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WAGE INEQUALITY AND PRODUCTIVITY GROWTH: MOTIVATING CARROTS AND CRIPPLING STICKS

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Editor's Foreword

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Wage inequality and productivity growth: motivating carrots and crippling sticks

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and

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Absract

Wage inequality is a particular focus of attention not only in public debates over the need for social regulation to support equity, but those over the implications of social regulation for productive performance. The present paper employs panel techniques to examine the comparative historical relationship between wage inequality and hourly labour productivity growth in the manufacturing sectors of nine advanced industrialised nations over the period 1970-1995. The results show that whilst greater inequality in the top half of the wage distribution is associated with greater productivity growth, greater inequality in the bottom half is associated with *lower* productivity growth. It appears that whilst wage inequality in the top half of the distribution productively motivates higher earners, wage inequality in the bottom half of the distribution is detrimental for productivity performance. The latter result is most likely attributable to the weak incentives to reorganise production where extremely low pay is feasible.

JEL classification: O40, J31.

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1. Introduction

There can be few themes more frequently recurring and more central to the advanced industrialised world than that of the relationship between the organisation of work, broadly conceived, and production and productivity. One of the startling features of advanced industrialised economies is the difference in wage dispersion between countries, as well as the marked historical shifts in dispersion that some countries have experienced over the last few decades. For example, in 1975 the ratio of the 90th to 10th percentile gross wage in the US was 3.75, rising to 5 in 1995; for Sweden the ratio was 2.2 in both 1975 and 1995. These cross-country and temporal differences might well be expected to have some impact on nations' productive performance.

Neo-liberalism suggests that although product market pressures may be productive, management must be left unshackled by social rights or joint regulation in its dealings with employees. The development of social rights and joint regulation at work is supposedly detrimental for productivity in large part because wage distributions are changed, with the subsequent distortion of incentives for both managers and workers. In contrast, advocates of social regulation often argue that its implications for wage inequality can have diverse benefits, including that of improving productivity performance.

This paper confronts this old debate with new data and new techniques, employing the established framework of productivity growth studies to explore the comparative historical relationship of wage inequality to the growth in value added per hour worked in manufacturing in 9 OECD countries over the period 1970 to 1995. The results indicate that analysing the 90th to 10th percentile – a summary measure of the entire wage distribution – is of little use in advancing this debate. Rather, variations in the wage distribution below and above the median have distinct associations with productivity growth. Moreover, the results suggest that it is not productivity performance that is driving the wage structure; rather wage structure seems to 'determine' productivity growth.

It might be thought that a focus on wage inequality as a causal influence is profoundly misguided. Although discussion of the possibility that the wage structure may influence productivity has a long pedigree, within the more recent economics literature the focus has largely been on the sense in which the wage structure is endogenous. The 'skill biased technical change' (SBTC) literature might well be taken to suggest that wage inequality is principally determined by machine embodied technical change. However, as we show here, this literature does not offer an explanation of cross-national developments in wage inequality. The current focus on SBTC exists alongside a longer standing presumption that wage dispersion can be viewed as the outcome of human capital dispersion. Yet, as we also show here, detailed recent work shows that cross-national variation in inequality in human capital plays a remarkably small role in accounting for such cross-national variation in wage inequality. There is thus no empirical basis for the view that wage inequality is an epi-phenomenon merely expressing either human capital or physical technology.

The structure of the paper is as follows. Section two considers the theoretical reasons why the extent of wage dispersion may have a casual influence on productivity. Section three outlines the literatures that discuss the determinants of wage dispersion, with a particular focus the relevance of human capital and skill biased technical change to comparative historical developments. An empirical test of any link between wage dispersion and productivity growth requires a framework for productivity growth, which is defined in section four. The fifth section discusses the empirical specification and provides an overview of the wage dispersion data. The sixth section contains the results of the main regression analysis along with an analysis of the robustness of the results. These results suggest that greater wage inequality above the median, as measured by the 90/50 ratio, is associated with higher productivity growth, whilst greater 50/10 inequality is associated with lower growth. The possible explanations for such an association are discussed in section 7. Section 8 features some concluding remarks.

2. How might wage inequality affect productivity growth?

The established theoretical literature on wage determination provides rather little guidance on the likely implications for comparative historical productivity growth of variations in wage inequality. It is far from clear what a simple notion of a perfectly competitive labour market in which factors of production are paid their marginal revenue products would lead one to expect, even with regard to the level of productivity (Hibbs and Locking, 2000). A more recent theoretical literature has firms, or more strictly managers, choosing an optimal wage structure with some regard to fairness or cohesiveness (e.g. Akerlof and Yellen, 1988, Lazear, 1989, Levine, 1992). If firms, or managers, always decide optimally, however, it appears difficult to divine any predictions on the cross-national relation between wage inequality and productivity, still less wage inequality and productivity growth. If there is any prediction at all, it appears that it is that there will be no relation.

It might simply be thought that wage inequality represents an incentive to work; an incentive for employees to accommodate themselves to the demands of their employers in the hope that they might earn more, or avoid earning substantially less. Similarly, the elementary human capital investment approach appears rather clear cut in its implications, with Becker (1964) suggesting that a compression of the wage distribution would reduce the incentives of individual employees or potential employees to invest in vocational educational and training to develop their human capital, with possibly detrimental implications for productivity growth.

The simple incentive effect on human capital accumulation, however, is not the only possible implication of wage inequality. Since compressing the wage distribution is likely to reduce the number of very low skilled jobs, this may act as a signal to workers to pursue human capital investment, or face unemployment. Thus, for example, the introduction of a minimum wage may lead to increased human capital accumulation (Agell and Lommerud, 1997, Agell, 1999). The extent of wage inequality may also affect the uncertainty faced by individuals investing in human capital, such that risk-averse individuals invest less in human capital where wage inequality is higher as they become less sure of the returns. Moreover, the economic growth literature features the notion that credit market imperfections imply difficulties for low paid individuals making investments in education and training (e.g. Aghion et al, 1999a).

It has recently been argued that the availability, and low cost of, skilled, or white collar, labour is complementary to productivity growth. Caroli and Van Reenen (2001) analyse the determinants and results of organisation changes in UK and French workplaces, finding that a higher ratio of skilled to unskilled pay (within workplaces) is negatively associated with organisational change, which, in turn, has a positive association with productivity growth. Their interpretation is that "cheap skills are beneficial to the introduction of organizational change" (p.1474), but they might equally have concluded that relatively expensive unskilled labour is beneficial. Other papers studying the relationship between workplace earnings and technology have found that workplaces with higher average earnings appear to adopt more new technology (Doms et al, 1997, Chennells and Van Reenen, 1997).

