A Comparative Evaluation of the Impact of UK Trade & Investment's R&D Programme and Other UKTI Support that Impacts R&D

Nigel Driffield, Jun Du, Mark Hart, Jim Love
and Stathis Tapinos

Economics & Strategy Group
Aston Business School
Aston University

Final Report

Prepared for UKTI

March 2010

Aston Business School

Acknowledgements

The research team would like to express our thanks to the UKTI and the Steering Group for this project. In particular, we would like to acknowledge the critical role of Nilum Patel (UKTI Project Manager) who has been an invaluable mentor to the research team throughout this project.

The analysis contained in this report is based on the quarterly Performance and Impact Monitoring Surveys (PIMS) undertaken by the UKTI as well as a new impact survey designed and implemented for Aston Business School by OMB Research Ltd. We would like to express our gratitude to the 800 business owners/senior managers who took time against a backdrop of very difficult trading conditions to answer our questions

Of course, the usual disclaimer applies and all errors are the responsibility of the research team.

The Research Team
Economics and Strategy Group
Aston Business School

Professor Nigel Driffield
Dr Jun Du
Professor Mark Hart
Professor Jim Love
Dr Stathis Tapinos

Executive Summary

Evaluation background and aims:

0.1. The Government is committed to increasing UK R&D investment to 2.5% GDP by 2014, from 1.9% in 2004. Against this background, the UKTI SR2007 Performance Framework Agreement included a target to increase the quantity of R&D activity in the UK through business internationalisation:

> "*Annually, over the 2008-2011 spending review period, at least 1,000 businesses increase their R&D activity in the UK as a result of UKTI support, including at least 70 foreign direct investment (FDI) R&D projects*." The SR2007 Agreement also included a supplementary reporting requirement relating to this target, to "*Undertake a comparative evaluation of the impact of the R&D programme and other UKTI support for R&D to identify the types of intervention which are most cost effective in generating increases to business R&D in the UK*."

0.2. The Economics & Strategy Group at Aston Business School was appointed to carry out this evaluation.

Methodology overview:

0.3. The research presented in this report was based on three main elements:

- **(a)** **A literature review of theory and evidence** about links between exporting, foreign direct investment (FDI) and R&D, looking at causality in both directions, to understand how support for trade and FDI might impact on R&D;
- **(b)** **Secondary analysis of UKTI Performance and Impact Monitoring Survey (PIMS) data for trade services:** This analysis was carried out using PIMS data by trade service, including details of client profile and export experience, and a range of reported qualitative benefits of the services on the client's business, including increased sales and increased R&D. Multivariate analysis was used to isolate any differences across services in reported R&D effects, and to identify client characteristics, or qualitative benefits, most likely to be associated with reported R&D effects. As this analysis was based on evidence from users only, it did not test the validity of the reported R&D effects;
- **(c)** **R&D impact assessment:** Using data collected through a new survey of 400 users and 400 non-users, a two stage econometric test for 'treatment' effect of trade support on R&D was carried out, controlling for selection effects. The purpose of the analysis was to provide a robust test of whether, and to what extent, trade services may impact on R&D, and to

identify client characteristics most likely to be associated with such impact.

0.4. The quantitative research covered the full portfolio of UKTI trade services delivered during the period July 2006 through June 2007. This choice of coverage was guided by methodological considerations, to allow a robust quantitative assessment of impact and comparison across trade services. For the R&D Programme itself, which was established in April 2007, a quantitative approach was not suitable. A programme of qualitative case studies of selected projects was therefore undertaken, and will be the subject of a separate report.

Key findings – Literature Review

0.5. The purpose of the literature review was to review the evidence on the links between international trade and investment on one hand, and business innovation and R&D on the other. Building on a previous literature review for UKTI (Harris & Li 2006a), the emphasis was on the role of exports and inward foreign direct investment (FDI). Particular attention was paid to evidence for the UK, and to recently-published empirical material.

0.6. The key points of the review can be summarised as follows:

- OECD comparative evidence suggests that for the majority of countries there is a positive relationship between exposure to foreign markets and innovation/R&D;

- Conceptually, there are reasons to expect exporting and inward investment activity to be (positively) linked to R&D and innovation. Exporters can benefit from increased competition, from learning-by-exporting, and from scale effects, all of which may enhance R&D and innovation;

- Inward investment's theoretical impact on R&D is less clear. It depends on the R&D capacity of the foreign entrants themselves, and on the competition and crowding out effects which foreign R&D may have. The motivation for FDI also plays a role i.e. *technology sourcing* versus *technology exploiting* FDI will have different effects. The net effect of FDI on total R&D is, therefore, unclear *a priori*;

- The econometric empirical evidence suggests a mutually self-reinforcing mechanism linking R&D, innovation and exporting. Firms performing R&D and innovating are more likely to export and to be more export intensive. Exporting in turn assist firms in performing R&D and innovating, even after endogeneity between R&D and exporting is allowed for;

- Both the econometric and more qualitative evidence from the UK suggests that competition, scale and (possibly) learning-by-exporting links exposure to international markets to R&D performance;

- Empirical evidence for the UK has found that UK-owned exporters accounted for the bulk of UK business R&D, with their share in R&D expenditure nearly twice that of their share in overall UK turnover. By contrast, inward investors contributed to R&D broadly in line with their share of turnover;

- Recent UK econometric evidence also suggests an important role for absorptive capacity in encouraging R&D at establishment level;

- The empirical evidence on the effect of inward investment on R&D is mixed. Foreign affiliates tend to be larger and more productive than domestic plants, but once allowing for this and their R&D capacity, they may be no more innovative than their domestic counterparts;

- There is very limited evidence on the wider issue of the effect of inward FDI on the R&D activity of domestic enterprises. There is some evidence of a significant, but small, crowding out effect in Belgium and the UK, but that foreign investment has a positive effect on levels of innovation (not R&D) among domestic enterprises in China;

- Part of the reason for the lack of consistency on the effects of inward investment on R&D and innovation may relate to different motivations for FDI. The internationalisation of R&D literature indicates that technology sourcing has become an increasingly important motivation for international investment.

- Technology sourcing FDI appears to represent a not insignificant minority of inward investment into the UK. Empirical evidence suggests that such investment leads to no identifiable productivity spillovers to the domestic sector. By contrast, FDI in which the foreign investor has higher R&D intensity (i.e. an ownership advantage) does lead to such productivity spillovers;

- Relationships between innovation, exporting and productivity are complex but suggest that innovation itself is not sufficient to generate productivity improvements;

- Only when innovation is combined with increased export activity are productivity gains evident, and Love *et al* conclude that regional innovation policy should be oriented towards helping firms to innovate only where it also helps firms to enter export markets or to expand their existing export market presence.

0.7. Overall, our review of the literature suggests there are good reasons to expect exposure to export markets to increase the likelihood that firms will innovate, and to increase the R&D and innovation performance of exporting firms.

- Once the exporting hurdle is overcome, however, it is less clear that increased export intensity has an effect on R&D intensity;

- The impact of inward investment on R&D and innovation is less clear. R&D performing foreign entrants may or may not increase the level of R&D in the UK, depending on the net effect of any competition or crowding out effects on domestic firms;

- In addition, the impact of inward investment on R&D will depend on the type of inward investment. Foreign investors engaging in technology sourcing FDI into the UK seem unlikely to enhance the net level of R&D in the economy, or to provide positive technology-based productivity spillovers.

Analysis of Performance and Impact Monitoring Survey (PIMS) data for UKTI trade services:

0.8. The purpose of this analysis was to isolate any differences across services in reported R&D effects, and to identify client characteristics most likely to be associated with reported R&D effects. As this analysis was based solely on evidence from users, captured via PIMS, it did not test the validity of the reported R&D effects.

0.9. Use of multivariate analysis, for the first time, allowed service effects to be distinguished from differences in client profile across services, which would also affect the likelihood of reporting additional R&D. The analysis covered PIMS waves 6-9, which involved interviews with around 3,000 firms.

0.10. The analysis took advantage of the fact that the PIMS dataset contains comparable data by service on details of client profile and export experience, as well as on a range of reported effects of services on the client's business, including increased sales and increased R&D. The measure of increased R&D used in this analysis is the one used by UKTI to report performance against its SR07 Target relating to increased business R&D. The measure relies solely on judgments made by the respondent about their experience, and does not take account of selection effects.

0.11. Key findings of the multivariate analysis are:

- Innovative and growing firms, especially in manufacturing, are more likely to report 'increased R&D'.

- Firms reporting 'increased sales' are more likely to report 'increased R&D'.

- In terms of comparing UKTI service effects, the analysis found that some services are significantly more likely to report increased R&D. These are: EMRS, TAP (group), Passport, and UKTI Website (users of the Business Opportunities Alert Service). Weakly significant effects were also found for: Overseas Posts; International Business Specialists, Market Visit Support, and Outward missions.

0.12. These findings broadly correspond to the pattern of impact which appears in the published bivariate PIMS results. However, two services – ECR, and advice provided by teams in the English regions to 'New to Export' clients – show comparatively less likelihood of reporting additional R&D when client profile is controlled for through the multivariate analysis.

0.13. Some insights into the possible dynamics behind the observed link between 'increased sales' and 'increased R&D' are provided in a report on a PIMS qualitative study of some 20 innovative firms who had initially been interviewed during PIMS waves 5 and 6.[1] The key effects of exporting on R&D/innovation identified by these respondents were that:

- exporting provides additional funds for R&D;
- their innovation activities are enhanced by being exposed to more demanding customers in export markets;
- exporting provides the incentive of a wider market over which to earn the potential returns to R&D.

0.14. These fit closely with the competition, learning-by-exporting and scale effects identified in the theoretical literature

The R&D impact assessment:

0.15. The purpose of this impact assessment was to test whether trade services have significant impact on R&D, and also to identify client characteristics most likely to be associated with such impact. The study thus provides a means of testing the validity of impact reported via PIMS, using robust econometric techniques, and controlling for selection effects. Data were captured for this purpose through a new bespoke survey of 400 beneficiaries and 400 non-beneficiaries.

0.16. Beneficiaries were taken from sample previously interviewed for PIMS 6-9. Non-beneficiaries were taken from purchased sample, screening for export activity either current or planned in short term, in order to provide a suitable comparison group for UKTI clients. The interview captured data on control variables covering factors expected to influence R&D activity and spend, including indicators of 'absorptive capacity', to ensure that effects of UKTI support could be isolated.

[1] Internationalisation, Growth and Novel Product Development in Young Innovative Businesses Research; OMB Research (2007)

0.17. The bespoke impact survey has revealed that UKTI supported firms differ significantly in a number of respects from non-users of these services. In particular, UKTI beneficiaries:

- report significantly higher levels of R&D activity and expenditure;
- were more likely to have introduced new products or services in the last 3 years;
- were more likely to hold IP such as patents, trademarks or licenses;
- were more likely to engage in R&D collaboration; and
- were more likely to have more than 75% employees with science and technology degrees.

0.18. In terms of increasing R&D, there was very little difference between the two groups in the proportion reporting some increased R&D (45.5% and 45.7%), but the mean increase in R&D over the period was over 50% higher for UKTI users than non-users (£126,900 and £81,000 respectively).

0.19. The econometric analysis has shown that once we control for sample selection effects there is indeed a positive and significant impact of UKTI support on R&D expenditure. Key findings are:

- Support from UKTI in terms of trade development does boost R&D, controlling for selection effects and other factors. The analysis showed that when selection effects were taken into account, the R&D impact was stronger than it had appeared in a simple comparison of users and non-users.
- UKTI support is given to firms who otherwise would not increase R&D compared with the non-user sample;
- There was clear evidence of **UKTI service complementarity** – examining the profile of service use by respondents evidence indicates that the impact on R&D is stronger with multiple service use – up to 10 instances of use;
- Models confirm that innovative and growing firms most likely to show positive R&D impact;
- Firms who engage in training (job entry and external off site) have more R&D growth;
- Firms who engage in collaborative R&D activity/projects with customers have more R&D growth;

- Using the coefficient on the UKTI support term of .51745 in the model (Heckman 2 stage) we estimate that the impact of UKTI support on R&D is around £65,664 per firm;
- To put this in context, average R&D spend for the sample of firms is £416,500 so UKTI support accounts for some 15% of R&D.

Conclusions

0.20. What we are able to say with a high degree of confidence is that there is clear evidence that the UKTI's standard trade development support has a positive and significant impact on R&D activity and spend. Further, there is evidence that a combination of support from UKTI under this heading enhances the level of R&D spend.

0.21. The findings of our quantitative empirical research for this evaluation reinforce conclusions of the literature review with respect to the links between trade and innovation, and policy implications:

- innovation itself is not sufficient to generate productivity improvements. Only when innovation is combined with increased export activity are productivity gains evident;
- Therefore, innovation interventions oriented towards helping firms to innovate can have even greater effects where it helps firms enter export markets or expand existing export market presence.

0.22. We conclude that trade development support is an important element in the armoury of policy instruments relating to innovation policy and specifically to the policy aim of increasing UK R&D by 2014.

Contents

Chapter 1: Evaluation Overview

1.1 Aims and Objectives

The Government is committed to increasing UK R&D investment as a proportion of GDP from 1.9% (2004 level) to 2.5% by 2014. Since private sector R&D is the principal component of overall R&D, achieving the 2.5% overall target requires that private R&D rises from 1.24% of GDP to 1.7% of GDP by 2014[2].

Business expenditure on R&D (BERD) represents around two-thirds of total R&D expenditure in the UK. Research suggests that investment in BERD generates substantial private and social returns: estimates of private returns typically vary between 10% and 30%, with estimates of social returns through spillovers etc being as high as 100%[3]. BERD in the UK is characterised by the following:

- Although it has increased in real terms since the 1980s, BERD as a percentage of GDP fell steadily until the mid 1990s to below the OECD average.
- UK BERD is relatively heavily dependent on R&D performed by foreign firms, often attracted by the UK's research base.
- The share of UK BERD accounted for by SMEs is relatively high by OECD standards.

UKTI has an important role to play in this policy context and there are essentially two ways in which it seeks to deliver positive outcomes with respect to increased investment in R&D. First, by providing support and information to foreign companies considering carrying out R&D in the UK, either directly or through partnerships with UK companies. Supporting the R&D activities of existing or potential inward investing firms may be a cost-effective method of increasing the UK's R&D and thus ultimately improving productivity and growth in the domestic sector. Second, by providing support to innovative companies whose R&D output can be boosted by trade development interventions. Appreciating the extent to which this UKTI activity boosts both R&D and ultimately domestic firms' productivity and growth requires an understanding of the complex relationships between exporting, R&D and productivity.

The role UKTI is expected to play in delivering increased R&D in the UK is reflected in the following 2007 Spending Review Target, and associated supplementary reporting obligations:

> **UKTI Target 3: Increase the quantity of R&D activity in the UK through business internationalisation.**
>
> *"Annually, over the 2008-2011 spending review period, at least [1,000] businesses increase their R&D activity in the UK as a result*

[2] HMG, Science & innovation investment framework 2004-14, July 2004
[3] HMG, Science & innovation investment framework 2004-14, July 2004

of UKTI support, including at least 70 foreign direct investment (FDI) R&D projects.

Supplementargy reporting requirement relating to Target 3: "*Undertake a comparative evaluation of the impact of the R&D programme and other UKTI support for R&D to identify the types of intervention which are most cost effective in generating increases to business R&D in the UK. Report to HM Treasury, BERR, and FCO on lessons learned, and on the implications for future UKTI policy priorities.*"

The overall aim of this evaluation project was set out in the following objectives:

- To undertake a comparative evaluation to assess the economic impact of UKTI's new R&D programme relative to all other UKTI support for trade and investment which stimulates R&D, and identify the most cost effective mechanisms which generate the impact on R&D;

- To evaluate the economic impact and cost effectiveness of UKTI's R&D programme, including an assessment of the value for money which it achieves for the UK taxpayer;

- To make recommendations, with a view to increasing value for money for the UK tax payer, in terms of increasing the level of business R&D investment.

1.2 Our Approach

To derive economic impact estimates of the relatively new UKTI R&D Programme and other more established support measures for R&D we propose a methodology combining econometric analysis with detailed case study work. The key features of our methodology are:

- Secondary econometric analysis of the PIMS datasets – Waves 6-9, relating to trade services delivered between July 2006 and June 2007;
- Design and implementation of a bespoke telephone survey (CATI) of 400 UKTI beneficiaries of trade development business support and 400 non-beneficiaries. The aim here is to:
    - Provide headline descriptives of the differences between the two groups.
    - Derive econometric estimates of the impact of UKTI trade development support using appropriate selection models
- Undertake qualitative case studies of UKTI R&D Programme beneficiaries under the three elements of Global Partnership Programme (GPP) and Inward and Outward services. Given the short period of time

since the launch of the new programme, this is the only component of the present evaluation that can provide any assessment of the additionality of the new R&D Programme and its impact on the overall UKTI objective of increasing R&D investment in the UK.

In addition, and to set the above evaluation in context, we were asked to undertake a literature review of the evidence on the links between international trade and investment on one hand, and business innovation and R&D on the other. The objective here was to ensure that UKTI have access to the most recent set of empirical studies on this topic.

This report covers findings of the literature review, and of the two quantitative elements of our methodology. Findings of the qualitative case studies will be reported separately.

1.3 Structure of the Report

The structure of the report is as follows:

- A review of some of the key evidence on the links between exporting, inward investment and R&D (Chapter 2).

- Secondary econometric analysis of the PIMS data for 2007 Waves (6-9) with a focus on the variable 'increased R&D'. The objective here is to assess the extent to which there are particular UKTI scheme effects (Chapter 3).

- The comparative profile of UKTI assisted businesses, together with the non-assisted control group of businesses, is presented and analysed as well as the econometric results of the effects of UKTI assistance on increased R&D (Chapter 4).

- A summary of the key conclusions and overall impact assessment (Chapter 5).

Chapter 2: Exporting, Inward Investment and R&D: a Review of the Literature

2.1 Introduction

The purpose of this chapter is to review the evidence on the links between international trade and investment on one hand, and business innovation and R&D on the other. In order to differentiate it from a previous comprehensive review carried out for UKTI (Harris and Li 2006a), the emphasis here is placed firmly on the role of exports and inward foreign direct investment (FDI), as these form the principal elements of UKTI's activities, and are integral to UKTI's R&D programme. Particular attention is paid to evidence for the UK, and recently-published empirical material.

2.2 Background

It is now widely accepted that the wealth of a country or region is directly linked to levels of R&D and innovation[4]. Innovative efforts, and R&D in particular, are the major factor behind technical change and long-term economic performance. In other words, low levels of investment in R&D will severely constrain innovation activity and performance at the business level and economic growth at the regional and national level.

