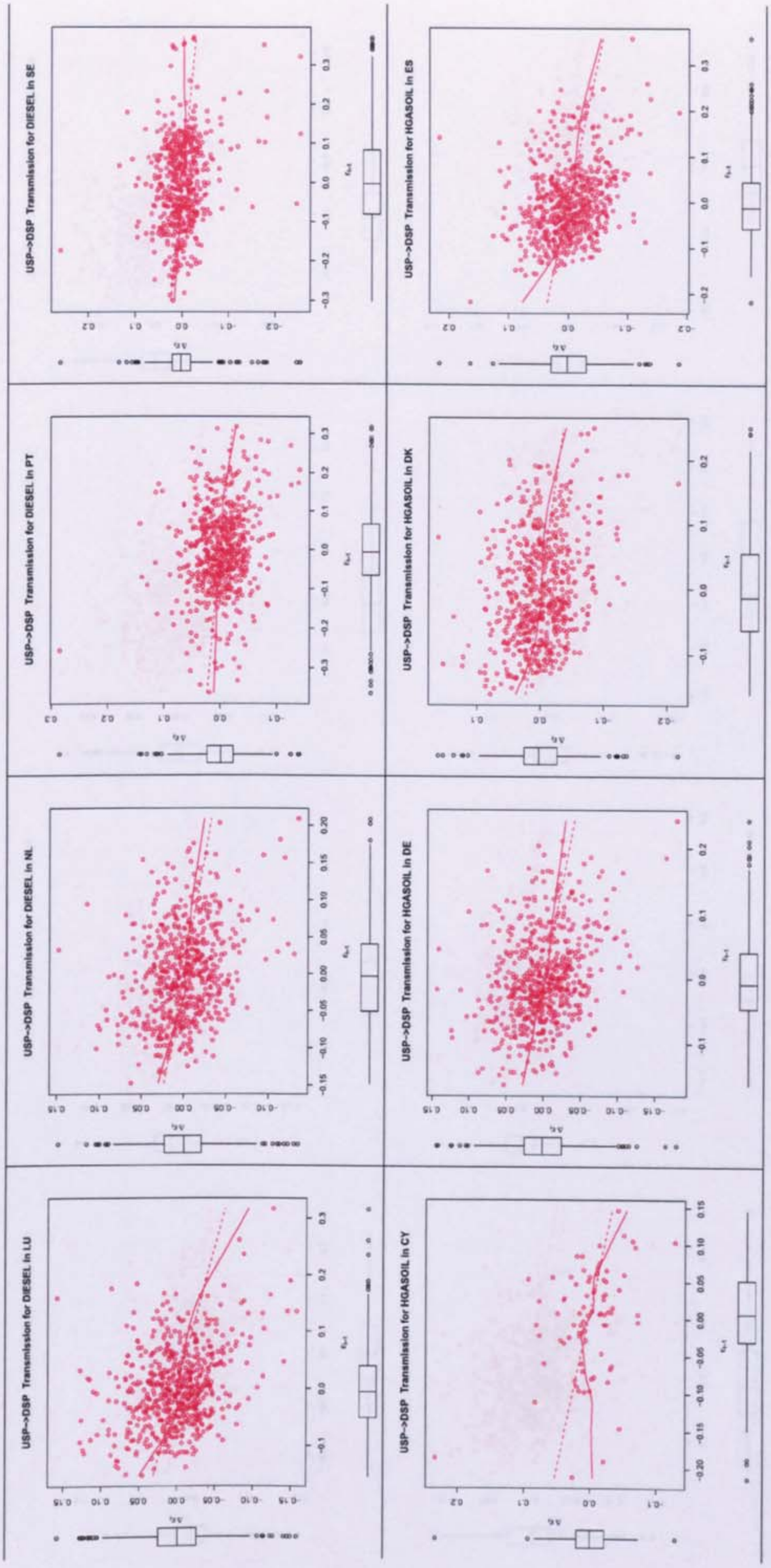
Variable	Coefficient	Standard Error	t-Value	Pr(≥ ‖t‖)
$\epsilon_{t-1}^{(LU)}$	−0.114	0.032	−3.499	0.001
$\epsilon_{t-1}^{(BE)}$	−0.006	0.049	−0.118	0.906
$\epsilon_{t-1}^{(FR)}$	−0.002	0.043	−0.054	0.957
$\Delta y^{(PT;LP)} = f(\Delta ex_t^{(PT)}; \Delta \text{MSP}; \epsilon_{t-1}^{(PT;LP)}; \epsilon_{t-1}^{(ES)}) \| ES < PT$				
$\epsilon_{t-1}^{(PT)}$	−0.076	0.020	−3.809	0.0
$\epsilon_{t-1}^{(ES)}$	0.029	0.043	0.675	0.5

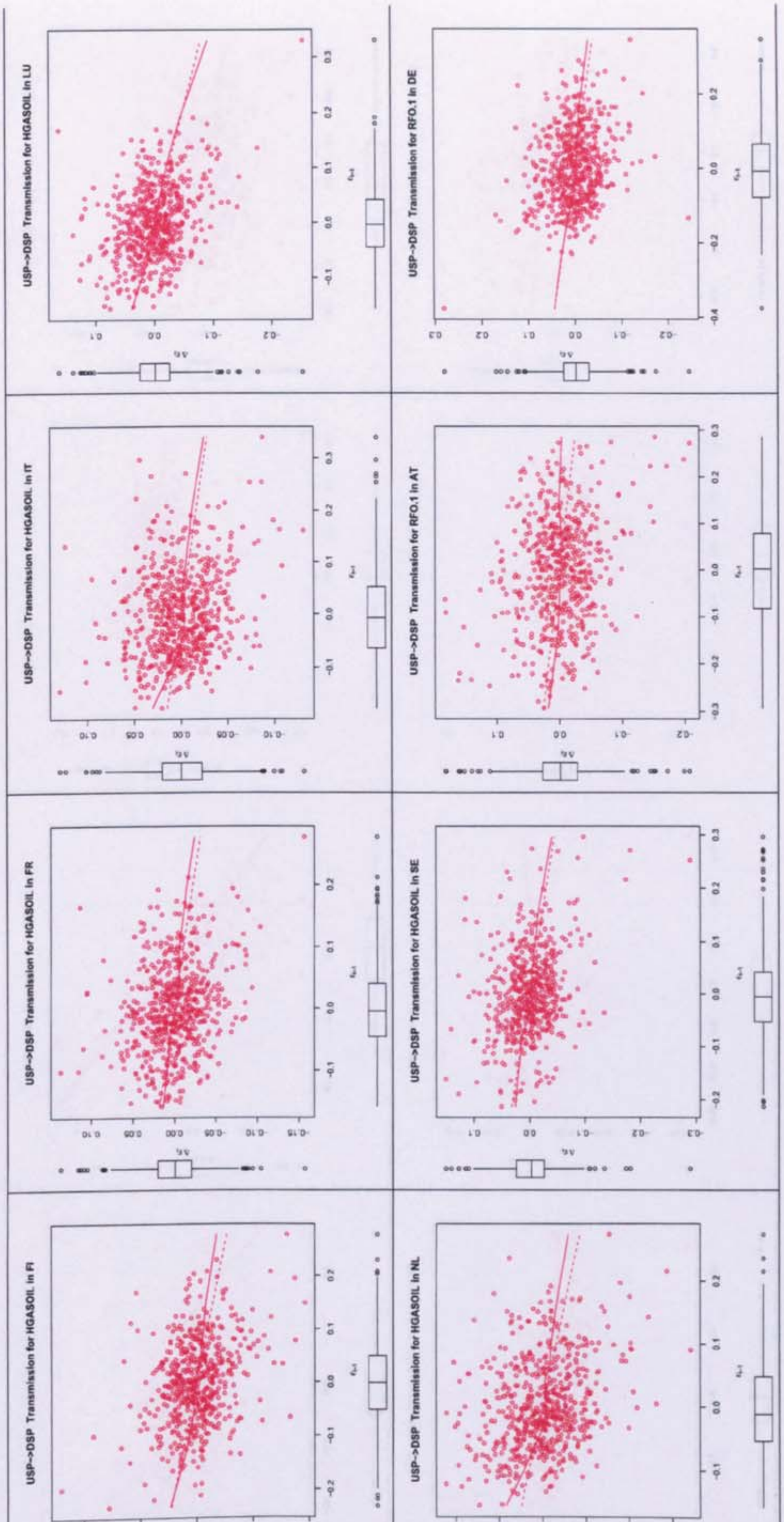
Table A.87: Scatter Plots - $\Delta\epsilon_t$ vs ϵ_{t-1}

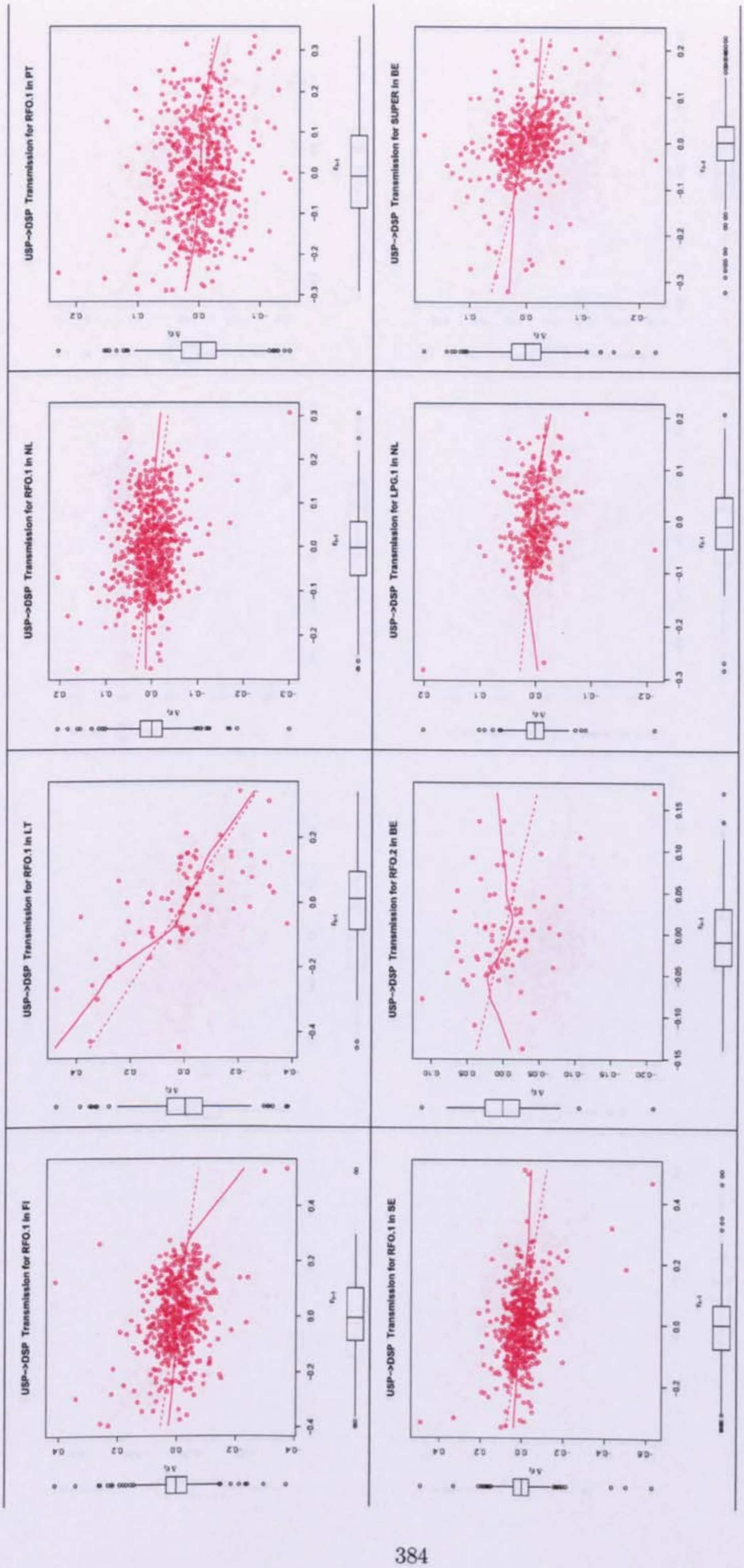


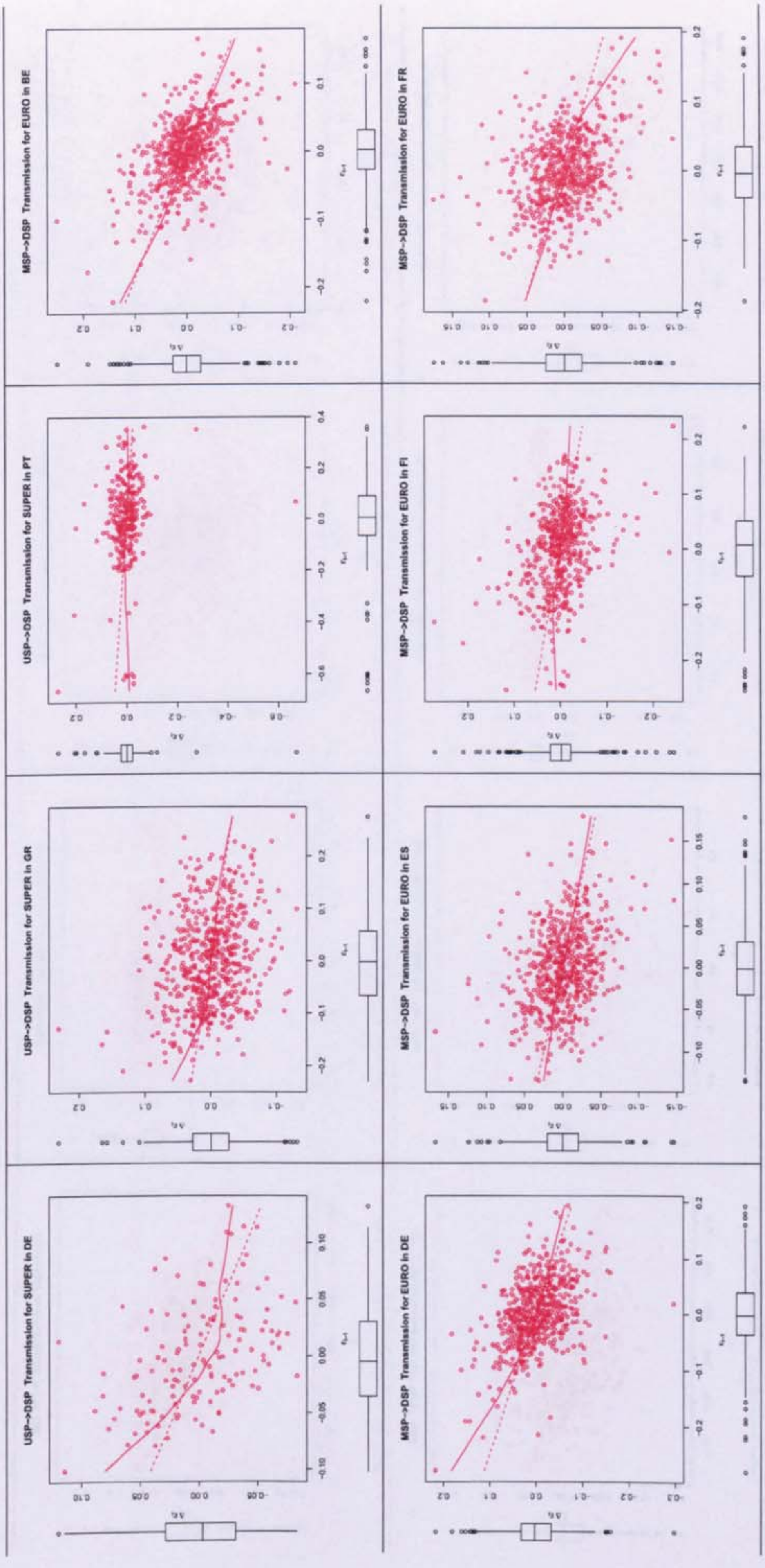


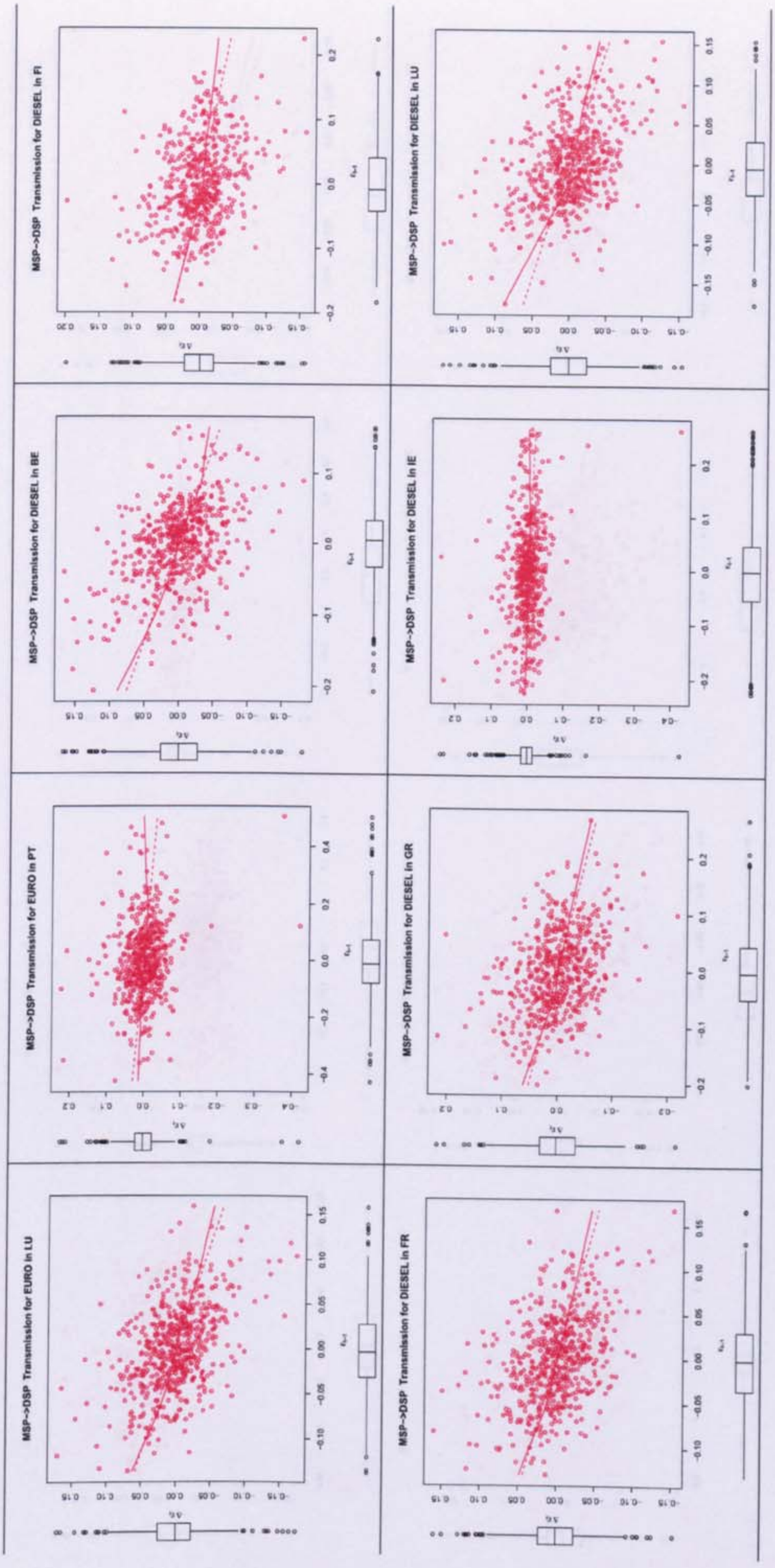
USP->DSP Transmission for DIESEL in BE
USP->DSP Transmission for DIESEL in DK
USP->DSP Transmission for DIESEL in EE
USP->DSP Transmission for DIESEL in ES
USP->DSP Transmission for DIESEL in FI
USP->DSP Transmission for DIESEL in FR
USP->DSP Transmission for DIESEL in GR
USP->DSP Transmission for DIESEL in IE

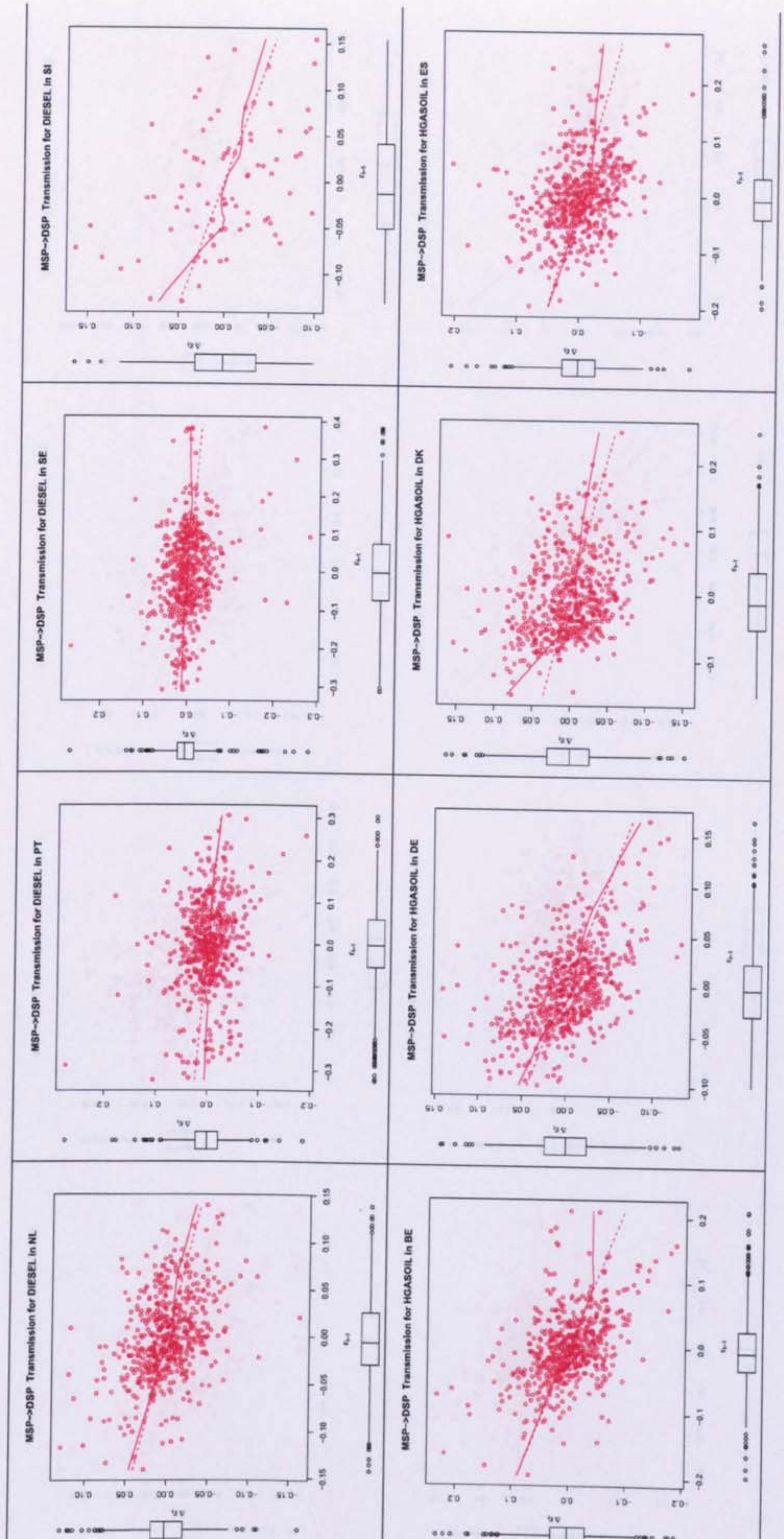

USP->DSP Transmission for DIESEL in SE
USP->DSP Transmission for DIESEL in PT
USP->DSP Transmission for DIESEL in NL
USP->DSP Transmission for DIESEL in LU
USP->DSP Transmission for HGASOIL in ES
USP->DSP Transmission for HGASOIL in DK
USP->DSP Transmission for HGASOIL in DE
USP->DSP Transmission for HGASOIL in CY