The literature on managerial slack or X-inefficiency (Liebenstein, 1966) also suggests a mechanism by which wage compression may promote productivity.[1] The basic idea is that wage distributions alter the external pressures that managers are under. The importance of managerial slack in determining productivity has been highlighted in the literature on product market competition (Nickell, 1996, Boone, 2001, Ahn, 2002). Aghion et al (1999a, b) incorporate the concept of managerial slack into endogenous growth models, creating a link between more competition and growth. In a similar way the extent of wage inequality is another factor that may constrain managers. The facility of managers to pay (relatively) low wages may reduce the pressure to introduce new technology or work practices, which would be introduced were such low pay precluded (i.e. slowing or even preventing the diffusion of 'best practice' techniques or equipment). This argument appears most relevant to wage dispersion in the lower part of the distribution.

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[1] A modern rendering of managerial slack features in principal-agent models in which agents are assumed to minimise 'effort' given remuneration. 'Effort' could be associated with reflection on the organisation of work, the implementation of new technologies, the management of change, the confrontation of employment relations issues and the like.

Relatedly, from outside the economics community and discourse, much research suggests that greater wage inequality may undermine production performance (see Streeck, 1992; Rogers and Vernon, 2002). Greater wage inequality may not only allow management a simpler route to profitability than that of nurturing productivity growth, but lead to the isolation of management. This may bring an ignorance amongst management of their workforce and its activities, and a dispiritment of lower paid employees which inhibits their commitment. A nexus of managerial complacency and workforce resignation in combination with limited employee self-assurance and a mis-direction of employee effort may result, possibly allied to illness, with detrimental implications for productivity growth.

Yet wage inequality may also be of relevance to aggregate productivity in a more straightforward sense. In the 1940s Gosta Rehn and Rudolf Meidner argued that wage solidarity – equal pay for equal work regardless of the characteristics of the firm – could raise productivity. Their basic argument was that high wages in low productivity firms (sectors) could force them to close, transferring resources to high productivity firms (sectors). Agell and Lommerud (1993) formalised this ‘structural change’ intuition within an endogenous growth model. The model has two sectors, a modern sector that drives growth via learning-by-doing and a traditional sector. They show that reducing wage dispersion may boost growth as it can increase the resources allocated to the modern sector. Implicit in the model is the idea that the learning-by-doing represents an externality not internalised by profit-seeking firms. Moene and Wallerstein (1997) provide another theoretical discussion of the role of wage dispersion by modelling its impact on firms’ profitability, the entry of new firms and capital stock. Their model assumes exogenous technical change and suggests that wage compression can raise profitability, increase the rate of new firm entry and lead to a more modern capital stock.[2]

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[2] Their model is a vintage capital model in which factor prices determine the longevity of the capital stock. Salter (1966) provides the seminal analysis. In his book he states “One of the most important ways by which public policy impinges on this process [structural change promoting increasing productivity] is through wages policies. Because wages play a major part in inducing such structural changes, it is particularly desirable that the market for labour should cut across inter-industry boundaries, thereby ensuring that comparable labour has the same price in expanding and declining industries.” (p.153 of 1969 paperback edition)

In summary, there are a number of mechanisms by which wage dispersion may influence productivity growth. Despite this, to our knowledge, there are no existing empirical studies of the relation between aggregate measures of wage dispersion and productivity growth.[3] There is, however, substantial comparative historical evidence that economic growth and income equality are positively correlated, and indeed particularly strongly amongst advanced industrialised countries (e.g. Persson and Tabellini, 1994, Benabou, 1996, Aghion et al, 1999a). Forbes (2000), however, has recently argued, on the basis of particular data and analysis, that whilst it may be the case that greater equality promotes growth in the long term, shifts towards greater equality impede growth.[4] These growth studies have a different purpose to the present paper, seeking to deal not only with the implications of income as opposed to wage inequality, but with the experiences of not only manufacturing (in which the measurement of output is very much simpler) but private and public services (mostly

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[3] There is, of course, an extensive literature on explaining productivity growth in OECD countries, focusing in particular on the roles of physical and human capital, R&D, government spending and taxation and trade (see Bassanini et al, 2001, for a recent analysis and review). There had also been some attempts to relate productivity to labour market institutions in cross-national analyses before Rogers and Vernon (2002). Nickell and Layard (1999, Table 17) show the results of simple cross-sectional regressions which explore the relationship between gauges of 'labour market institutions' and productivity growth. The measure of productivity is either GDP per person hour or total factor productivity, and the analysis spans 20 OECD nations for the years 1976-1992. They find that there is no relation of their gauge of productivity growth to union density, nor to their gauges of the coordination and coverage of collective bargaining. They find some evidence of a positive relation between productivity growth and an employment protection index and, much more weakly, lower total taxes, but this relation disappears when allowance is made for technological 'catch-up'. Nickell and Layard (1999) suggest in this context that 'unions' need not reduce productivity, but that this depends on managerial activity, the nature of industrial relations, and indeed on the character of product markets. Buchele and Christiansen (1995; 1999) have employed indices of employees' rights to conduct simple cross-sectional examinations of their relation to hourly labour productivity growth for the G7 over 1972-1988, which suggest that there is a (positive) relationship. No controls for other influences on productivity growth are made.

[4] Forbes does not present any results confined to the advanced industrialised world, and, in any event, those familiar with the seminal Luxembourg Income Study, or indeed of the generality of sources on inequality and poverty in the OECD, would be astonished by the estimates of overall income inequality she takes (Forbes, 2000, Table 2) from Deininger and Squire (1996) for these nations; these have, for example, the UK more equal than Sweden around 1990.

beyond the OECD), and often disregarding not only working hours but employment rates and demography. Moreover, in contrast to the current paper, these contributions employ summary measures of inequality, not exploring, as here, whether the inequality of the top and bottom half of the distribution may have distinct consequences.

3. Influences on wage dispersion

Evidently, wage inequality does not fall from the sky. This acknowledgement should not be taken as an indication of the inappropriateness of a focus on wage inequality, as it can hardly be argued that any variable is entirely autonomous from the larger political economy. Yet if it were the case that wage inequality were more or less exclusively determined by a single well-defined influence it might be quite reasonably argued that the focus of attention should be this influence. A consideration of the basis of comparative historical developments in wage inequality is thus of relevance here.