This presents a considerable challenge for the UK, where investment in R&D as a proportion of GDP has been declining steadily relative to other countries in recent years. While cuts in defence spending have contributed to this decline, most of the reduction in R&D spend results from cuts in business sector spend[5]. The Government is committed to increasing UK R&D investment as a proportion of GDP from 1.9% (2004 level) to 2.5% by 2014. Since private sector R&D is the principal component of overall R&D, achieving the 2.5% overall target requires that private R&D rises from 1.24% of GDP to 1.7% of GDP by 2014[6].

Business expenditure on R&D (BERD) represents around two thirds of total R&D expenditure in the UK. Research suggests that investment in BERD generates substantial private and social returns: estimates of private returns typically vary between 10% and 30%, with estimates of social returns through spillovers etc being as high as 100%[7]. BERD in the UK is characterised by the following:

- Although it has increased in real terms since the 1980s, BERD as a percentage of GDP fell steadily until the mid 1990s to below the OECD average.

---

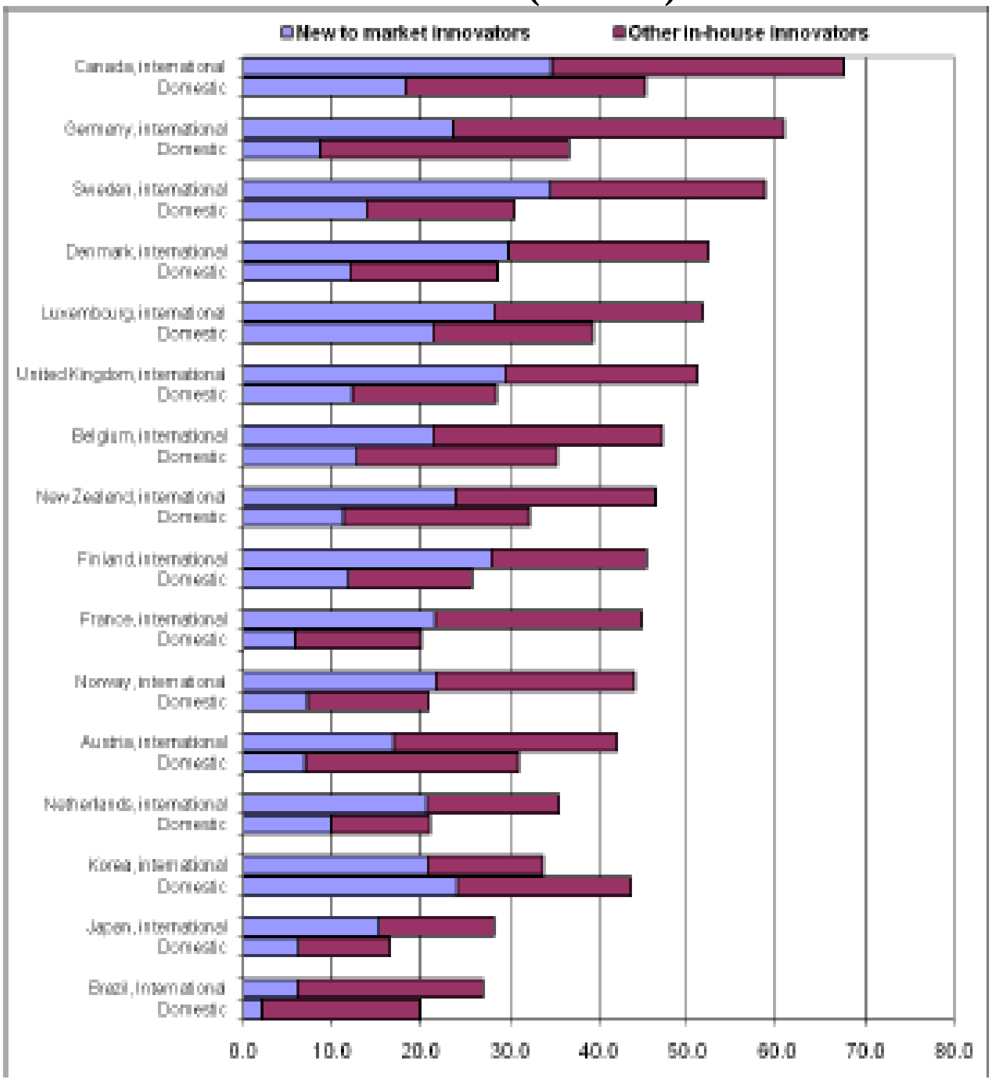
[4] HM Treasury (2003) *Productivity in the UK: 4 – The Local Dimension*.
[5] Exceptions to this are the pharmaceuticals and aerospace-defence sectors which have comparatively high levels of business sector investment in R&D relative to other countries.
[6] HMG, Science & innovation investment framework 2004-14, July 2004
[7] HMG, Science & innovation investment framework 2004-14, July 2004

- UK BERD is relatively heavily dependent on R&D performed by foreign firms, often attracted by the UK's research base.

- The share of UK BERD accounted for by SMEs is relatively high by OECD standards.

Internationally, there is evidence of a link between international activity and innovation. The OECD Innovation Microdata project analyses data gained from innovation surveys in many countries. Figure 1 shows evidence from 2002-2004 on the extent to which there is innovative activity among firms which operate in domestic only and international markets respectively. With the exception of Korea, the proportion of firms which are innovative is substantially higher for firms operating in international markets than for firms operating in domestic markets only. This suggests that exposure to international markets is strongly linked to innovation, but of course says nothing about the direction of causality.

Figure 2.1: Proportion of Innovators Operating in Domestic and International Markets (2002-04)



Source: Onodera (2008)

2.3 Theory

2.3.1 Conceptual Overview

Conceptually, there are reasons to expect trade and investment activity to be linked to R&D and innovation. A summary of possible linkage mechanisms is provided in Table 1. This is concerned entirely with the effect of investment and trade on R&D/innovation, which is the orientation implicitly assumed by several of UKTI's activities and especially by the R&D Programme. In the conceptual discussion below we concentrate on the links involving exporting and inward FDI.

Table 2.1: Summary of Effects of Trade and Investment on Innovation/R&D

Mode	Effect on Innovation		Positive /negative	Supplementary Explanation
Imports	Technology transfer	technology effect	+	More important for developing and smaller countries. Importance increasing due to increasing convergence of technology.
		price effect	+	Important for network products such as ICT.
	Competition		+ or -	Decreased rents can lead to decrease in resources available for innovation. Competition generally increases incentives to innovate. For firms far below the technology curve, sudden increase in competition can decrease innovation.
	Scale economies		(-)	Imports can lead to decreases in scale economies. Scale economies can improve if inefficient manufacturers are weeded out. Scale economies can improve in the medium term if user industries increase exports.
Exports	Competition		+ or -	Competition generally increases incentives to innovate. For firms far below the technology curve, sudden increase in competition can decrease innovation.
	Scale economies		+	Especially important for countries with smaller domestic markets.
	Learning from exporting		(+)	Considerable differences depending good and/or export market
Licensing	Technology transfer		+	Importance increasing due to increasing convergence of technology (e.g. broadcasting and telecommunications, automobiles and electronics).
Inward FDI	Technology transfer		+	MNEs have better technology than purely domestic counterparts. Joint ventures can enhance technology transfer.
	Competition		+ or -	Competition generally increases incentives to innovate. For firms far below the technology curve, sudden increase in competition can decrease innovation.
	Spill overs		(+)	MNEs can have spill-over effects through imitation and demonstration, worker mobility and spin-offs, backward and forward linkages
Outward FDI	Technology sourcing		+	MNEs invest abroad to source foreign technology and also to use the foreign pool of research talent.
	Learning by investing		+	Application of technology in new environments provide opportunities for knowledge creation. The effect of FDI on productivity would be negative if the investment project itself fails even if there is a positive effect in terms of knowledge within the firm.

Source: Onodera (2008)

2.3.2 Theory: R&D/Innovation and Exporting

Two main conceptual approaches exist to modelling the determinants of export performance, (Wakelin, 1998). ‘neo-endowment’ models in which firms' competitive advantage is based on factor endowments and, 'technology-based' models in which competitive advantage derives from the quality of firms' products or services. Both of these imply a positive link between R&D/innovation and exporting. Studies in the neo-endowment tradition argue that factor-based advantages may be important if the firm has either a natural monopoly of a particular factor or is, for example, located in a particular region where a factor is plentiful. Extending the more traditional range of factors included in such models beyond labour and capital to include different dimensions of human and organisational resources, emphasises the parallels between this type of explanation and resource-based models of company competitiveness.

Technology-based models of export performance focus primarily on firms’ investments or achievements in implementing new technologies, or the development of new products or processes. This capability will depend on the internal strengths of the plant, where applicable its links to other group companies, and on the support available from the regional or national innovation system within which the firm is operating (Nelson, 1993; Metcalfe, 1997). The presence of an R&D function within a plant, for example, may stimulate innovation through the type of technology-push process envisaged in linear models of innovation. R&D staff may also, however, contribute to firms’ creativity as part of multi-functional groups, or may allow firms to utilise extra-mural networks or information sources more effectively (Veugelers and Cassiman, 1999; Love and Roper, 2001). Braunerhjelm (1996), for example, provides evidence from Sweden that R&D expenditures and investment in skilled labour both have a positive effect on firms’ export intensity, while more conventional cost factors have no effect.

In both these approaches the implied causation runs from R&D/innovation to exporting. By contrast, endogenous growth models in the tradition of Grossman and Helpman (1991a,b) recognise the possibility of causality running from exporting to R&D and innovation. The channels for this are threefold, and summarised in Table 1 above. First, the stronger competition in foreign markets forces firms to invest in R&D in order to improve both products and processes and thus remain competitive. This may also include the need for a firm to undertake R&D (especially development work) in order to adapt to a different set of requirements in a foreign country, such as different technical standards. Second, there is the possibility of ‘learning by exporting’, principally involving being exposed to superior foreign knowledge and technology which also helps to boost the productivity of exporting firms (Kobrin 1991; Grossman and Helpman 1991a). Policymakers frequently regard this as an important element of the benefits of exporting: indeed, the World Bank regards the transmission of tacit and (occasionally) proprietary knowledge from customers and suppliers to exporters as an important dimension of export-led growth for developing economies (World Bank, 1993). The nature of this effect may be two-fold: a one-off productivity effect arising from exposure to export markets *per se*; and an effect arising from the extent of exporting, with productivity rising as exposure to export markets rises (Clerides et al 1998). Finally, scale effect may be important. Exporting extends the market over which margins may be earned, and since R&D costs are largely fixed, such investments may be recouped over a larger sales volume. This aids productivity, and providing greater incentives to invest in R&D and innovation.

2.3.3 Theory: Inward FDI and R&D/innovation

While theory suggests a generally mutually positive link between exporting and R&D/innovation, the situation with regard to the link between inward FDI and (domestic) R&D is much less clear. As a recent contribution points out (Beladi et al 2008) not only are theoretical explanations of the link under-developed, this is also reflected in the contradictory empirical literature on the subject.

To the extent that incoming multinational enterprises (MNEs) are more productive and have higher R&D and innovative capacity than their domestic counterparts, then the direct effect of inward FDI should be positive in theory. This may occur simply as a result of a 'batting average' effect as higher R&D MNEs increase the average level of R&D in the economy as a result of entry. The internationalisation of MNEs R&D activities (Cantwell 1995) is part of this process, although there is mixed evidence on whether developed OECD countries gain or lose by this process (Onodera 2008). The assumption of net benefits from foreign entrants' R&D activities is also consistent with the standard OLI model of FDI (Dunning 1988).

The situation is complicated, however, by the possible interaction of MNE subsidiaries with domestic firms. There may be a complementary or substitute relationship between R&D and innovation undertaken by MNE subsidiaries and that of domestic enterprises, so that the net effect of entry of R&D-producing MNEs is uncertain. Competition from MNEs may stimulate the R&D activities of domestic enterprises, encouraging them to be more innovative in order to compete both domestically and abroad. In addition, the ability of domestic enterprises to benefit from both intra- and inter-industry spillovers from MNEs depends on their absorptive capacity, an important element of which is in-house R&D (Cohen and Levinthal 1989).

However, there may be a substitute relationship between domestic and foreign R&D. In part this may arise from a *direct substitution* effect: if domestic enterprises recognise that the R&D and technology produced by MNE subsidiaries is available at a lower cost and less risk than they can produce themselves, firms may opt to obtain technology this way, with a result that foreign R&D substitutes for domestic R&D. Note that while this may result in a reduction in total R&D carried out in the economy, it may nevertheless be beneficial if access to improved technology is achieved by market means rather then (relatively inefficient) R&D carried out by domestic enterprises.

There is also the possibility of a *crowding out effect* occuring via the market, and involves foreign subsidiaries' R&D spending increasing the demand for R&D and hence its price. This may occur through bidding up the wages of researchers or other investment inputs, which may lead to firms altering their investment priorities. The net result of this may be that even if MNE research spending raises the total amount of R&D in the economy, the real amount of R&D (after adjusting for the higher cost of research) will actually be reduced.

These effects may be especially acute for SMEs, whose R&D capacity is generally relatively low and more easily competed with or crowded out. Given that UK business R&D (BERD) is already relatively heavily dependent on R&D performed by foreign firms, and that the share of UK BERD accounted for by SMEs is relatively high by OECD standards, this may be a particular issue for the UK.

And the area is further complicated by recent conceptual analysis indicating that FDI can be motivated not by 'ownership' advantages which are exploited by an MNE, but by the desire to access the superior technology of a host nation through direct investment (Fosfuri and Motta 1999; Siotis 1999). Entry by relative technology 'laggards' (i.e. MNEs which are less R&D intensive than the average for the host economy industry) is unlikely to add to the R&D capacity of the host economy. In addition, Driffield and Love (2007) argue that there is no theoretical reason to expect beneficial spillover effects from technology-sourcing entry (although there may be other beneficial effects, such as payment for contract research undertaken by UK firms, for example).

This suggests that determining the net effect of inward investment on domestic and total R&D is essentially an empirical issue.

2.4 Review of Empirical Literature

2.4.1 R&D/innovation ➔ exports

Empirical studies of the link between R&D, innovation and export performance are dominated by manufacturing, and the majority implicitly assume causality running from innovation to exports. Several early time-series studies for the UK at the industry level found positive links between R&D and patent counts to industry export performance (Buxton et al 1991; Greenhalgh 1990; Greenhalgh et al 1994). Subsequent firm-level studies have maintained this orientation, and have the advantage of being able to allow for heterogeneity between exporters and non-exporters. Generally such studies find that there are indeed significant differences between manufacturing exporters and non-exporters, and generally find a positive link between innovation and exporting in a variety of countries including the UK, Canada, Italy, Ireland and Germany (Wakelin 1998; Lefebvre and Lefebvre 2001; Sterlacchini 1999; Bleaney and Wakelin 2002; Roper and Love 2002; Lachenmaier and Wößmann 2006; Roper et al 2006).

The last of these studies (Roper et al 2006) also indicates that issues of multinationality, external ownership and firm size heavily influences the R&D-exporting link. They find that structural factors (e.g. ownership, industry) explain almost all of the difference in export propensity between larger plants in Northern Ireland and Ireland but only around one third of that between smaller plants. Significant differences are also evident between plants in terms of their sources of new technology. For indigenously-owned plants, in-house R&D is important, both formal and informal. For externally-owned plants, R&D conducted elsewhere in the group - typically outside Ireland and Northern Ireland - proves more significant.

Direct evidence on the link between R&D/innovation and exports in services is much more restricted. Gourlay et al (2006) study the determinants of export behaviour for a panel of over 1000 UK service firms for the period 1988 to 2001. They use R&D intensity (R&D expenditure as a percentage of sales) as an indicator of innovation i.e. an input rather than an output measure of innovation, and find that R&D intensity has strong positive effect on both the probability and intensity of exporting. By contrast, Love and Mansury (2007) employ a direct measure of innovation (whether the firm has produced at least one new service) in their study of exporting in US business services. They also find that innovation has a strong positive effect on the probability of exporting, but unlike Gourlay et al, they find a negative effect on export intensity, conditional on being an exporter.

In contrast to most of the studies reviewed above, two recent papers attempt to deal explicitly with endogeneity between R&D, innovation and exports in determining the nature and scale of any links. Lachenmaier and Wößmann (2006) employ a sample of 981 manufacturing firms in Germany, and use a set of 'impulses' (i.e. push factors) and impediments to innovation as instruments to perform IV estimation of exporting with innovation as an endogenous determinant. They find that innovators have an export share on average 12.6 percentage points higher than those of non-innovators, and that slightly more than half of this can be attributed to the effect of innovation on exports. By using careful controls for industry sectors, they conclude that "..being innovative causes firms to have substantially larger export shares than non-innovative firms in the same sector." (p. 346).

Harris and Li (2009) take a different approach to the endogeneity issue, employing a two-stage Heckman approach coupled with simultaneous estimation to allow for joint endogeneity of exports and R&D. They combine data from CIS3 and the ARD, and perform estimations for both manufacturing and services. The key findings are that (endogenous) R&D plays a substantial role in helping establishments become exporters, but conditional on entering export markets, R&D expenditure does not increase export intensity. Harris and Li also find that absorptive capacity (i.e. the ability to absorb externally generated knowledge) plays an important role in overcoming entry barriers to internationalisation, mainly through complementarity with R&D. They conclude that policy should encourage investment in elements of absorptive capacity as well as R&D alone in order to encourage entry to export markets.

However, not all firm-level studies find a positive association running from R&D/innovation to exporting. Specifically, a number of studies have found an insignificant relationship between R&D investment and export intensity (e.g. Lefebvre et al 1998; Sterlacchini; 2001). This leads to the suggestion that what really matters for exporting is *innovation* (both product and process) rather than *R&D*, because the ability to compete in international markets is ultimately influenced by the firm's capacity to compete internationally, rather than its investment in research activity (Harris and Li 2006a). This may be especially true for SMEs, where formal R&D measures markedly under-report their research activity and degree of innovativeness (Kleinknecht 1987). Although compelling, this argument is contradicted somewhat by Roper et al's (2006) analysis of Ireland and Northern Ireland. As indicated above, they find that formal and informal R&D activity had a significant effect on exporting, especially for SMEs. By contrast, when direct measures of product innovation were employed (similar to those used in the CIS), no relationship could be found with exporting activity.