USP->DSP Transmission for HGASOIL in LU
USP->DSP Transmission for HGASOIL in IT
USP->DSP Transmission for HGASOIL in FR
USP->DSP Transmission for HGASOIL in FI
USP->DSP Transmission for RFO.1 in DE
USP->DSP Transmission for RFO.1 in AT
USP->DSP Transmission for HGASOIL in SE
USP->DSP Transmission for HGASOIL in NL

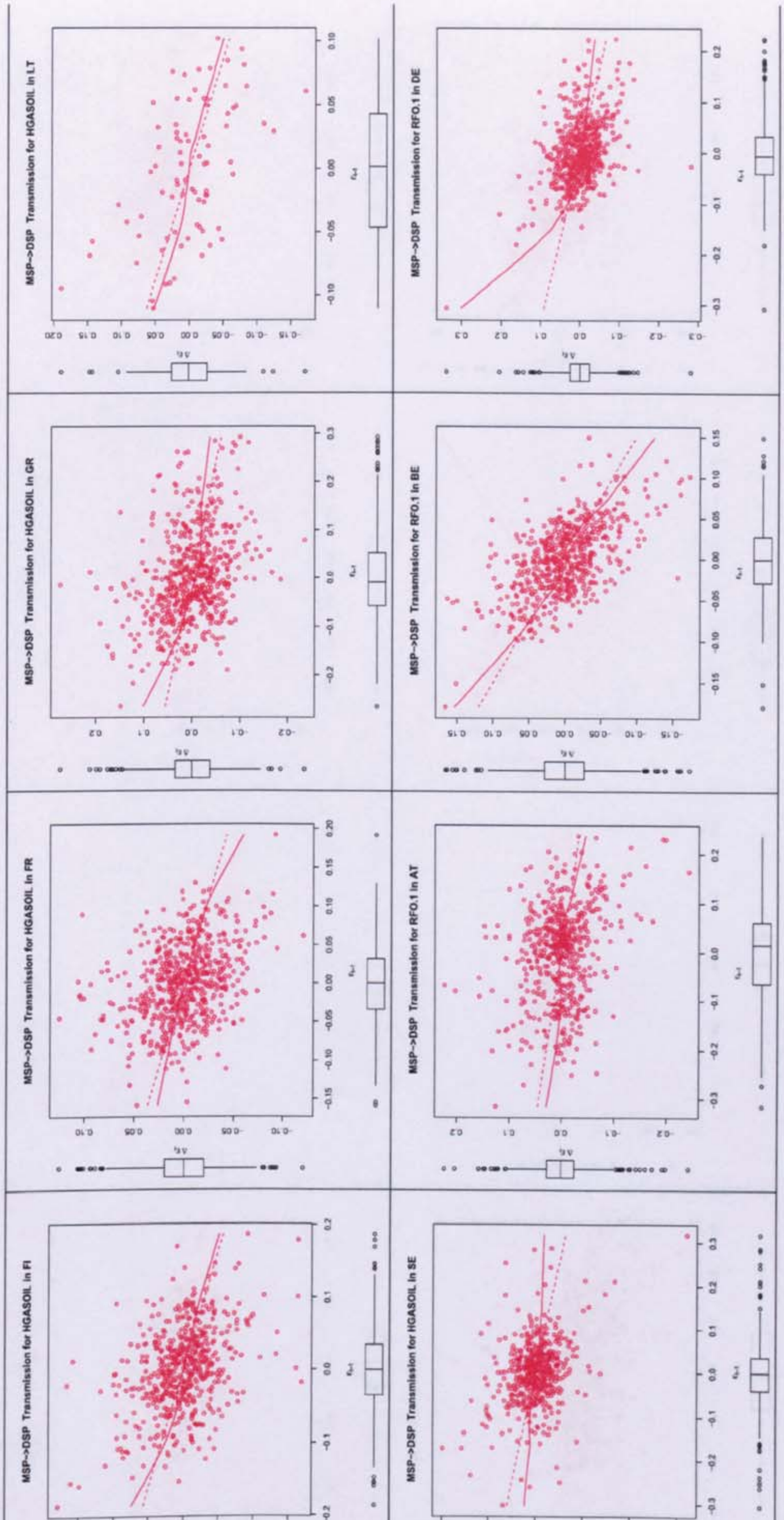

USP->DSP Transmission for RFO.1 in FI
USP->DSP Transmission for RFO.1 in LT
USP->DSP Transmission for RFO.1 in NL
USP->DSP Transmission for RFO.1 in PT
USP->DSP Transmission for RFO.1 in SE
USP->DSP Transmission for RFO.2 in BE
USP->DSP Transmission for LPG.1 in NL
USP->DSP Transmission for SUPER in BE

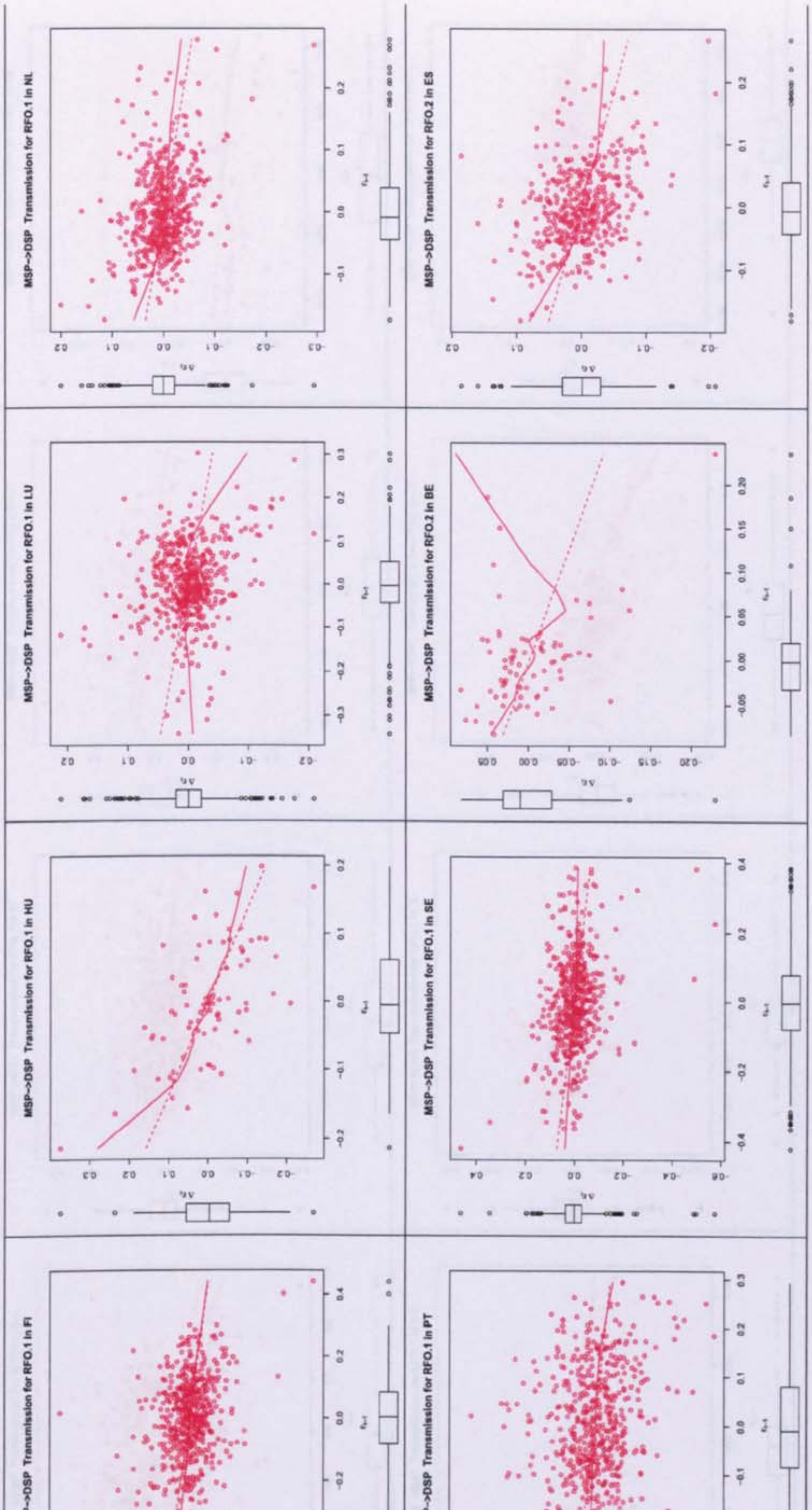

USP->DSP Transmission for SUPER in DE
USP->DSP Transmission for SUPER in GR
USP->DSP Transmission for SUPER in PT
MSP->DSP Transmission for EURO in BE
MSP->DSP Transmission for EURO in DE
MSP->DSP Transmission for EURO in ES
MSP->DSP Transmission for EURO in FI
MSP->DSP Transmission for EURO in FR

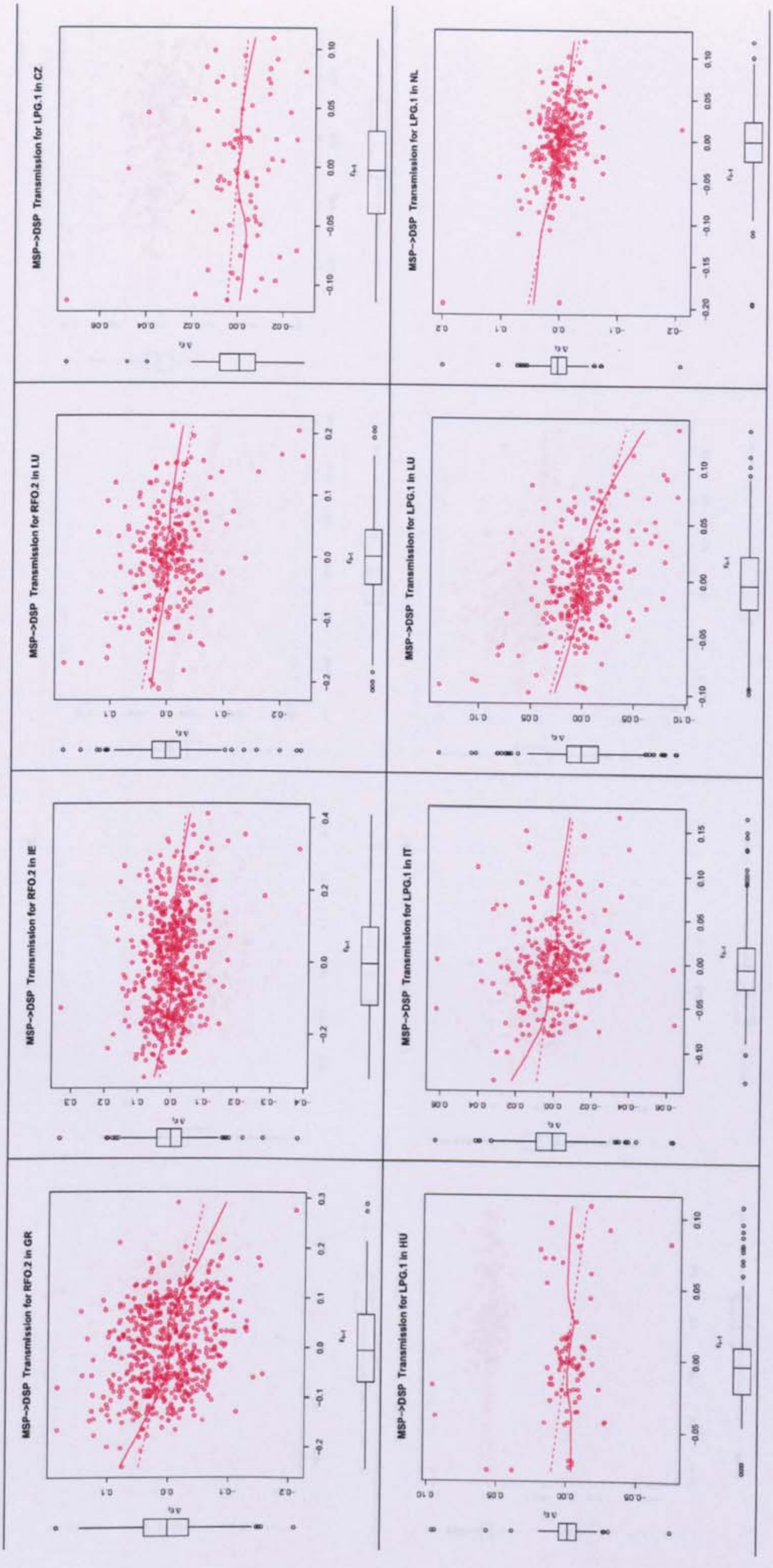

MSP->DSP Transmission for DIESEL in FI
MSP->DSP Transmission for DIESEL in BE
MSP->DSP Transmission for EURO in PT
MSP->DSP Transmission for EURO in LU
MSP->DSP Transmission for DIESEL in LU
MSP->DSP Transmission for DIESEL in IE
MSP->DSP Transmission for DIESEL in GR
MSP->DSP Transmission for DIESEL in FR



MSP->DSP Transmission for DIESEL in NL
MSP->DSP Transmission for DIESEL in PT
MSP->DSP Transmission for DIESEL in SE
MSP->DSP Transmission for DIESEL in SI
MSP->DSP Transmission for HGASOIL in BE
MSP->DSP Transmission for HGASOIL in DE
MSP->DSP Transmission for HGASOIL in DK
MSP->DSP Transmission for HGASOIL in ES


MSP->DSP Transmission for HGASOIL in FI
MSP->DSP Transmission for HGASOIL in FR
MSP->DSP Transmission for HGASOIL in GR
MSP->DSP Transmission for HGASOIL in LT
MSP->DSP Transmission for HGASOIL in SE
MSP->DSP Transmission for RFO.1 in AT
MSP->DSP Transmission for RFO.1 in BE
MSP->DSP Transmission for RFO.1 in DE


MSP->DSP Transmission for RFO.1 in FI
MSP->DSP Transmission for RFO.1 in HU
MSP->DSP Transmission for RFO.1 in LU
MSP->DSP Transmission for RFO.1 in NL
MSP->DSP Transmission for RFO.1 in PT
MSP->DSP Transmission for RFO.1 in SE
MSP->DSP Transmission for RFO.2 in BE
MSP->DSP Transmission for RFO.2 in ES


MSP->DSP Transmission for LPG.1 in CZ
MSP->DSP Transmission for RFO.2 in LU
MSP->DSP Transmission for RFO.2 in IE
MSP->DSP Transmission for RFO.2 in GR
MSP->DSP Transmission for LPG.1 in NL
MSP->DSP Transmission for LPG.1 in LU
MSP->DSP Transmission for LPG.1 in IT
MSP->DSP Transmission for LPG.1 in HU