A human capital perspective would stress the implications of societal arrangements for schooling, training and human capital formation for wage inequality, whilst leaving aside the political economic basis of these arrangements. Estevez-Abe et al (2001) present some diagrammatic indication of an inverse cross-national comparative relationship between the extent of nations' provision of vocational educational and training (VET) and the extent of wage inequality. More specifically, it has been suggested by Nickell and Layard (1999) that inequality across educational opportunities may drive much wage inequality. Yet the detailed work of Devroye and Freeman (2000) on the results of the international adult literacy survey (IALS), demonstrates that the cross-national variation in the inequality in scores can account only for a very small proportion of the cross-national variation in the inequality in wages. It is, rather, returns to 'skill' (literacy), and variation in wage at a given 'skill' (literacy) level, which are of most importance to comparative wage inequality. The presumption that wage inequality simply, or even principally, expresses educational or human capital inequality is thus contradicted by the available evidence.

Alternatively, it might be thought that wage inequality merely expresses physical technology. The skill biased technical change (SBTC) suggests that there is a technical basis to developments in wage inequality left unaccounted for by developments in human capital (e.g. Bound and Johnson, 1992, Katz and Murphy, 1992, Katz and Autor, 1999, Brown and Campbell, 2002). Indeed, this literature might be imagined even to invalidate the current study through its general demonstration of the determination of not only wage inequality, but perhaps also productivity, by technical change. The literature thus warrants a detailed examination here.

SBTC refers to the general idea that increasing demand for the skilled has shifted the availability, terms and conditions of work further in their favour over the last 20-30 years. In a prominent recent paper, Bresnahan et al (2002, p.340) conceive SBTC as 'technical progress' which shifts demand in favour of the skilled, whilst noting that it 'tends to be something of a residual concept, whose operational meaning is "labour demand shifts with invisible causes".' Attempts to operationalise it as a causal factor in empirical work have involved the use of various proxies for technical change. Bresnahan et al's (2002) conceptualisation of SBTC as encompassing change in each of 'IT use', 'organization practices' and indeed 'products and services' seeks explicitly to greatly extend its meaning beyond some notion of physical technology or machine embodied technical change, blurring a critical issue. Caroli and Van Reenen (2001) seek to distinguish 'skill biased organisational change' from SBTC, implicitly seeking to delimit and thus retain the latter's meaning.

In empirical practice, as Bresnahan et al (2002) note, the focus has often been on information technology (IT) as a source of SBTC. More specifically, the focus has been on the presence of computing equipment, as in Krueger (1993), Autor et al (1998) and Haskel and Heden (1999). There has also, however, been some work around the commitment to investment in R&D, treating R&D intensity as an indicator of embodied technical change (e.g. Berman et al, 1994, Machin, 1996, Machin and Van Reenen, 1998). It seems clear that if SBTC is to have meaning as an explanatory concept it must refer to the inherent or intrinsic characteristics of physical technologies, or machine embodied technical change, to something outside the black box of the employment relationship; else it is a residual category so vague that it must 'explain' everything and will obscure rather than enlighten.

Critically in the current context, it should be underlined that the SBTC literature does not seek to establish any relationship between the skill bias of machine embodied technical change it posits and productivity growth. The view that there is such a relationship, even at firm or industry level within the borders of the US, let alone cross-nationally, is thus unsubstantiated. The comparative historical pattern of productivity growth which is the focus here cannot reasonably be regarded as an expression of SBTC.

Much else is left unestablished by the SBTC literature, despite the claims made in and for it. The SBTC literature is littered with suggestions that the relationship between technical change, or the implementation of new technology, and developments in wage inequality over the last 20 or 30 years is well established. As a prominent recent example, Bresnahan et al (2002) suggest that Autor et al (1998) provide a corroborative review of the evidence of this relationship. Yet whilst Autor et al (1998) do indeed claim to be addressing not only the relationship between upskilling and the implementation of new technologies (specifically, computer intensity), but also the distinct issue of the relationship between this implementation and wage differentials, their empirical focus is on accounting for shifts in the non-production, or college educated, employee share of the total wage bill. It is not clear how these data relate to wage inequality, even if this is conceived as educational wage differentials. Moreover, their discussion relates solely to the US.

The very limited published work on SBTC that does actually seek to account for wage inequality uses inter-industry or inter-firm data, particularly for the US (e.g. Brown and Campbell, 2002).[5] Yet, even here the evidence is hardly overwhelming. Card and Di Nardo (2002, 776) conclude their detailed survey of the US experience by noting that ‘the evidence linking rising wage inequality to SBTC is surprisingly weak’. Moreover, such a national focus is quite uninformative about cross-national comparative developments. It is quite conceivable that whilst technical change may be of relevance for developments in wage inequality within a particular nation, it may have little or no relevance to comparative developments, being swamped, or rendered

[5] One prominent study does make some reference to wage inequality, and indeed to experience in many nations other than the US. Berman et al (1998, Table 2) briefly present data for twelve nations on the non-production/production wage ratio. The data show marked differences in national experience but the authors do not seek to explain these via differential SBTC.

impotent, by other influences.[6] A claim for the importance of SBTC must rest on evidence of a cross-national association between developments in physical technology and wage inequality.

The seminal comparative study of the SBTC literature is Machin and Van Reenen (1998).[7] This focuses on the shift to non-production from production work in manufacturing, and on the shift in the share of wage costs accounted for by non-production employees, rather than on wage inequality per se. The absence of a comparative relation between recent trends in wage bill shares and those in wage inequality is apparent, though implicit, even in the passing reference to developments in non-production-production wage differentials in Machin and Van Reenen (1998). It is still clearer from a comparison of Machin and Van Reenen's (1998, Figure I) summary of change in non-production wage bill shares over 1973-89, with the development of 90/10 wage inequality detailed by Rueda and Pontusson (2000, Figs 1 and 2) from OECD data. The figures on 90/10 show wage inequality in the US exploding over this period, with that in the UK growing a little,, whilst those on the non-production wage bill share show substantially more growth in the UK than the US. Unfortunately, the figures on 90/10 available on the other three nations featuring in Machin and Van Reenen (1998) do not extend across 1973-89, but there is certainly no indication of a general relationship from that data available on these other nations. Machin and Van Reenan (1998) thus focus on phenomena which bear no apparent relation to wage inequality.