More generally, however, this discussion points to a wider issue What ultimately matters for a firm's performance, both at home and in export markets, are its internal capabilities and capacity to access and use knowledge generated elsewhere. These capabilities are indicated by, but not necessarily determined by, innovation. For example, using UK firm-level data from 1972-83, Geroski and Machin (1992) and Geroski et al. (1993) find that there are positive effects of firm-level innovation on profits, but these are relatively small and transitory. Indirect effects are larger and more long lasting: that is, it is the *process* of innovation that really matters for performance (i.e. the transformation of internal capabilities), rather than the returns from individual innovations. In an analysis of Irish manufacturing plants, Love, Roper and Du (2009) find similar results. Innovators are not simply plants that innovate: their level of profitability is subject to different determinants from those of non-innovators. Innovation *per se* has a negligible effect on the profitability of indigenous innovators at the upper end of the profitability distribution, supporting the view that it is not the quasi-monopoly rents of innovation which distinguishes the best performing innovators from the rest, but the fact that these plants have capabilities or competences which others lack. These capabilities may be linked the *process* of innovation, but they are unlikely to be solely determined by innovating.

2.4.2 Exporting ➔ innovation/R&D

Some early studies of the determinants of innovation simply used exporting as a conditioning variable without consideration of any degree of endogeneity between them (e,g, Veugelers and Cassiman 1999). While this can be taken as an indication of positive association, more recent studies have tended to be couched in terms of endogenous innovation and growth theories, and have either explicitly or implicitly allowed for some degree of two-way interaction.

Many of these studies involve emerging or developing economies, which may be hypothesised as those which have most to gain technological catch-up and learning-from-exporting effects. For example, the technology-gap model used by Hobday (1995) in a study of latecomer firms in the context of East Asian electronics illustrates how innovation rates are accelerated by foreign consumer demand and a firm's exporting activities. He shows that knowledge is cumulative and its progression pushes forward a firm's growth trajectory. And in a study of the Taiwanese electronics industry, Aw et al (2007) find that exporting significantly boosts productivity, especially if accompanied by investment in R&D and/or labour training. They find that exporters not investing in R&D or training have lower productivity rates than firm investing in R&D. They conclude that exporters need to produce effective R&D or training in order to generate efficiency gains: exporting alone is not enough. Zhao and Li (1997) also find a two-way relationship between export intensity and R&D expenditure in a sample of Chinese firms.

Empirical studies from Western economies are relatively few. An exception is Girma, Gorg and Hanley (2007), who examine the two-way relationship between R&D and exports using British (BERD, ONS) and Irish firm-level data (Forfás) as comparison.

They initially adopt a bivariate probit framework that permits modelling of the export and R&D decisions simultaneously, and subsequently replace the dichotomous export and R&D variables with their truncated counterparts (i.e. intensities) and estimate simultaneously using 3SLS. The key findings are: first, exporting stimulates R&D for Irish firms, but not for British firms. Second, exporting status matters, not exporting intensity.

Girma et al explain the differences between the UK and Irish findings in three ways. First, firms in the two countries have different starting points: Irish firms export at an earlier stage than British firms, so have more to learn from becoming exporters Second, the destinations of outputs are different: Irish firms export to more (relatively) advanced economies, hence have more to learn from exporting. Finally, being an exporter is what appears to matter for enhancing a firm's knowledge, not the extent to which a firm exports. Potentially another reason for the different results is that the study compares two quite different datasets, and the issue of BERD data including only firms believed to be engaged in R&D activity.

As with the innovation-exporting research reviewed above, service sector studies, especially using UK data, are very few. Blind and Jungmittag (2004) examine the effect of exporting on innovation in German services . Their cross-sectional analysis of 2,019 service firms finds evidence that being an exporter is strongly correlated with the probability both of being a product innovator and of being a process innovator. Love, Roper and Hewitt-Dundas (2009) examine how Northern Ireland service firms' innovation activity relates to productivity and export behaviour. Their analysis is based on matched data from the 2005 UK Innovation Survey – the UK component of the Fourth Community Innovation Survey – and the Annual Business Inquiry for Northern Ireland. Echoing some of the findings of Aw et al (2007) and Girma et al (2007) they find that R&D, firm size, newness and innovation-related training and investment increase innovation outputs. Relationships between innovation, exporting and productivity prove complex but suggest that innovation itself is not sufficient to generate productivity improvements. Only when innovation is combined with increased export activity are productivity gains evident, and Love et al conclude that regional innovation policy should be oriented towards helping firms to innovate only where it also helps firms to enter export markets or to expand their existing export market presence.

Two recent studies shed considerable light on the exporting-R&D issue, using UK data for both manufacturing and services (Harris and Li 2006b; Harris 2008). In the first of these, Harris and Li perform two sets of cross-sectional analysis, combining UK data from CIS3 and CIS4 with relevant ARD data and comparing results with an earlier study using CIS3-ARD alone (Harris and Li 2005). Using a Heckman procedure to allow for endogeneity between exporting and R&D, Harris and Li find that exporters are more likely to engage in R&D, but that the effect is small: in manufacturing, exporters are 5% more likely to engage in R&D, in services around 4% more likely. In addition, there was evidence that engaging in exporting leads to increased R&D intensity (R&D as a proportion of sales), conditional on engaging in R&D. Harris and Li (2006b) find that for 2004, the impact of exporting was to increase the R&D intensity of both manufacturing and non-manufacturing establishments by around 72%. This study also highlights the importance of absorptive capacity as a determinant of R&D, and hence indirectly of exporting.

Harris (2008) employs longitudinal data over the period 1996-2004 using a merged BERD-FAME dataset. Descriptive statistics from this study, relating to the respective contributions to UK R&D of UK and foreign owned exporters and non-exporters respectively, are presented in Table 2.2. Unlike Girma et al (2007) this merged dataset is weighted to make it representative of UK industry, using CIS weightings. In this analysis it proved impossible to find suitable instruments to estimate a reliable model of whether a firm conducted R&D while allowing for the endogeneity of exporting. However, this study also examines the determinants of R&D intensity, specifically allowing for the effect of exporting intensity (rather than exporting/non-exporting as in Harris and Li 2006b). Interestingly, this suggests that doubling export intensity *reduces* R&D intensity by up to 5%, but that this negative effect applies only to young establishments (i.e. less than 10 years old). Harris concludes that such young firms may face a financial constraint on the timing of earning a suitable return on R&D investment. Thus, after a successful product launch arising from R&D investment, such firms may concentrate on exporting to recoup their investment, resulting in increased revenues which reduce the R&D intensity ratio.

While increasingly sophisticated empirical studies are teasing out the link between exporting and R&D/innovation, econometric studies tell us little about the mechanisms by which exporting may affect R&D. Analysis by OMB Research (2007) attempts to flesh out the story by conducting qualitative interviews with 20 'young, innovative exporters' identified from the PIMS database. While these can be regarded as no more than indicative, the interviews shed light on whether the causal mechanisms identified in Table 2.1 above actually accord with the experiences of firms. The key effects of exporting on R&D/innovation identified by the respondents were:

- first, that exporting provides additional funds for R&D;
- second, that their innovation activities are enhanced by being exposed to more demanding customers in export markets; and finally
- that exporting provides the incentive of a wider market over which to earn the potential returns to R&D.

These fit closely with the competition, learning-by-exporting and scale effects identified in the theoretical literature (Table 2.1)

Table 2.2: Shares of total turnover and R&D by ownership and exporting status[a], 1997 and 2004

	(real) turnover		*(real) R&D spending*	
	1997	2004	1997	2004
UK-owned non-exporter	40.0 *(64.5)*	37.0 *(44.1)*	2.6 *(27.4)*	9.5 *(32.3)*
UK-owned exporter	**44.0** ***(25.3)***	**43.0** ***(26.5)***	**87.9** ***(44.2)***	**72.8** ***(43.2)***
FO-owned non-exporter	4.0 *(3.7)*	6.0 *(11.1)*	0.2 *(11.3)*	4.3 *(4.2)*
FO-owned exporter	12.0 *(6.5)*	14.0 *(18.3)*	9.3 *(17.1)*	13.3 *(20.3)*
Total	100 *(100)*	100 *(100)*	100 *(100)*	100 *(100)*

[a] Harris (2008) final report, Table 4.2. Figures in italicised parenthesis are based on *CIS*3 data for 2000 and *CIS*4 data for 2004 (see Tables 3.7 and 3.8 in Harris and Li, 2006)
Source: (CIS4) weighted *FAME-BERD* database

2.4.3 Inward investment ➔ Innovation/R&D

In contrast with the extensive literature on exporting and R&D, direct empirical evidence on the links between inward investment and R&D activity is more limited. A number of studies in the 1980s and 1990s were concerned with a related issue: are foreign firms located in a host economy more or less innovative than domestic enterprises? Conceptually, the literature on the direct link between foreign ownership and innovation suggests the effect could be positive or negative, depending on whether the beneficial effects of access to group resources outweigh the potentially detrimental ‘branch plant’ effect. Foreign-owned plants may have access to technological resources such as access to large-scale R&D facilities operated by the parent, or to proprietary knowledge developed by the parent (Brugger and Stuckey, 1987).

Alternatively, access may be available to a wide range of non-scientific resources such as finance, an international marketing organisation through which new products can be diffused, or through patenting or other support functions. On the other hand, the ‘branch plant’ literature suggests that foreign-owned plants are less likely to have in-situ R&D facilities on which innovation crucially depends. For example, early work by Malecki (1980) and Howells (1984) suggests that the location of R&D is likely to be heavily influenced by corporate decisions, with basic scientific research, for example, typically assumed to be the most scale-intensive activity and therefore more likely to be centralised by the parent company than applied research and development work.

The limited empirical evidence on this issue appears to suggest that, on balance, a positive effect of foreign ownership on innovation is likely. Harris and Trainor (1995) conclude that externally-owned plants in Northern Ireland are more likely to innovate, at least in part because they devote more resources to R&D. This conclusion is supported by Love et al. (1996) and Love and Ashcroft (1999), who find evidence that foreign-owned manufacturing plants in Scotland (but not other UK-owned plants) are more likely to innovate than their indigenous counterparts. In an analysis of innovation among UK, German and Irish manufacturing plants, Love and Roper (2001) find that external ownership generally has a negative effect on innovation intensity (number of innovations per employee); in Germany and Ireland, however, external ownership is positively associated with innovation success (the proportion of sales attributable to new products). The implication is that although plants which are foreign owned tend to make relatively fewer innovations than indigenously owned enterprises, these innovations are typically more successful commercially.

There are, however, contrary findings. Harris (1991) for Northern Ireland and Bishop and Wiseman (1999) for the UK conclude that, on balance, external ownership is negatively associated with innovative activity at plant level. This may suggest that, once allowance is made for the larger size, higher productivity and greater R&D capacity of foreign entrants, they may not necessarily be more *innovative* than local firms.

However, as indicated in the theoretical section above, direct evidence on the R&D and innovation foreign entrants is only part of the story. Consideration must also be given to the impact of foreign R&D on domestic R&D, which may be positive or negative.

There is very limited evidence on the wider issue of the effect of inward FDI on the R&D activity of domestic enterprises, and almost none that satisfactorily teases out the potentially conflicting complementary or substitute relationship between inward FDI and domestic R&D and innovation. Veugelers and Vanden Houte (1999) find evidence of a negative effect of multinational firms on domestic R&D and the innovative efforts of domestic enterprises in Belgium, especially among producers with undifferentiated products. They speculate that the small size of Belgium's economy may in part be responsible for this effect. More recently, Liu and Zhou (2008) undertake a panel analysis of the impact of FDI through both greenfield and M&A entry on the innovation activity of Chinese high-tech enterprises. Greenfield R&D activities of foreign multinationals are found to have a positive effect on the innovative performance of domestic enterprises, through both intra- and inter-industry spillover effects, with M&As having a positive effect via inter-industry spillovers only. The one available piece of UK data suggests that there is a small but statistically significant negative effect of R&D investment by foreign plants on the R&D activity of domestic enterprises, suggesting a limited degree of crowding out (Driffield 2001). The reason for this is unclear. As indicated in the theory section above, it may be a direct substitution effect of (more productive) foreign R&D for that of indigenous enterprises, or be the result of a crowding out effect occuring via the market, with foreign subsidiaries' R&D spending increasing the demand for R&D and hence its price.

Some of the reason for the lack of consistency on the effects of inward investment on R&D and innovation may relate to different motivations for FDI. The internationalisation of R&D literature indicates that technology sourcing has become an increasingly important motivation for international investment (Cantwell, 1995; Cantwell and Janne 1999; Pearce, 1999). Where the primary motive for investment is technology sourcing, perhaps through locating R&D facilities close to high-quality UK research departments, this may or may not make a net contribution to total R&D depending on the substitution/complementarity issue discussed above.

Part of UKTI's R&D Programme involves providing support and information to foreign companies considering carrying out R&D in the UK, either directly or through partnerships with UK companies and universities, or through contract research. Supporting the R&D activities of existing or potential inward investing firms may be a cost-effective method of increasing the UK's R&D and thus ultimately improving productivity and growth in the domestic sector. However, this cannot be assumed. Apart from the crowding-out issue above, there is the danger that firms locating in the UK for reasons of technology or knowledge sourcing may not bring long-term benefits. This may be of importance for the UK: Driffield et al (2009) show that between 1987 and 1996 25-35% of inward investment into the UK could be characterised as technology sourcing i.e. took place from a foreign sector which had a lower R&D intensity than the corresponding UK sector.

Driffield and Love (2003) and Driffield et al (2009) also show that the motivation for inward investment into the UK is strongly related to its productivity spillover effects. FDI from sectors more technologically advanced than the UK does act to stimulate productivity growth in the relevant UK sector, as would be expected. However, inward FDI motivated by technology sourcing considerations leads to no productivity spillovers. And inward FDI by relative (to the UK sector) technology laggards which is also motivated by accessing cheaper labour costs in the UK can actually lead to *reduced* domestic productivity through market-stealing competition effects. This is pertinent as "UK business R&D is heavily dependent on foreign affiliates, attracted to the UK science base and the relative cheapness of UK researchers"[8].

2.5 Summary and Conclusions

The purpose of this report is to review the evidence on the links between exporting, inward investment and R&D/innovation, paying particular attention to UK evidence and to empirical work available after the review contained in Harris and Li (2006a).

The key points of the review can be summarised as follows:

- OECD comparative evidence suggests that for the majority of countries there is a positive relationship between exposure to foreign markets and innovation/R&D. By itself, this tells us nothing of the nature of the causal links between them.

- Conceptually, there are reasons to expect exporting and inward investment activity to be (positively) linked to R&D and innovation. Exporters can benefit from increased competition, from learning-by-exporting, and from scale effects, all of which may enhance R&D and innovation.

[8] HMG, Science & innovation investment framework 2004-14, July 2004, p 57.

- Inward investment's theoretical impact on R&D is less clear. It depends on the R&D capacity of the foreign entrants themselves, and on the competition and crowding out effects which foreign R&D may have. The motivation for FDI also plays a role i.e. technology sourcing versus technology exploiting effects. The net effect of FDI on total R&D is therefore unclear *a priori*.

- The econometric empirical evidence suggests a mutually self-reinforcing mechanism linking R&D, innovation and exporting. Firms performing R&D and innovating are more likely to export and to be more export intensive. Exporting in turn assist firms in performing R&D and innovating, even after endogeneity between R&D and exporting is allowed for.

- Both the econometric and more qualitative evidence from the UK suggests that competition, scale and (possibly) learning-by-exporting links exposure to international markets to R&D performance.

- Recent UK econometric evidence also suggests an important role for absorptive capacity in encouraging R&D at establishment level.

- The empirical evidence on the effect of inward investment on R&D is mixed. Foreign affiliates tend to be larger and more productive than domestic plants, but once allowing for this and their R&D capacity, they may be no more innovative than their domestic counterparts.
- There is very limited evidence on the wider issue of the effect of inward FDI on the R&D activity of domestic enterprises. There is some evidence of a significant, but small, crowding out effect in Belgium and the UK, but that foreign investment has a positive effect on levels of innovation (not R&D) among domestic enterprises in China.

- Part of the reason for the lack of consistency on the effects of inward investment on R&D and innovation may relate to different motivations for FDI. The internationalisation of R&D literature indicates that technology sourcing has become an increasingly important motivation for international investment.

- Technology sourcing FDI appears to represent a not insignificant minority of inward investment into the UK. Empirical evidence suggests that such investment leads to no identifiable productivity spillovers to the domestic sector. By contrast, FDI in which the foreign investor has higher R&D intensity (i.e. an ownership advantage) does lead to such productivity spillovers.

Overall, the literature suggests there are good reasons to expect exposure to export markets to increase the likelihood that firms will innovate, and to increase the R&D and innovation performance of exporting firms. Once the exporting hurdle is overcome, however, it is less clear that increased export intensity has an effect on R&D intensity. The impact of inward investment on R&D and innovation is less clear. R&D performing foreign entrants may or may not increase the level of R&D in the UK, depending on the net effect of any competition or crowding out effects on domestic firms. In addition, foreign investors engaging in technology sourcing FDI into the UK seem unlikely to enhance the net level of R&D in the economy, or to provide positive technology-based productivity spillovers.

Chapter 3: UKTI Trade Development – Scheme Assessment using PIMS Data

3.1 Introduction

The UKTI Performance and Impact Monitoring Survey (PIMS) has been developed over the last 4 years and the quarterly survey is used to report client satisfaction with the range of business support provided and to derive measures of economic impact and financial benefit. Analysis of the PIMS quarterly data has mainly concentrated on bivariate descriptives around the key UKTI measures of satisfaction, performance and impact. One of those derived performance measures is 'increased R&D'. This is defined as the proportion of UKTI beneficiaries that have or expect to increase the amount they spend on R&D or new product development (NPD); and increase the amount of time spent on R&D or NPD, adjusted for non-additionality

There are two broad aims of this part of our study.

- First, to undertake a more thorough multivariate analysis of the PIMS data in order to understand the key determinants of 'increased R&D' (the variable we are seeking to explain) in terms of basic firm characteristics such as firm size, business age, sector and region as well as additional behavioural variables related to exporting and innovative activity.

- Second, to introduce a range of dummy variables to reflect the type of UKTI business support received by the respondents to the PIMS survey. The question here is a relatively simple one – is it possible to suggest which UKTI schemes are more likely to drive 'increased R&D' while controlling for other characteristics of the firm?

We undertake the analysis based on PIMS Waves 6-9 (interviews undertaken in the four quarters of 2007) which contain the common UKTI measure – 'increased R&D'. There are two limitations to this analysis which should be understood from the outset. First, the dataset only has data on UKTI beneficiaries (n=3,048) and as a result we are unable to account for 'selection bias' in the estimations. In brief, we do not have a control group for this part of our study. Second, each of the 3,048 firms in PIMS Waves 6-9 were included as a <u>'representative'</u> of a UKTI Scheme – they may well have had other UKTI support, and indeed support from other government business support schemes. This is an important caveat because while the results may point towards the positive effect of a particular scheme on the outcome 'increased R&D' we are unsure as to whether the effect can be attributed solely to the effects of that scheme. Therefore, the results presented in this econometric analysis of the PIMS data should be treated as a preliminary indication of scheme effectiveness.