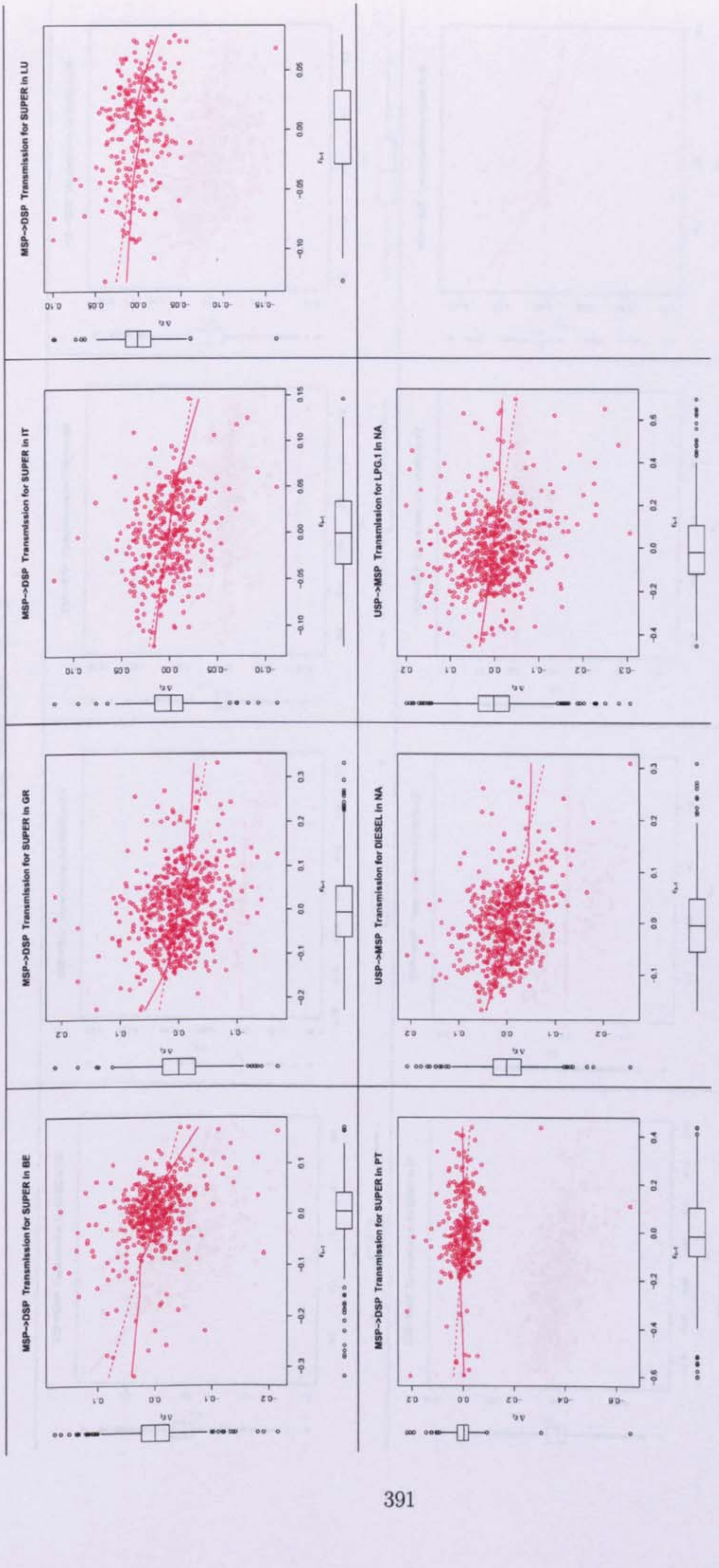
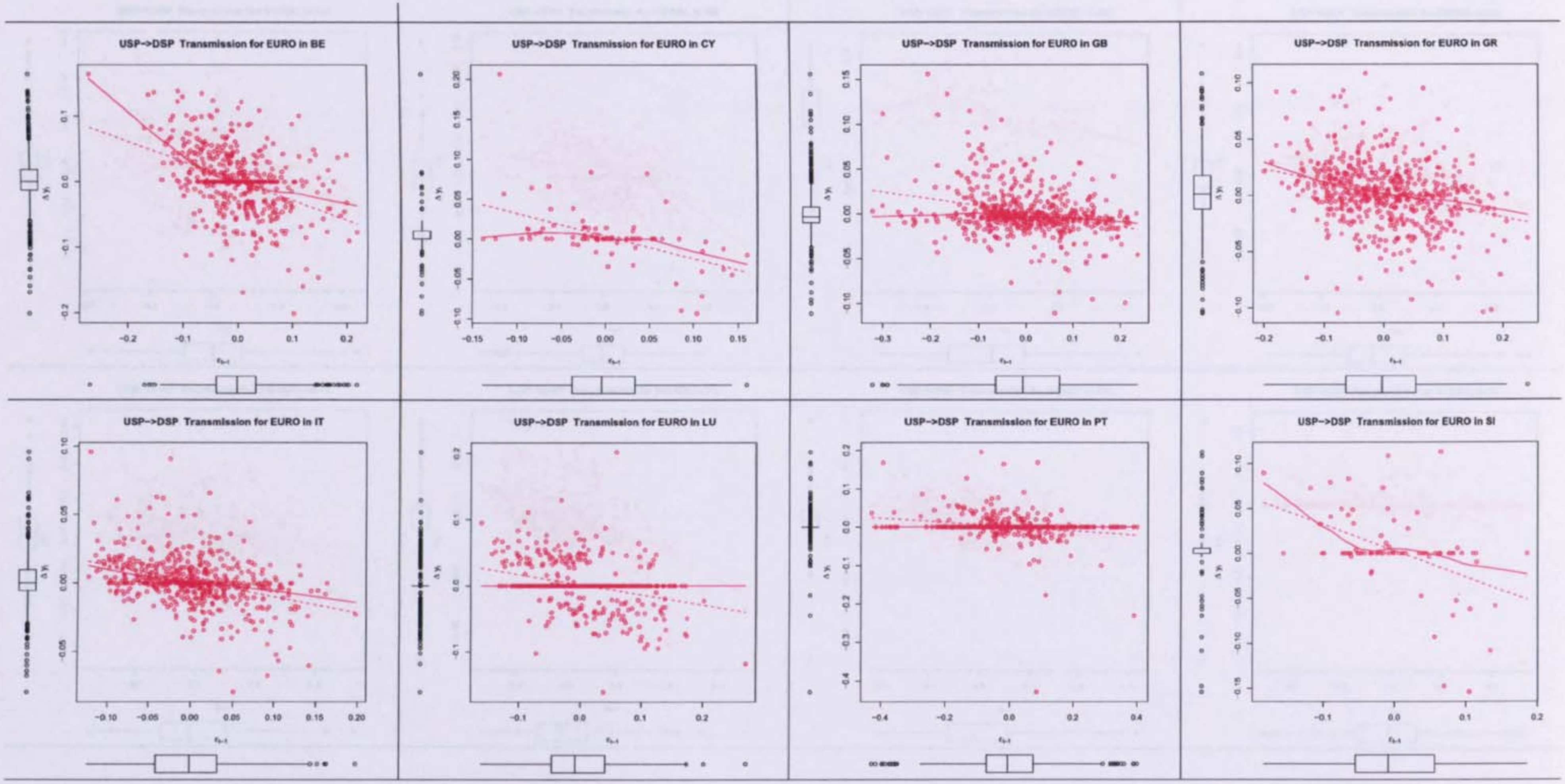
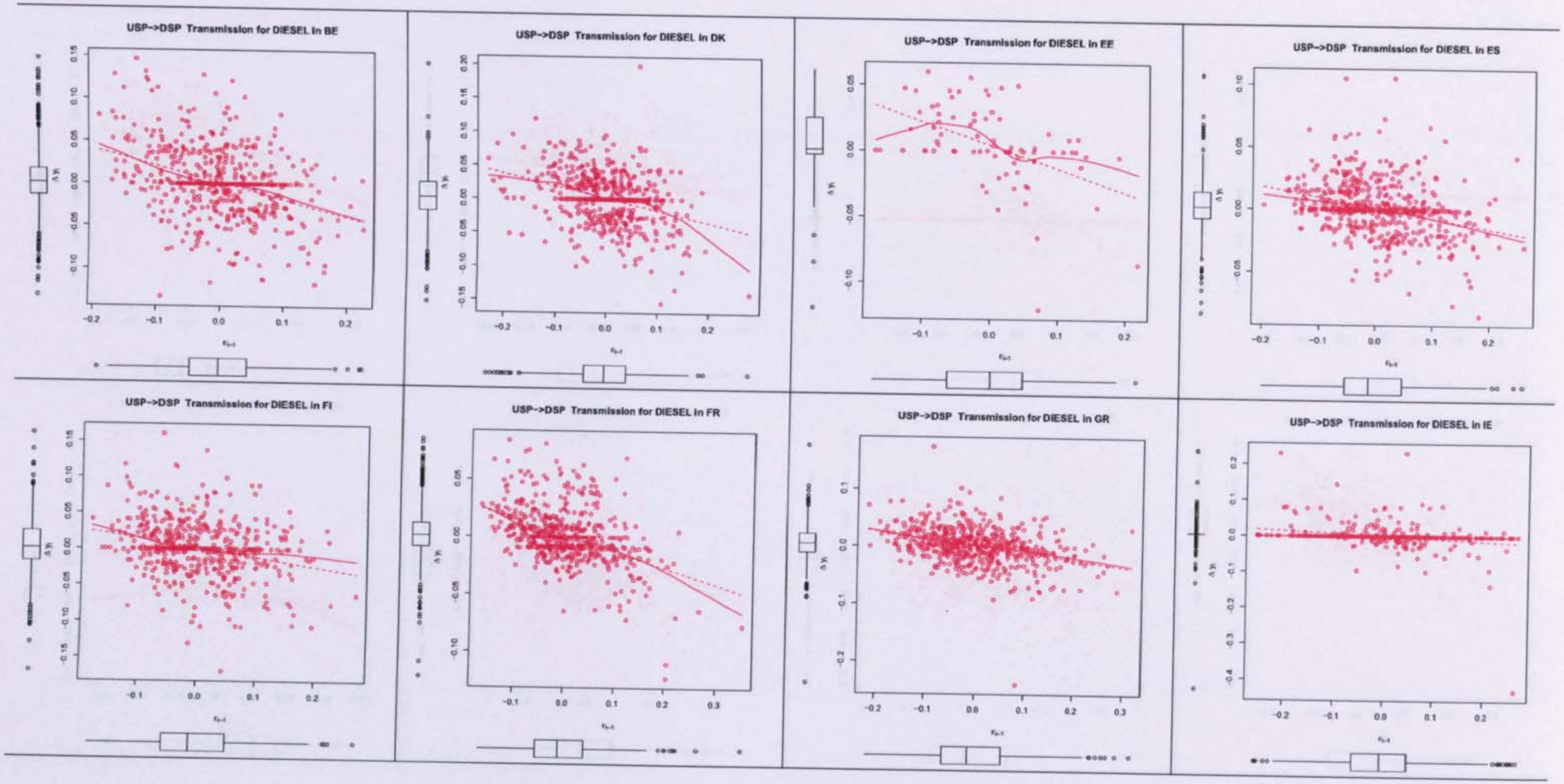
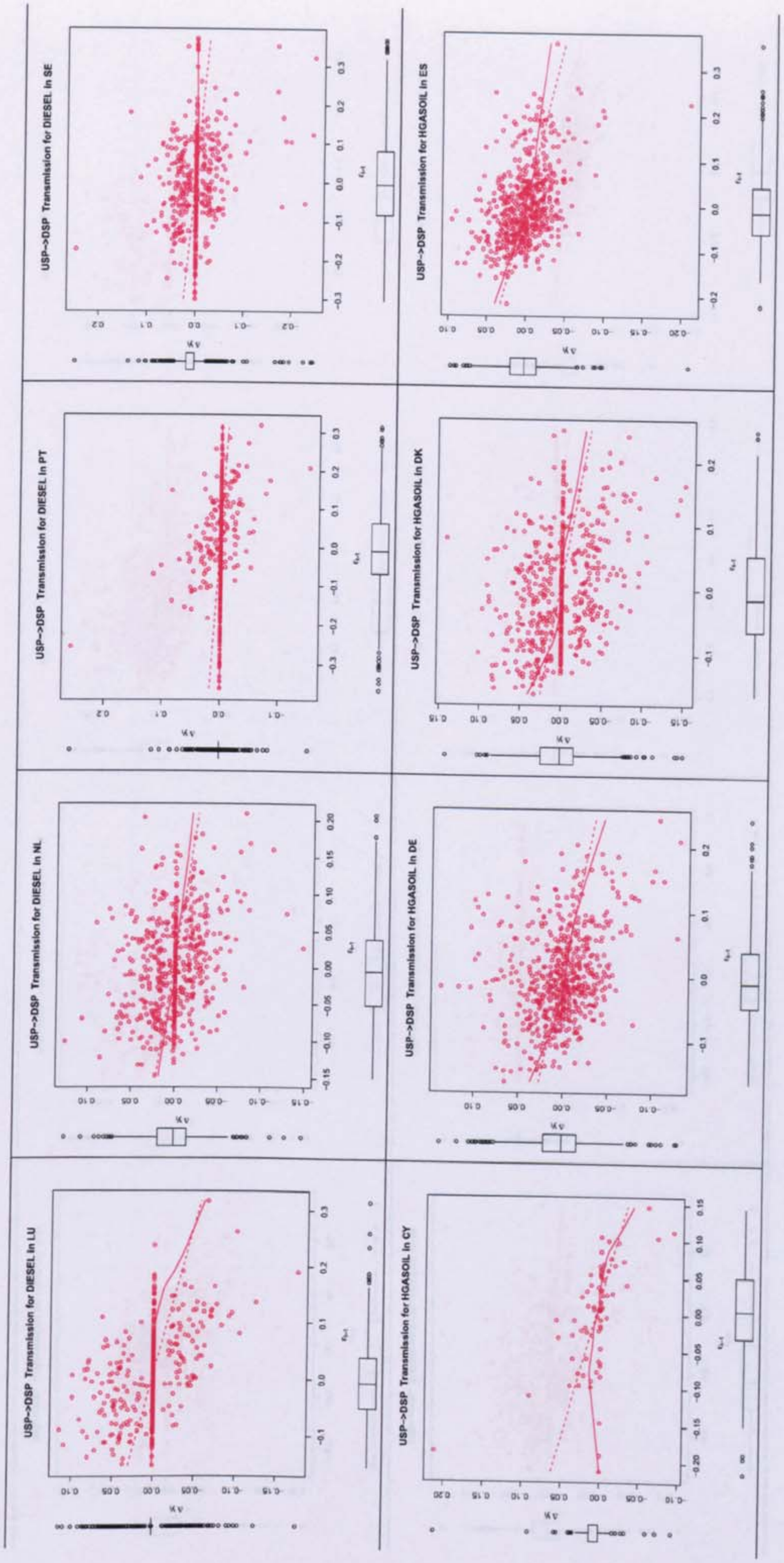
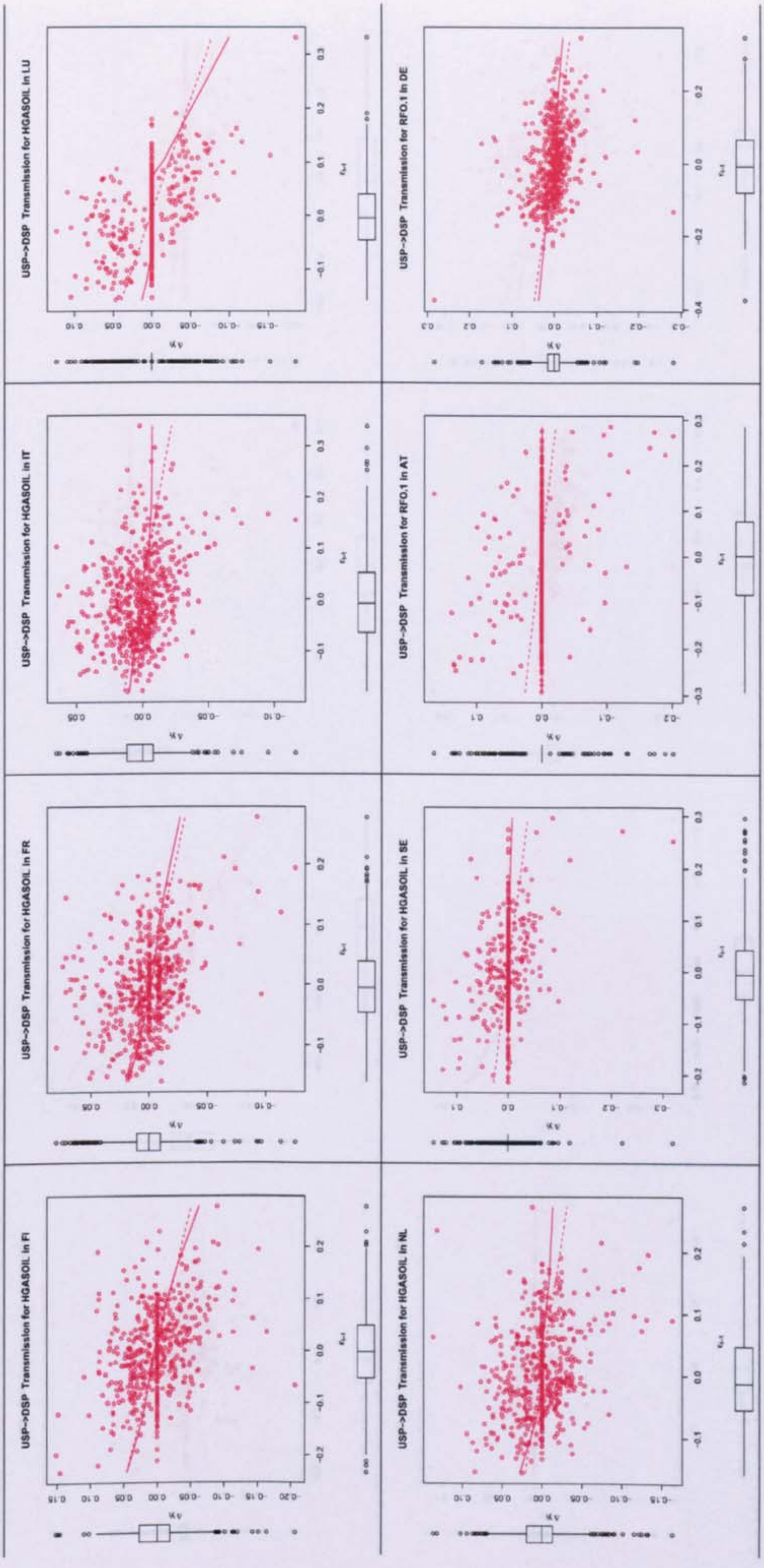

MSP->DSP Transmission for SUPER in BE
MSP->DSP Transmission for SUPER in GR
MSP->DSP Transmission for SUPER in IT
MSP->DSP Transmission for SUPER in LU
MSP->DSP Transmission for SUPER in PT
USP->MSP Transmission for DIESEL in NA
USP->MSP Transmission for LPG.1 in NA

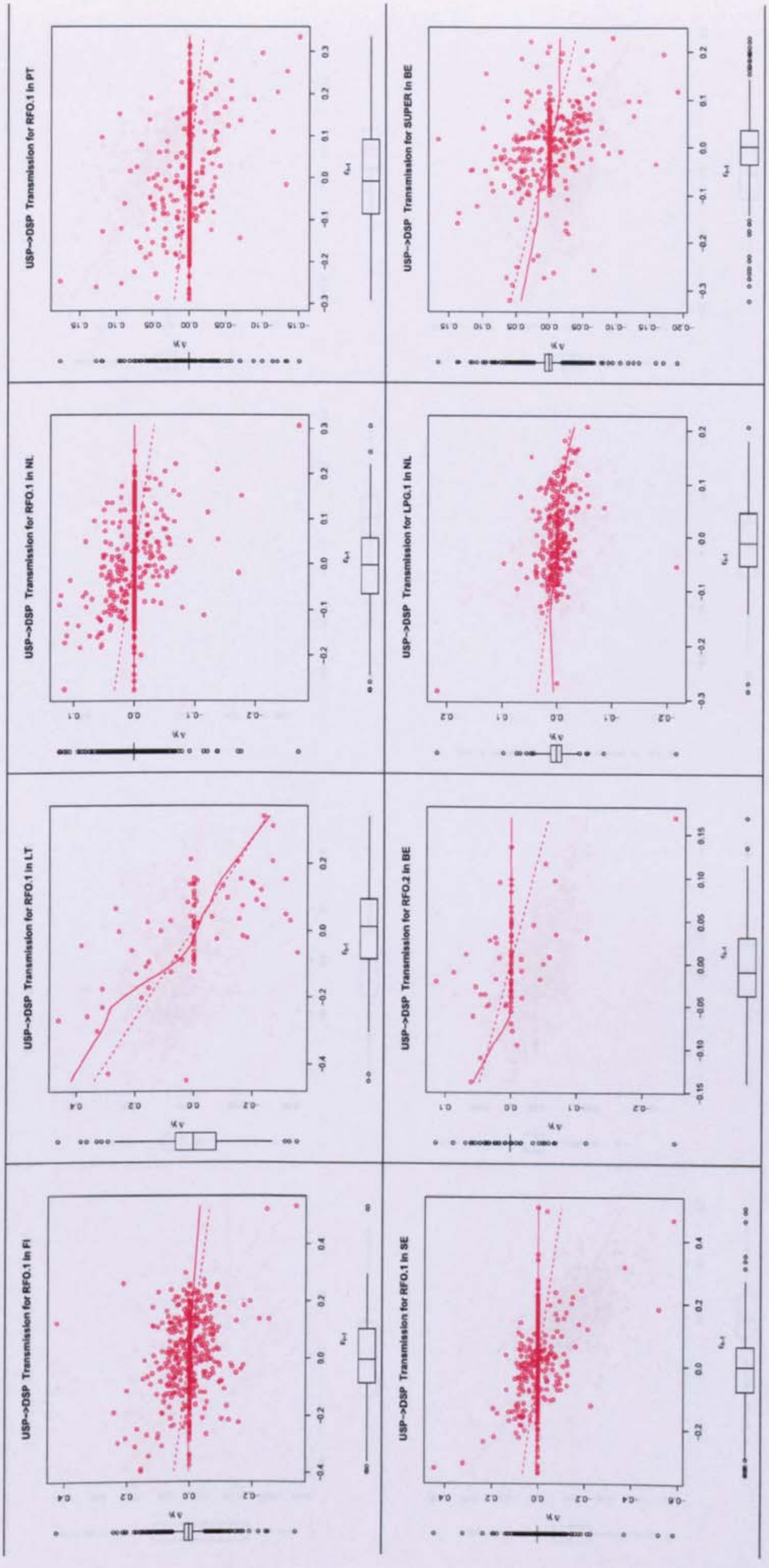
Table A.88: Scatter Plots - $\Delta\epsilon_t$ vs y_t

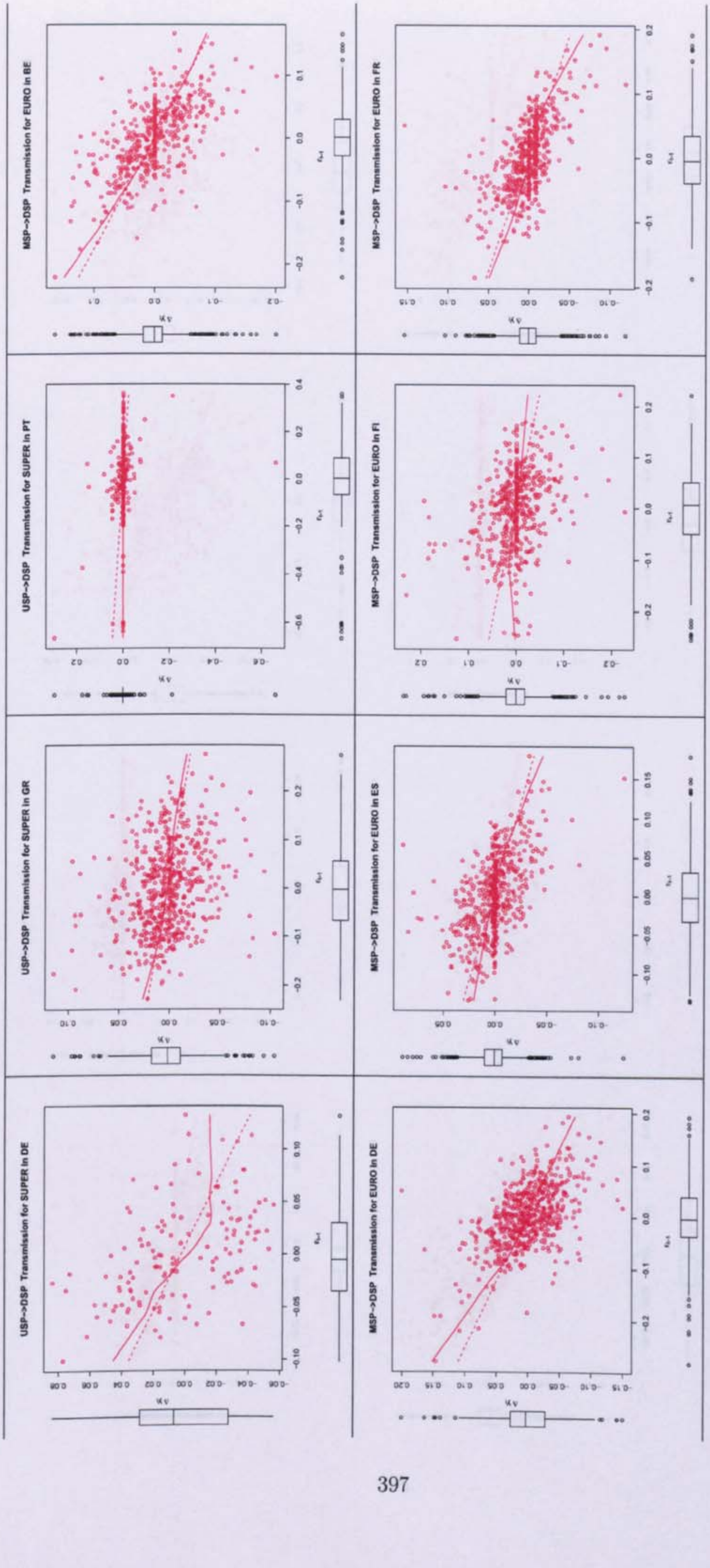


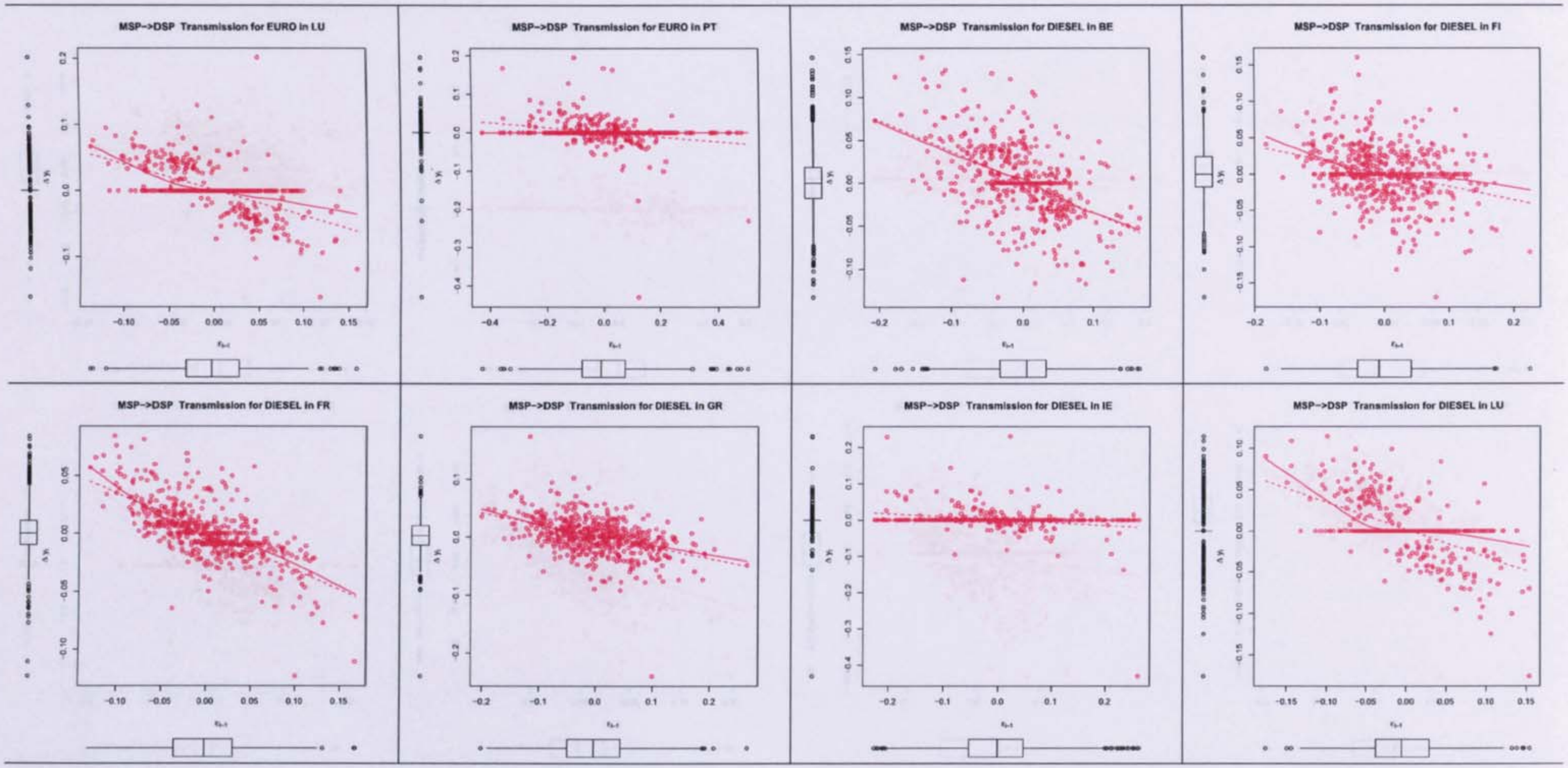

USP->DSP Transmission for DIESEL in BE
USP->DSP Transmission for DIESEL in DK
USP->DSP Transmission for DIESEL in EE
USP->DSP Transmission for DIESEL in ES
USP->DSP Transmission for DIESEL in FI
USP->DSP Transmission for DIESEL in FR
USP->DSP Transmission for DIESEL in GR
USP->DSP Transmission for DIESEL in IE