In summary, the evidence accumulated in the SBTC literature does not establish that there is a comparative historical relationship between machine embodied technical change and productivity growth. Perhaps more surprisingly, the literature does not even establish such a relation between machine embodied technical change and

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[6] Even those SBTC studies seeking to account for developments in the demand for skilled labour (rather than wage inequality) within national borders other than those of the US, generally find a much weaker and more unstable relation between the company or branch level R&D intensity or deployment of IT and 'upskilling' (Piva and Vivarelli, 2001).

[7] Berman et al (1998) is international in its coverage, but does not seek to account for any of the comparative variations it uncovers via differential SBTC.

developments in wage inequality. For the most part, moreover, it does not even purport to account for comparative wage inequality per se. There is thus no empirical basis for the view that comparative historical patterns of both, or either, productivity and wage inequality are traceable to skill biases in physical technology.

This is very far from saying that the organisation of work, broadly conceived, is of no relevance to wage inequality. Political economic, or institutional, factors do affect the overall wage distribution. Of particular interest, Rueda and Pontusson (2000) analyse the determinants of wage inequality for 16 advanced industrialised countries, finding in particular that higher union density, but also more centralised wage setting, higher government spending and lower female labour force participation are associated with lower wage inequality.[8] It is doubtless the case that each of these variables in turn is expressive of more fundamental political economic conditions, although it is difficult to imagine how they might be driven by purely economic factors. All this makes wage inequality a fascinating focus (see also Freeman, 1988). Yet given the relationships between wage inequality and other variables, and in particular with the political economic context and social regulation of employment, it might be thought that wage dispersion will act as a proxy for another (omitted) well defined casual factor in the econometric analysis. This suggests an interest in additional robustness tests featuring the inclusion of such possible factors.

4. Modelling productivity growth

The empirical specification for analysing productivity is derived from a standard Cobb-Douglas production function with constant returns to scale:

$$Y = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta} \qquad 0 < \alpha < 1 \quad 0 < \beta < 1, \qquad [1]$$

where Y is output, K is capital stock, H is human capital and L is (physical) labour input in hours. A is technology, in the most encompassing sense, referring not only to embodied technology but to the organisation of work. Let the rate of growth of labour-augmenting technology equal g (i.e. $A_t = A_0 e^{gt}$) and assume that the growth of

[8] Rueda and Pontusson (2000) find no robust relationship to trade, even though they focus in particular on trade with developing countries; this is perhaps unsurprising.

labour hours is equal to n (i.e. $L_t = L_0 e^{nt}$). While there are alternative specifications, equation [1] is common in economy-, sector- and firm-level studies of productivity growth and is regarded as the baseline model.

To derive the rate of growth of output per hour, we can express [1] in terms of output and capital per hour and differentiate with respect to time, yielding

$$\frac{\dot{y}}{y} = (1-\alpha-\beta)g + \alpha\frac{\dot{k}}{k} + \beta\frac{\dot{h}}{h} \ , \qquad [2]$$

where $y = Y/L$, $k=K/L$ and $h=H/L$ (the dot notation denotes a time derivative). If the necessary data are available, [2] allows direct econometric estimation of both the degree of diminishing returns to both types of capital (α, β) and the rate of technological progress, g . A functional form like [2] is used in calculations of multi- (or total) factor productivity. Equation [2] is also found in neoclassical growth regressions, based on the models of Solow (1956) and Swan (1956), and popularised for empirical work by Mankiw et al (1992).

Assuming y, k and h can be measured, the problem with estimating [2] is capturing technology growth, g. One solution is to use country-level fixed effects, but this assumes that technology growth can vary across countries but is constant over time (at least over the period spanned by the data). To the extent that technology growth varies over time, alternative explanatory variables can be investigated. Specifically, the technological catch-up literature suggests that the size of the technology gap (with the lead country) should be an important factor. Assuming the technology gap can be proxied by the log of the ratio of value added per hour (i.e. $\ln(y_{\text{leader}}/y_{\text{follower}})$), this leads to the inclusion of $\ln y_{t-1}$ as an explanatory.[9] It is clear, however, that additional

[9] Most studies only enter $\ln y_{\text{follower}}$ as an explanatory variable, allowing the $\ln y_{\text{leader}}$ to enter the constant term of the regression (or time period dummy if a panel estimator). There is, in fact, an alternative theoretical justification for including $\ln y_{t-1}$ as an explanatory. Mankiw et al (1992) assume that g (technology growth) is constant across countries and then estimate 'convergence' to steady state capital to labour ratios. Their methodology involves using the log of initial GDP per worker to control for distance from steady state in a Solow-Swan model. The technological catch-up approach considers g as varying across countries and uses the log of initial GDP per worker to proxy the technology gap (on the assumption that the greater the technology gap, ceteris paribus, the higher g and economic growth). The confusion between these approaches - both have initial log income as explanatory variables -

variables could be related to technology growth, for example, R&D intensity, the level of human capital and the nature of the labour market. As is common in the existing literature on productivity growth, the time varying data are aggregated over 5 year periods.

The arguments above suggest the general specification for estimation is:

$$\left(\frac{\dot{y}}{y}\right)_{it} = \ln y_{i,t-1} + \eta_i + f(Z) + \alpha\left(\frac{\dot{k}}{k}\right)_{it} + \beta\left(\frac{\dot{h}}{h}\right)_{it} + \varepsilon_{it} \qquad [3]$$

where ε_{it} is a standard error term, η_i is the time invariant component of country *i*'s technology growth and *Z* is a set of additional variables that capture time varying aspects of technology growth (independent of the technology gap effect).

Estimating equation [3] requires data on the previously defined variables, but also variables for *Z*. The specific focus here is whether wage dispersion is a member of *Z*. The various arguments above suggest that either the change or level of wage dispersion could be important. To see this, note that *A* in [1] can be interpreted as an efficiency parameter, hence if the level of wage dispersion (WD) affects efficiency then ΔWD will be associated with Δ*A*. If this is the case then since wage dispersion cannot increase or decrease indefinitely it can have no impact on growth in the long run.[10] Alternatively, and of greater interest in the long run, the level of WD may affect the growth of *A*. This possibility is the focus here.