3.2 The Modelling Approach

We model the probability that firms reported 'increased R&D' expenditure in the following form:

$$IncRD_{it}^{*} = \beta' UKTI_{it} + \gamma_0' RI_{it} + \gamma_1' Own_{it} + \gamma_2' \mathrm{Re}\,gion_{it} + \gamma_3' Sector_{it} + \varepsilon_{it}\,,$$

$$IncRD_{it} = 1 \text{ if } IncRD_{it}^{*} > 0\,;\; IncRD_{it} = 0 \text{ otherwise,} \qquad (1)$$

Where $IncRD_{it}$ is a dichotomous variable that equals to 1 if a firm increases its R&D (which depends on a latent variable *IncRD**), and 0 if not. ε_{it} is an error term following a bivariate normal distribution. $UKTI_{it}$ represents the UKTI schemes firms' were involved in during the examined period and we are interested in the signs and levels of βs that reflect the effects of the schemes on R&D activity.

In order to isolate the impact of the range of UKTI schemes on determining a firms' 'increased R&D', some firm characteristics must be controlled in the model. RI_{it} is a set of indicators of firms' resource base, which include firm size, age (in nonlinear fashion), international nature of the firm's establishment, innovativeness, export activity, growth potential, labour skills and firm strategy. Own_{it} is a set of indicators intended to capture the impact of firms' owership structure, and we also include industrial sector indicators and regional dummies to allow for firm heterogeneity across sectors and the influence of regional development processes and policy interventions at the sub-national level. Due to the time series cross-sectional nature of our data i.e. across 4 quarters in 2007, the estimations are based on pooled probit models.

3.3 Econometric Issues

For this type of cross-sectional data analysis there are two econometric issues of central concern. The first issue is sample selection. The coefficients of the policy support variables may reflect a mixture of assistance effects and selection effects. Put differently, it would become a concern when observations included in the analysis are not a random sample, but selected into the sample by some selection mechanisms. In our case, though it is likely that the selection effects are blended in the treatment effects, additional data are required to deal with the issue, and other approaches need to be adopted to separately identify the selection and assistance effects (see Maddala, 1993). We seek to do this through the modelling of the impact of UKTI trade development support using the bespoke telephone survey that was designed and implemented as part of this evaluation project (see Chapter 4).

Secondly, we are aware of the findings in the literature review of exporting, innovation and productivity that export is commonly found to play an important role in the R&D equations. It is, thus, necessary to assess the potential endogeneity in the model that may be associated with exporting (see the discussion in Chapter 2). To do this we construct an export determinants function and test if increased R&D plays any important role in determining export activity. The estimates from this model suggest this is not the case. To this end, the following findings and discussions are based on the probit estimations.

3.4 Data and Summary Statistics

The explained variable is increased R&D (**IncRnD**), which is a dichotomous variable capturing if a firm has or expect to increase the amount they spend on R&D or new product development (NPD); and increase the amount of time spent on R&D or NPD, adjusted for non-additionality. In our sample, there are 12% of firms (firm-quarter observation) that reported to have increased R&D. It is also noticeable that the average number of firms that increase R&D tends to increase over the four quarters, from 9% in the PIMS Wave 6, to 15% in Wave 9.

There is a great deal of information on each UKTI beneficiary contained in the PIMS dataset that may be used to explain the phenomenon of a firm's increasing R&D activity. Our main interest is a series of dummy variables that capture each of the UKTI schemes. In our sample, the beneficiaries can be supported by, or participate in, one of more schemes provided by UKTI (Table 3.1).

Table 3.1: Participation of the UKTI R&D Programme for PIMS Waves 6-9

UKTI Schemes during PIMS wave 6-9	Number of companies interviewed	%
E - Passport to Export	360	11.81
F - OMIS	351	11.52
G1 - TAP (group) - formerly known as SE	210	6.89
G2 - TAP (SOLO) - formerly known as SOL	120	3.94
J - Direct Users of Overseas Posts	457	14.99
K - International Business Specialists	118	3.87
L - UK Regions New to Market	224	7.35
M - EMRS	73	2.4
P - Market Visit Support (Region)	121	3.97
R - Inward Missions (ISG)	149	4.89
S - Sector Events in the UK (ISG)	180	5.91
T - UKTI Web Users	40	1.31
G4- Outward Missions (Sectors - ISG - n	112	3.67
U - New to Export	127	4.17
B - Sector events overseas (seminars an	228	7.48
C - Export Communications Review	58	1.9
V - Special Reports	81	2.66
W - Aid Agency Workshops	39	1.28
Total	**3,048**	**100**

Source: UKTI PIMS Data

We are seeking, notwithstanding the obvious problem with this approach described above, to assess the relative impact of these schemes on the dependent variable – that is, increased R&D – after allowing for a vector of controls. We now discuss some of these other characteristics of the UKTI beneficiaries. The main variables and their definitions are set out in Table 3.2.

The average size of the sample firms is 109 employees, but the median size is only 5 employees, suggesting that the majority of the beneficiaries are small companies (**Size**). The average age of these firms is 6 years, with the youngest being 1 year while the oldest firm in the sample is only 11 years (**Age**). In other words this is a relatively youthful age profile compared to the business stock overall. Around 1 in 10 firms (10.4%) claim that they were born global (**Born**) defined as having been set up within the previous 5 years and operating immediately in export markets.

There are two variables that indicate the company's innovativeness. Overall, three-quarters (77%) of firms are 'innovative' (**Inn**) in that they…

- Have more than one employee engaged in R&D activity <u>and</u> more than one employee engaged in new product or service development
- <u>Or</u>, have employed someone external to conduct new product or service development in the last year
- <u>Or</u>, derive at least some turnover from products & services introduced in the last 3 years *except firms established in the last 2 years*

Using a more strict definition of innovation, there are just under two-thirds (60.5%) of the firms that can be described as 'innovative (**Superinn**). These firms (the additional conditions are highlighted in bold) are defined as those that….

- Have more than one employee engaged in R&D activity <u>and</u> more than one employee engaged in new product or service development **<u>and</u> at least some R&D employees are engaged in the 'development of scientific or technical knowledge that is not commonly available'**
- <u>Or</u>, have employed someone external to conduct new product or service development in the last year
- <u>Or</u>, derive at least some turnover from products & services introduced in the last 3 years (E2) *except firms established in the last 2 years* **<u>and</u> these products & services are either 'new to the world' or 'new to the industry/sector'**

Half of the firms in the sample are characterized as exporters, and the average length of time exporting is 3.9 years (**Export history**, defined as the log of the years of exporting history). Among exporters, the average proportion of overseas sales out of total turnover reaches a maximum of 53% (**Export intensity**).

Just under half of the firms (45.7%) report that their business had grown in the last five years or since it was established (**Grow**). The educational level of the respondent in our sample is quite high with around three-quarters (72%) of the firm owners or managers stating that their highest level of qualification is a degree. Finally, three-quarters (76%) of the firms report that they have a business plan and within this group 4 out of 5 respondents state that it contains targets relating to generating revenues from overseas sales. A correlation matrix of these control variables is included as an Appendix to this Chapter.

Table 3.2: Variable Definitions and Summary Statistics

Variables	No. of obs.	mean	Sd	min	max	Note
DEPENDENT VARIABLE Increased R&D (net of non-additionality)	3040	0.119	0.324	0	1	The mean of each wave: PIMS 6: 0.094; PIMS 7: 0.096; PIMS 8: 0.132; PIMS 9: 0.158; PIMS 10: 0.119; PIMS 11: 0.111
UKTI scheme: based on Sample group	3048	8.062	6.083	1	21	See Table 3.1. Participation of the UKTI R&D programmes for PIMS Wave 6-9.
Number of employees	3040	109	302	0	998	
Size: ln of number of employees	3040	2.135	1.798	0	6.907	
age: based on S4. How long ago was your business established	3048	6.291	1.969	1	11	
Born global (5 year definition)	3041	0.104	0.305	0	1	
Innovative firms	3048	0.772	0.420	0	1	
Innovative firms (but new products or services have to be completely new)	3048	0.605	0.489	0	1	
Export Experience (exporter=1)	3048	0.508	0.500	0	1	
export history (log of the exporting years)	3048	1.235	0.527	0	1.946	
Export intensity (for exporters only)	1448	53.87	27.37	12	100	
Growing firms	1216	0.457	0.498	0	1	
Education: education level of the owners/managers (% of managers with a degree)	2654	0.719	0.387	0	1	
Business Plan 1: if there is a business plan (F10)	2935	0.762	0.426	0	1	
Business Plan 2: if there is a business plan that contains any targets relating to revenues from overseas sales (F13) (among companies which report to have a business plan, F10=1)	2173	0.789	0.408	0	1	
Increased sales (D3Q: 4&5)	3048	0.341	0.474	0	1	

Source: UKTI PIMS Waves 6-9

There are two caveats linked with the analysis that follows. Firstly, all the sample firms are UKTI Scheme beneficiaries. This means that the current observations will not allow us to assess the total effect on **IncRnD** due to the participation of the UKTI Schemes (i.e. treatment effects). Rather, we will be able to discover the relative or comparative effects between different schemes (i.e. relative treatment effects). Secondly, the sample companies may well have had other support under other UKTI services around the same period, which are not all recorded in this dataset. Hence, it would be difficult to separate out the effect of individual UKTI Schemes and as a result the estimates below should be treated with some caution.

3.5 Probit Results

The estimation results from the pooled probits are reported in Table 3.3. Three models are estimated for both all industry sectors and then for the manufacturing sector on its own. The rationale for this distinction is that we set out to provide a focus on a sector where one might expect R&D to be more relevant and also to connect with a substantial body of the literature which has focused on manufacturing. These three models are:

(i) a baseline probit model for firm (increased) R&D;
(ii) the baseline model modified with the inclusion of the UKTI scheme dummies;
(iii) model (ii) plus additional control variables. Ensuring robustness of the estimates is the essential purpose of estimating and comparing three models.

We report both estimated coefficients (Column 1-6) and marginal effects (Column 7-12) for overall sectors and manufacturing industries.

Baseline Models

Firm size and age have an inverted U-shaped relationship with increased R&D. Larger and older firms tend to increase investment in R&D until a certain point, after which the increase in R&D investment slows down. This finding is consistent with the prior expectations from previous studies which state that the R&D capacity of SMEs is generally low and are more readily susceptible to competition effects and crowding out.

The only statistically significant sector dummy is the Finance sector and the sign is negative. This is not surprising given that it is traditionally one of the least R&D intensive industries. Although not being statistically significant, several sectors tend to obtain economically significant positive coefficients, such as Education, Community, Social and Personal Services; Transport, Storage and Communication, as well as Manufacturing.

In the overall model (all sectors) the South East and South West regions are found to have a negative coefficient, although not significant after controlling for additional firm characteristics. Further, in the Manufacturing only model with the full set of control variables London has a negative and significant sign.

UKTI Scheme Effects

When we introduce the UKTI Scheme dummies into the model we find that some of them have significantly positive impacts on firms' increased R&D compared to others. The reference groups in the estimations are Special Reports (V) and Aid Agency Workshops (W), due to their low numbers of observations. So the coefficient for each UKTI Scheme is relative to these reference Schemes.

For the model for all sectors, the most significantly positive effects come from EMRS (M), TAP group (G1), UKTI web users (T), Passport to Export (E) and statistically less significant effects from Direct users of Overseas Posts (J), International Business Specialists (K), Market Visit Support (P) and Outward Missions (G4), which were statistically significant even after we control for firm characteristics.

Other UKTI Schemes, such as TAP SOLO (G2) and Inward missions (R), are found to have significant impacts but they tend to be weakened by the inclusion of other covariates in the model. This may suggest the selection issues, which cannot be tackled at this stage given the sample used in this analysis, contains only scheme users. For manufacturing sectors, UKTI Web Users (T) is the only scheme that is found to shed significantly positive impacts on firms' increased R&D, but it loses its statistical significance after controlling for more firm characteristics. On the other hand, UK regions new to markets (L) is found the have significantly less impact on increased R&D compared to the rest of the schemes.

Control Variables – Firm Behaviour

We concentrate here on the set of variables related to innovation, exporting, strategy, growth, and ownership. Innovative firms tend to 'increase R&D' more than less innovative firms. This tends to be the case for both the all sector and the manufacturing sector models. This is consistent with the literature of the mutually self-reinforcing mechanism linking R&D and innovation. The highly significant positive impact stays the same even if we use the more strict definition of innovation (**Superinn**). The implication here is that innovation inputs are very likely to be associated with innovation output.

Export activity has positive but statistically insignificant impacts on increased R&D, regardless of being defined as an experienced exporter or export intensity (i.e., number of years exporting). It is worth noting that this is not the same as saying that export activity has no impact on R&D activity, as the opposite evidence has been found widely in the literature. Although the possibility of having an endogenous export variable in the increased R&D model is not high, we nevertheless tested the reverse causality in two ways. We firstly investigate whether firms' increased R&D determined export history or intensity, and secondly we allow simultaneous determination of increase R&D and export. As a result, we find that there is no significant reverse causality of export and increased R&D for the firms in the sample used in this analysis.

Having a business plan containing targets relating to overseas sales revenue seems to have negative and insignificant impact on increased R&D. A more relaxed definition of this variable (i.e., without the export condition) does not change the results. By contrast, increased R&D appears to be associated with increased sales, and the coefficients are highly significant. It is hardly surprising as increased sales may contribute to higher expected profits that provide funds of conducting additional R&D. However, the magnitudes of the increased sales' marginal effects reach 12-17%, which are much higher than most of other determinants. This is an interesting result, in that it reveals what might be the most important driving factor to promote R&D activities. This is underlined by the fact that firms that have grown in the last five years (or since they were established if aged more than 2 years) are more likely to have 'increased R&D' particularly in manufacturing sectors.

Finally, we note that the ownership structure does not make any significant difference in firms' increased R&D. The estimates of ownership dummy variables suggest that UK-owned companies register higher increased R&D than partially foreign-owned companies and totally foreign-owned firms, which are however not statistically significant. This is in contrast with what has been found among OECD countries where for most of the countries, foreign ownership appears to correlate positively with the innovation or R&D. As discussed in detail in the literature review section, the impact of inward investment on R&D depends on the R&D capacity of the foreign entrants, and on the competition and crowding out effects which foreign R&D may have. One possible explanation of our result may be that foreign investments in our sample enter the UK markets with the intention of technological exploiting rather that technological sourcing.

3.6 Summary

For the first time we have undertaken a multivariate analysis of the UKTI PIMS dataset and we have selected Waves 6-9 which were undertaken in 2007. There were two objectives. First, to provide UKTI with an indication of the profile of businesses which fall within the PSA measure 'increased R&D'. Second, to determine if it is possible to isolate particular Schemes under the broad heading of UKTI trade development activity which are more likely to impact upon 'increased R&D'. There are methodological issues which constrain the analysis and interpretation of the results not least of which is selection bias and the absence of a control group that would enable us to set out clear UKTI effects

With that in mind, for this group of UKTI beneficiaries we are able to state that larger and older firms are more likely to report 'increased R&D' but with a diminishing effect. Innovative and growing firms, especially in manufacturing, are more likely to be contributing to 'increased R&D'.

What can we say about UKTI Scheme effects? The analysis shows that there are some Schemes that, relative to others, are more likely to be associated with 'increased R&D'. These are EMRS (M), TAP group (G1), UKTI web users (T), Passport to Export (E) with statistically less significant effects from Direct users of Overseas Posts (J), International Business Specialists (K), Market Visit Support (P) and Outward Missions (G4).

However, we do need to address the issue of selection bias before we can begin to conclude that UKTI trade development activities have had a positive impact on increased levels of R&D activity in assisted firms. We now turn to this issue in the next Chapter when we set out the results from a more robust survey of UKTI beneficiaries which contained a non-beneficiary control group.