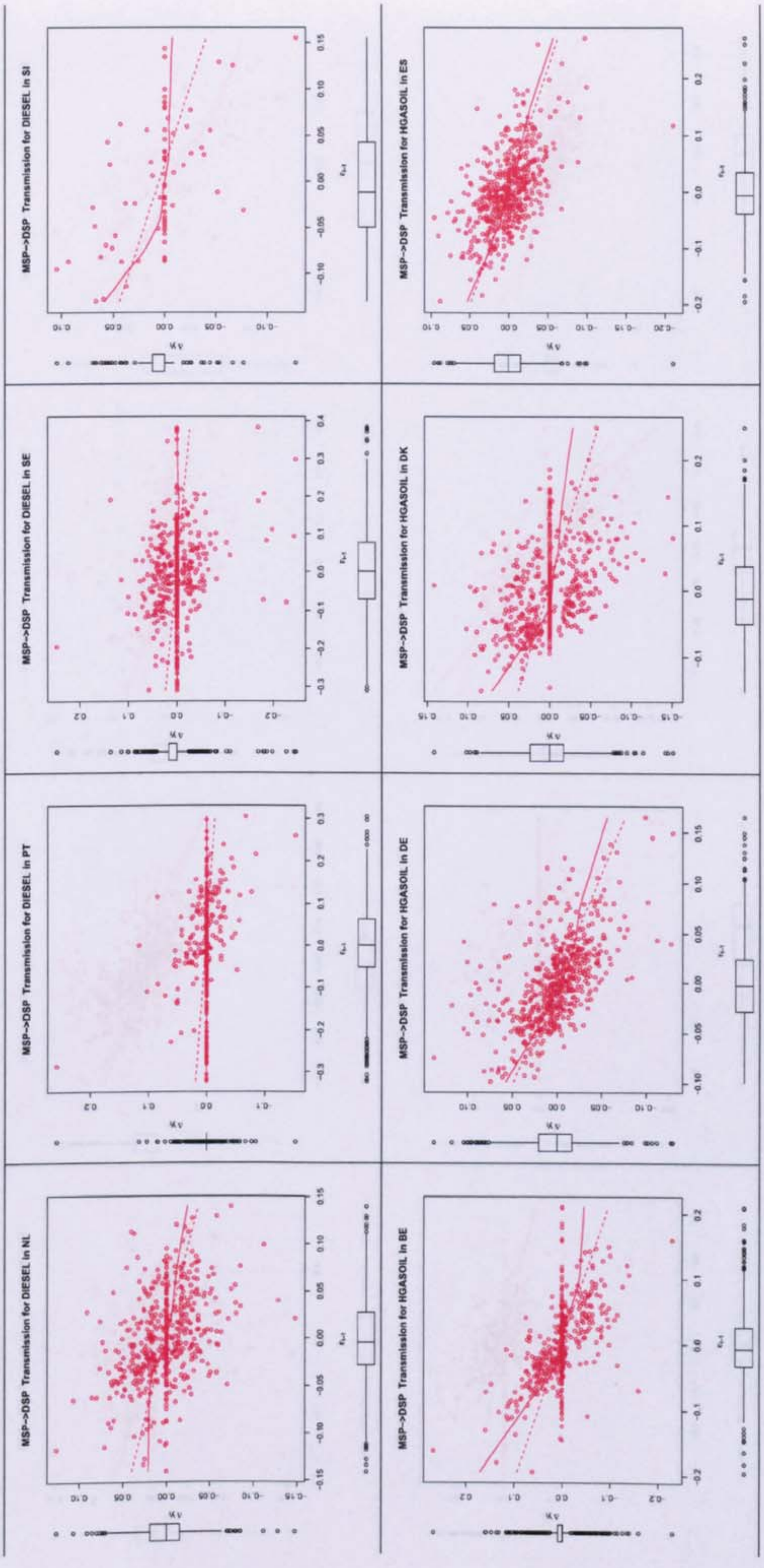

USP->DSP Transmission for DIESEL in LU
USP->DSP Transmission for DIESEL in NL
USP->DSP Transmission for DIESEL in PT
USP->DSP Transmission for DIESEL in SE
USP->DSP Transmission for HGASOIL in CY
USP->DSP Transmission for HGASOIL in DE
USP->DSP Transmission for HGASOIL in DK
USP->DSP Transmission for HGASOIL in ES

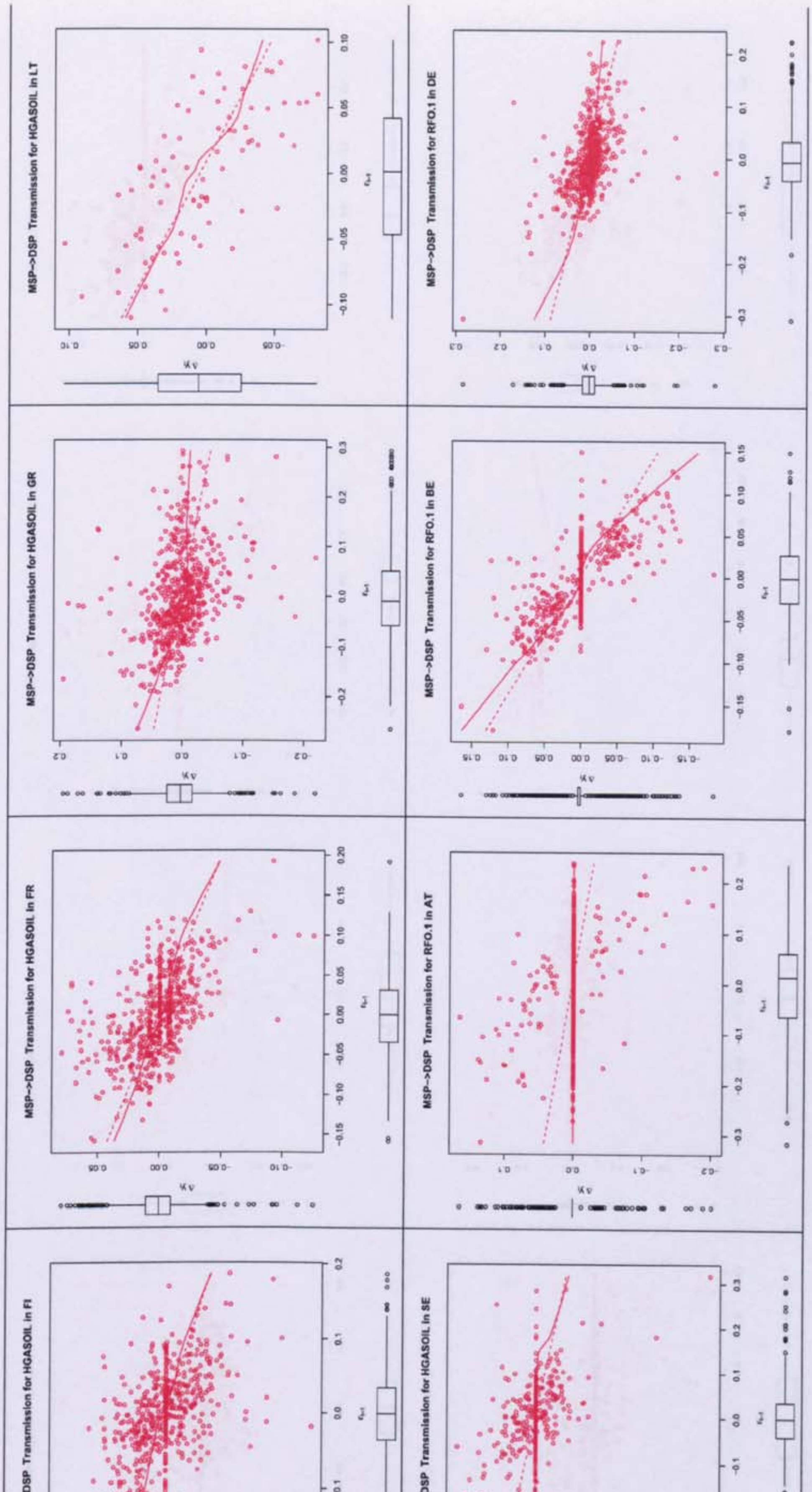

USP->DSP Transmission for HGASOIL in LU
USP->DSP Transmission for HGASOIL in IT
USP->DSP Transmission for HGASOIL in FR
USP->DSP Transmission for HGASOIL in FI
USP->DSP Transmission for RFO.1 in DE
USP->DSP Transmission for RFO.1 in AT
USP->DSP Transmission for HGASOIL in SE
USP->DSP Transmission for HGASOIL in NL

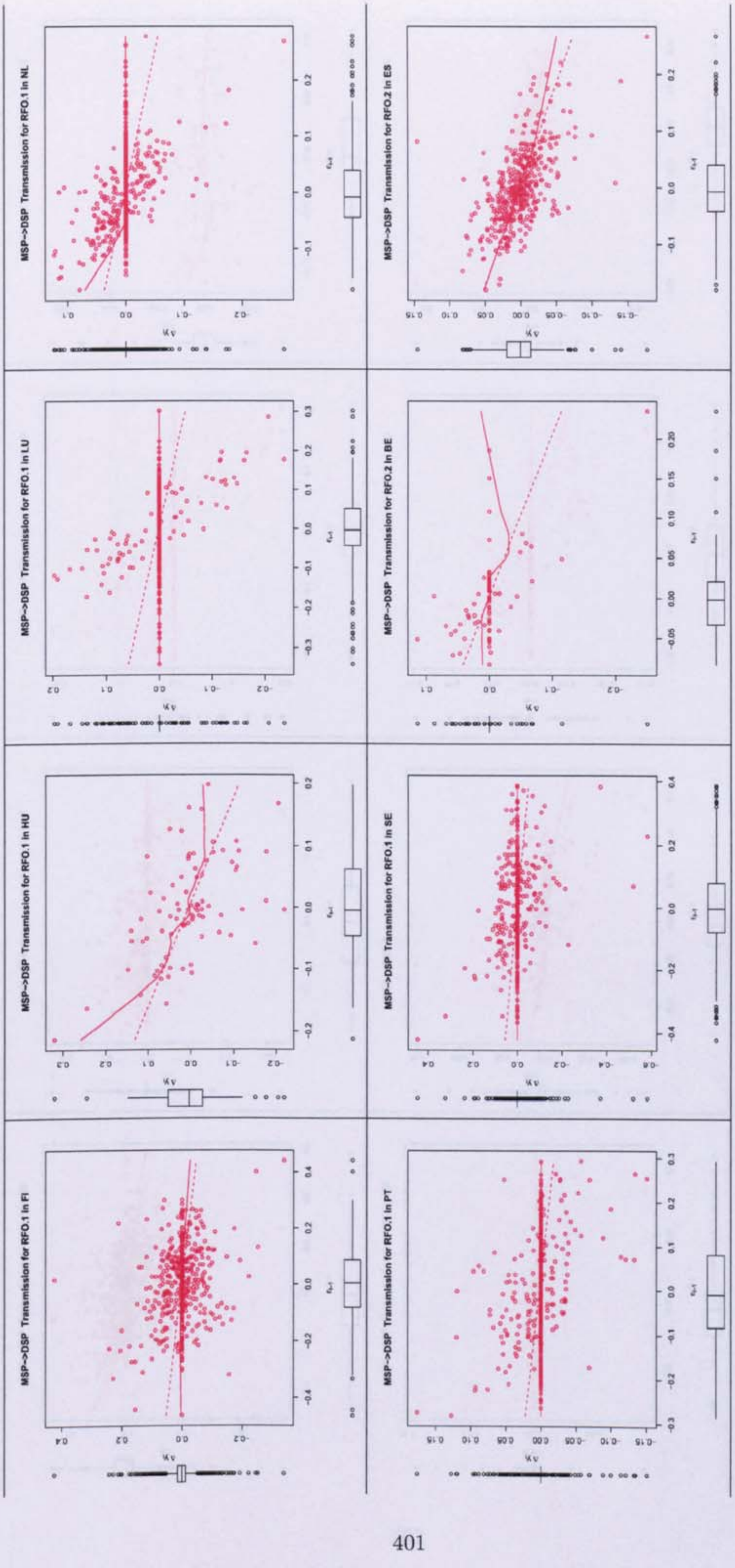

USP->DSP Transmission for RFO.1 in PT
USP->DSP Transmission for SUPER in BE
USP->DSP Transmission for RFO.1 in NL
USP->DSP Transmission for LPG.1 in NL
USP->DSP Transmission for RFO.1 in LT
USP->DSP Transmission for RFO.2 in BE
USP->DSP Transmission for RFO.1 in FI
USP->DSP Transmission for RFO.1 in SE

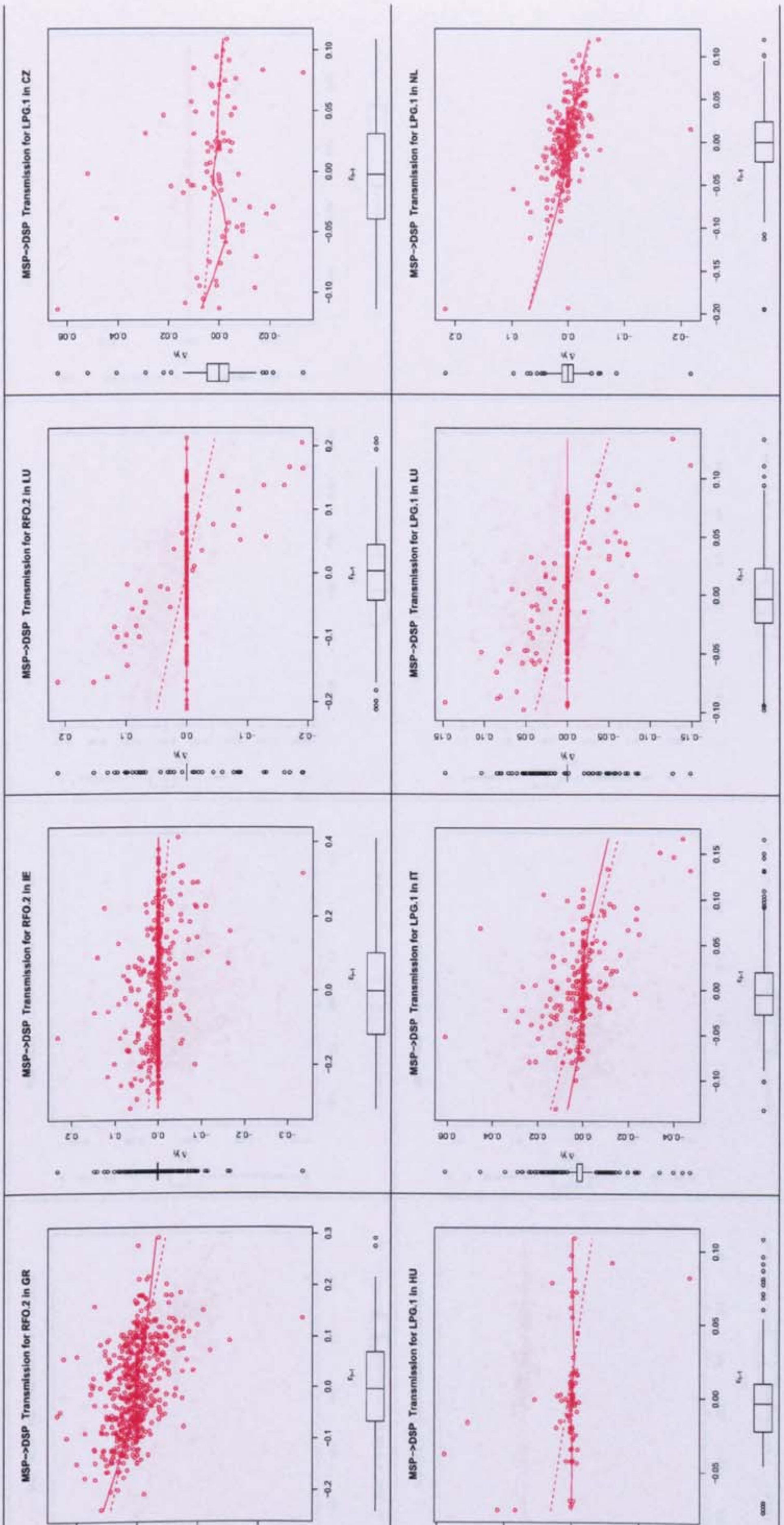

USP->DSP Transmission for SUPER in DE
USP->DSP Transmission for SUPER in GR
USP->DSP Transmission for SUPER in PT
MSP->DSP Transmission for EURO in BE
MSP->DSP Transmission for EURO in DE
MSP->DSP Transmission for EURO in ES
MSP->DSP Transmission for EURO in FI
MSP->DSP Transmission for EURO in FR


MSP->DSP Transmission for EURO in LU
MSP->DSP Transmission for EURO in PT
MSP->DSP Transmission for DIESEL in BE
MSP->DSP Transmission for DIESEL in FI
MSP->DSP Transmission for DIESEL in FR
MSP->DSP Transmission for DIESEL in GR
MSP->DSP Transmission for DIESEL in IE
MSP->DSP Transmission for DIESEL in LU


MSP->DSP Transmission for DIESEL in SI
MSP->DSP Transmission for DIESEL in SE
MSP->DSP Transmission for DIESEL in PT
MSP->DSP Transmission for DIESEL in NL
MSP->DSP Transmission for HGASOIL in ES
MSP->DSP Transmission for HGASOIL in DK
MSP->DSP Transmission for HGASOIL in DE
MSP->DSP Transmission for HGASOIL in BE


MSP->DSP Transmission for HGASOIL in FI
MSP->DSP Transmission for HGASOIL in FR
MSP->DSP Transmission for HGASOIL in GR
MSP->DSP Transmission for HGASOIL in LT
MSP->DSP Transmission for HGASOIL in SE
MSP->DSP Transmission for RFO.1 in AT
MSP->DSP Transmission for RFO.1 in BE
MSP->DSP Transmission for RFO.1 in DE


MSP->DSP Transmission for RFO.1 in FI
MSP->DSP Transmission for RFO.1 in HU
MSP->DSP Transmission for RFO.1 in LU
MSP->DSP Transmission for RFO.1 in NL
MSP->DSP Transmission for RFO.1 in PT
MSP->DSP Transmission for RFO.1 in SE
MSP->DSP Transmission for RFO.2 in BE
MSP->DSP Transmission for RFO.2 in ES


MSP->DSP Transmission for LPG.1 in CZ
MSP->DSP Transmission for RFO.2 in LU
MSP->DSP Transmission for RFO.2 in IE
MSP->DSP Transmission for RFO.2 in GR
MSP->DSP Transmission for LPG.1 in NL
MSP->DSP Transmission for LPG.1 in LU
MSP->DSP Transmission for LPG.1 in IT
MSP->DSP Transmission for LPG.1 in HU

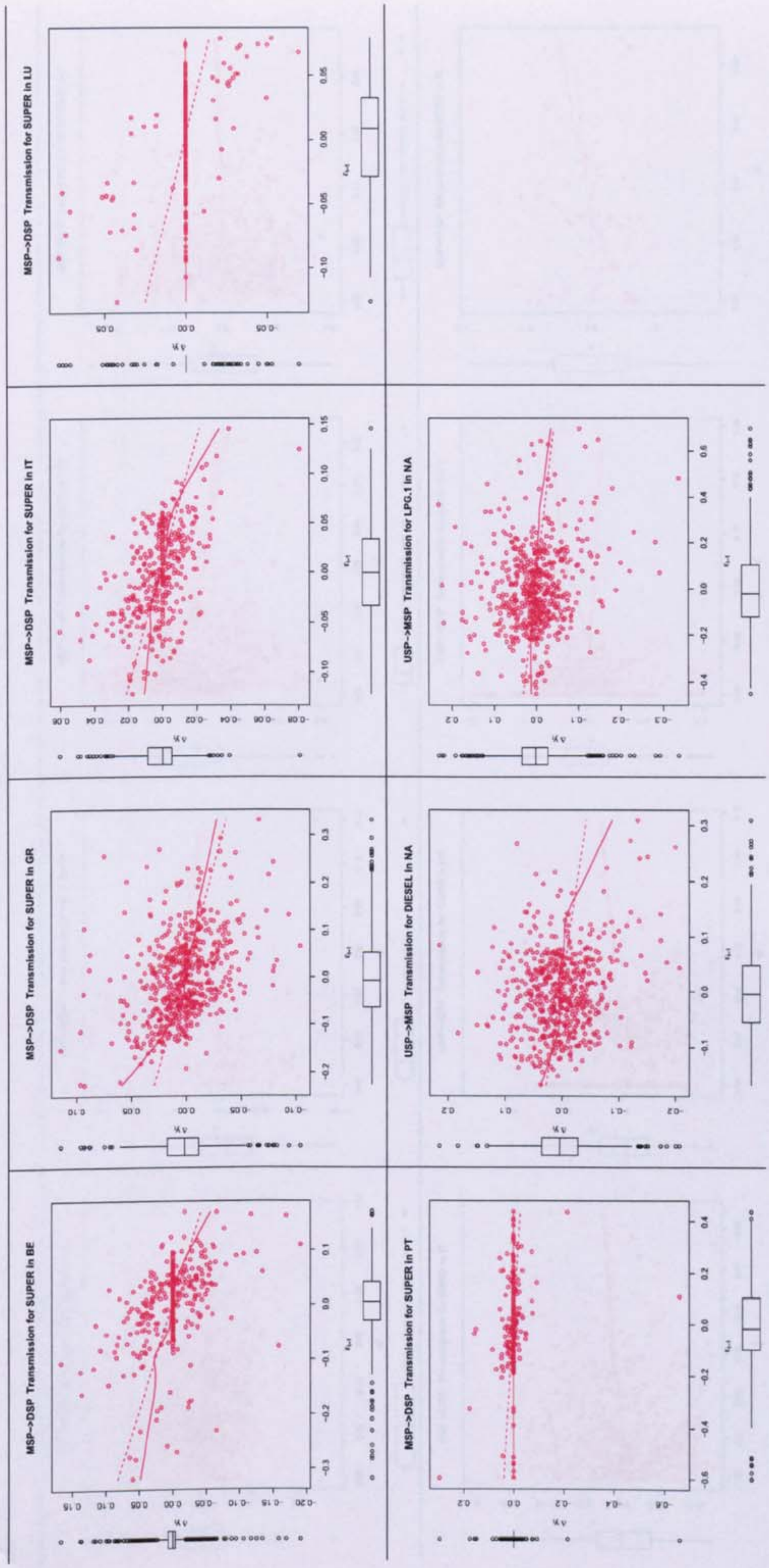
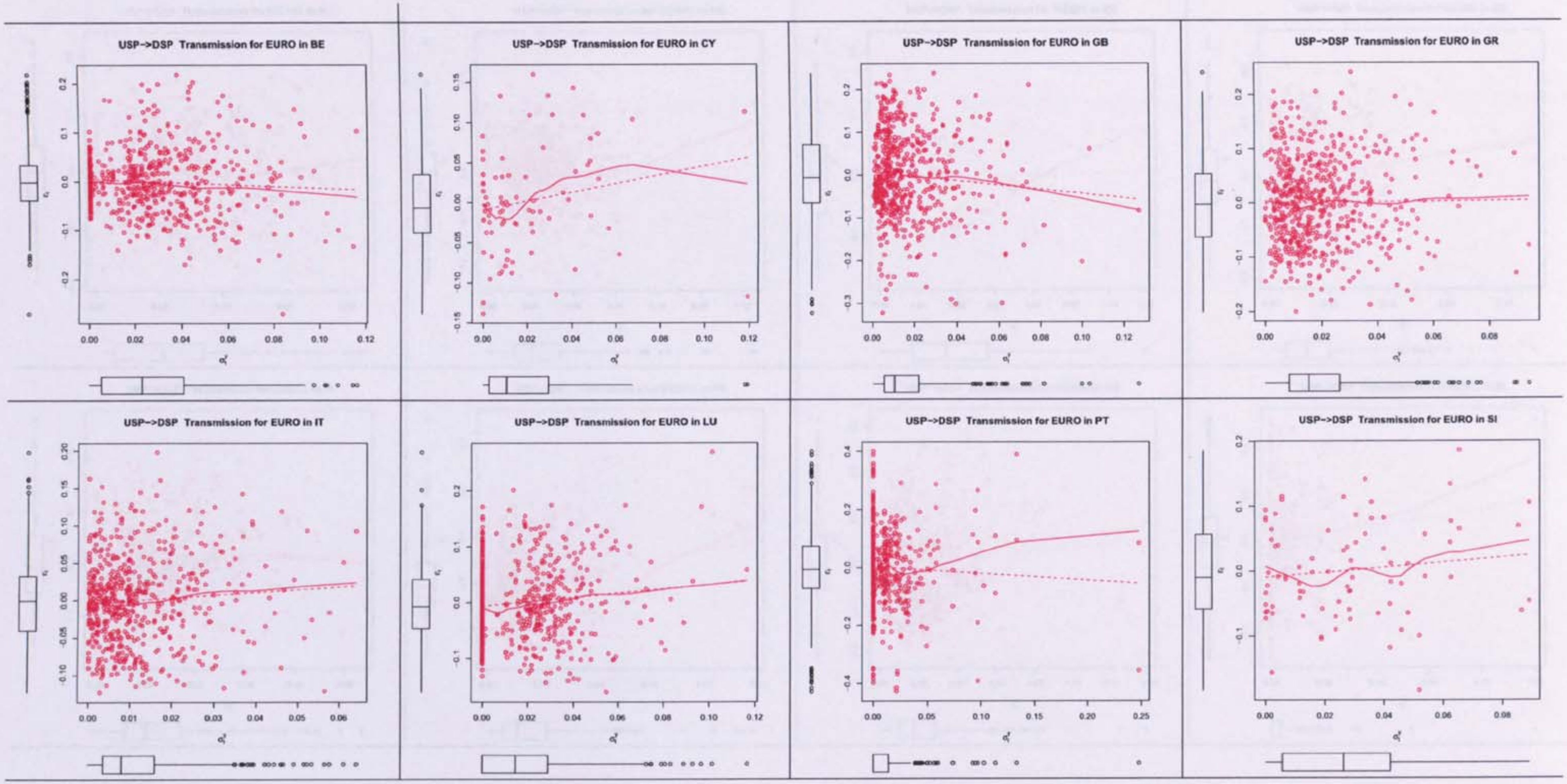
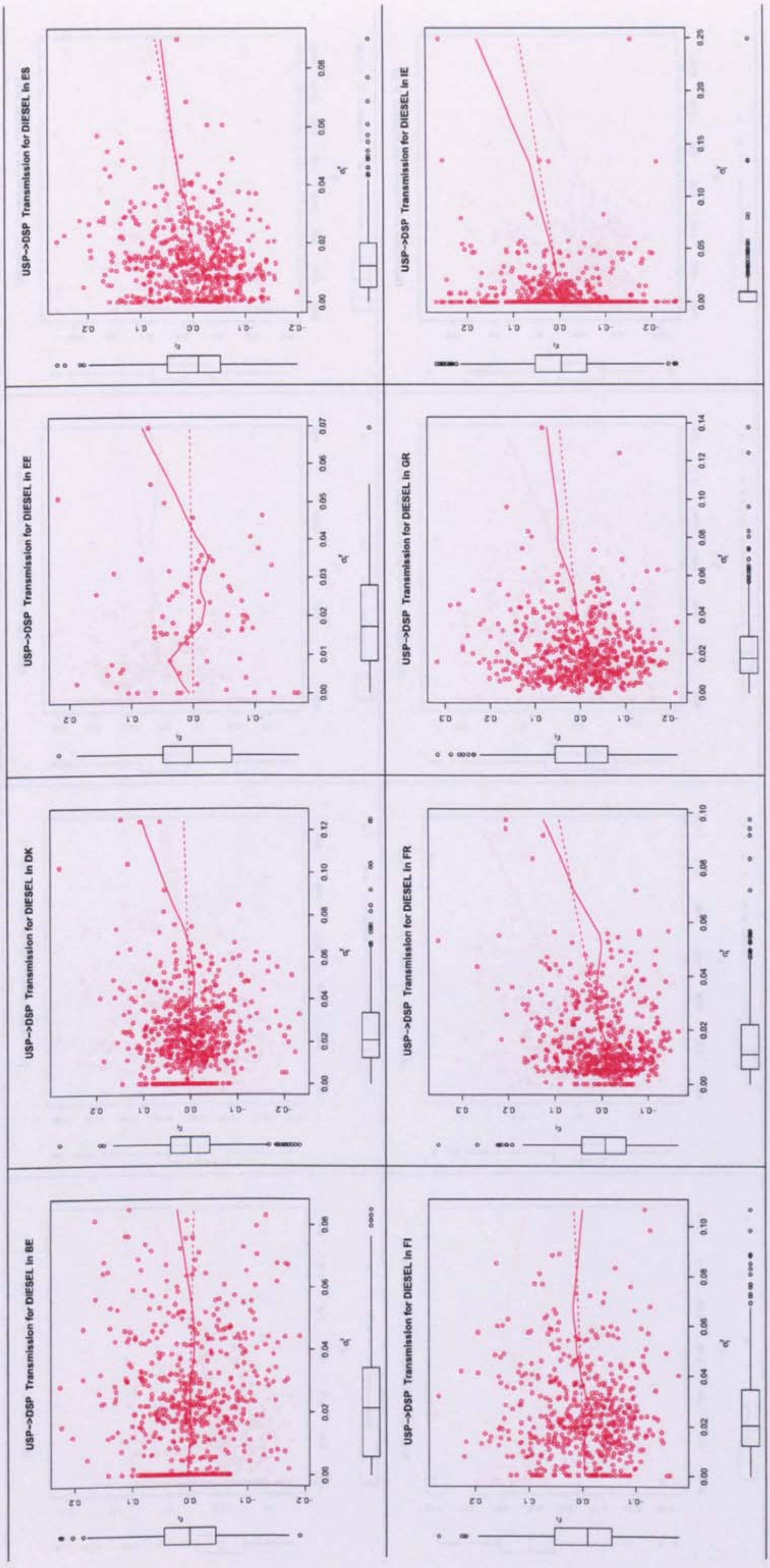