Another important member of *Z*, with prior empirical support, particularly in manufacturing, is investment in R&D.[11] At the firm-level a number of review articles (Cohen, 1995, Griliches, 1995, Mohnen, 1992, Nadiri, 1993) suggest a strong link between R&D and productivity. At the sector and economy level various studies have included R&D, with the results indicating a positive role (Englander and Gurvey,

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provides a rationale for using [3]. In [3] it is clear that the significance of the coefficient on initial GDP per worker relates solely to the presence of technology catch-up (see Dowrick and Rogers, 2002).

[10] Put another way, wage inequality is likely to be I(0) while *A* is likely to be I(1).

[11] In the current context, lest there is any remaining doubt that wage inequality (and/or productivity) merely express physical technology, R&D intensity also serves as a control for any supposed SBTC. Of course, the inclusion of capital accumulation may be expected to capture embodied technical change.

1994, Park, 1995, Engelbrecht, 1997, Bassanini et al, 2001, Guellec and van Pottelsberghe, 2001). Equation [3] also suggests that the growth in human capital should also be included as an explanatory variable (this is often proxied by level of schooling in the working age population, as training or experience data are unavailable). However, some have suggested that the level of human capital may be a member of Z, or that human capital may boost technology transfer from overseas (Benhabib and Spiegel, 1994). There is a substantial debate over the importance of schooling in GDP per capita growth, with some recent evidence supporting a positive association in OECD countries (de la Fuente and Domenech, 2001).

A final explanatory variable included is the change in unemployment level. In analyses of UK productivity since 1980 there has been widespread debate about the role of major recessions on productivity levels. Specifically, authors note that the harsh recession in the early 1980s, especially in manufacturing, may have caused inefficient business to exit (raising the average level of productivity). Equally, at the firm level the least productive workers may be made redundant first, again raising average productivity (Oulton, 1995, Eltis and Higham, 1995). Moreover, one might well imagine that a threat to an establishment's or firm's survival might productively pressure those still working there. While this alone is a strong rationale for including change in unemployment, there is a further issue in the current context. Some might argue that differences in wage inequality may affect unemployment; for example a common slow down in demand may be thought likely to have less impact on unemployment in countries with relatively more wage inequality. An association between wage inequality and productivity could then be thought due to the unemployment implications. For all these reasons the change in unemployment can also be regarded as a control for short run productivity growth changes associated with recessions.

5. Empirical specification and data overview

The focus of attention here is the determination of the growth of value added per hour worked for manufacturing (derived from OECD and national sources). Economy-wide GDP per worker is avoided since it is affected by the problems of measuring service and particularly public service productivity (Pilat, 1996), and of variations in a nation's endowment of natural resources (e.g. oil). While some of these issues can in principle be tackled econometrically, it seems appropriate to focus on manufacturing where productivity measurement is both less difficult and less expressive of resource endowments. In addition, measured R&D expenditures appear to more accurately reflect innovative effort in the manufacturing sector. Multi- or total factor productivity measures are avoided since they constrain the capital coefficient (in [1]), which can be estimated directly. Value added per hour, rather than per worker, is chosen since this removes any bias due to changing hours of work.

The study spans the experience over 1970-95 of nine nations; Canada, Finland, France, UK, Japan, Norway, Sweden, USA and West Germany. These nations were selected partly on the grounds of data availability, but also to offer a range of patterns of social regulation. The data employed in estimation are for 5 year periods. In part this is to smooth out annual fluctuations in productivity growth and focus on medium term movements, and for sheer consistency with the existing literatures, but is also required as some explanatory variables are only available quinquennially. Table 1 below shows the main variables used in the analysis. The data on capital, schooling and R&D are largely self-explanatory. Note that there are no time series data solely for schooling stocks in the manufacturing sector, or for that matter for training, hence the growth in average years of schooling in population over 25 is used.

Table 1 Variables used in analysis

Variable	Definition, Source	Mean	s.d.
Growth in GDP per hour (manufacturing)	Growth rate over five year period. GDP in 1990 constant PPP US dollars. OECD (1997)	0.034	0.015
Log of initial GDP per hour, manufacturing	As above.	2.76	0.30
Growth in capital to labour ratio	Growth in ratio over five years. OECD (International Sectoral Database).	0.045	0.019
Growth in total schooling	Growth in average years of schooling in population over five years. Barro and Lee (2001).	0.013	0.012
R&D Intensity	Business R&D to value added in manufacturing, averaged over five year period. OECD (1997)	0.051	0.021
Change in unemployment	Change in ratio of unemployed to labour force from one five year period to next.	0.011	0.023
Wage inequality	Three distinct measures available based on the ratio of percentiles in gross wages (males and females) (OECD database). Each measure is an average of five year period.		
	Log of 90th to 10th percentile	1.093	0.236
	Log of 90th to 50th percentile	0.566	0.091
	Log of 50th to 10th percentile	0.527	0.166

Note: More details of the variables are in data appendix.

The data for wage dispersion use the ratios based on the 90th, 50th and 10th percentile, allowing us to investigate changes in wage distributions above and below the median, something that may be important given the conceptual issues discussed above. Figures 1 to 3 show time plots of the three wage dispersion measures over time. These confirm the fact that inter-country differences are large, and also show that there are substantial inter-temporal changes within countries, implying that panel analysis for this period has variation on which to estimate coefficients. Rowthorn (1992) stresses the relation between the various gauges of comparative wage inequality available for manufacturing and the entire economy.