Table 3.3: Probit Estimation Results

Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Overall, coefficient			**Manufacturing, coefficient**			**Overall, marginal effects**			**Manufacturing, marginal effects**		
Model	*Baseline*	*With scheme dummies*	*With additional controls*	*Baseline*	*With scheme dummies*	*With additional controls*	*Baseline*	*With scheme dummies*	*With additional controls*	*Baseline*	*With scheme dummies*	*With additional controls*
UKTI Schemes												
E - Passport to Export		**0.684****	**0.564***		0.258	0.241		**0.168****	0.137		0.0544	0.0467
		(0.269)	**(0.332)**		(0.333)	(0.435)		**(0.0813)**	(0.0969)		(0.0781)	(0.0943)
F - OMIS		0.353	0.124		-0.117	-0.582		0.0763	0.0248		-0.0207	**-0.0758***
		(0.270)	(0.330)		(0.329)	(0.447)		(0.0668)	(0.0698)		(0.0551)	**(0.0425)**
G1 - TAP (group) - formerly known as SESA		**0.718*****	**0.716****		0.275	0.376		**0.184****	0.189*		0.0586	0.0779
		(0.276)	**(0.339)**		(0.336)	(0.443)		**(0.0894)**	(0.112)		(0.0805)	(0.108)
G2 - TAP (SOLO) - formerly known as SOLO		0.496*	0.376		0.0748	-0.204		0.118	0.0869		0.0146	-0.0309
		(0.296)	(0.366)		(0.372)	(0.492)		(0.0860)	(0.0994)		(0.0754)	(0.0654)
J - Direct Users of Overseas Posts		**0.509***	**0.523***		0.0367	0.219		0.116	0.123		0.00696	0.0413
		(0.265)	**(0.317)**		(0.325)	(0.406)		(0.0713)	(0.0877)		(0.0626)	(0.0840)
K - International Business Specialists		**0.605****	**0.695***		0.280	0.357		0.151	0.184		0.0608	0.0749
		(0.297)	**(0.361)**		(0.386)	(0.512)		(0.0931)	(0.121)		(0.0959)	(0.128)
L - UK Regions New to Market		0.416	0.0401		**-0.403**	**-1.149****		0.0941	0.00777		-0.0610	**-0.106*****
		(0.280)	(0.353)		**(0.362)**	**(0.531)**		(0.0749)	(0.0699)		(0.0429)	**(0.0237)**
M - EMRS		**0.878*****	**0.771****		0.225	0.340		**0.246****	0.212		0.0476	0.0711
		(0.308)	**(0.388)**		(0.414)	(0.583)		**(0.112)**	(0.136)		(0.0982)	(0.145)
P - Market Visit Support (Region)		**0.703****	**0.856****		0.355	0.364		**0.183***	0.242*		0.0799	0.0762
		(0.292)	**(0.370)**		(0.361)	(0.472)		**(0.0968)**	(0.134)		(0.0951)	(0.117)
R - Inward Missions (ISG)		**0.565***	0.410		-0.223	-0.223		0.138	0.0961		-0.0365	-0.0332
		(0.293)	(0.369)		(0.455)	(0.615)		(0.0891)	(0.103)		(0.0643)	(0.0784)
S - Sector Events in the UK (ISG)		0.415	0.229		-0.00531	-0.188		0.0946	0.0490		-0.000988	-0.0288
		(0.293)	(0.350)		(0.383)	(0.493)		(0.0794)	(0.0830)		(0.0711)	(0.0669)
T - UKTI Web Users		**0.957*****	**0.909****		**0.917****	0.687		**0.278****	0.265		0.265	0.171
		(0.348)	**(0.456)**		**(0.468)**	(0.630)		**(0.131)**	(0.171)		(0.175)	(0.205)
G4- Outward Missions (Sectors - ISG - not SESA)		**0.524***	**0.632***					0.127	0.164			
		(0.305)	**(0.378)**					(0.0910)	(0.123)			
U - New to Export		0.371	0.415		-0.112	0.226		0.0833	0.0979		-0.0196	0.0441
		(0.306)	(0.382)		(0.394)	(0.514)		(0.0810)	(0.107)		(0.0645)	(0.113)
B - Sector events overseas (seminars and others)		0.449	0.528		0.178	0.234		0.103	0.128		0.0363	0.0453
		(0.279)	(0.337)		(0.340)	(0.444)		(0.0764)	(0.0991)		(0.0757)	(0.0964)
C - Export Communications Review		0.364	0.164		-0.181			0.0820	0.0342		-0.0304	
		(0.349)	(0.460)		(0.468)			(0.0930)	(0.104)		(0.0697)	

Firm Characteristics												
Size	0.590***	0.498***	0.268**	0.730***	0.631***	0.492**	0.111***	0.0917***	0.0509**	0.139***	0.118***	0.0841**
	(0.0738)	(0.0858)	(0.121)	(0.113)	(0.135)	(0.206)	(0.0135)	(0.0156)	(0.0229)	(0.0209)	(0.0249)	(0.0347)
size2	-7.355***	-6.320***	-3.613**	-9.789***	-8.711***	-6.844**	-1.380***	-1.163***	-0.687**	-1.864***	-1.626***	-1.171**
	(0.944)	(1.081)	(1.559)	(1.510)	(1.755)	(2.755)	(0.174)	(0.197)	(0.295)	(0.277)	(0.321)	(0.462)
age	0.192**	0.186**	0.183	0.185	0.182	-0.0280	0.0360**	0.0342**	0.0348	0.0352	0.0341	-0.00479
	(0.0864)	(0.0874)	(0.134)	(0.144)	(0.148)	(0.248)	(0.0162)	(0.0160)	(0.0254)	(0.0274)	(0.0277)	(0.0424)
age2	-2.203***	-2.056**	-2.404*	-2.218*	-2.098	-0.648	-0.413***	-0.378**	-0.457*	-0.423*	-0.392	-0.111
	(0.819)	(0.829)	(1.283)	(1.327)	(1.371)	(2.293)	(0.153)	(0.152)	(0.243)	(0.252)	(0.255)	(0.392)
Born global (born)			-0.115			-0.387			-0.0208			-0.0532
			(0.164)			(0.336)			(0.0279)			(0.0361)
Innovative firm (inn)			0.658***			0.636*			0.0938***			0.0778***
			(0.165)			(0.337)			(0.0166)			(0.0274)
Export history (exp_history, ln(S5anew))			0.230			0.240			0.0438			0.0410
			(0.202)			(0.354)			(0.0383)			(0.0605)
Export intensity (X1A)			-0.000217			0.00193			-4.13e-05			0.000330
			(0.00159)			(0.00290)			(0.000302)			(0.000497)
Growing firm (Grow)			0.0853			0.292*			0.0162			0.0496*
			(0.0920)			(0.158)			(0.0174)			(0.0265)
Education level of the owners, managers			-0.0646			-0.348*			-0.0123			-0.0596*
			(0.124)			(0.191)			(0.0235)			(0.0327)
Business plan (F13)			0.0503			0.129			0.00938			0.0209
			(0.123)			(0.230)			(0.0225)			(0.0348)
Increased sales (D3Q)			0.604***			0.905***			0.125***			0.174***
			(0.0909)			(0.155)			(0.0201)			(0.0319)
Ownership: UK-owned	0.202	0.188	0.171	0.0647	0.0376	-0.542	0.0342	0.0314	0.0297	0.0119	0.00690	-0.120
	(0.269)	(0.274)	(0.368)	(0.421)	(0.429)	(0.631)	(0.0409)	(0.0412)	(0.0585)	(0.0754)	(0.0773)	(0.172)
Ownership: totally foreign owned	0.195	0.215	0.299	-0.0795	-0.149	-0.615	0.0403	0.0441	0.0659	-0.0146	-0.0259	-0.0751
	(0.294)	(0.298)	(0.400)	(0.458)	(0.468)	(0.676)	(0.0665)	(0.0676)	(0.100)	(0.0805)	(0.0749)	(0.0553)
Manufacturing	-0.0560	-0.00698	0.0451				-0.0104	-0.00128	0.00861			
	(0.248)	(0.252)	(0.419)				(0.0461)	(0.0463)	(0.0803)			
Construction	0.0756	0.0949	-0.194				0.0148	0.0185	-0.0328			
	(0.369)	(0.375)	(0.591)				(0.0757)	(0.0772)	(0.0876)			
Wholesale, retail and certain repairs	-0.148	-0.0940	0.116				-0.0261	-0.0166	0.0232			
	(0.259)	(0.264)	(0.434)				(0.0424)	(0.0446)	(0.0914)			
Hotels and restaurants	-0.279	-0.297	0.0901				-0.0439	-0.0452	0.0181			
	(0.615)	(0.628)	(0.802)				(0.0789)	(0.0766)	(0.169)			
Transport, storage and communication	-0.173	-0.105	0.335				-0.0292	-0.0182	0.0764			
	(0.328)	(0.333)	(0.513)				(0.0496)	(0.0538)	(0.137)			
Finance	-0.874*	-0.876*	-0.482				-0.0937***	-0.0915***	-0.0678			
	(0.509)	(0.519)	(0.664)				(0.0238)	(0.0234)	(0.0642)			
Real estate, renting and business activities	-0.200	-0.145	-0.0163				-0.0356	-0.0256	-0.00308			
	(0.252)	(0.257)	(0.426)				(0.0425)	(0.0437)	(0.0804)			
Education	-0.117	-0.0625	0.0797				-0.0205	-0.0111	0.0158			

	(0.297)	(0.302)	(0.483)				(0.0485)	(0.0515)	(0.100)			
Health and social work	-0.279	-0.192	0.452				-0.0440	-0.0313	0.110			
	(0.442)	(0.445)	(0.742)				(0.0571)	(0.0637)	(0.220)			
Community, social and personal services	0.0663	0.0928	0.286				0.0129	0.0180	0.0631			
	(0.274)	(0.279)	(0.459)				(0.0553)	(0.0567)	(0.116)			
North West	-0.175	-0.180	-0.307	0.00466	0.0221	-0.139	-0.0301	-0.0302	-0.0499	0.000889	0.00417	-0.0221
	(0.163)	(0.164)	(0.249)	(0.263)	(0.272)	(0.443)	(0.0254)	(0.0250)	(0.0341)	(0.0502)	(0.0519)	(0.0649)
Yorkshire and Humberside	-0.0773	-0.0699	0.0134	-0.157	-0.105	0.0205	-0.0139	-0.0124	0.00256	-0.0278	-0.0186	0.00354
	(0.164)	(0.166)	(0.242)	(0.265)	(0.275)	(0.431)	(0.0284)	(0.0284)	(0.0467)	(0.0431)	(0.0462)	(0.0753)
East Midlands	-0.0873	-0.103	-0.119	-0.0526	-0.0521	-0.164	-0.0157	-0.0179	-0.0213	-0.00975	-0.00947	-0.0257
	(0.163)	(0.166)	(0.253)	(0.268)	(0.278)	(0.451)	(0.0280)	(0.0273)	(0.0424)	(0.0485)	(0.0492)	(0.0640)
West Midlands	-0.0682	-0.0687	-0.145	-0.230	-0.237	-0.359	-0.0124	-0.0122	-0.0256	-0.0394	-0.0396	-0.0518
	(0.161)	(0.163)	(0.246)	(0.260)	(0.270)	(0.431)	(0.0283)	(0.0280)	(0.0403)	(0.0397)	(0.0400)	(0.0517)
East England	-0.195	-0.219	-0.140	0.0900	0.102	0.300	-0.0332	-0.0361	-0.0248	0.0179	0.0200	0.0598
	(0.162)	(0.164)	(0.244)	(0.258)	(0.268)	(0.428)	(0.0249)	(0.0240)	(0.0401)	(0.0535)	(0.0550)	(0.0974)
London	-0.235	-0.233	-0.204	**-0.464***	**-0.505***	-0.784	**-0.0399***	**-0.0388***	-0.0355	**-0.0693****	**-0.0721****	**-0.0869*****
	(0.152)	(0.156)	(0.234)	**(0.282)**	**(0.291)**	(0.480)	**(0.0232)**	**(0.0232)**	(0.0370)	**(0.0317)**	**(0.0304)**	**(0.0322)**
South East	**-0.367****	**-0.390****	-0.378	-0.341	-0.337	-0.346	**-0.0581*****	**-0.0597*****	**-0.0605***	-0.0557	-0.0539	-0.0500
	(0.160)	**(0.164)**	(0.242)	(0.262)	(0.274)	(0.443)	**(0.0210)**	**(0.0205)**	**(0.0320)**	(0.0361)	(0.0369)	(0.0532)
South West	**-0.303***	**-0.295***	-0.301	-0.353	-0.334	-0.289	**-0.0488****	**-0.0468****	-0.0493	-0.0568	-0.0531	-0.0429
	(0.163)	**(0.166)**	(0.247)	(0.267)	(0.278)	(0.436)	**(0.0223)**	**(0.0223)**	(0.0345)	(0.0355)	(0.0369)	(0.0557)
Wales	-0.360	-0.318	-0.567	-0.528	-0.514	-0.494	**-0.0541***	-0.0481	**-0.0762****	**-0.0729***	**-0.0699***	-0.0618
	(0.276)	(0.281)	(0.384)	(0.424)	(0.436)	(0.599)	**(0.0319)**	(0.0337)	**(0.0332)**	**(0.0390)**	**(0.0400)**	(0.0514)
Scotland	0.00269	0.0466	0.0792	-0.268	-0.300	-0.221	0.000505	0.00880	0.0157	-0.0438	-0.0472	-0.0333
	(0.177)	(0.184)	(0.255)	(0.324)	(0.339)	(0.479)	(0.0333)	(0.0355)	(0.0526)	(0.0447)	(0.0438)	(0.0628)
Northern Ireland	0.299	0.320	0.246	0.537	0.473	0.696	0.0665	0.0707	0.0538	0.136	0.114	0.174
	(0.291)	(0.299)	(0.434)	(0.444)	(0.454)	(0.660)	(0.0750)	(0.0773)	(0.108)	(0.140)	(0.135)	(0.216)
Constant	**-2.069*****	**-2.545*****	**-3.199*****	**-2.057*****	**-2.009*****	-1.883						
	(0.438)	**(0.509)**	**(0.794)**	**(0.600)**	**(0.677)**	(1.155)						
Observations	**2840**	**2840**	**1468**	**1186**	**1161**	**602**	**2840**	**2840**	**1468**	**1186**	**1161**	**602**

Note 1: The reference group of UKTI scheme variables for the regressions are: V - Special Reports and O - English Regions Events for their few observations.
Note 2: The reference group for the industrial dummies in the overall regressions (1) and (2) are: Agriculture, hunting or forestry, Fishing, Mining and quarrying, Public administration and defence, and Extra territorial organisations.
Note 3: The reference group for the location indicators is North East.
Note 4: For discrete change of dummy variable from 0 to 1, the z and P>|z| of the marginal effects correspond to the test of the underlying coefficient being 0
Note 5: Standard errors in parentheses,*** p<0.01, ** p<0.05, * p<0.1.

Appendix
Table A3.1: Correlation matrix of Control Variables

Variable name	IncRnD	size	age	born	inn	superinn	exper	exp_history	Export intensity	grow	educ	BP 1	BP2
IncRnD	1												
size	0.056	1											
age	-0.0593	-0.0433	1										
born	0.0044	-0.0065	-0.5401	1									
inn	0.1163	-0.0261	0.1071	-0.0713	1								
superinn	0.119	-0.0213	0.0439	-0.0239	0.6575	1							
exper	-0.0014	-0.0654	0.1494	0.0769	0.0775	0.0602	1						
exp_history	-0.0648	-0.0578	0.6651	-0.1892	0.0877	0.0529	0.3899	1					
Export intensity	-0.0077	-0.0535	0.0522	0.1151	-0.0003	0.0359	0.7361	0.2714	1				
grow	0.0397	-0.0084	-0.054	0.0156	0.1346	0.1485	0.0317	-0.0439	0.0409	1			
educ	-0.0023	-0.0319	-0.0655	0.0313	0.0208	0.0737	0.0508	0.0168	0.0913	0.0358	1		
Business Plan 1	0.0133	-0.0061	0.0034	0.0249	0.1063	0.1479	-0.0062	0.0036	0.0059	0.1286	0.1431	1	
Business Plan 2	0.026	0.0334	0.0578	0.0097	0.1217	0.1192	0.2103	0.1741	0.155	0.0723	0.0644	.	1

Chapter 4: Role of UKTI Trade Development Support in Raising R&D Investment

4.1 Introduction

This chapter seeks to build on the analysis of the PIMS dataset in the previous chapter by seeking to determine the impact of UKTI's various schemes to support internationalisation activity and exports, in terms of their impact on recipient firms change in R&D spend. The objective is to compare the R&D trajectory of UKTI supported firms, with a robustly defined and matching control group of unsupported firms. This sample of supported and unsupported firms was then surveyed through a specially designed telephone survey.

The survey instrument was designed to include a set of control variables reflecting factors which will have a bearing on R&D activity and spend to ensure that we are able to isolate the effects of UKTI support. Therefore, we include questions on the profile of the business (size, age, ownership, sector and location); market orientation, strategic direction of the business, owner-manager/management profiles alongside questions designed to record R&D and innovation activity and spend as well as measures of absorptive capacity.

The methodology developed here builds on the previous two chapters, in terms of developing the analysis of UKTI supported firms, and also basing the specification of the various models on the literature review. The review of the evidence presented in Chapter 2 highlights the strong correlation between exporting and innovation, and also discusses in detail the attempts that have been made to establish a direction of causation in this. This chapter then seeks to determine the extent to which not exporting *per se*, but the support for exporting leads firms to become more innovative, measured through R&D. This chapter then contrasts with the previous chapter, by looking at supported and non-supported firms, and comparing the characteristics of these. In order to do this, we conducted a new bespoke survey of recipients of UKTI support, and a matched sample of non-recipients.

The fundamental aim of this chapter is to build on the previous one by analysing not the relative effects of different schemes, but the impact of support compared with similar firms who have not received UKTI support. This enables the researcher to quantify the extent to which UKTI support has led to an increase in R&D investment. This seeks to proceed in four stages:

1. to compare UKTI beneficiaries of trade development support and non-beneficiaries in terms of a number of key variables relating to R&D and innovation activity;

2. to determine what explains the likelihood of a given firm receiving UKTI support to engage in internationalisation activity and exporting;

3. to determine the extent to which UKTI support has boosted R&D expenditure;

4. To seek to derive an overall average estimate for any such increase in R&D expenditure by UKTI supported firms.

This chapter begins with some simple bivariate comparisons of the two subsamples, and then leads on to the econometric analysis of the data, with some discussion of the modelling and the sample selection issues. The central aim here is to establish whether UKTI support for trade development generates an increase in R&D at the firm level.

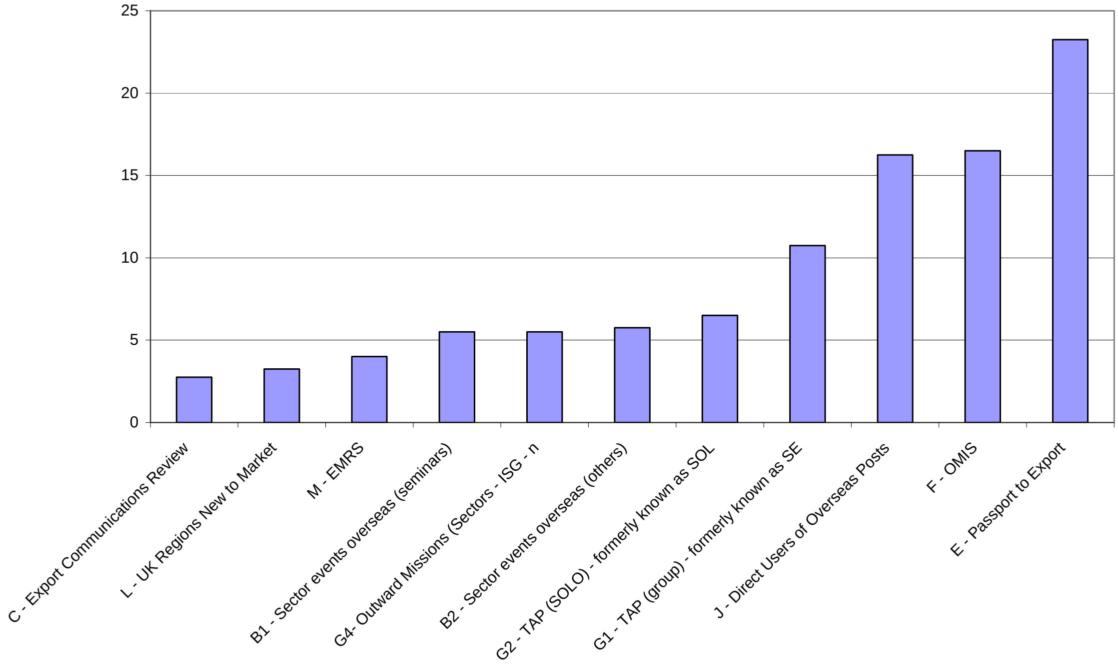
4.2 UKTI Beneficiary and Non-Beneficiary Survey Methodology

The survey for this evaluation took the population of firms who had received support from a range of UKTI schemes in the 12 months to December 2007 (e.g., Passport to Export; Overseas Market Introduction Service, Tradeshow Access Programme) to assist trade development and a matched sample (stratified by size and sector) of non-beneficiaries. The sample was drawn from the population of firms sampled for Waves 6-9 of PIMS which was the focus of attention in Chapter 3.