MSP->DSP Transmission for SUPER in LU
MSP->DSP Transmission for SUPER in IT
MSP->DSP Transmission for SUPER in GR
MSP->DSP Transmission for SUPER in BE
USP->MSP Transmission for LPG.1 in NA
USP->MSP Transmission for DIESEL in NA
MSP->DSP Transmission for SUPER in PT

Table A.89: Scatter Plots - $\Delta\epsilon_t$ vs σ_t^y

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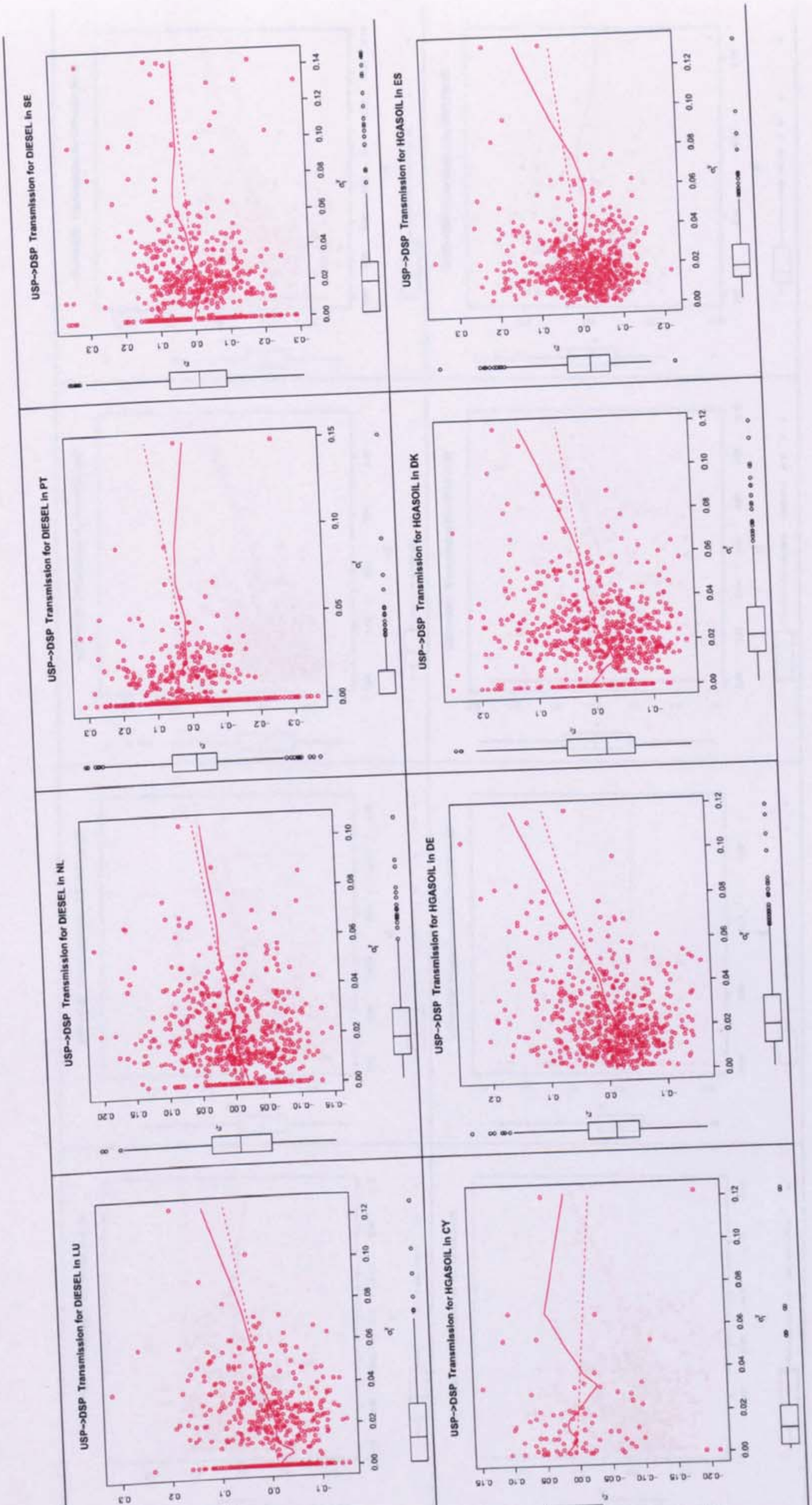
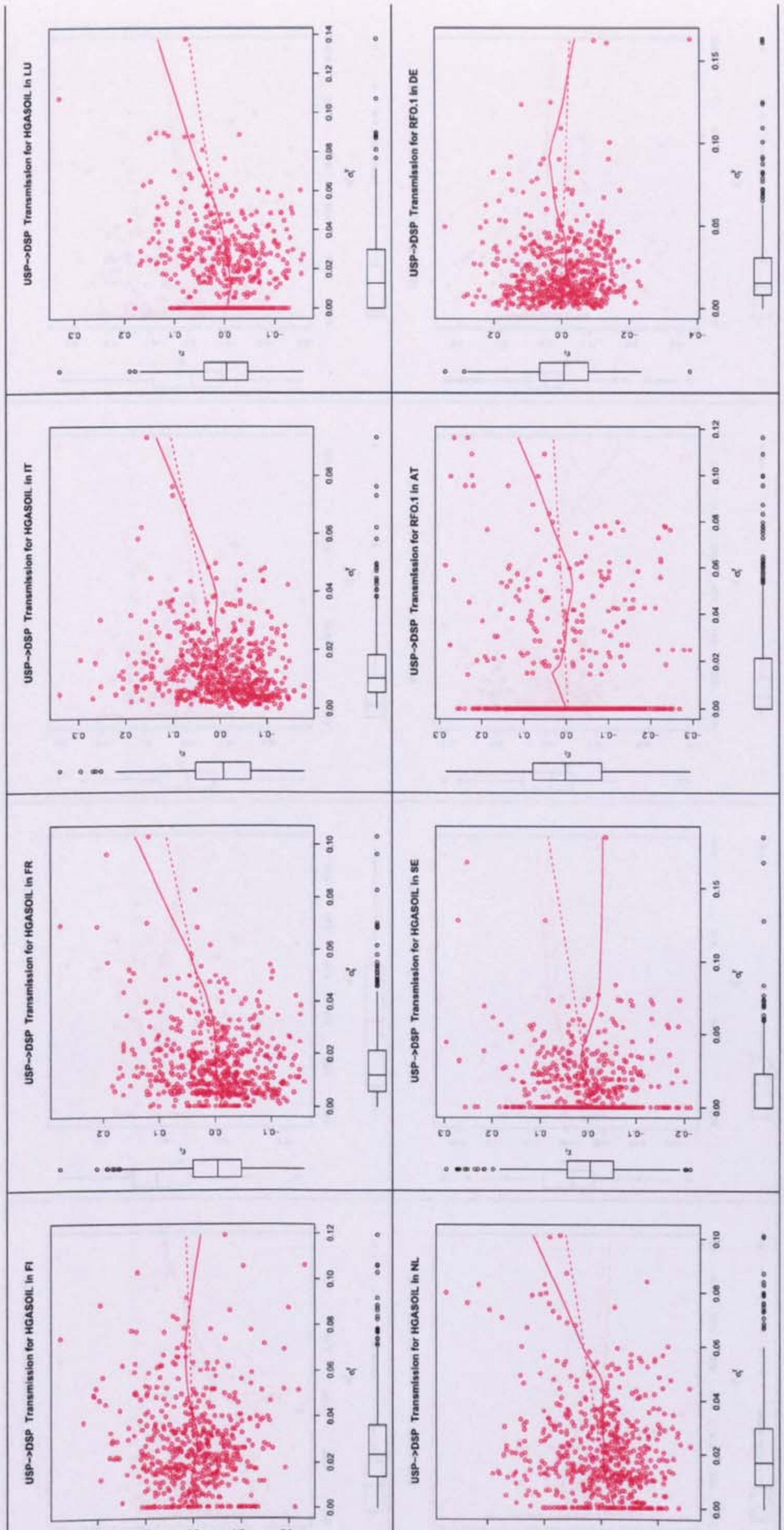
USP->DSP Transmission for DIESEL in DK
USP->DSP Transmission for DIESEL in EE
USP->DSP Transmission for DIESEL in ES
USP->DSP Transmission for DIESEL in FI
USP->DSP Transmission for DIESEL in FR
USP->DSP Transmission for DIESEL in GR
USP->DSP Transmission for DIESEL in IE