Figure 1 Time series plot of 90/10 wage inequality

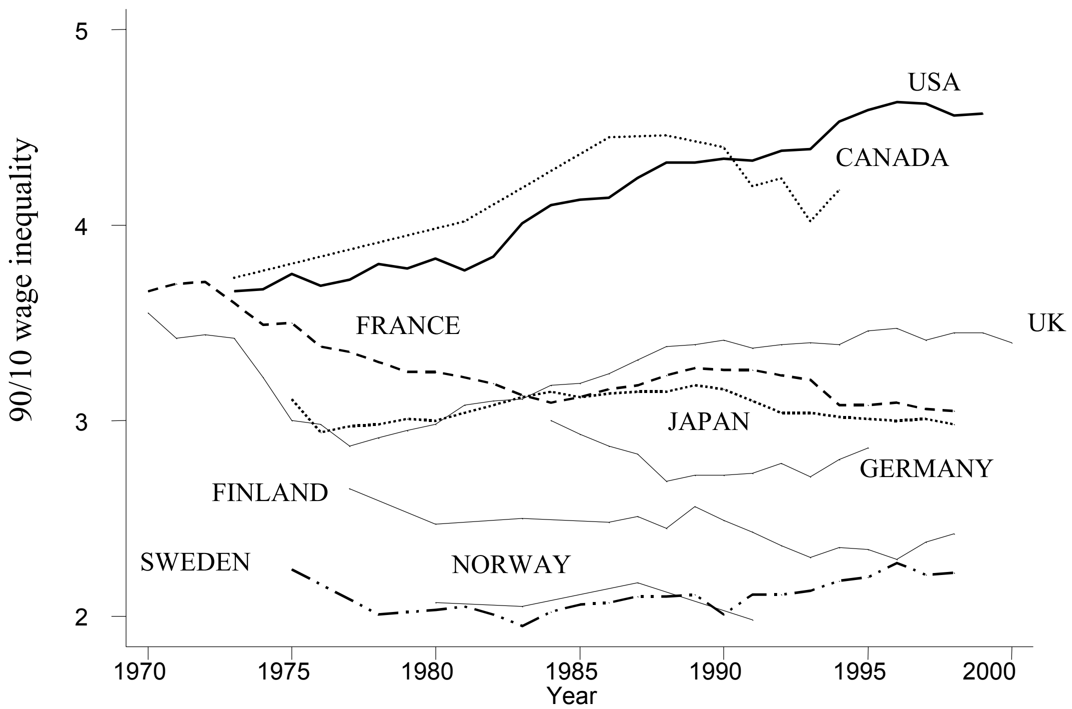


Figure 2 Time series plot of 90/50 wage inequality

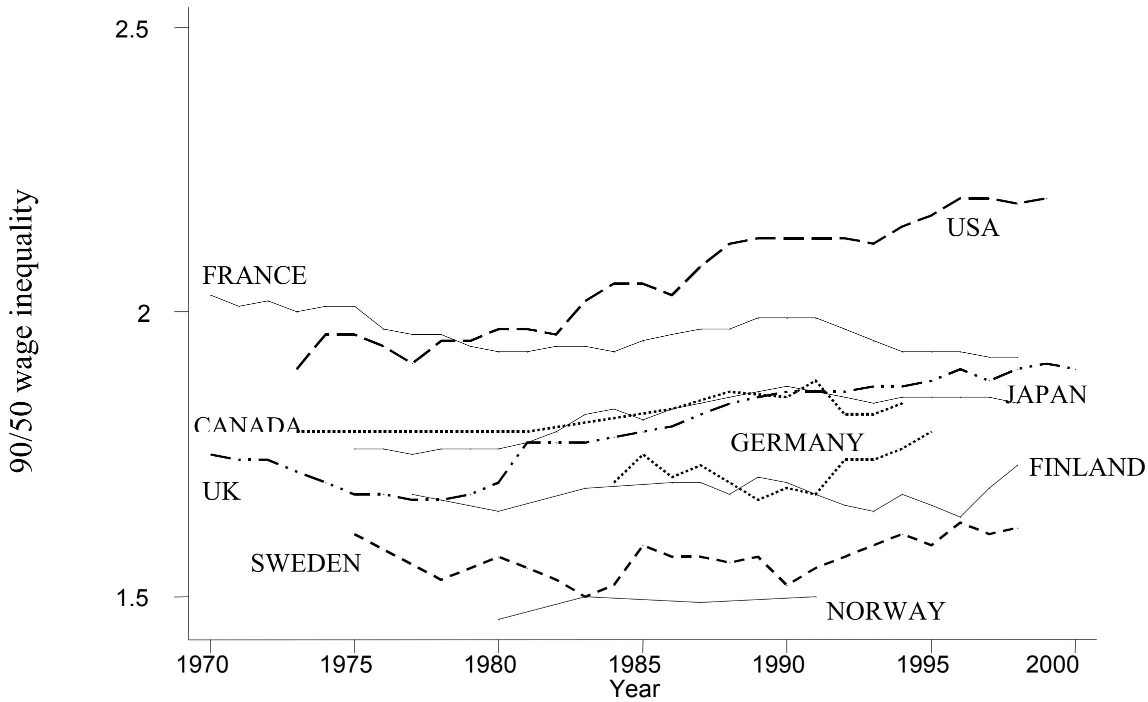
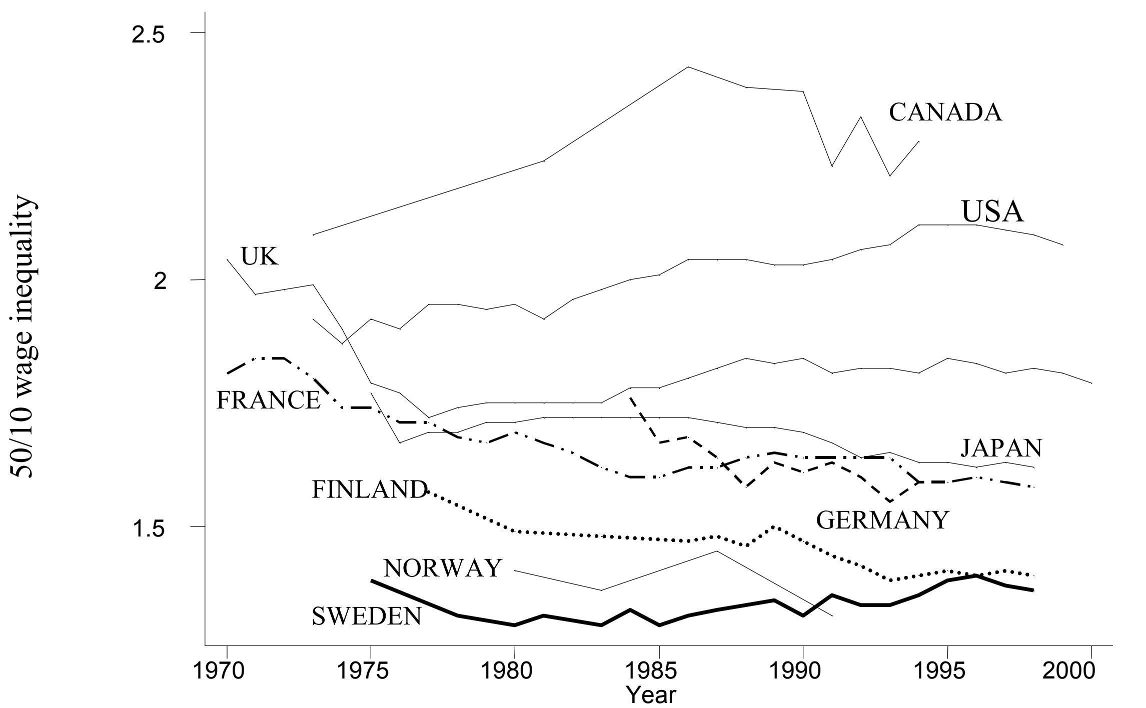
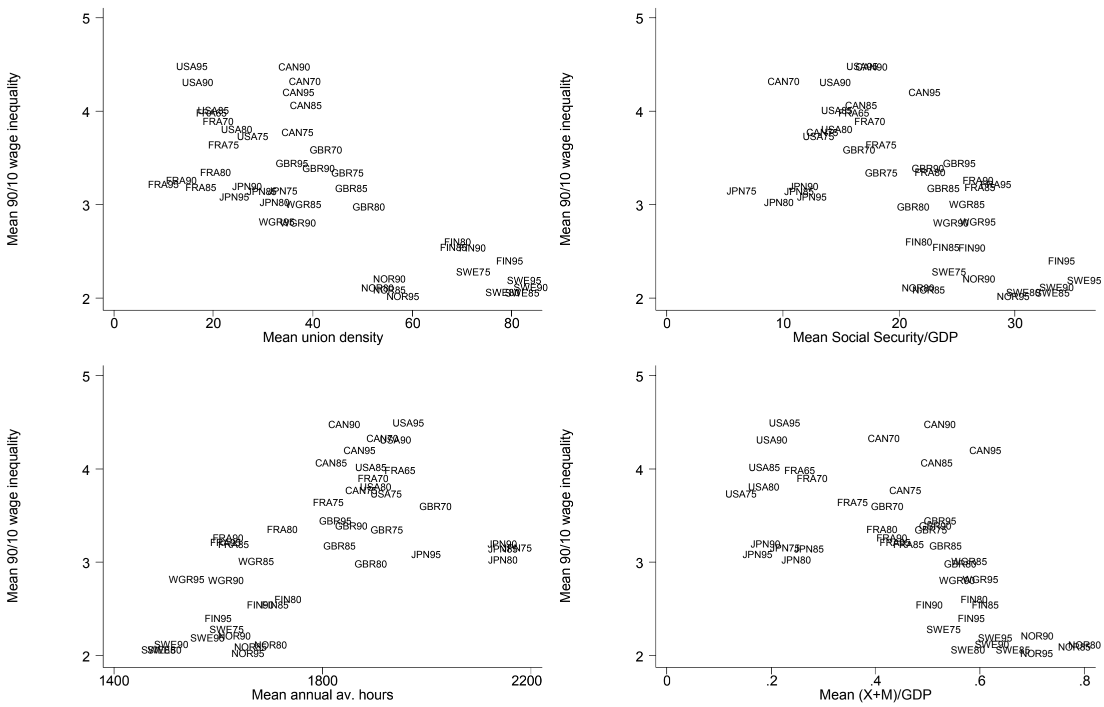