The survey took place in the last quarter of 2008 and the respective sample sizes were 400 UKTI beneficiaries of support and a matched sample of 400 non-beneficiaries. The response rates for the survey were 52% and 21% respectively for these two groups (see Table A4.1 in Appendix A to this chapter). Screening for overseas sales activity was undertaken and firms were only included in the survey if 'active' in export markets in the last two years.

Figure 4.1 shows the particular schemes the UKTI beneficiaries in the sample were selected to represent in the survey. We return to the issue of other UKTI support later in the Chapter. Almost a quarter of the respondents were in receipt of Passport to Export support while a further third accessed OMIS and Direct Users of Overseas Posts. The sample was distributed across the four quarterly waves of PIMS in 2007 (i.e., Waves 6-9) with a slight underrepresentation in Wave 6 (15%).

Figure 4.1: UKTI Beneficiaries – Selected Scheme Participation



Before undertaking the econometric analysis to determine the effects of UKTI trade development activity on R&D investment we set out in the next section some of the headline descriptive comparisons between the two groups of surveyed firms.

4.3 Characteristics of UKTI Beneficiaries and Non-Beneficiaries

There is clear evidence that helping firms internationalise has a direct effect on their innovation and R&D activities. One of UKTI's PIMS measures is whether clients increase their innovation activity, for instance, if supported companies have made improvements to their products or services; or made improvements to processes or management practices; or made improvements to their new product development strategy, net of non-additionality. Around one-third of UKTI beneficiaries reported that they had increased innovation (UKTI Measure A04) as a result of support provided under the range of trade development schemes.

More specifically, existing PIMS evidence illustrates that companies increase R&D as a result of UKTI support. Firms that have or expect to increase the amount they spend on R&D or NPD; and increase the amount of time spent on R&D or NPD, adjusted for non additionality are captured in the increased R&D measure, see chart below. Around one in ten UKTI beneficiaries (12%) report that they had increased R&D

It is clear from the survey that UKTI beneficiaries are significantly more likely to have been engaging in R&D and innovative activity. Table 4.1 illustrates some of the headline differences between UKTI beneficiaries and a control group of non-assisted firms.

Table 4.1: Innovation and R&D Activity: UKTI Beneficiaries and Non-Beneficiaries

	UKTI beneficiary (%)	**Non-beneficiary (%)**
Introduced new products or services in last 3 years?	77	57
Does your firm conduct any in-house new product or service development activity?	75	54
Does your firm conduct any in-house R&D activity?	58	33
Does your firm in the UK hold any patents, trademarks, licenses..?	54	31
R&D Collaboration?	50	31
More than 75% employees with Science and Technology Degrees	15.5	4

Source: UKTI R&D Evaluation Survey (2008)

More specifically for the task in this chapter we observe that UKTI beneficiaries in our sample were no more likely than non-beneficiaries to report that they increased their expenditure on R&D in 2006-07 (45.5 and 45.7% respectively). However, UKTI beneficiaries were more likely to report a greater increase in the actual amount of R&D expenditure: £126,900 compared to £81,000.

However, these bivariate analyses do not provide the evidence to conclude that UKTI trade development support is having a positive impact on R&D expenditure in the supported firms. As outlined above we now turn to the econometric analysis to more formally isolate the effects of assistance on the R&D activity of UKTI beneficiaries.

4.4 Econometric Analysis of the Impact UKTI Support on R&D

4.4.1 The Approach

When seeking to evaluate the impact of an intervention, there are essentially two concerns. Firstly, whether there a sample selection effect, and secondly whether there is an endogeneity problem.

The sample selection effect within a study of this type can arise for two reasons. Firstly, there is the standard "theoretical" rationale, that there is the possibility that "better firms" are better at obtaining support, (or alternatively that governments 'prop up' the worst performing firms) so that any apparent link between support and performance is erroneous. This would apply most typically where one was seeking to model firm performance – through say profits, productivity. Whether it applies to the case of R&D is less clear.

However, there is then the structural consideration. In order to evaluate the impacts of a policy initiative, one would ideally, survey the whole population of potential recipients, and then determine the relationship between the policy instrument and firm performance. For obvious reasons, this is not practical, and so one constructs a stratified sample of non-recipients to match as closely as possible the recipient group, in terms of firm size, type, location, industry sector, type of ownership etc, with a view to comparing this stratified sample of non-recipients with the recipient firms.

If receipt of a policy instrument is essentially a random event, and if everyone who is surveyed replies, then a straightforward ordinary least squares (OLS) regression will suffice, and providing no other econometric problems arise, will provide an unbiased estimate of the policy effects. In practice however, these conditions seldom arise. Also, while one can seek to obtain a stratified sample of non-recipients that matches closely the recipient group, this can never be perfect as there are essentially an infinite number of firm level characteristics. We test for this using the well known Heckman model. However, in practice the sample selection effects are not apparent. We also present the standard OLS results.

The procedure is explained in detail in the Appendix C to this chapter which sets out the detailed econometric methodology, but we begin by estimating a model to relate the probability of a firm receiving UKTI support for trade development to a set of firm level characteristics. The structure and notation of the equation is explained in detail in equations (4.1 to 4.4) in Appendix C.

4.4.2 Probability of a Firm Receiving UKTI Support

The results from this estimation are provided in Appendix B, Table B4.1. Detailed interpretation of the results of this procedure is provided in the second part of the Methodological Appendix. The variables that, *ex ante,* are assumed to be correlated with the probability of receiving UKTI support, but uncorrelated with R&D growth, are the existence of a formal business plan, the legal form of company ownership (i.e., in the form of partnerships) and the existence of other forms of support, in this case

Knowledge Transfer Partnerships (KTPs). Taking these variables first, the results show that having a formal business plan increases the probability of receiving UKTI support by 17 per cent. This is not say that UKTI deliberately select firms who have a formal business plan, simply that such firms are better placed to access support. This is consistent with recent evaluation studies of Business Link and Regional Selective Assistance (RSA) in Great Britain and Selective Financial Assistance (SFA) in Northern Ireland (see, for example, Mole *et al.*, 2006 or Hart *et al.*, 2007). Engaging in the UK Knowledge Transfer Partnerships (KTP) scheme increases the likelihood of receiving UKTI support by 50 per cent compared with firms who do not. This is an indicator perhaps of firms that are willing to engage with publicly funded schemes are more likely to engage with other forms of support. Finally, firms legally established as partnerships are nearly 15 per cent more likely to receive UKTI support than other types of firms, even allowing for firm size.

Moving on to the wider set of variables, it is interesting to note that R&D at the start of the period is uncorrelated with the probability of receiving support. This is indicative of the fact that the UKTI schemes do not target R&D intensive firms *per se*, but are designed to boost innovative activity through exposure to international markets.

In general, however, these results should confirm that the UKTI schemes are reaching an important section of the economy. Firms who engage in R&D directly related to sales are more likely to obtain support, while the results show a 4 per cent (albeit only marginally significant) difference in the probability of support for firms who focus R&D on product rather than process. It is clear that firms run by highly qualified people are more likely to obtain support, and foreign owned firms are 28 per cent more likely than domestic firms to receive support. Firms that have high export intensity are also more likely to receive support.

Firms with highly skilled managers are 24 per cent more likely to receive support than other firms, with start up firms (firms less than a year old) 38 per cent less likely to receive support. In addition, it turns out that the firm having existing formal Intellectual Property Rights (IPR) is uncorrelated with future R&D spend, but is correlated with UKTI support. This is not necessarily at odds with Rogers and Helmers (2008) who relate IPR to R&D spending in the context of the Passport to Export scheme. IPR in the form of patents (as opposed to trademarks or copyright) is typically related to R&D in the past, not in the future. Equally, as Rogers and Helmers (2008) show in their analysis of the FAME data, firms with IPR are disproportionately distributed in the low growth category of firms.

In all of the models presented in this section, there are a full set of industry and regional dummies. For brevity, they are not included in Table B4.1, which summarises the key results, but are included in Appendix B (Table B4.4) to this Chapter, for the probit, the baseline Heckman and the OLS model.

4.4.3 Modelling R&D

R&D is of interest because it captures the innovation capacity of the economy. R&D spend, however, in a given year is generally treated as a flow rather than a stock. As such, to measure the change in R&D between years would be to measure the acceleration in innovatory capacity, rather than the change. However, R&D spend varies a good deal at the firm level. It is unreasonable to assume that a small scheme can change the total R&D spend by a firm, so we model the change from one year to the next.

The R&D models were derived based on what information was available from the survey, though as the survey was designed to capture the incentives for firms to engage in R&D. The equations are provided in detail in equations (4.11 to 4.13) in Appendix C. Variables are used to capture variation in firms' abilities to both generate and appropriate knowledge, types of firms, and experience in exporting and innovation. This is then estimated by ordinary least squares (OLS).

Table B4.2 presents the baseline model, and compares the results from the Heckman estimation (Model 1 including the inverse Mills ratio) with its OLS equivalent (Model 2). The purpose of presenting both of these is to highlight the difference in the UKTI effect, when controlling for the sample selection bias, and when not doing[9]. Equally, the sign on the inverse Mills ratio (IMR) illustrates the nature of the selection bias. A positive coefficient illustrates a positive sample selection effect – that is to say that UKTI support firms who would have increased R&D anyway. A negative coefficient implies that firms who have sought support are those who would have spent less on R&D in the subsequent period. This result then has to be interpreted along side the coefficient on the support term. In the former case, a positive coefficient on support would indicate that support and R&D growth are self enforcing, that UKTI "picks winners" and supports them. In the latter case, a positive coefficient is indicative of UKTI reversing what otherwise may have been a downward trend.

Turning to the results, the R&D growth models overall work well and explain a high proportion of the variation in R&D growth over the period. The IMR is significant in the Heckman model, but is negative, suggesting that UKTI support is given to firms who otherwise would not increase R&D compared with the unsupported sample. The results also show that if one does not take this into account, and simply does the estimation using OLS, then this will under-estimate the UKTI effect, with the coefficient on UKTI support being smaller and significant only at the 10% level. This suggests that firms who seek support are not necessarily those firms that are contemplating further growth in R&D. However support from UKTI in terms of internationalisation of these firms does boost R&D.

The results in Table B4.2 can be summarised as follows. The training, export experience and collaborative R&D variables are designed to capture absorptive capacity, while the motives for R&D, in terms of boosting sales, R&D being "science" or "design", and the objectives of the firm more generally capture the motivation of the firm to be innovative. Finally, we include variables to capture more general heterogeneity within the sample, for example, whether the firm is a single plant or a subsidiary, and its age.

[9] See equations 4.6 and 4.7 in Appendix C for a discussion and derivation of the selection term "the inverse mills ratio".

We also include the (log of) the level of R&D at the start of the period to capture differences in R&D spend in general. It should be noted here that this should not be treated as a lagged dependent variable, and in such models one typically observes a negative sign on such a term, firms with higher levels of activity by definition typically grow more slowly in percentage terms.

The models behave very much as expected, with variables related to absorptive capacity and motivation significant and positive. Other significant findings from the analysis are as follows (Table B4.2):

- Single plant firms and firms that are subsidiaries of other firms do less R&D.
- Firms with training have more R&D growth
- Seeking to grow is associated with R&D growth
- While full sets of industry and regional dummies were included, only Scotland (negative) and south west of England (only significant at 15% level) even approach significance. There is, therefore, only a very small difference across regions with respect to R&D growth, allowing for all the firm level effects.

4.4.4 Further Examination of the Impact of the 'Totality' of UKTI support

The baseline result presented above shows that UKTI support is associated with R&D growth. The range of UKTI schemes that are considered here vary considerably in focus, in lightness of touch, and also in their intended impact. However, this says nothing about the intensity, the type, or the timing of that support.

Also, we know that the UKTI beneficiaries in the sample (drawn from PIMS Waves 6-9) have been included as they have received assistance under one particular Scheme (see Section 4.2 above). We know that they may have had other forms of UKTI support prior to the assistance they received or indeed in parallel to the support they received to be included in Waves 6-9 of PIMS

We, therefore, sought to determine the relative effects of the various schemes. This section, therefore, seeks to address this by incorporating into the survey database some measure of the 'totality' of assistance. This, however, proved problematic for a number of reasons. Firstly, it is not clear from the data UKTI provided that all the participations are covered, it was clear for example that some firms were included in the survey as representative of a particular scheme, for example "Passport to Export", but this was not flagged on the main PIMS database. To, therefore, seek to capture a large range of schemes with individual dummies would lead to significant bias in the results. Secondly, there is a large amount of overlap in participation – some firms have over 10 such entries. To model these properly with dummies one would have to assume that these are independent events, which again is perhaps unlikely. We, therefore, focus on support, and different measures of intensity, rather than seeking to determine the relative impact of a given scheme over another.

What we seek to determine are the following questions.

1. Does repeated support have an additional effect over and above that already identified?

2. Does support in earlier time periods have a similar effect (based on PIMS 2-5 for example)?

3. Is there a threshold level of support above which the impact increases or diminishes?

The results are reported in Table B4.3. The first model (Model 3) focuses on those firms who are shown as having received support in the previous period (identified from PIMS 2-5). We include an additional variable for this (PREVIOUS), in addition to the variable that captures support in PIMS 6-9. The second model (Model 4) focuses on those firms who received only one intervention of support, and compares these firms with the unsupported firms (to prevent bias those firms who received multiple support were removed from this sample). Finally, we seek to estimate a threshold model (Model 5), seeking to identify thresholds above or below which the number of UKTI supports has a differential effect[10]. The final set of variables are derived from the threshold analysis, the number of supports within the ranges less than 6 interventions, between 6 and 9, and more than 9. These approaches all involve augmenting the baseline regression and the results are presented in Appendix B (Table B4.3).

Model 3 that includes the term PREVIOUS, for where the firm had additional support in an earlier period (captured from PIMS waves 2-5) is particularly informative. Even for firms who have received support in the previous period, additional support still generated further returns in the form of R&D increases. The support variable is still significant at the 5% level, though the coefficient declines from 0.517 to 0.455, suggesting that the impact on support in a given period is less if the firm also received support in the previous period.

No additional effect from earlier support can be determined, suggesting that the incidence of support in the previous period is not related to R&D growth in the future. This suggests that in order to maintain the R&D growth effect continuing support is required, the cumulative effects of the impacts of UKTI support on R&D growth is relatively short lived, at least for those firms where we have information. This is not surprising for a phenomenon such as R&D, where continuing spend is required in order to retain a competitive advantage.

Model 4 focuses on a completely different subset of firms, those who only received one support from UKTI. These firms are compared only with the unsupported firms. This allows the identification of the first incidence of UKTI support under these schemes. The coefficient is much smaller (0.127) but significant at the 5% level,

[10] The threshold model, where the cut off points are determined from the data is a rather involved procedure, best described in Girma (2005). This essentially involves estimating the model using a grid search to derive the break points, determining whether these break points are significant, then re-estimating the model to bootstrap the standard errors. The interpretation of the results however is straightforward.

suggesting that the initial incidence of support, even where there is no repeat does have an impact on R&D.

Finally, we present the results of a threshold model (Model 5). This involves determining the break points, the range of the threshold, and then estimating the model with the number of supports below, within and above the range. This shows an increasing tendency for support to stimulate R&D growth, and essentially identifies a range over which the number of interventions is most significant. Increasing the number of interventions within the mid-range will increase R&D, but beyond that the effect is less certain. This shows that increasing the number of interventions from say 1 to 6 will increase R&D, but that then the effect is greater as one increases from 6 to 9, after that, no more effect can be determined. This suggests that from the point of view of maximising R&D spend repeat users are to be encouraged, but that once the number of supports in a relatively short period reaches 10, no additional effect can be identified.

4.4.5 Does UKTI support have regional differences?

This builds on a question from UKTI - "we would like to know where we make a difference". This model then augments the original model, but replaces the support term, with support across different industries and regions (i.e., interacting the support dummy with the sectoral / regional dummies. This of course does not test whether UKTI has a significant effect on a particular region, but whether the effect of UKTI support on firms in a particular region is different from that in other regions (see Table B4.4). It is apparent from these results that the differences in the regional effects are minimal. Equally, support for the (one) utility company in the sample is the only significant positive effect. Again, this does not say that UKTI support has no effect, but that there are no differences in that effect across sectors.

4.4 UKTI's impact on R&D.

The calculation to estimate the impact of UKTI support for internationalisation activity and exports on R&D is set out in detail in Appendix C (section 8). The mean value for the change in R&D from the surveyed firms is £126,900[11], which implies that the impact of UKTI support on R&D is **£65,654** per firm. To put this in context, average R&D spend for the sample of firms is £416,500 (again ignoring the same outlier) so based on this calculation UKTI support accounts for **15 per cent of total R&D expenditure.** We set out various alternative approaches to deriving such an estimate in the appendix below. The preferred method is standard in project evaluation, and is also least sensitive to outliers. As we outline in the appendix, other measures may under-state the UKTI effect on R&D if the sample of non-beneficiary firms are above average in terms of R&D growth. Nevertheless, the alternative

[11] This excludes an outlier, which is the largest firm in the sample where R&D fell from £150m to £100m

measures do provide a range of estimates that are broadly consistent. This is the preferred estimate of the UKTI impact on R&D[12].

Alternative estimates are explored in Appendix C, which, for example, ignore the apparent selection effect (that firms who are contemplating reducing R&D appear to be those who use support). The estimate based on Model 2 (Table B4.2) falls very slightly. Further, given the problems with identifying the impact of a given UKTI support the estimate based on the first UKTI support for single users reduced the estimate further still. Developing this approach we also calculate the impact of the marginal intervention of support at the maximum possible impact using the threshold model discussed above – that is, the point at which incremental UKTI supports add no significant effect. This is as the number of supports moves from 9 to 10.

4.5 Summary

The bespoke impact survey of 800 UKTI beneficiaries and non-beneficiaries has revealed that UKTI supported firms report significantly higher levels of R&D activity and expenditure. The question we need to answer is the extent to which these differences are due to UKTI support for trade development activities.

The econometric analysis has shown that once we control for sample selection effects there is indeed a positive and significant impact of UKTI support on R&D expenditure. The mean value for the change in R&D from the surveyed firms is £126,900[13], which implies that the impact of UKTI support on R&D is **£65,654** per firm. To put this in context, average R&D spend for the sample of firms is £416,500 (again ignoring the same outlier) so based on this calculation UKTI support accounts for **15 per cent of total R&D expenditure**.