USP->DSP Transmission for DIESEL in SE
USP->DSP Transmission for DIESEL in PT
USP->DSP Transmission for DIESEL in NL
USP->DSP Transmission for DIESEL in LU
USP->DSP Transmission for HGASOIL in ES
USP->DSP Transmission for HGASOIL in DK
USP->DSP Transmission for HGASOIL in DE
USP->DSP Transmission for HGASOIL in CY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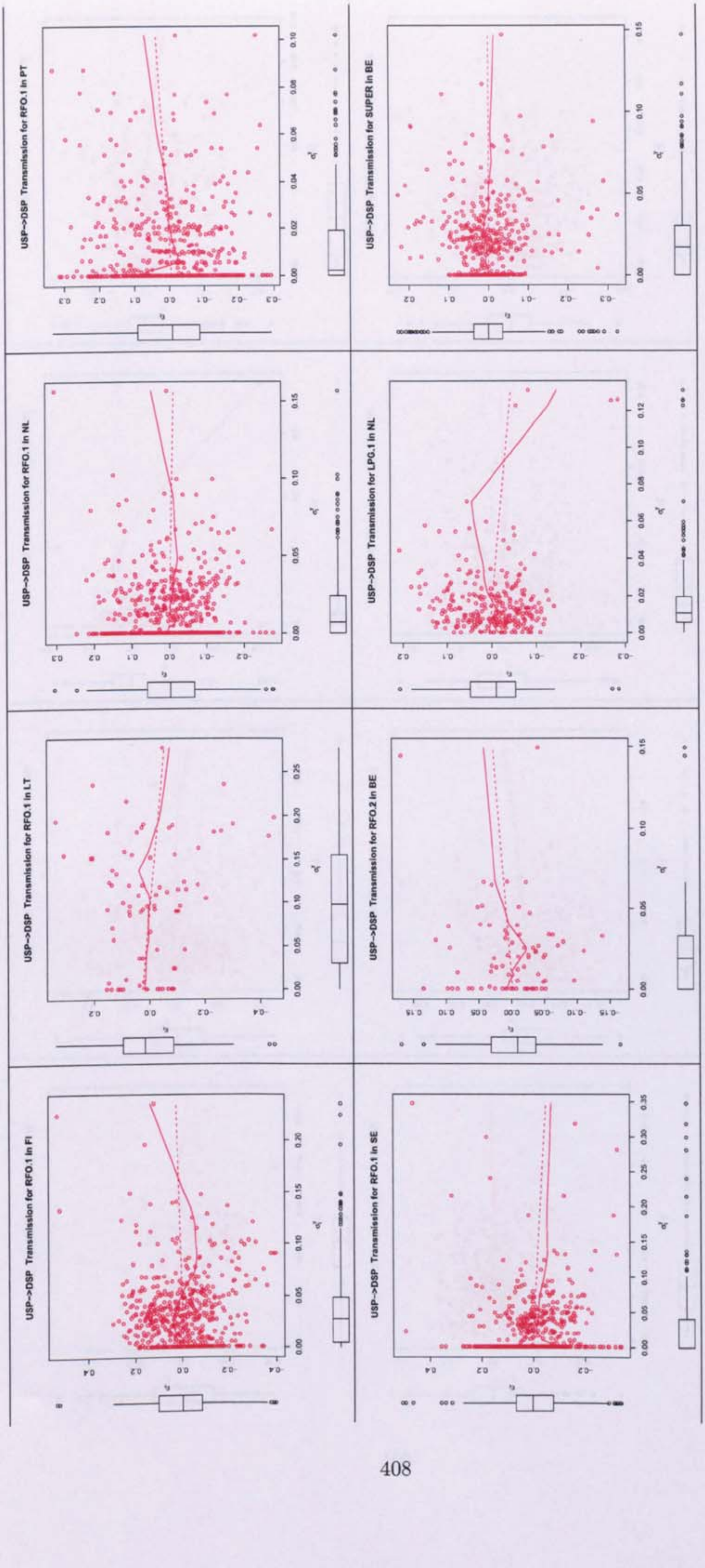
USP->DSP Transmission for RFO.1 in AT
USP->DSP Transmission for HGASOIL in SE
USP->DSP Transmission for HGASOIL in NL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USP->DSP Transmission for RFO.1 in FI
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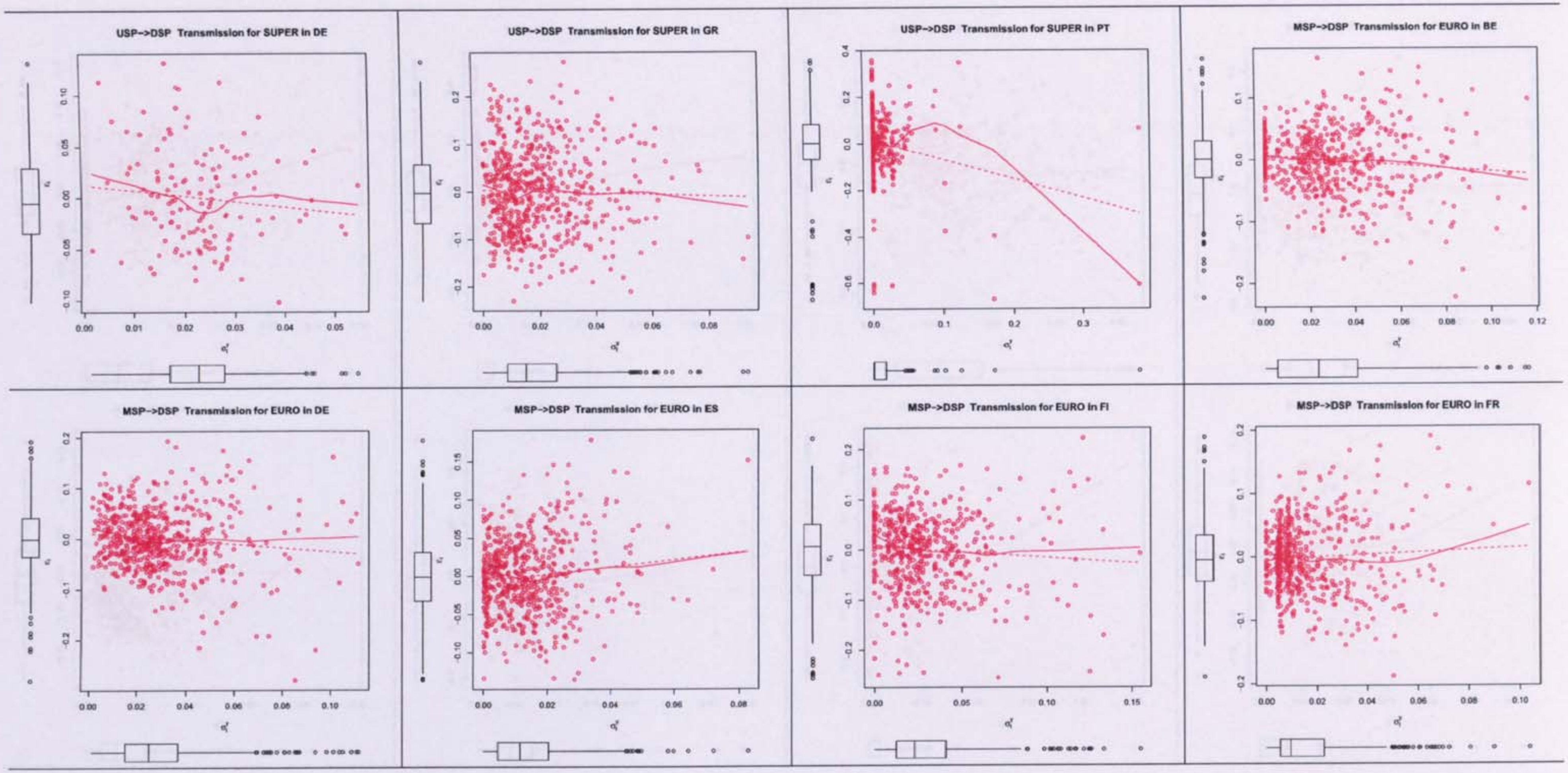
USP->DSP Transmission for LPG.1 in NL
USP->DSP Transmission for RFO.2 in BE
USP->DSP Transmission for RFO.1 in SE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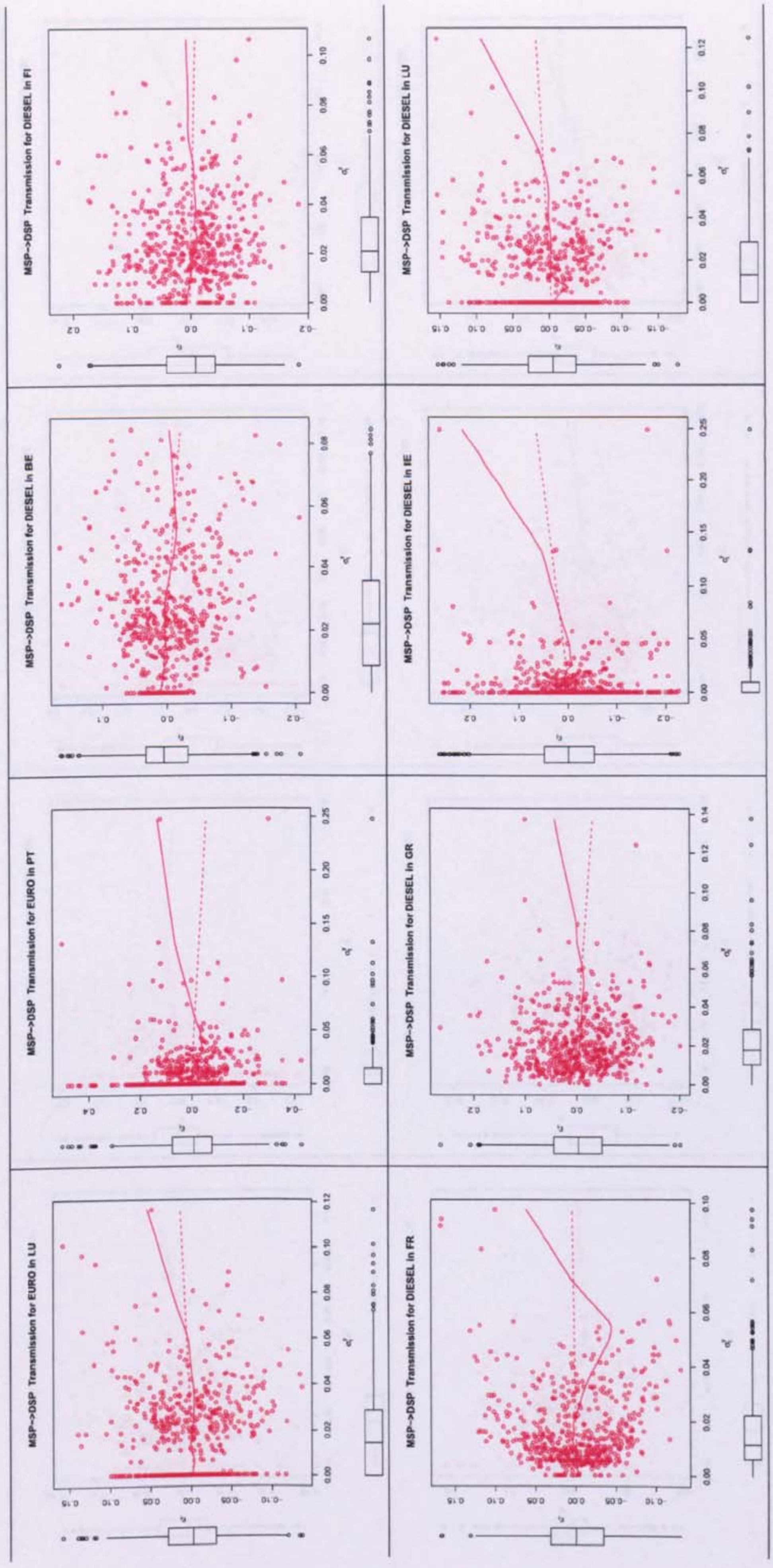
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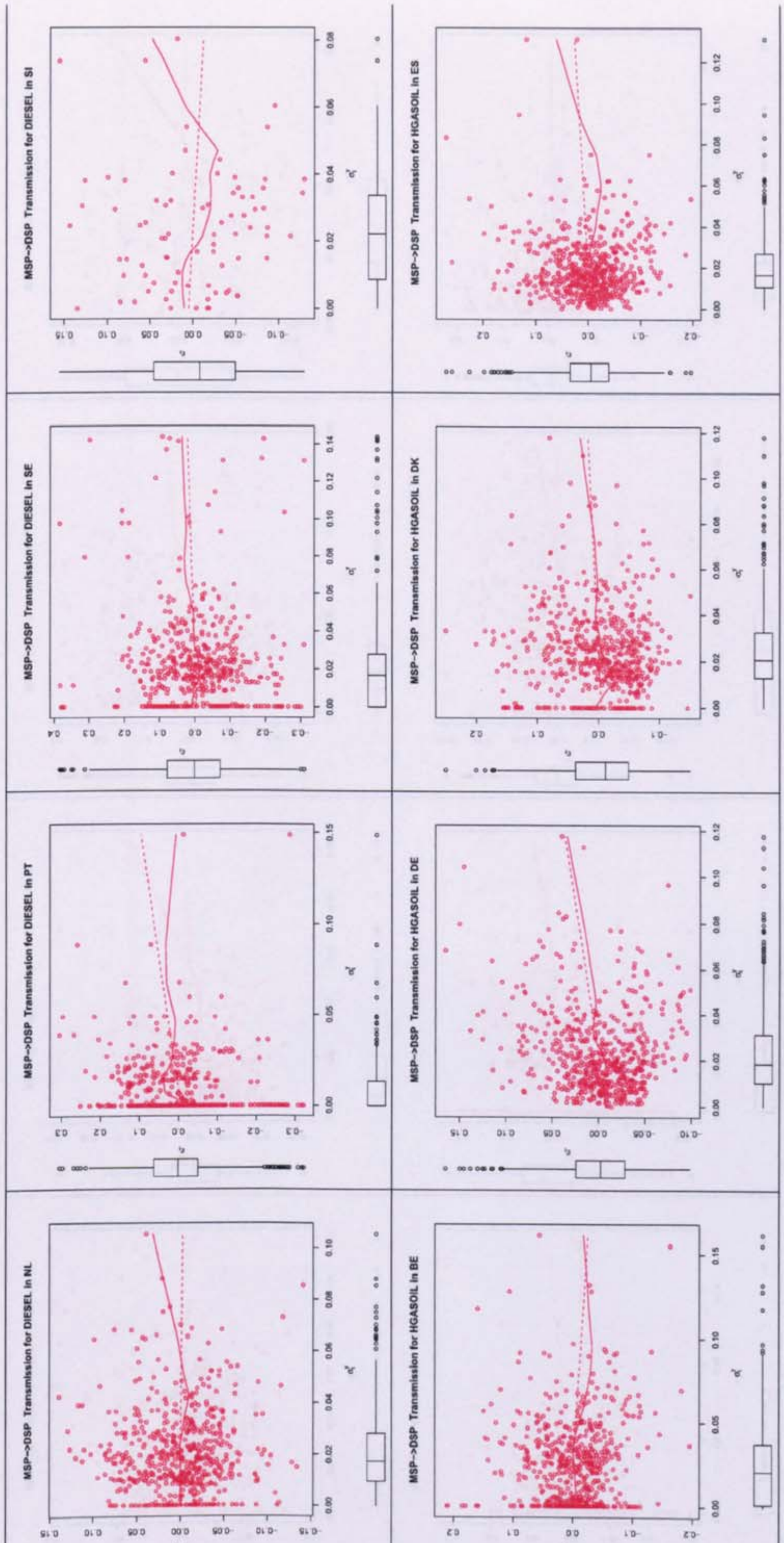
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MSP->DSP Transmission for DIESEL in SI
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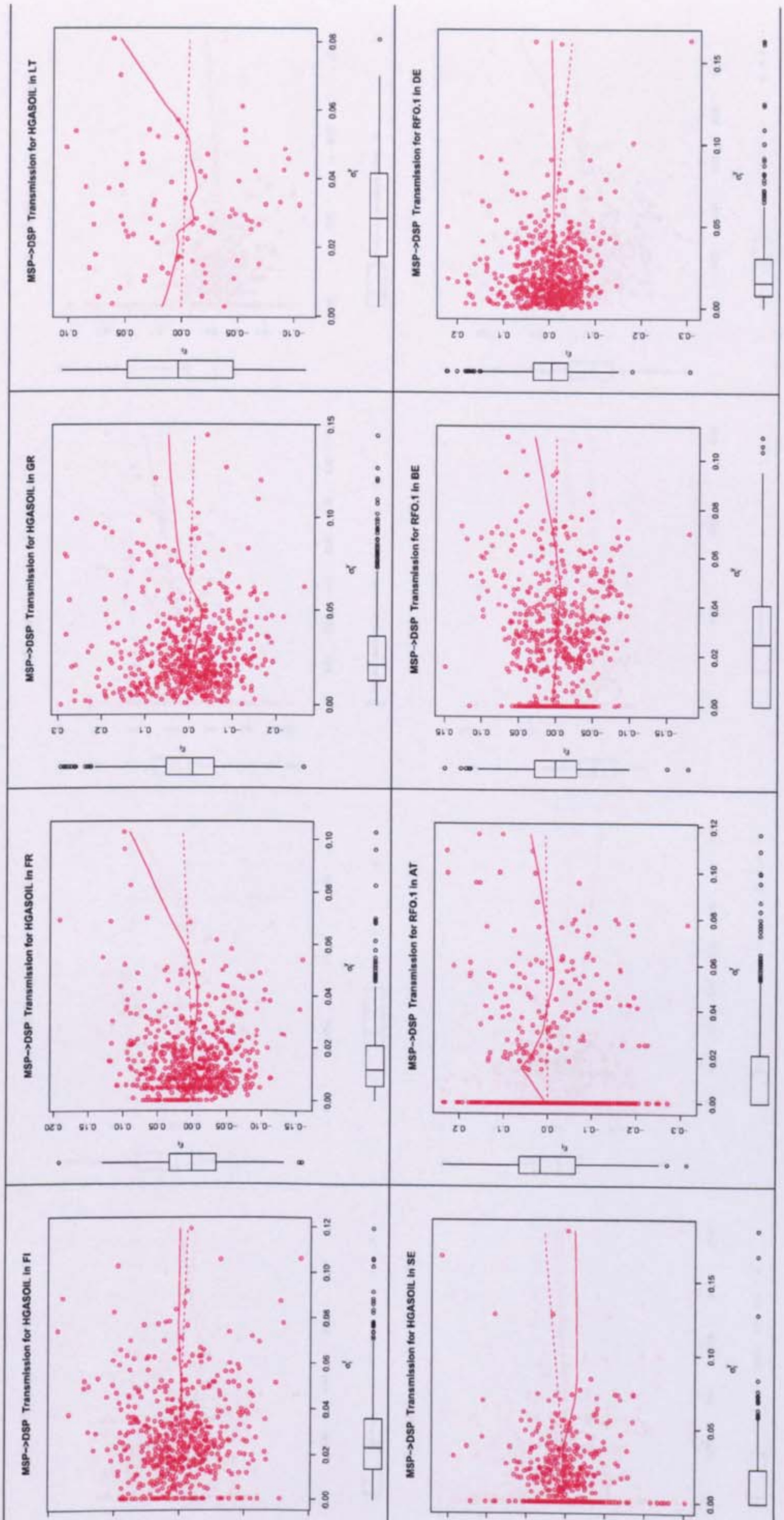
MSP->DSP Transmission for HGASOIL in DE
MSP->DSP Transmission for HGASOIL in DK
MSP->DSP Transmission for HGASOIL in ES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MSP->DSP Transmission for HGASOIL in FI
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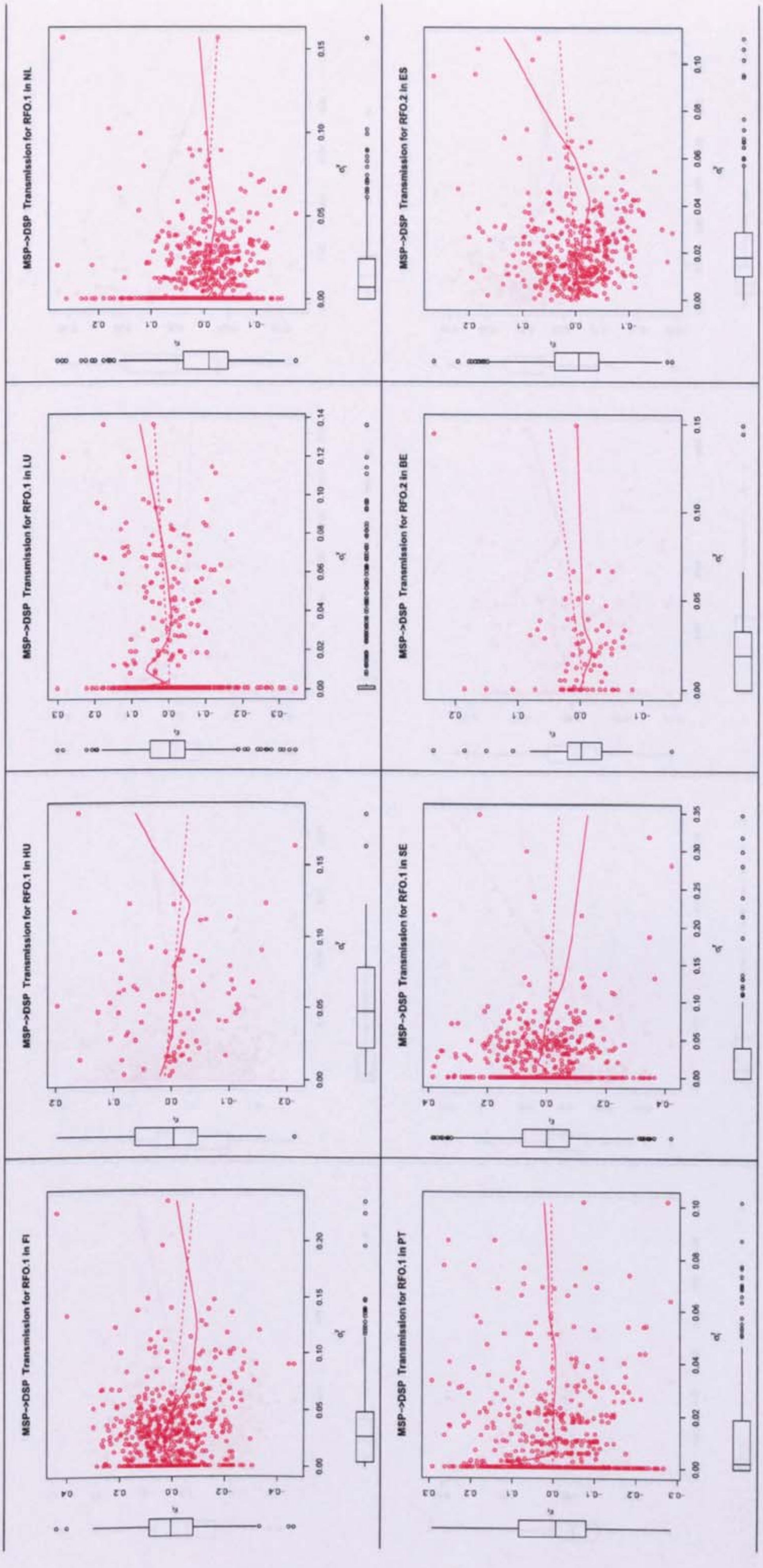
MSP->DSP Transmission for RFO.1 in BE
MSP->DSP Transmission for RFO.1 in AT
MSP->DSP Transmission for HGASOIL in SE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MSP->DSP Transmission for RFO.1 in FI
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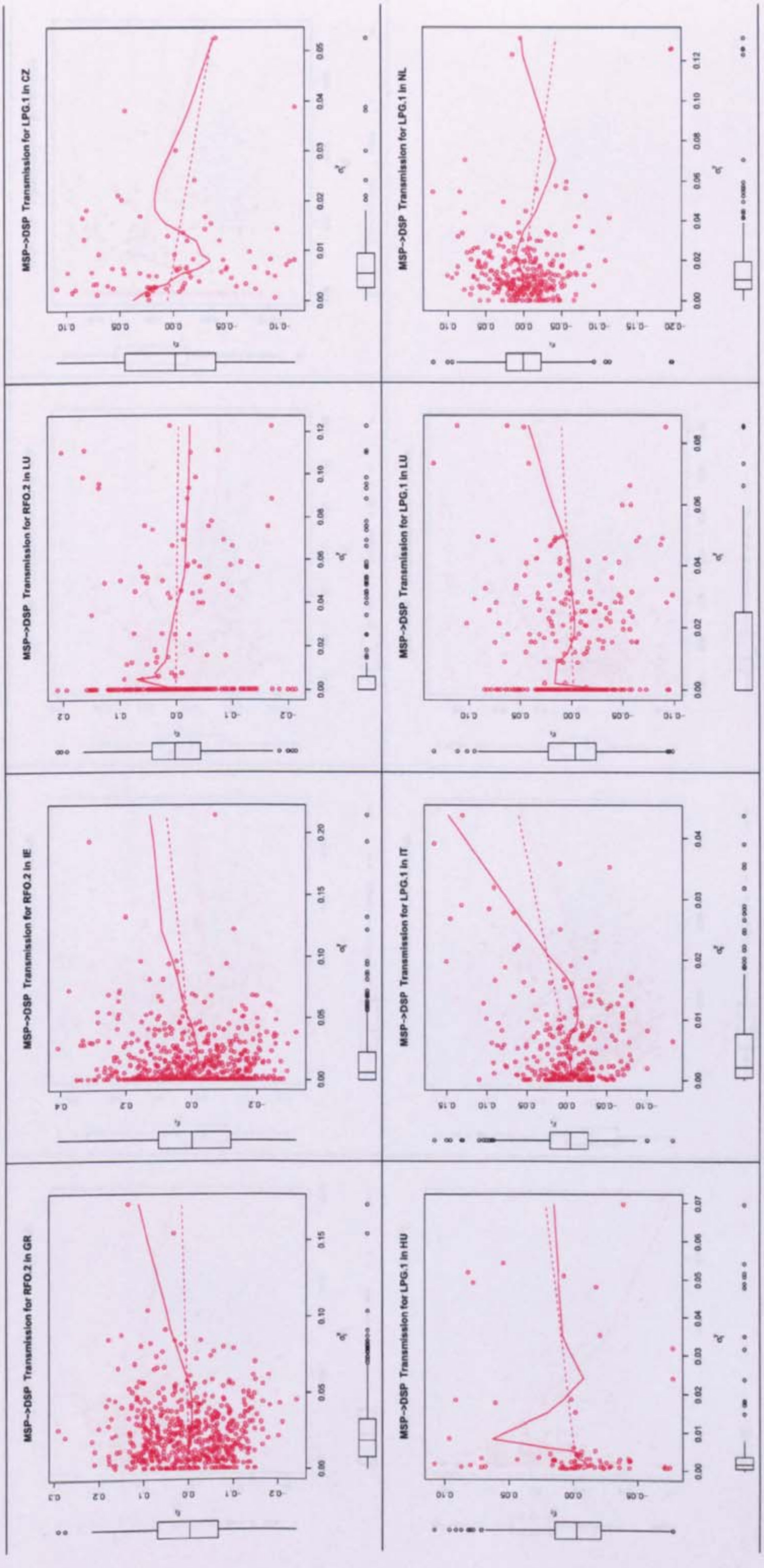
MSP->DSP Transmission for RFO.2 in BE
MSP->DSP Transmission for RFO.1 in SE
MSP->DSP Transmission for RFO.1 in PT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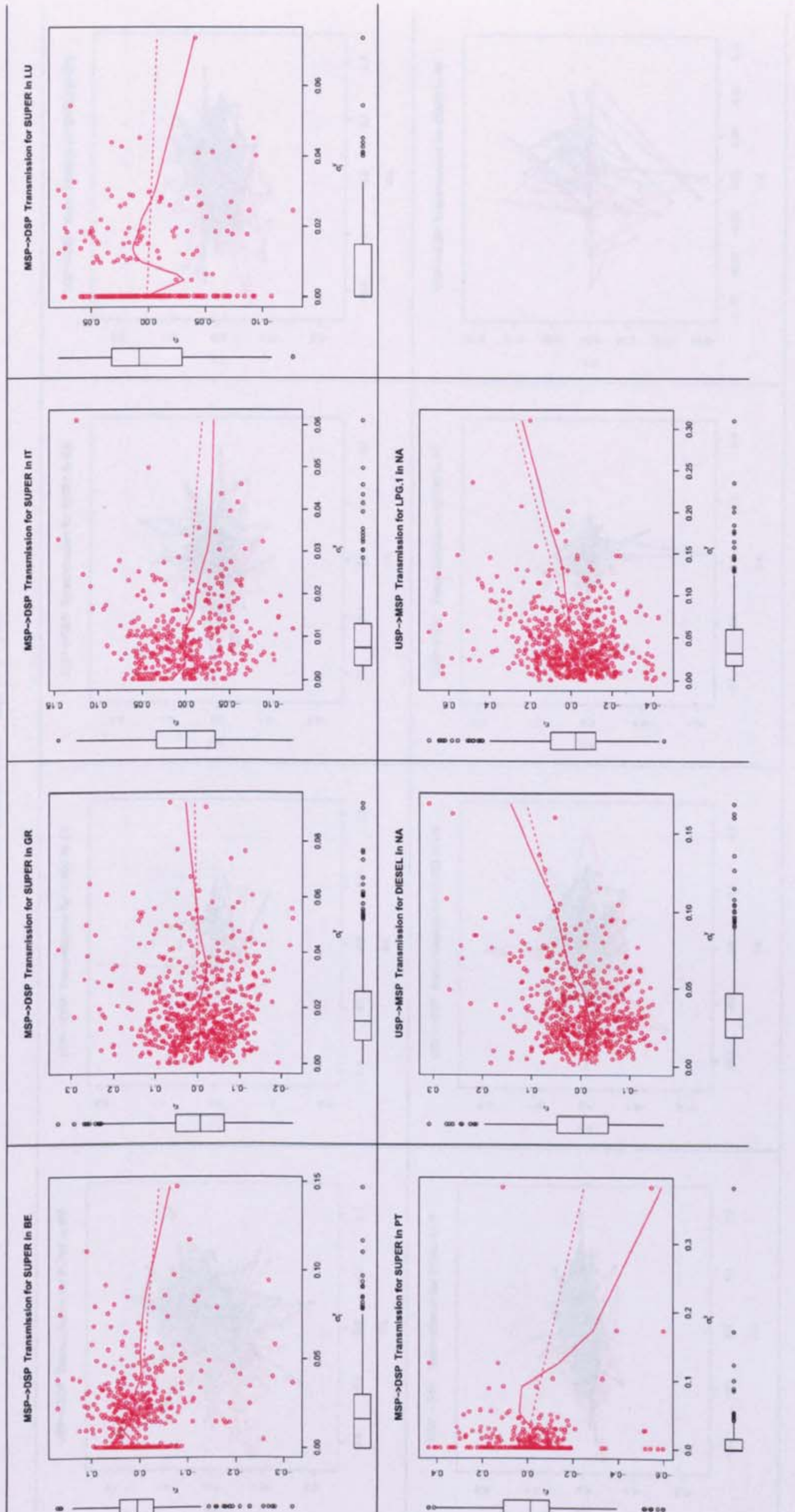
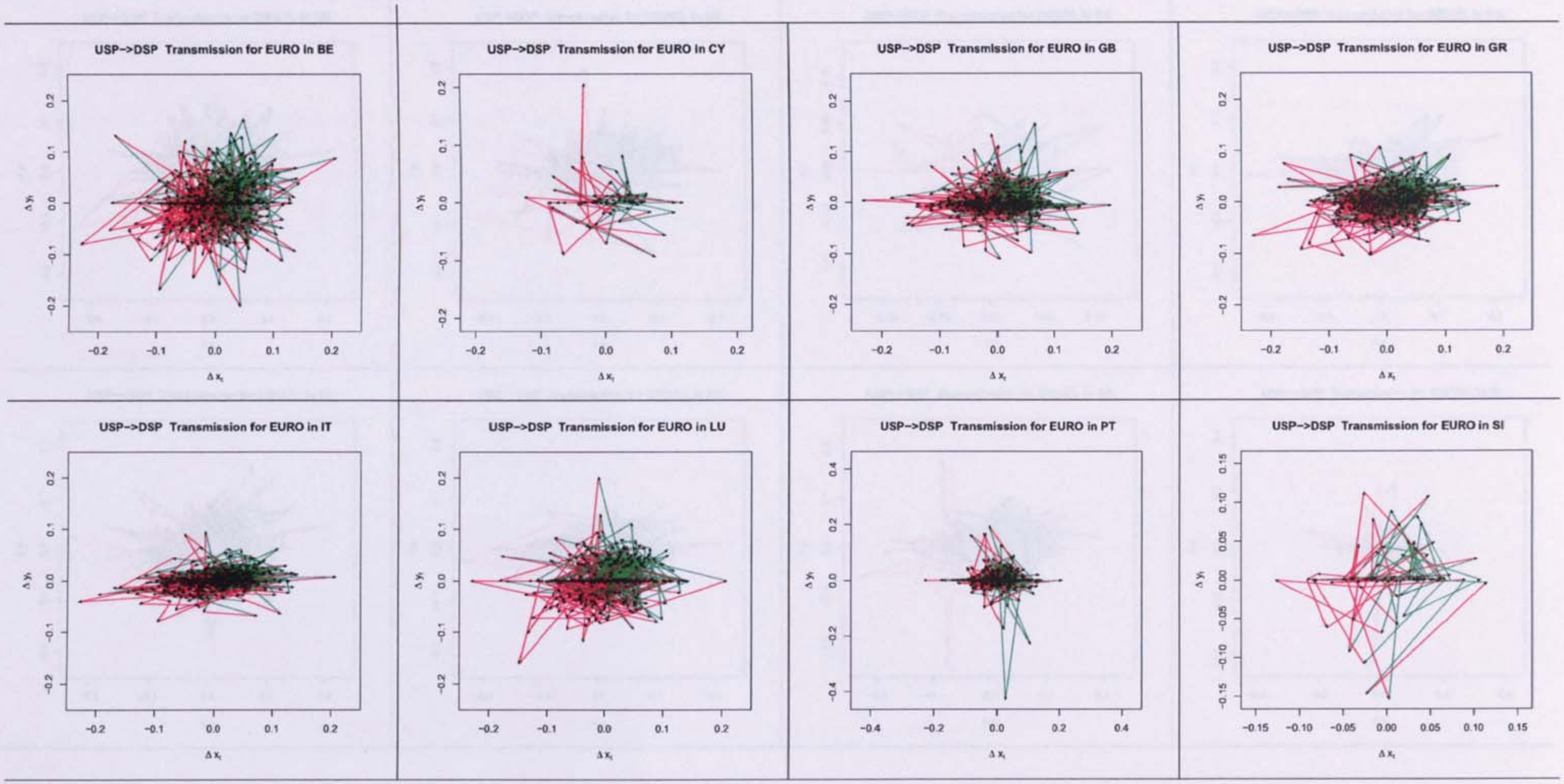
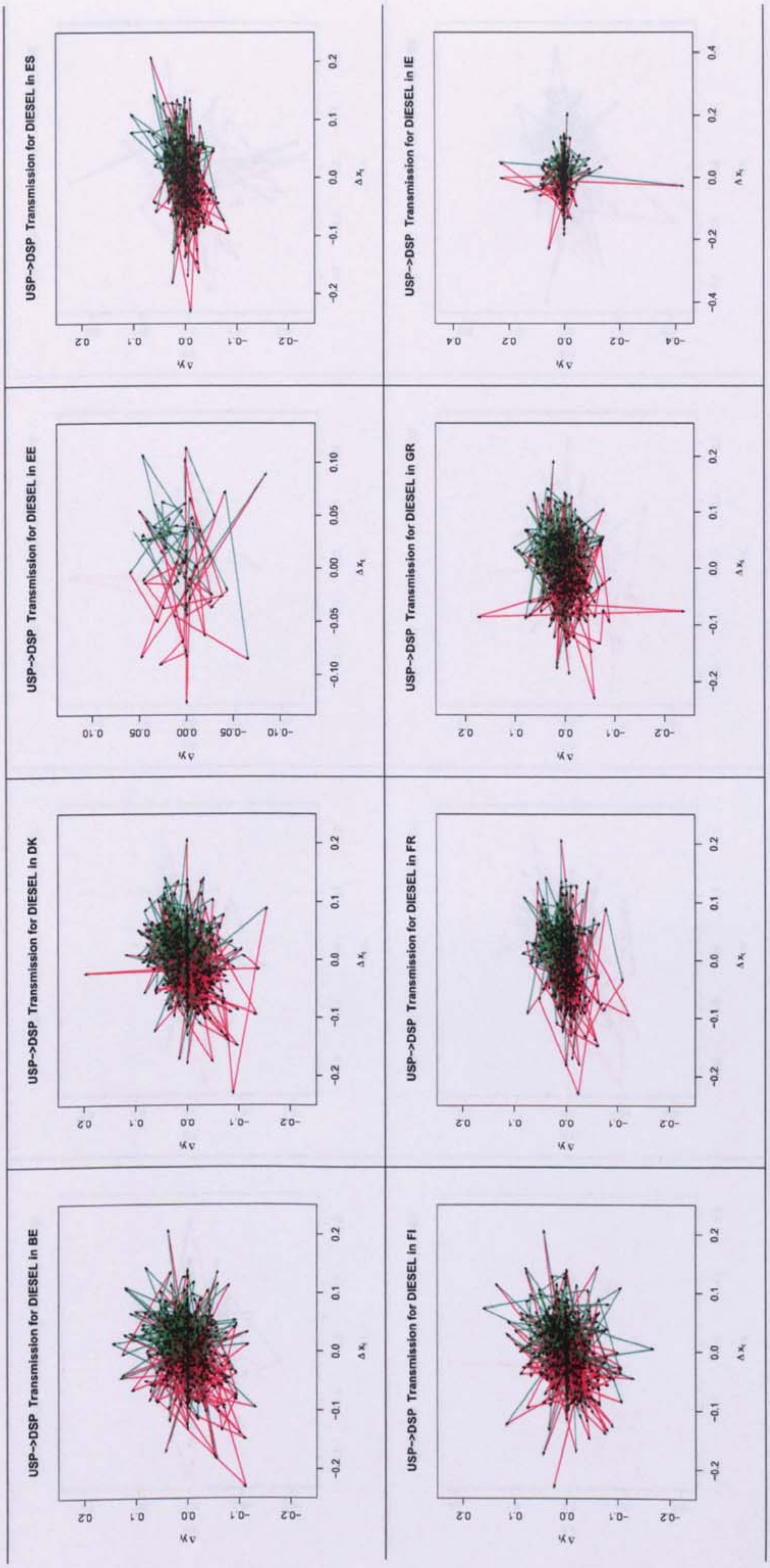
MSP->DSP Transmission for LPG.1 in IT
MSP->DSP Transmission for LPG.1 in HU