Figure 3 Time series plot of 50/10 wage inequality



As noted above, the nature of wage dispersion is linked to other features of the economy. Figure 4 shows plots of the five year averages of 90/10 wage dispersion measure against similar averages for union density, social security expenditures as a percentage of GDP, average annual hours and trade openness (exports plus imports over GDP). Each data point is represented by the country code (see Appendix) followed by the end year for the averages. The plots confirm the broad expectation that these variables are linked, although it is clear the relationships are far from perfect. The first three plots suggest that wage dispersion may be a useful index of social rights and joint regulation. The last plot shows that increased trade openness is associated with low wage dispersion, an issue highlighted by Agell (1999).

Figure 4 Wage inequality (90/10) vs. other variables



6. Regression analysis

The objective of this section is to use regression analysis to investigate the association between wage inequality and productivity growth. Most recent analyses of productivity growth use panel data techniques, since these allow the specification to include a time invariant, country specific effect (the η_i in equation [3]). A fixed effect estimator could be used, but this can be judged inappropriate due to the (potential) endogeneity of wage dispersion measures and due to the presence of a lagged dependent variable in [3] (Nickell, 1981).[12] One solution is to use a GMM-based, dynamic panel estimator due to Arellano and Bond (1991), which was initially used in cross-country growth studies by Caselli et al (1996). Although, the use of dynamic panel estimators represents 'best practice' in the growth literature, there are certain concerns over dynamic panel estimators, especially for small samples. Given this, the second sub-section below uses more established techniques – fixed effects and OLS models – to check the robustness of the findings on wage inequality.

GMM estimation

The GMM dynamic panel estimator removes the fixed effects by first differencing the data, hence the actual estimation is based on first differences. Lagged values are used as instruments for the endogenous variables: initial productivity and wage inequality (where the latter is included). The first column in Table 4 shows the GMM estimation for the basic model without wage inequality. The regression also includes a set of year dummies, as required by the catch-up specification (see footnote 7). The coefficient on initial labour productivity is negative and significant, indicating the presence of a technological catch-up effect. The coefficients on capital per hour growth, schooling growth and R&D intensity are all positive but not significant.[13] The coefficient on change in unemployment, an influence neglected in the existing literature, is positive and significant. The second column introduces wage inequality to the estimation, adding the log of the ratio of the 90^{th} to 10^{th} wage percentile (log 90/10), with the results showing the coefficient is not significantly different from zero.

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[12] This may not be directly obvious. Note that the growth of labour productivity is $(\ln y_t - \ln y_{t-5})/5$, and the ratio of the initial labour productivities (the catch-up term), both contain $\ln y_{t-5}$. Hence it is possible to rearrange [3] to yield a standard lagged dependent variable model.

[13] The insignificant coefficient on the capital growth is of concern. Further investigation shows the result is largely due to the inclusion of the R&D intensity variable (omitting this variable results in the coefficient on capital growth rising to 0.25, with a t-stat of 2.3). This pattern of results – an increase in magnitude and significance of the capital growth coefficient when other explanators are omitted – is common to the other regressions reported in Tables 4 and 5. In general, as other explanators are omitted the coefficient on capital growth rises to between 0.25 and 0.3 (magnitudes more in line with

The third column distinguishes between top and bottom end wage inequality, entering both the log of the ratio of 50/10 and 90/50 wage percentiles. The results here are quite startling; there is a positive and highly significant coefficient on the 90/50 ratio and a negative and highly significant coefficient on the 50/10 ratio. Testing the equality of the coefficients we reject the null of equality at the 1% level. The implication is that wage inequality above and below the median have converse relationships with productivity growth. Column three also shows that the coefficients on schooling and R&D are now more significant.