Other significant conclusions from the analysis illustrate aspects of the role of absorptive capacity in enhancing the increase in R&D expenditure. For example,

- Single plant firms and firms that are subsidiaries of other firms do less R&D.
- Firms with training have more R&D growth
- Firms that are seeking to grow are associated with R&D growth

Finally, we observe that increasing the number of UKTI interventions to supported firms will increase R&D, but there is a diminishing effect. This suggests that from the point of view of maximising R&D spend repeat users are to be encouraged by UKTI.

---

[12] It should be pointed out that the estimates presented here are subject to a relatively high degree of error. Firstly, because of the nature of what one is seeking to measure. These calculations rely on the mean level of the change in R&D from 2006 to 2007. A high proportion of firms were unable to report R&D for 2006. If just 20 more firms had answered "the same as 2007" rather than "don't know" for their R&D for 2006, this would have brought the mean value of R&D change down by 22%, which in turn would reduce all of these estimates by 22%. If 40 firms had done this it would reduce all the figures by 37%. The reader should bear in mind that 140 firms said (don't know) to R&D in 2006 who answered the question for 2007, so it is apparent how sensitive to this these calculations are.

[13] This excludes an outlier, which is the largest firm in the sample where R&D fell from £150m to £100m

Appendices to Chapter 4

Appendix A

Table A4.1: UKTI Impact Survey – Response Rates

UKTI Beneficiaries	**UKTI Beneficiaries**	**Non-Beneficiaries**
Number of firms selected	1,015	10,776
Unusable (Not exporting)[14]	37	7,891
Unusable (Contact details incorrect)[15]	215	972
Useable sample	763	1,913
Interviews achieved	400	400
Response rate	**52%**	**21%**

[14] The 'Unusable (Not exporting)' category consists of firms that indicated that they had not conducted business overseas in the previous 2 years, and had not considered or attempted to do so within this time period.

[15] The 'Unusable (Contact details incorrect)' category consists of firms where it was not possible to conduct an interview because the telephone number was unobtainable, it was not a business, the named conact had left the firm, etc.

Appendix B: Econometric Models

Table B4.1: The Probit For Determining Likelihood of Support

Parameter	Estimate	Marginal effect	t-statistic	P value
C	-1.33501	-0.43134	-4.98135**	[.000]
Firm size (SALES)	-.011754	-0.0037976	-1.64383**	[.100]
Firm has a formal business plan	.526647	0.17016	4.82734**	[.000]
Log R&D in 2006	-.000867	-0.00028014	-.075191	[.940]
R&D focussed on generating exports	.126508	0.040875	.900974	[.368]
R&D focussed on sales	.296865	0.095916	2.00386**	[.045]
Export intensity (% of sales)	.406916E-02	0.0013147	2.31680**	[.021]
Foreign owned firm	.870753	0.28134	5.09498**	[.000]
Partnership	.454088	0.14671	2.10627**	[.035]
Firm < 1 year old	-1.17379	-0.37925	-2.74080**	[.006]
Firm 1-2 years old	-.486108	-0.15706	-1.67278**	[.094]
Firm 2-3 years	.351133	0.11345	1.47937*	[.139]
Exports to a foreign agent	.160968	0.052008	1.53662*	[.124]
5-10 years R&D experience	.227765	0.073590	1.23484	[.217]
10-20 years R&D experience	.270484	0.087393	1.43251	[.152]
R&D focussed on products	.195766	0.063252	1.42956	[.153]
R&D focussed on process	-.180554	-0.058337	-1.22848	[.219]
Firm has KTPs	1.57310	0.50826	2.79976**	[.005]
75% or more of senior management have degrees	.739117	0.23881	3.94724**	[.000]
Firm has some form of formal IPR	.342518	0.11067	3.29446**	[.001]
Industry and regional dummies	yes			
	Number of observations = 318 Scaled R-squared = .325123 Number of positive obs. = 174 LR (zero slopes) = 273.899 [.000] Sum of squared residuals = 142.312 Log likelihood = -417.568 Fraction of Correct Predictions = 0.726250			

Table B4.2: Modelling R&D spend

	Model 1 – Heckman Δ Log R&D		**Model 2 – OLS Δ Log R&D**	
Variable	Coefficient	t-statistic	Coefficient	t-statistic
C	5.83070	7.35076**	6.34944	8.35553**
UKTI SUPPORT	0.51745	2.26967**	.427511	1.67900*
Selection term (inverse MILLs ratio)	-1.05222	-2.09254**		
Log of R&D at the start of the period	-.919426	-9.5260**	-.912651	-9.2354**
R&D spend to boost sales	1.28188	2.48523**	1.53517	3.03589**
Age 1-2 years	-1.13506	-1.41978	-1.34107	-1.67602*
Export to an agent	-.854702	-2.82715**	-.808678	-2.65931**
Firm is a single plant firm	-.793972	-2.27103**	-.794426	-2.25309**
Firm is a subsidiary	-1.00825	-1.82247*	-1.16410	-2.10552**
R&D is "SCIENCE"	1.48718	4.37212**	1.62771	4.84000**
R&D is "DESIGN"	.736043	2.45613**	.778776	2.58273**
Cooperative R&D with customers	.979303	2.48221**	.942580	2.37125**
Main objective is to grow	1.34888	3.64397**	1.47999	4.02234**
Job entry training	1.24582	3.46398**	1.24510	3.43266**
Regular external off site training	1.73131	2.91541**	1.72299	2.87690**
75% or more of senior management have degrees	1.21763	3.12409**	1.14708	2.92914**
Scotland dummy	-.19530	-2.94447**	-.14561	-2.85491**
South West dummy	.681435	1.54225*	.636001	1.42896
utility firm	.49304	2.92269**	.42674	2.85579**
Industry and regional dummies	yes		yes	
	R-squared = .880331 Adjusted R-squared = .869341 Std. error of regression = 2.06460 F (zero slopes) = 80.1031 [.000] Sum of squared residuals = 835.466 F (zero slopes) = 80.1031 [.000]		R-squared = .877658 Adjusted R-squared = .867100 Sum of squared residuals = 854.131 variance of r Std. error of regression = 2.08223 F (zero slopes) = 83.1317 [.000]	

Note: Only 2 regional dummies were included as they are the only two that were significant

Table B4.3: Modelling the Effects of the Intensity of UKTI Support

	Model 3 – previous support		**Model 4– one support only**		**Model 5 – threshold model**	
Variable	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
C	6.23839	8.33328**	6.21228	8.39775**	-0.268851	-0.493433
SUPPORT	0.45521	1.88941*			0.544226	0.650745
Previous	0.383665	1.00093				
One support only			0.127882	2.02857**		
supports<6					0.276332	1.77565*
6<supports<10					0.413445	2.11921**
SUPP>9					0.085366	0.842716
Mills ratio	-0.563496	-2.54776**	-0.610648	-2.52149**	-0.746374	-1.47259*
Previous R&D	-0.919937	-9.7269**	-0.917214	-10.5472**	-0.614343	-10.2441**
R&D focussed on sales	1.44787	2.87358**	1.44758	2.90100**	1.74813	4.66055**
1<age <2	-1.23665	-1.55106*	-1.21067	-1.52379*	1.24817	1.57219*
Exports to a foreign agent	-0.801581	-2.61921**	-0.783087	-2.56376**	-0.221357	-0.769066
Single site firm	-0.825421	-2.33925**	-0.8548	-2.43902**	0.304498	0.921071
Firms is subsidiary	-1.07842	-1.94027*	-1.07931	-1.96415*	-0.737108	-1.52766*
R&D is "science"	1.52205	4.49255**	1.52598	4.52586**	2.39349	6.17310**
R&D is "design"	0.73119	2.41128**	0.708229	2.32930**	0.525118	1.3704
R&D done in collaboration with research unit	0.934698	2.34754**	0.930866	2.34912**	-0.240091	-0.485629
Main objective to grow	1.39773	3.79109**	1.37431	3.72125**	0.10738	0.332099
Basic on the job training	1.17424	3.15017**	1.17577	3.20684**	-0.149233	-0.430981
Advanced off site training	1.62276	2.68285**	1.63015	2.70788**	-0.376484	-0.76888
More than 20 years export experience	1.17267	2.99880**	1.16598	3.00956**	0.355985	1.01272
Scotland dummy	-2.16936	-2.86189**	-2.24264	-2.97313**	-0.613629	-0.770083
SW England dummy	0.686131	1.53492*	0.63995	1.44384	0.14061	0.32426
Utility dummy	4.09279	2.49998**	4.05851	2.56767**	-0.159646	-0.132912
Adj. R-sq	0.867		0.869		0.898	

Table B4.4: The industry and regional dummies for the baseline models

	PROBIT (support)		Heckman		OLS	
	Marginal effect	**T stat**	**coefficient**	**T stat**	**coefficient**	**T stat**
EE	0.0013894	.024756	.328177	.543298	.704822	1.35823
EM	0.082600	1.36595	.269957	.424892	1.13159	1.93905*
LON	0.059502	1.03780	-.152549	-.235393	1.21591	2.26265**
NE	0.14968	1.81619*	.587753	.701117	-.158043	-.208561
NI	2.63448	.645620E-05	-.926688	-.418809	-2.12963	-1.38775
NW	0.076593	1.30336	-.017258	-.026917	.894569	1.61651*
SCOT	2.52599	.107869E-04	.681435	1.54225*	.636001	1.42896
SW	0.092797	1.65132*	.793214	1.31748	.762345	1.43942
WALES	0.36237	1.84885*	.723140	.421675	.293571	.205341
WM	0.046465	.817146	.120076	.176441	.024312	.045151
YH	0.13536	2.19499**	.080315	.137906	1.67617	2.95830**
AGRIC	2.53728	.521927E-05	-.141779	-.089885	.955577	.582765
FISHING						
MINING						
UTILITY	0.12414	.952839	.49304	2.92269**	.42674	2.85579**
CONSTRUCT	0.13224	.808911	.089437	.073644	.759585E-02	.533185E-02
WHOLES	-0.0079881	-.187745	-1.07136	-2.07833**	-.582771	-1.45243*
HOTEL	2.26818	.253869E-05	0.	0.	-2.14921	-.775026
TRANSPT	-0.15772	-1.70503*	.246441	.242837	-.299925	-.411154
FIN_INT	-0.19554	-1.00644	1.61905	.967280	.915969	.559585
REAL_EST	0.069125	1.76598*	.392215	.983896	-.697784	-1.96347**
PUBADMIN						
EDU	0.31098	2.50991**	-2.11036	-2.09302**	-.549857	-.529521
HEALTH	2.39589	.417381E-05	.603411	.376182	.835742	.422752

Appendix C: Detailed Econometric Methodology

1. Testing for sample selection effects

The essential problem here is to determine whether there is any structural explanation of which firms receive support. This is examined using a probit model (0/1) for support by UKTI. This, therefore, employs a probit model. The fundamental principle of this class of models is that there exists a latent variable y_i^* that can be specified in terms of:

$y_i^* = \beta x_i + e_i$ ….. (4.1)

where e and x are independent. However, y_i^* in this case (i.e., the probability of a firm receiving support) cannot be observed. Rather what is observed is simply whether the firm received support or not. Formally this can be expressed as:

$$y_i = \begin{cases} 1 & if \quad y_i^* > 0 \quad \text{.................(4.2)} \\ 0 & if \quad y_i^* < 0 \quad \text{.................(4.3)} \end{cases}$$

It is then to show that $p(y_i = 1 \mid x_i) = p(y_i^* > 0 \mid x_i) = p(\beta x_i + e_i > 0 \mid x_i)$
In other words that the actual value of the latent variable is positive, given x, is equal to the probability that the observed value (the 0/1) is equal to 1.

The final equation that is estimated then becomes:
$y_i = \beta x_i + \gamma z_i + e_i$ ……. (4.4)

The vector of x terms are the variables that are correlated with the probability of a firm receiving support, while the z terms are those variables (there must be at least 1) that are correlated with the probability of receiving support, but uncorrelated with the likelihood of increasing the spend on R&D. The full set of variables used in the regression are given in Table B4.1. The terms than enter the z vector are the existence of a formal business plan, and the use of knowledge transfer partnerships. These variables are uncorrelated with R&D increase, but are related to the probability of support.

2. Interpreting the output from a probit regression.

The regression output from a probit produces two sets of output. The first is the estimates of the equation (4.4) – the coefficients from the model β and γ such that:
$\hat{y}_i = \hat{\beta} x_i + \hat{\gamma} z_i$ ……. (4.5)
These show how the terms in the regression relate to the predicted probability. In addition however, the model also provides estimates of the marginal effects. In binary regression models such as the probit, the marginal effect is the slope of the probability curve relating x to p(y=1|x), holding all other variables constant. Suppose

for example that one estimates (4.4) and obtains an estimate of b for a given variable of 0.5, with a standard error of 0.1. This would yield the information that the variable is related to the probability of obtaining support, and that the t value was 5, such that the coefficient was significantly different from zero. However, this coefficient would not tell the investigator the extent to which, holding all other variables constant, an increase in this particular variable would increase the probability of obtaining support. For example, in Table 4.2, focussing on the "formal business plan" variable, the estimated coefficient and respective t value indicate that the variable is positively related to the probability of support, and that this coefficient is "significant". The marginal effect of 0.17 however indicates that, ceteris paribus, forms with a formal business plan are 17 per cent more likely to receive support than those without.

Finally, the probit model generates a further variable referred to as the inverse mills ratio. The inverse Mills ratio, named after John P. Mills, is the ratio of the probability density function over the cumulative distribution function of a distribution. Use of the inverse Mills ratio is often motivated by the following property of the truncated normal distribution. If x is a random variable distributed normally with mean μ and variance σ^2, then it is possible to show that:

$$E(x \mid x > \alpha) = \mu + \sigma\left[\frac{\varphi((\alpha-\mu)/\sigma)}{1-\Phi((\alpha-\mu)/\sigma)}\right] \quad \text{….. (4.6)}$$

and

$$E(x \mid x < \alpha) = \mu + \sigma\left[\frac{-\varphi((\alpha-\mu)/\sigma)}{1-\Phi((\alpha-\mu)/\sigma)}\right] \quad \text{…. (4.7)}$$

where α is a constant, $\varphi(\cdot)$ denotes the standard normal density function, and $\Phi(\cdot)$ denotes the standard normal cumulative distribution function. The terms in brackets are inverse Mills ratios.

A common application of the inverse Mills ratio (sometimes also called 'selection hazard') arises in regression analysis to take account of a possible selection bias. If a dependent variable is censored (i.e., not for all observations a positive outcome is observed) it causes a concentration of observations at zero values. This problem was first acknowledged by Tobin (1958), who showed that if this is not taken into consideration in the estimation procedure, an ordinary least squares estimation (OLS) will produce biased parameter estimates. With censored dependent variables there is a violation of the Gauss–Markov assumption of zero correlation between independent variables and the error term. Heckman (1976) proposed a two-stage estimation procedure using the inverse Mills' ratio to take account of the selection bias. The estimated parameters are used to calculate the inverse Mills ratio, which is then included as an additional explanatory variable in the OLS estimation. This is discussed in more detail below.

3. Testing for selection bias

In order to evaluate the impacts of a policy initiative, one would ideally, survey the whole population of potential recipients, and then determine the relationship between the policy instrument and firm performance. For obvious reasons, this is not practical, and so one constructs a stratified sample of non-recipients, to match as closely as possible the recipient group, in terms of firm size, type, location, industry sector, type of ownership etc, with a view to comparing this stratified sample of non-recipients with the recipient firms.

If receipt of a policy instrument is essentially a random event, and if everyone who is surveyed replies, then a straightforward ordinary least squares (OLS) regression will suffice, and providing no other econometric problems arise, will provide an unbiased estimate of the policy effects. In practice, however, these conditions seldom arise. Also, while one can seek to obtain a stratified sample of non-recipients that matches closely the recipient group, this can never be perfect as there are essentially an infinite number of firm level characteristics.

4. Testing for endogeneity.

The standard approach to testing for endogeneity is the Hausman test (updated to the Durbin-Wu-Hausman test). This involves the following:

Consider a regression

$$y = \beta_0 + \beta_1 * \mathbf{z} + \beta_2 * x_3 + e_1 \qquad (4.8)$$

where z is endogenous. Suppose that x1 and x2 are instrumental variables for z. One should decide whether it is necessary to use an instrumental variable, i.e., whether a set of estimates obtained by least squares is consistent or not.

An augmented regression test can easily be formed by including the residuals of each endogenous right-hand side variable, as a function of all exogenous variables, in a regression of the original model. We would first perform a regression

$$\mathbf{z} = \gamma_0 + \gamma_1 * x1 + \gamma_2 * x2 + \gamma_3 * x3 + u \qquad (4.9)$$

to get residuals **z_res**, then perform an augmented regression:

$$y = \delta_0 + \delta_1 * z + \delta_2 * x3 + \delta_3 * \mathbf{z\_res} + \varepsilon \qquad (4.10)$$

If δ_3 is significantly different from zero, then OLS is not consistent.

In this context, the potentially endogenous variable is whether the firm received UKTI assistance (**SUPPORT**). This means that formally the equation (a3) must be estimated as a probit, for reasons discussed above. One can rely on the t test of the estimate of δ_3

in such circumstances, although the 'variable addition' likelihood ratio test is potentially more stringent.

5. The identification problem and finding a suitable instrument

In all of the cases discussed above, the essential problem remains. That the two equations are separately identified, that is, that there is at least one variable that impacts on stage 1 but not on stage 2, and vice versa. The existence of such variables is notoriously problematic in policy evaluation as one is seeking a factor that impacts on whether the policy is "turned on", but not subsequently on firm performance. Equally, these factors will vary across the sub-samples, being different for multi-plant firms compared with small single plant domestic firms.

The selection of these variables is as follows:

1. Formal business plan – this is typically linked to the ability to obtain funding but independent of performance.

2. What firms were seeking to do R&D for – in terms of sales, innovation, exports etc. These appear correlated with UKTI support, but uncorrelated with R&D spend.

6. Econometric Approach – Allowing for Selectivity in support

Our focus here is the impact of support provided during 2007 on R&D between the 2007 and 2008 business years. If π is any potential indicator of R&D, a basic model that encapsulates these effects can be defined as follows:

$$\pi = \beta x \quad + \quad \delta z \quad + \varepsilon \qquad (4.11)$$

Where: x is a vector of firm characteristics, and z is a binary variable taking value 1 if a firm received UKTI support, and 0 otherwise. In this model, the size, sign and significance of the coefficient on the 'treatment' term (i.e., δ) will give an indication of the impact of support on R&D. Other studies have shown, however, that such treatment coefficients will give an unbiased indication of the real effect of assistance only if assistance is randomly distributed across the population of small firms. Where there is any element of systematic targeting or selection, the coefficient on the treatment term will reflect a combination of 'assistance' and 'selection' effects.