MSP->DSP Transmission for SUPER in BE
MSP->DSP Transmission for SUPER in GR
MSP->DSP Transmission for SUPER in IT
MSP->DSP Transmission for SUPER in LU
MSP->DSP Transmission for SUPER in PT
USP->MSP Transmission for DIESEL in NA
USP->MSP Transmission for LPG.1 in NA

Table A.90: Scatter Plots - Δy_t vs $x * fex_t$





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USP->DSP Transmission for DIESEL in EE
USP->DSP Transmission for DIESEL in ES
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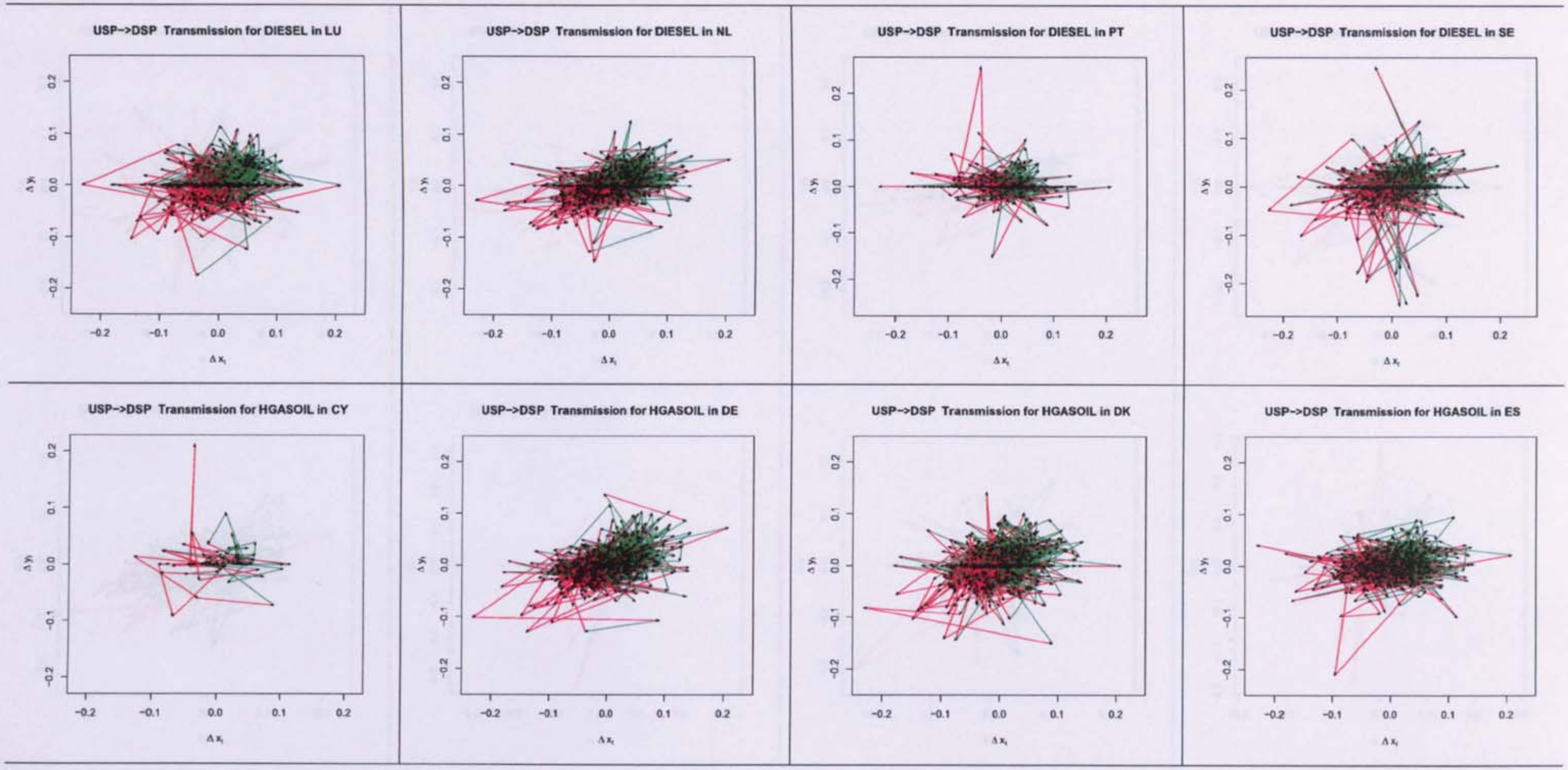
USP->DSP Transmission for DIESEL in FR
USP->DSP Transmission for DIESEL in GR
USP->DSP Transmission for DIESEL in IE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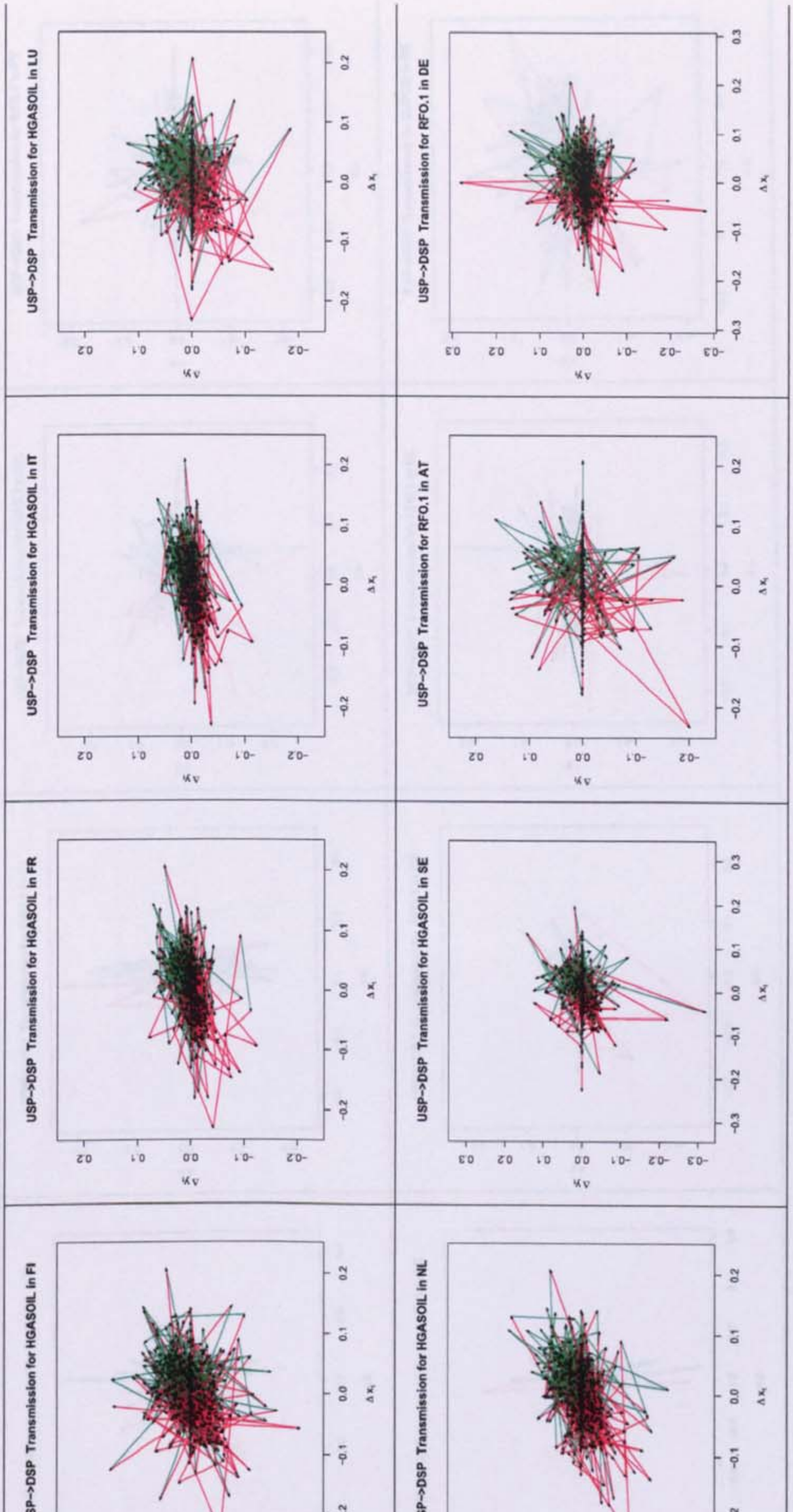
USP->DSP Transmission for DIESEL in SE
USP->DSP Transmission for HGASOIL in CY
USP->DSP Transmission for HGASOIL in DE
USP->DSP Transmission for HGASOIL in DK
USP->DSP Transmission for HGASOIL in ES
Δ x_t
Δ y_t
-0.2
-0.1
0.0
0.1
0.2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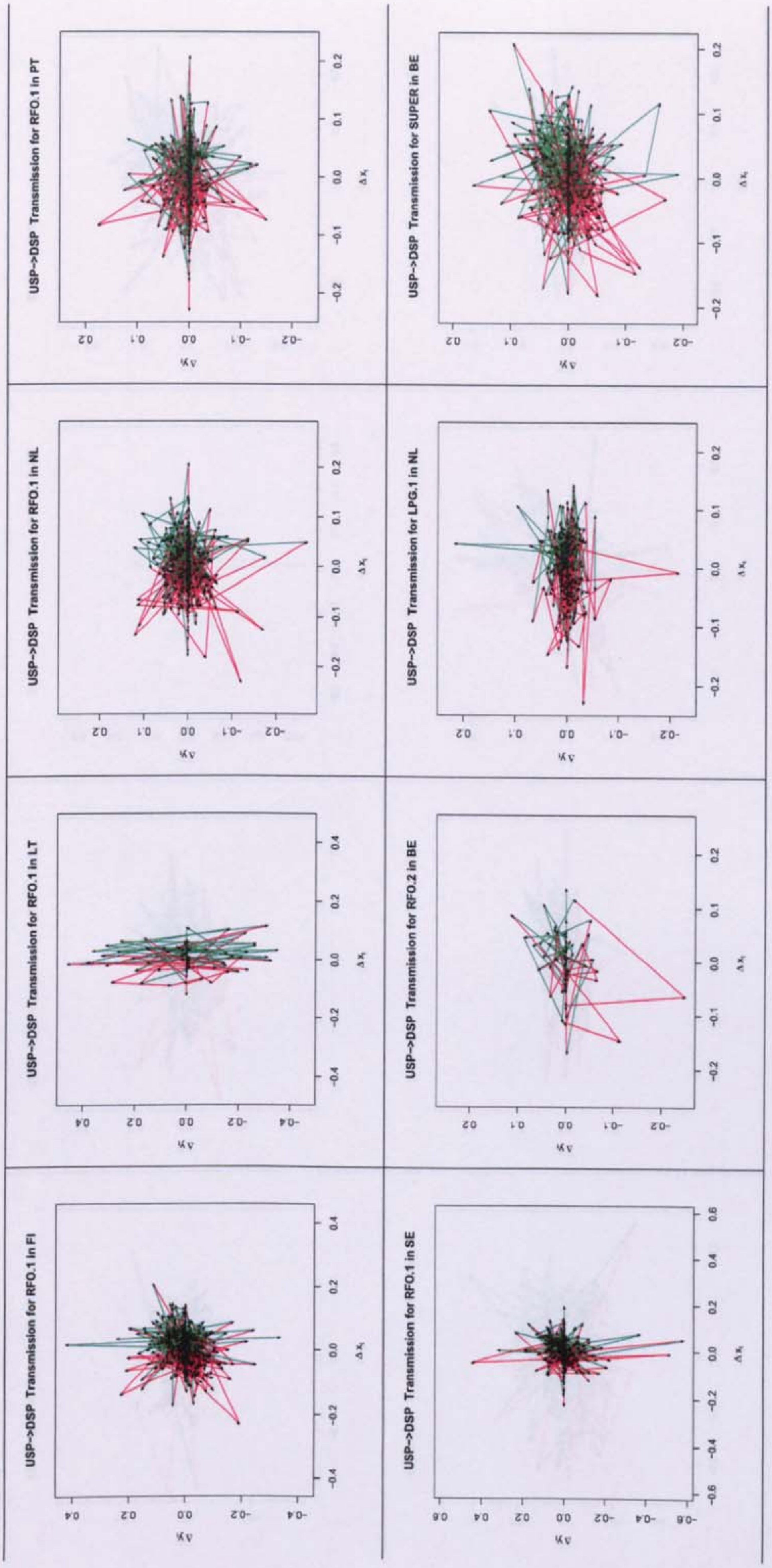
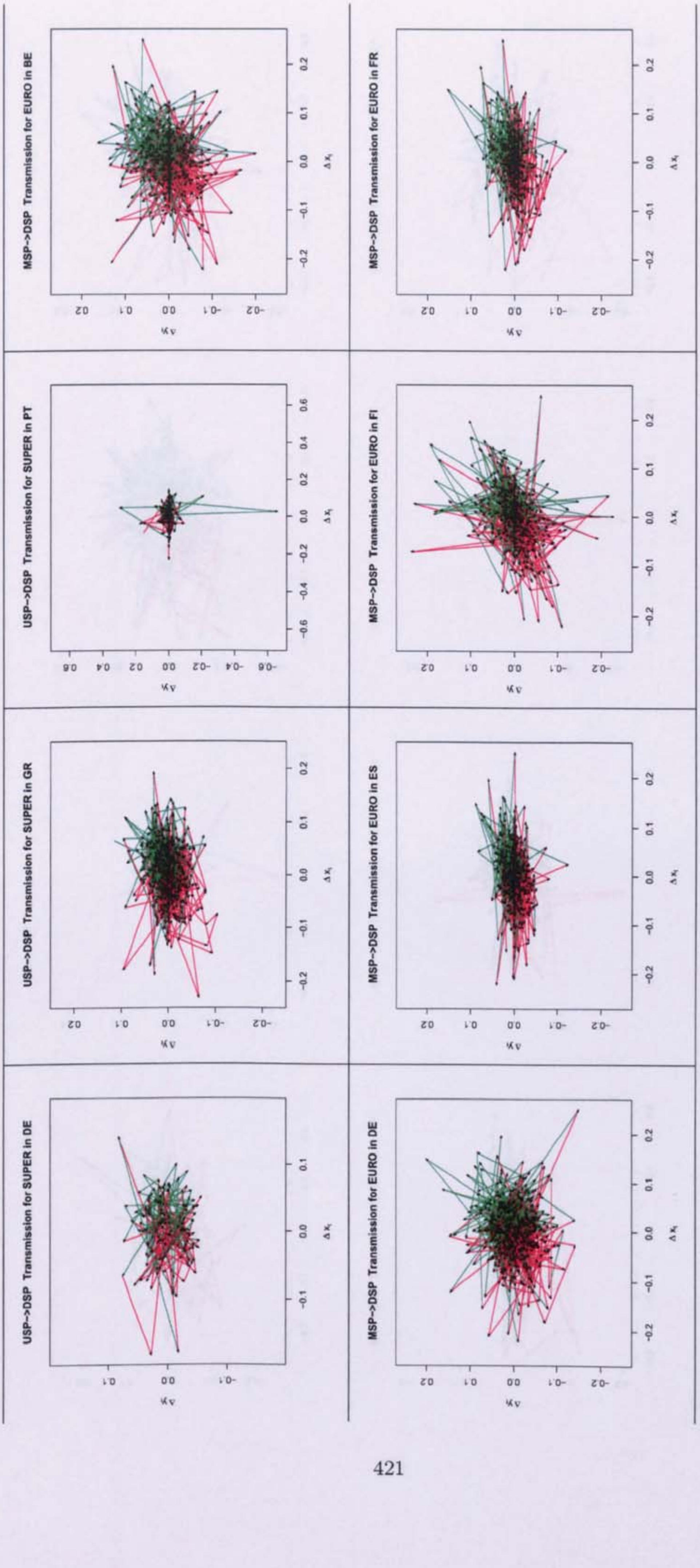
USP->DSP Transmission for HGASOIL in LU
USP->DSP Transmission for HGASOIL in NL
USP->DSP Transmission for HGASOIL in SE
USP->DSP Transmission for RFO.1 in AT
USP->DSP Transmission for RFO.1 in DE


USP->DSP Transmission for RFO.1 in FI
USP->DSP Transmission for RFO.1 in LT
USP->DSP Transmission for RFO.1 in NL
USP->DSP Transmission for RFO.1 in PT
USP->DSP Transmission for RFO.1 in SE
USP->DSP Transmission for RFO.2 in BE
USP->DSP Transmission for LPG.1 in NL
USP->DSP Transmission for SUPER in BE
Δx_i
Δy_i