Rather than direct estimation of equation (1) a preferable approach is therefore to allow explicitly for this type of selection bias. Specifically, we assume that the likelihood or probability of receiving support (z^*) is itself related to a set of business and owner-manager characteristics, v. This suggests a model of the form (Greene, 1995, p. 642):

$$\pi = \beta' x \quad + \quad \delta' z \quad + \varepsilon$$
$$z^* = \gamma' v + w \qquad (4.12)$$

What is observed, however, is not the probability of receiving support (z_i*) but a categorical variable which indicates whether a firm received support or not during 2007. In this situation the standard estimation method for this type of model is the two-stage procedure outlined in Heckman (1979). This involves the estimation of a Probit model to estimate the probability of a firm receiving support and the incorporation of a selection parameter in the treatment model for business performance (see Greene, 1995, p. 639 for details). In these terms, a positive (negative) and significant coefficient on the Mills ratio is indicative of a positive (negative) sample selection problem, support being skewed towards high (low) performance firms.

An important issue in operationalising the Heckman type model is the avoidance of too much overlap between the selection and performance models. In the probit models we therefore focus on external characteristics of the firm which may have been visible ex ante, and which may have provided the basis for administrative criteria for the targeting of assistance. In the growth models, wherever possible, we include more organisational factors which may initially have been unobservable but which may nonetheless have contributed to performance.

The approach here, and indeed with all of the models presented below is a general to specific one, allowing for differences in sector for example. A set of variables that are theoretically linked to the dependent variables were tried, with insignificant ones discarded until one derives the final robust model. In all cases the standard errors are robust to heteroskedasticity.

7. The R&D models

The second stage in the estimation is then to specify an equation for the change in R&D spend by the firm. This seeks to explain the change in R&D spend (in logs) over the period.

$$\Delta R_i = \phi + \omega S_i + \delta Z_i + \lambda M_i + \varepsilon_i \qquad \text{.... (4.13)}$$

Where S is the dummy variable for UKTI support, Z is the vector of other terms that impact on R&D growth, and M is the inverse Mills ratio (i.e., the selection term).

8. Calculation of the UKTI impact of UKTI on R&D.

In order to generate a calculation for the amount of additional R&D that UKTI's support has generated, one has to bear in mind several caveats. Firstly, many firms have received multiple supports, so seeking to identify the outcome of a particular intervention. This means it is impossible to determine whether the first intervention is the crucial one (where the coefficient is much smaller) or a subsequent one.

The basic approach, which ignores the issue of multiple use of UKTI schemes, simply takes the coefficient from the UKTI support term in the Heckman model (Model 1 in

Table B4.3) and treats this as an elasticity[16].One can then work out the marginal effect of support for the mean firm:

From the estimation of equation (4.8) the value of $\hat{\omega}$ is treated as the elasticity of R&D growth with respect to support:

$$\frac{d \log \Delta R}{d \log S} = \hat{\omega} = 0.51745$$

One can then calculate the impact of UKTI on the mean firm, setting the mean level of R&D growth to the average from the sample (£126,900). For these purposes, where we have a firm that is either supported or not, the support variable is simply set to the mean value of S for the recipient firms, i.e., 1.

This can be expressed as a standard elasticity:

$$\hat{\omega} = \frac{d\Delta R}{\Delta R} \div \frac{\Delta S}{S} \qquad \text{….(4.14)}$$

And re-arranging this, gives the average effect for the average recipient firm:

$$d\Delta R = \hat{\omega}\frac{\Delta S}{S}\Delta R \qquad \text{…..(4.15)}$$

This then gives an estimate of the increase in R&D spend for the recipient firm at the mean (of R&D change). Setting ΔS and S to be 1, i.e., the change from being supported to not being supported, then this simplifies to:

$$d\Delta R = \hat{\omega}\Delta R$$

The mean value for the change in R&D from the surveyed firms is £126,900[17], which implies that the impact of UKTI support on R&D is **£65,654** per firm. To put this in context, average R&D spend for the sample of firms is £416,500 (again ignoring the same outlier) so based on this calculation UKTI support accounts for **15 per cent of R&D.**

If one ignores the apparent selection effect (that firms who are contemplating reducing R&D appear to be those who use support) this estimate falls to **£54,247,** or **13 per cent of R&D** of the supported firms.

It is also instructive to do the same calculation based on Model 4 (see Table B4.4 above), which captures the impact of the first support for single users. In this case, the

---

[16] Formally, though common this is not correct, see Halvorsen and Palmquist (1980) for further discussion.

[17] This excludes an outlier, which is the largest firm in the sample where R&D fell from £150m to £100m

estimate of the impact of UKTI support on R&D falls to **£16,225** per firm, or **3.8 per cent of R&D** of the supported firms.

Finally, it is possible to calculate the impact of the marginal intervention of support at the maximum possible impact. This is derived from the threshold model, which gives the point at which incremental supports add no significant effect. This is as the number of supports moves from 9 to 10. This can be done using a similar calculation:

$$d\Delta R = \hat{\omega}\frac{\Delta S}{S}\Delta R \qquad \text{…. (4.14)}$$

where this time ΔS is set to 1, but S is set to the maximum and minimum values of the threshold range and the $\hat{\omega}$ term is the coefficient derived from the threshold model, on the coefficient on the 6-9 supports. Calculating this at the mean for all firms gives an ***incremental value*** of the impact of UKTI support of £10,493 for the 6th UKTI intervention, declining to £5,829 for the 9th UKTI intervention.

An **alternative calculation** to estimate the average UKTI effect can be derived in the following manner. This has the advantage of being easier to calculate, but on the other hand is more sensitive to the R&D spend of the non-recipients. Therefore, if the sample of non recipients is above average in R&D, then this will understate the size of the UKTI effect[18]. It is also more sensitive to outliers, for example one non recipient firm reported an increase in R&D spending of £370,000. In relatively small samples this can have a large impact on the average R&D growth of non recipients. This takes the following approach:

Log (UKTI effect) = log (R&D growth (non-recipients) +0.517) – log (R&D growth (non recipients).

The average R&D growth of non recipients was £58,750. The detailed algebra is set out below, but essentially this derives a result where the average UKTI effect on R&D expenditure is **£39,152**, or **9 per cent of R&D**.

The basic equation estimated is:

$$\Delta R_i = \phi + \omega S_i + \delta Z_i + \lambda M_i + \varepsilon_i \qquad \text{….(4.13)}$$

where R is R&D and S is the support dummy, and X is all other control variables including the IMR.

The result suggests:

$$\hat{\Delta}\log R = \hat{\alpha} + \hat{\beta}\cdot S + \hat{\chi}\cdot X \ ,$$

[18] This approach is also more sensitive to firms answering "same as this year" for R&D in the previous year, such that R&D growth for these firms becomes zero.

which means when S changes 0 to 1, the average treatment effects is $\hat{\beta}$. Put differently, we know that the change in the change of log R&D (i.e., $\Delta \log R|_{S=1} - \Delta \log R|_{S=0}$) is 0.517.

The problem is how to calculate the change of log R&D (i.e. $\log R|_{S=1} - \log R|_{S=0}$) based on this.

Since $\Delta \log R|_{S=1} - \Delta \log R|_{S=0} = 0.517 + e$ then we can expand the differences with respect to time i.e. based on the fact that $\Delta X = X_t - X_{t-1}$:

$$\Delta \log R|_{S=1} - \Delta \log R|_{S=0} = 0.517 + e \Leftrightarrow \log R_t|_{S=1} - \log R_{t-1}|_{S=1} - \log R_t|_{S=0} + \log R_{t-1}|_{S=0} = 0.517 + e$$

Since we want: $\log R_t|_{S=1} - \log R_t|_{S=0}$ we need simply to rearrange the above and have:

$$\log R_t|_{S=1} - \log R_t|_{S=0} = 0.517 + \log R_{t-1}|_{S=1} - \log R_{t-1}|_{S=0} + e$$

Therefore, by calculating from the data at the base year (t=0) the mean of $\log R|_{s=1}$ and subtract from it the mean of $\log R|_{s=0}$, and by setting the error term equal to 0 (e=0) we can add 0.517 to get the mean effect of DS at year t=1, and so on. The average of all annual differences will be an approximation of the UKTI effect. This gives an average UKTI effect of **£39,152,** or **9 per cent of R&D** of the supported firms.

Chapter 5: Conclusions

5.1 Overall Assessment

What we are able to say with a high degree of confidence is that there is clear evidence that the UKTI's standard trade development support has a positive and significant impact on R&D activity and spend. Further, there is evidence that a combination of support from UKTI under this heading enhances the level of R&D spend.

The findings of our quantitative empirical research for this evaluation reinforce conclusions of the literature review with respect to the links between trade and innovation, and policy implications:

- innovation itself is not sufficient to generate productivity improvements. Only when innovation is combined with increased export activity are productivity gains evident;

- Therefore, innovation interventions oriented towards helping firms to innovate can have even greater effects where it helps firms enter export markets or expand existing export market presence.

We conclude that trade development support is an important element in the armoury of policy instruments relating to innovation policy and specifically to the policy aim of increasing UK R&D by 2014.

References

Aw B Y, Roberts M J and Winston T (2007) 'Export market participation, investments in R&D and worker training, and the evolution of firm productivity', *The World Economy*, 30, 83-104.

Beladi H, Firoozi F and Co C (1998) 'Link between domestic R&D and inflow of FDI: a game-theoretic analysis', *Pacific Economic Review*, 13, 209-222.

Bishop, P. and Wiseman, N. (1999) External Ownership and Innovation in the United Kingdom. *Applied Economics*, 31(4), 443-450.

Bleaney M and Wakelin K (2002) 'Efficiency, innovation and exports' *Oxford Bulletin of Economics and Statistics*, 64, 3-15.

Blind, K, and A Jumgmittag. (2004) 'Foreign direct investment, imports and innovations in the service industry', *Review of Industrial Organisation* 25, 205-227.

Braunerhjelm P (1996) 'The relation between firm-specific intangibles and exports', *Economics Letters*, 53, 213-219.

Brugger E A and Stuckey B (1987) 'Regional economic structure and innovative behaviour in Switzerland', *Regional Studies*, 21, 241-254.

Buxton T, Mayes D and Murfin A (1991) 'UK trade performance and R&D' *Economics of Innovation and New Technology*, 1, 243-256.

Cantwell, J. (1995) 'The globalization of technology: what remains of the product life cycle model?' *Cambridge Journal of Economics*, 19,155-74.

Cantwell, J. and Janne, O. (1999) 'Technological globalisation and innovation centres: the role of technological leadership and location hierarchy' *Research Policy*, 28,119-44

Clerides S K, Lach S and Tybout J R (1998) 'Is learning-by-exporting important? Micro-dynamic evidence from Colombia, Mexico and Morocco', *Quarterly Journal of Economics*, 113, 903-947.

Cohen, W.M., Levinthal, D.A. (1989) 'Innovation and learning: the two faces of R&D'. *The Economic Journal*, 99, 569–596.

Driffield, N. (2001) 'The impact on domestic productivity of inward investment in the UK', *The Manchester School*, 69,103-119.

Driffield N and Love J H (2007) 'Linking FDI Motivation and Host Economy Productivity Effects: Conceptual and Empirical Analysis', *Journal of International Business Studies,* 38, 460-473

Driffield N and Love J H (2003) 'FDI, Technology sourcing and reverse spillovers' *Manchester School*, 71, 659-72.

Driffield N, Love J H and Taylor K (2009) 'Productivity and Labour Demand Effects of Inward and Outward FDI on UK Industry' *Manchester School*, 77, 171-203.

Dunning, J.H. (1988) The Eclectic Paradigm of International Production: A Restatement and Some Possible Extensions. *Journal of International Business Studies*, 19(1), 1-31.

Fosfuri, A. and Motta, M. (1999) 'Multinationals without advantages', *Scandinavian Journal of Economics*, 101, 617-30.

Geroski P and Machin S (1992) 'Do innovating firms outperform non-innovators?', *Business Strategy Review,* Summer, 79-90.

Geroski P , Machin S and Van Reenen J (1993) 'The profitability of innovating firms', *RAND Journal of Economics,* 24 198-211.

Girma, Gorg and Hanley (2007) 'R&D and exporting: A comparison of British and Irish firms', Research Paper 2007/18, GEP, University of Nottingham.

Gourlay A, Seaton J and Suppakitjarak J (2005) 'The determinants of export behaviour in UK service firms', *Service Industries Journal*, 25, 879-889.

Greenhalgh C (1990)'Innovation and trade performance in the United Kingdom', *Economic Journal*, 100, 105-118.

Greenhalgh C, Taylor P and Wilson R (1994) 'Innovation and export volumes and prices: a disaggregated study' *Oxford Economic Papers*, 46, 102-134.

Grossman, G.M. and Helpman, E. (1991a) 'Trade, Knowledge Spillovers, and Growth'. *European Economic Review*, 35, 517-526..

Grossman, G, and Helpman, E (1991b) *Innovation and Growth in the World Economy* (Cambridge, MA: MIT Press).

Harris R I D (2008) An empirical study of the respective contributions of exporting and foreign direct investment to UK R&D. Report to UKTI.

Harris, R.I.D. (1991) Technology and Regional Growth: a Case Study of Northern Ireland. *Applied Economics*, 23, 685-695.

Harris R I D and Li Q C (2009) 'Exporting, R&D, and absorptive capacity in UK establishments' *Oxford Economic Papers*, 61, 74-103.

Harris, R.I.D. and Li, Q.C. (2006a) Review of the Literature: Causal Links between Innovation and International Trade and Investment. Report to UKTI, April 2006

Harris, R.I.D. and Li, Q. C (2006b) Establishment Level Empirical Study of Links between Exporting, Innovation and Productivity – CIS 4. Report to UKTI.

Harris, R.I.D and Li, Q.C. (2005) Establishment Level Empirical Study of Links between Exporting, Innovation and Productivity. Report to UKTI, December 2005.

Harris R I D and Trainor M (1995) 'Innovations and R&D in Northern Ireland manufacturing: a Schumpeterian approach', *Regional Studies*, 29, 593-604.

Hobday, M. (1995) East Asian latecomer firms: Learning the technology of electronics. *World Development*, 23(7), 1171-1193.

Howells J (1984) 'The location of research and development: some observations and evidence from Britain', *Regional Studies,* 18, 13-29.

Kleinknecht A (1987) 'Measuring R&D in Small Firms: How Much are we Missing?', *Journal of Industrial Economics*, 36, 253-256.

Kobrin S J (1991) 'An empirical analysis of the determinants of global integration', *Strategic Management Journal*, 12, 17-37.

Lachenmaier S and Wößmann L (2006) 'Does innovation cause exports? Evidence from exogenous innovation impulses and obstacles using German micro data', *Oxford Economic papers*, 58, 317-350.

Lefebvre, E. and Lefebvre, L. (2001) Innovative Capabilities as Determinants of Export Behaviour and Performance: A Longitudinal Study of Manufacturing SMEs. In: Kleinknecht, A. and Mohnen, P.(eds.) *Innovation and Firm Performance, Econometric Exploration of Survey data*, London: Palgrave.

Lefebvre, E., Lefebvre, L.A., and Bourgault, M. (1998) R&D-Related Capabilities as Determinants of Export Performance. *Small Business Economics*, 10(4), 365-377.

Liu X and Zou H (2008) 'The impact of greenfield FDI and mergers and acquisitions on innovation in Chinese high-tech industries', *Journal of World Business*, 43, 352-364.

Love J H and Ashcroft B (1999) 'Market versus corporate structure in plant-level innovation performance', *Small Business Economics,* 13, 97-109.

Love J H, Ashcroft B and Dunlop S (1996) 'Corporate structure, ownership and the likelihood of innovation', *Applied Economics,* 28, 737-46.

Love J H and Mansury M A (2007) 'Exporting and productivity in business services:

evidence from the United States', Aston Business School Research Paper 0705, Birmingham.

Love J H and Roper S (2001) "Location and network effects on innovation success: evidence for UK, German and Irish manufacturing plants", *Research Policy*, 30, 643-661.

Love J H, Roper S and Du J (2009) 'Innovation, Ownership and Profitability', *International Journal of Industrial Organization*, 27, forthcoming.

Love J H, Roper S and Hewitt-Dundas N (2009) 'Service Innovation, Embeddedness and Business Performance: Evidence from Northern Ireland', *Regional Studies*, forthcoming.

Malecki E J (1980) 'Corporate organisation of R&D and the location of technological activities', *Regional Studies*, 14, 219-234.

Metcalfe S (1997) 'Technology Systems and Technology Policy in an Evolutionary Framework', in *Technology, Globalisation and Economic Performance*, Archibugi D and Michie J (eds), Cambridge University Press.

Nelson R R (1993) '*National Innovation Systems: A Comparative Analysis*', Oxford University Press.

OMB Research (2007) Internationalisation, growth and novel product development in young innovative businesses, Report to UKTI.

Onodera O (2008) 'Trade and investment project: a synthesis paper', OECD Trade Policy Working Papers No 72, OECD, Paris.

Pearce, R. D. (1999) 'Decentralised R&D and strategic competitiveness: globalised approaches to generation and use of technology in multinational enterprises (MNEs)' *Research Policy*, 28, 157-78

Roper S and Love J H (2002) 'Innovation and Export Performance: Evidence from UK and German Manufacturing Plants', *Research Policy*, 31, 1087-1102.

Roper, S, Love, J H and Añon Hígon, D (2006) 'The Determinants of Export Performance: Evidence for Manufacturing Plants in Ireland and Northern Ireland', *Scottish Journal of Political Economy*, 53, 586-615.

Siotis, G. (1999) 'Foreign direct investment strategies and firms' capabilities', *Journal of Economics and Management Strategy*, 8, 251-70.

Sterlacchini A (1999) 'Do innovative activities matter to small firms in non-R&D-intensive industries? An application to export performance', *Research Policy*, 28, 819-832.

Sterlacchini, A. (2001) The Determinants of Export Performance: A Firm-Level Study of Italian Manufacturing. *Review of World Economics*, 137(3), 450-472.

Veugelers R and Cassiman B (1999) 'Make and buy in innovation strategies: evidence from Belgian manufacturing firms', *Research Policy*, 28, 63-80.

Veugelers R and Vanden Houte P (1990) 'Domestic R&D in the presence of multinational enterprises' *International Journal of Industrial Organization*, 8, 1-15.

Wakelin K (1998) 'Innovation and Export Behaviour at the Firm Level', *Research Policy*, 26, 829-841.

World Bank (1993) *The East Asian Miracle* (New York: Oxford University Press).

Zhao, H. and Li, H. (1997) R&D and Export: An Empirical Analysis of Chinese Manufacturing Firms. *Journal of High Technology Management Research*, 8(1), 89-105.