USP->DSP Transmission for SUPER in DE
USP->DSP Transmission for SUPER in GR
USP->DSP Transmission for SUPER in PT
MSP->DSP Transmission for EURO in BE
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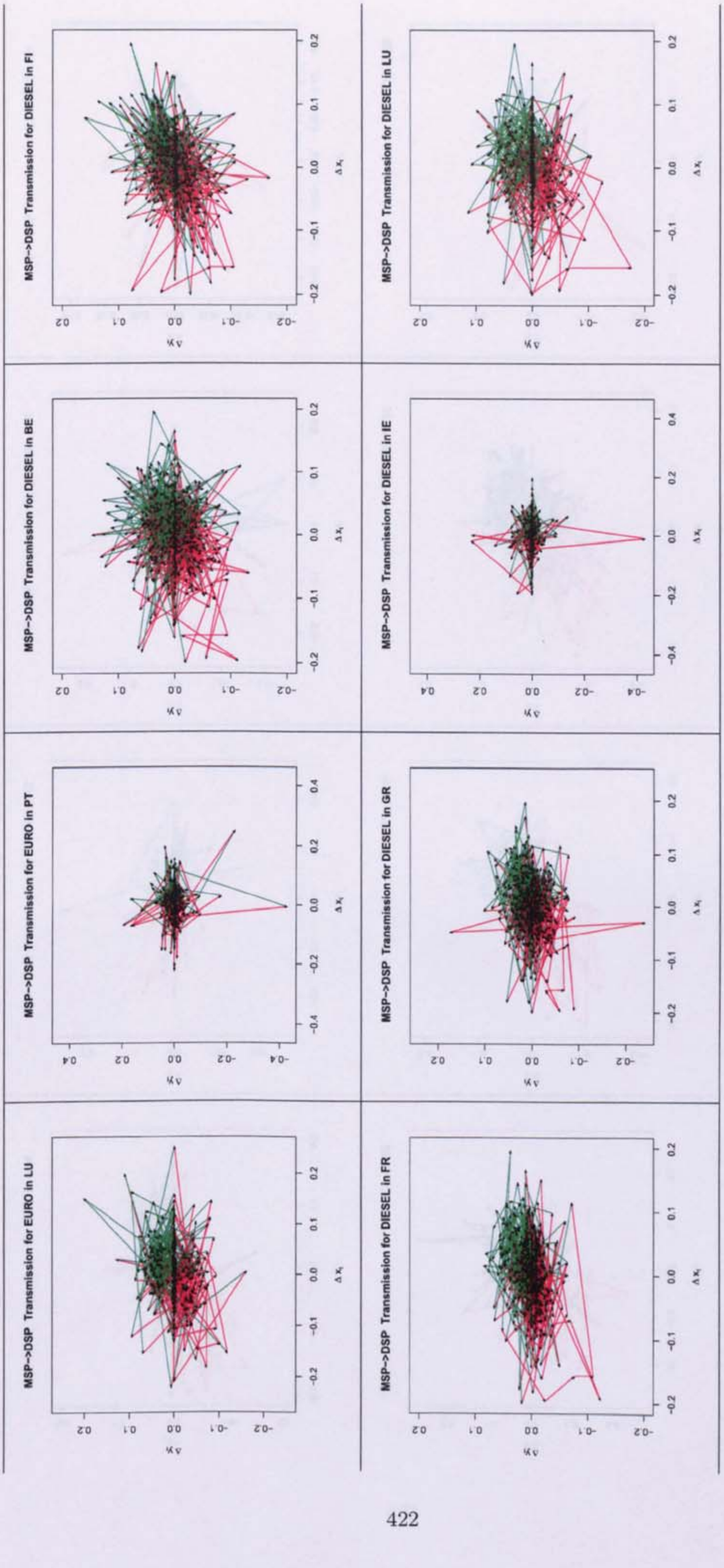
MSP->DSP Transmission for EURO in ES
MSP->DSP Transmission for EURO in FI
MSP->DSP Transmission for EURO in FR
Δy
Δx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MSP->DSP Transmission for EURO in PT
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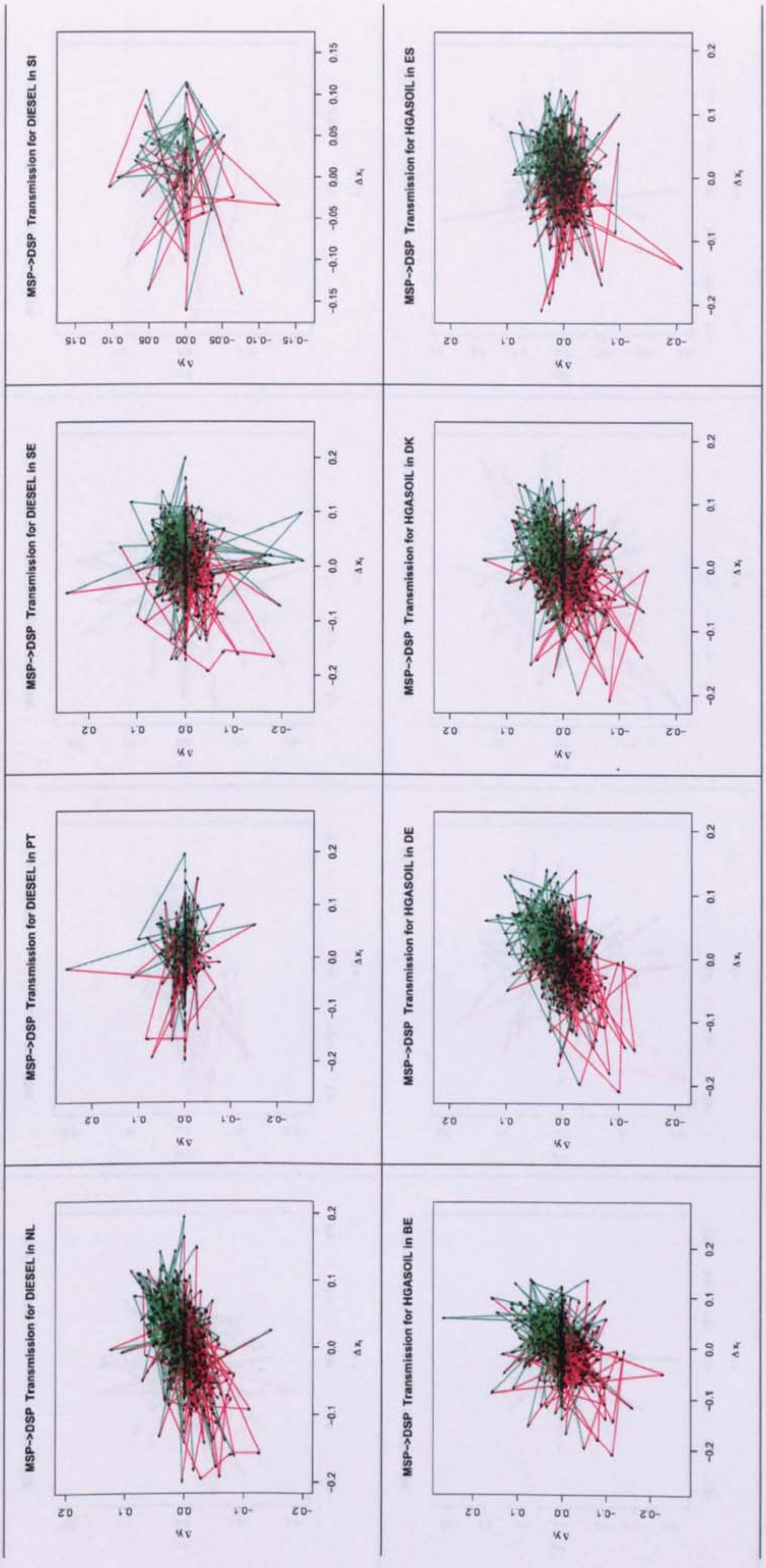
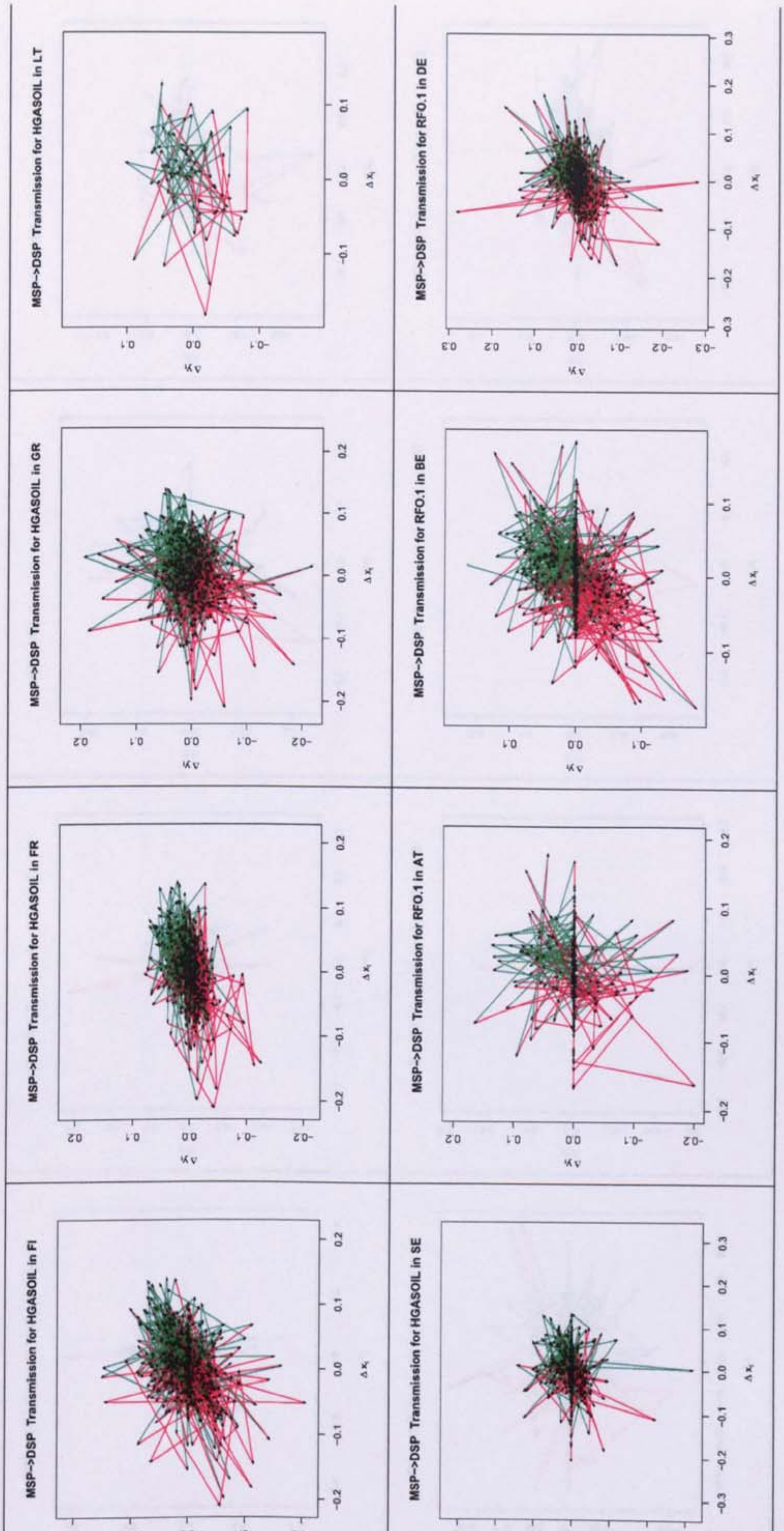
MSP->DSP Transmission for DIESEL in FI
MSP->DSP Transmission for DIESEL in FR
MSP->DSP Transmission for DIESEL in GR
MSP->DSP Transmission for DIESEL in IE
MSP->DSP Transmission for DIESEL in LU
Δx_t
Δy_t



MSP->DSP Transmission for DIESEL in NL
MSP->DSP Transmission for DIESEL in PT
MSP->DSP Transmission for DIESEL in SE
MSP->DSP Transmission for DIESEL in SI
MSP->DSP Transmission for HGASOIL in BE
MSP->DSP Transmission for HGASOIL in DE
MSP->DSP Transmission for HGASOIL in DK
MSP->DSP Transmission for HGASOIL in ES
Δ x_t
Δ y_t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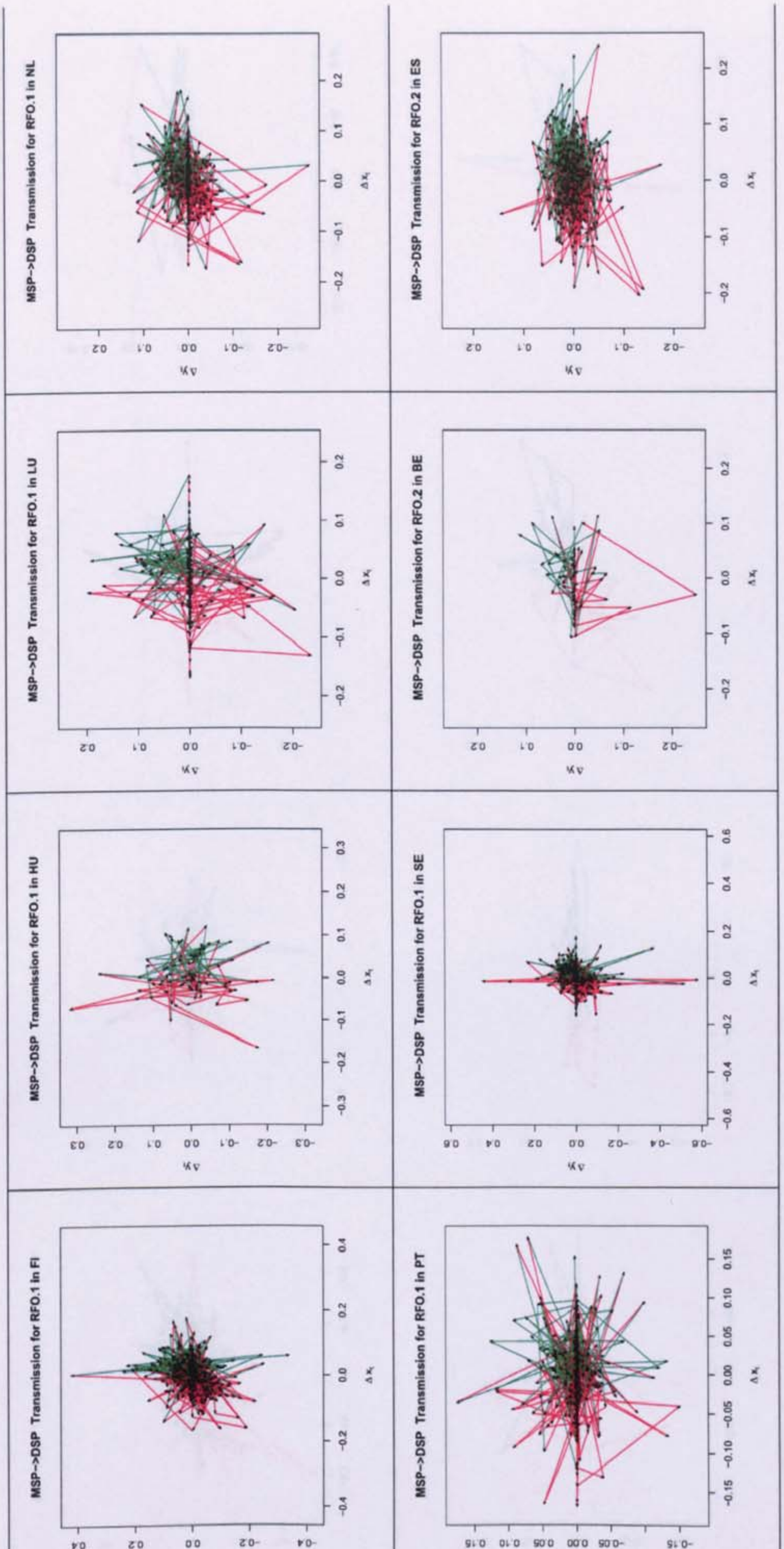
MSP->DSP Transmission for HGASOIL in GR
MSP->DSP Transmission for HGASOIL in LT
MSP->DSP Transmission for HGASOIL in SE
MSP->DSP Transmission for RFO.1 in AT
MSP->DSP Transmission for RFO.1 in BE
MSP->DSP Transmission for RFO.1 in DE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MSP->DSP Transmission for RFO.1 in HU
MSP->DSP Transmission for RFO.1 in LU
MSP->DSP Transmission for RFO.1 in NL
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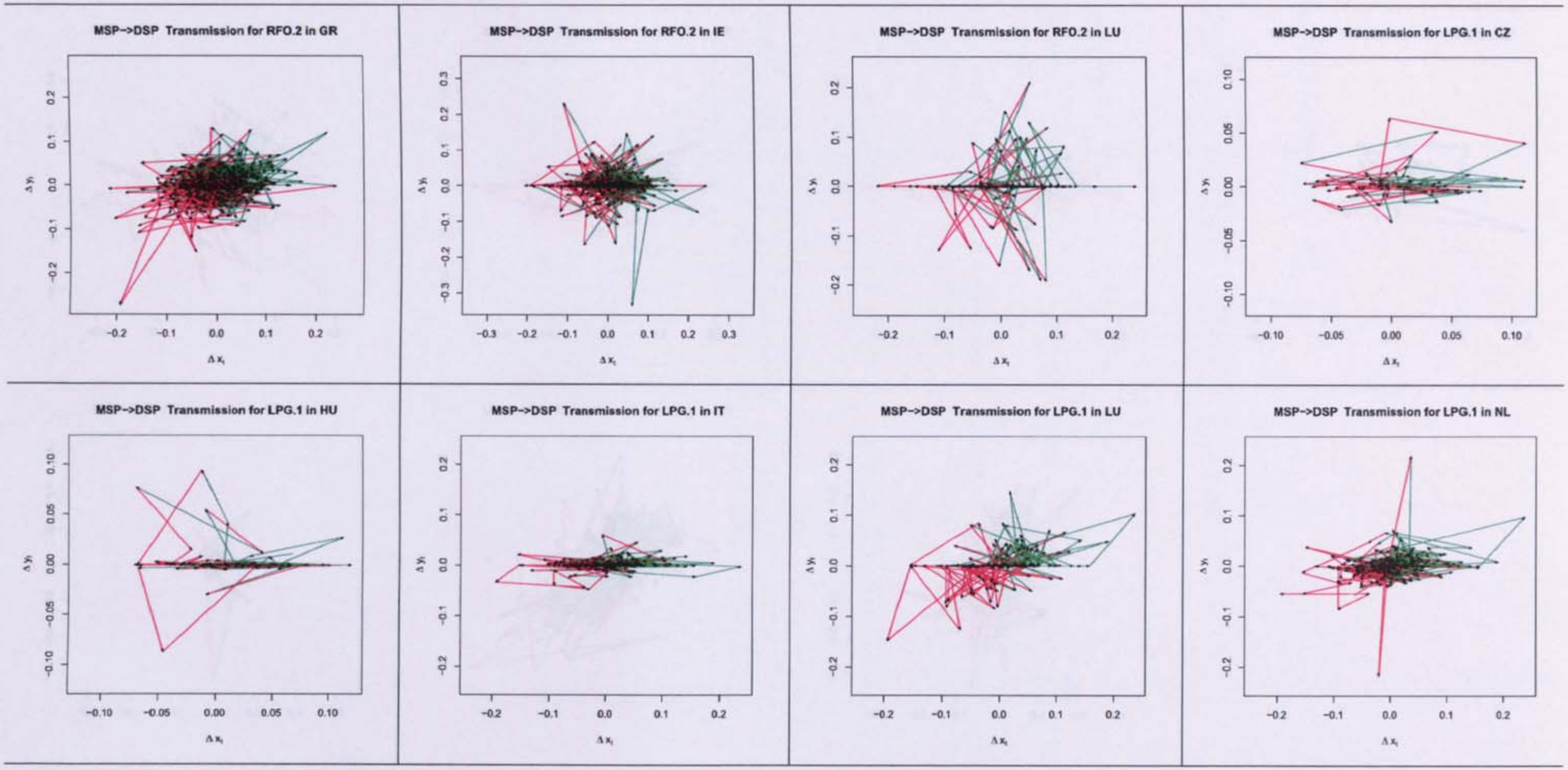
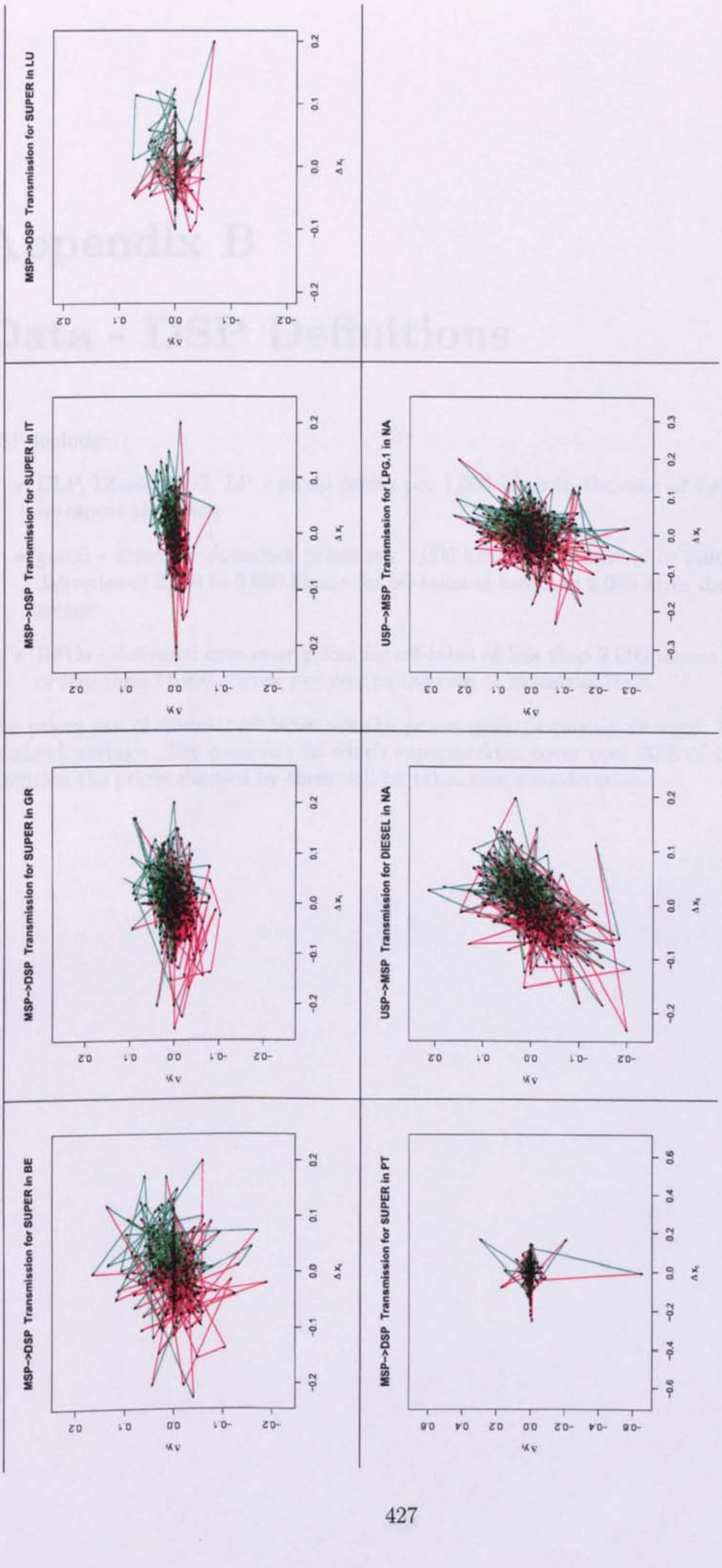
MSP->DSP Transmission for RFO.2 in ES


MSP->DSP Transmission for RFO.2 in GR
MSP->DSP Transmission for RFO.2 in IE
MSP->DSP Transmission for RFO.2 in LU
MSP->DSP Transmission for LPG.1 in CZ
MSP->DSP Transmission for LPG.1 in HU
MSP->DSP Transmission for LPG.1 in IT
MSP->DSP Transmission for LPG.1 in LU
MSP->DSP Transmission for LPG.1 in NL
Δ x_t
Δ y_t


MSP->DSP Transmission for SUPER in LU
MSP->DSP Transmission for SUPER in IT
MSP->DSP Transmission for SUPER in GR
MSP->DSP Transmission for SUPER in BE
USP->MSP Transmission for LPG.1 in NA
USP->MSP Transmission for DIESEL in NA
MSP->DSP Transmission for SUPER in PT

Appendix B

Data - DSP Definitions

DSP include:

- ULP, Diesel, LPG, LP - pump prices per 1,000 litres in the case of fuels for road transport purposes;
- gasoil - delivered consumer prices per 1,000 litres in the case of or paid prices for deliveries of 2,000 to 5,000 litres - for off-takes of less than 2,000 litres the industrial sector;
- RFOs - delivered consumer prices for off-takes of less than 2,000 tonnes per month or less than 24,000 tonnes per year in the case of industrial fuels.

The prices net of duties and taxes are the prices most frequently charged, based on a weighted average. For countries in which supermarkets cover over 20% of inland consumption the prices charged by them will be taken into consideration.

Appendix C

STAR Estimation

The estimation was performed using the GNU R package (see Ihaka & Gentleman (1996) for details), with the help of constrained optimization algorithm by Byrd, Lu, Nocedal & Zhu (1995). The parameter plane was spanned by:

- the AR parameters from the linear models (γ^Ls, γ^Hs, ψ^Hs and ψ^Ls);
- the smoothing parameter ζ;
- the threshold percentile c.

The smoothing parameter was expressed in terms of standard deviation of the disequilibrium ϵ. The threshold parameter was zeroed around 1/2 following the results of the cointegration analysis. The following constraints were used:

- ζ parameter - [.1; 50] of the standard deviation;
- the threshold percentile c - $\pm 45^{th} percentile$;
- the AR parameters - ± 10 (those values were found to encompass all cases in the estimation).

The optimization was performed over maximum 1000 iteration. The changes in this number did not affect the results.

The following starting points were chosen:

- for the ESTAR model, ζ was set equal to the lowest value for which at least 25% of observations yield the transition function value lower than .5;
- for the LSTAR model, ζ was set equal to 1;
- for the AR estimates, the starting positions were taken from the linear estimation with lags set to optimize the AIC criterion.