The last two columns of Table 4 check the robustness of the results on wage inequality by omitting the change in unemployment and the growth in schooling. In both regressions the coefficient on the log 90/50 shows little change in significance or magnitude. Column 4 shows the coefficient on the log 50/10 increases in significance and magnitude if the change in unemployment is omitted. Column 4 also shows that the exclusion of change in unemployment greatly affects the estimated coefficients on growth in schooling, R&D intensity and initial productivity. The inclusion of the change in unemployment variable can, therefore, substantially alter results for conventional variables. Column 5 shows a specification that omits the growth of human capital; the coefficient magnitude on the log 50/10 wage inequality falls, but is still statistically significant at the 5% level.

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traditional estimates). The implication that high rates of investment are correlated with other national characteristics is, perhaps, to be expected.

Table 4 Results from GMM regressions using level of log wage inequality

Dependent variable: growth in value added per hour (over 5 year periods)

	1	2	3	4	5
Log of initial Labour Productivity	-0.076	-0.060	-0.061	-0.047	-0.063
	(5.12)***	(6.02)***	(4.37)***	(3.77)***	(4.63)***
Growth in Capital/Labour ratio	0.119	0.176	0.137	0.113	0.162
	(1.12)	(1.56)	(1.45)	(1.45)	(1.56)
Growth in Total Schooling	0.098	0.016	0.145	0.289	
	(0.66)	(0.10)	(1.74)	(4.09)***	
Business R&D/value added	0.276	0.116	0.533	0.873	0.421
	(1.41)	(0.84)	(1.88)*	(4.10)***	(1.66)
Change in Unemployment rate	0.218	0.242	0.214		0.251
	(3.32)***	(4.39)***	(2.42)**		(3.44)***
Log of 90th/10th Wage		0.020			
		(0.51)			
Log of 50th/10th Wage			-0.155	-0.200	-0.122
			(3.23)***	(5.75)***	(2.43)**
Log of 90th/50th Wage			0.277	0.277	0.259
			(2.89)**	(2.33)**	(2.99)***
Time dummies	Yes	Yes	Yes	Yes	Yes
Observations	29	29	29	29	29
Number of group(WBCODE)	9	9	9	9	9
Joint sign. of year dummies (prob)	0.06	0.01	0.01	0.00	0.01
Equality of 90/50 and 50/10 (prob)	Na	Na	0.01	0.01	0.01

Notes: Regressions shown are based on Arellano and Bond (1991) GMM, first step, robust estimator. The Sargan test of over-identifying restrictions indicates that the GMM instruments are valid; the null hypotheses of no serial correlation in the errors (which is required for consistency of GMM estimators) is not rejected. Columns 2 to 5 treat wage inequality measures as endogenous. Estimates were made using STATA 7.0 Absolute value of t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

Fixed effects and OLS estimation

Although the GMM based dynamic panel data estimator is becoming the standard technique in growth analyses, GMM estimators are known to be unreliable in small samples. Specifically, there is a concern that coefficients may be biased and test statistics unreliable, especially when variables are treated as endogenous (Kiviet, 1995, Dornik et al, 2001, Newey and Smith, 2001, Hahn et al, 2001). One alternative option is to use a fixed effects model. Use of this estimator implies that the coefficient on the initial level of productivity will be biased, but this coefficient is not the central issue here.[14]

The first column in Table 5 uses the specification from column 3 in Table 4. The FEIV estimator uses lagged values of log 50/10 and log 90/50 wage inequality as instruments for the contemporaneous values and the results show no significance on these variables. Note also that the other results are weak, with only the change in unemployment showing a significant coefficient. In addition, an F-test cannot reject the null hypothesis that the fixed effects are jointly equal to zero. These results therefore suggest that the FEIV estimator is inappropriate, yet the signs of the coefficients on 90/50 and 50/10 are as expected. The second column of Table 5 uses a basic fixed effect estimator, with no instruments for wage inequality, which allows the sample size to rise to 39.[15] The results show that the significance of the coefficient on the 90/50 measure has increased and its magnitude has fallen, but otherwise coefficient magnitudes are little changed. This pattern of results is similar if either the change in unemployment or growth in schooling is omitted, or even if the sample size is restricted to 31 as in the FEIV estimator.

Both fixed effect models find that the fixed effects are not significant as a group, providing support for the use of OLS (as long as year dummies remain included).[16] The fourth column of Table 5, therefore, estimates a 2SLS model, treating both wage dispersion measures as endogenous and using lagged values as instruments. The results show that the log 90/50 ratio has a positive association with productivity

[14] In general, estimating a fixed effect (FE) model when η_i are present introduces a downward bias in the coefficient on initial productivity (i.e. the lagged dependent variable); in contrast, the bias on this coefficient in an OLS estimator will tend to be upwards. The GMM estimator should, in theory, correctly estimate the coefficient which should be between OLS and FE. Jumping ahead and comparing the GMM, FE and OLS results on $\ln y_{t-1}$ across Tables 4 and 5, it does appear that OLS has the highest value (-0.035), with the GMM between -0.05 and -0.08, while the FE results are between -0.06 and -0.14 (although these estimates are generally not significant).

[15] Intuitively, one would expect the sample size to rise by nine – the number of countries in the sample – as this regression does not use lagged values of wage inequality as instruments. However, the sample is, in fact, constrained by lack of OECD capital stock data in some cases.

[16] A common alternative estimator is a random effects (RE) model. However, with the current data if one attempts to estimate RE the model degenerates into simple OLS.

growth and the log 50/10 ratio has a negative association. These results reflect qualitatively the findings of the GMM-based estimators in Table 4, although the coefficients for the 2SLS are around half the magnitude of coefficients in Table 4. The last column of Table 5 checks this result using a basic OLS estimator. Again, the wage inequality coefficients have similar magnitudes and significances as in the 2SLS, suggesting that endogeneity bias is not severe. These results are again robust to excluding either the change in unemployment of growth in schooling.

Table 5 FE and OLS regressions

Dependent variable: growth in value added per hour (over 5 year periods)

	FEIV	FE	2SLS	OLS
Log of initial Labour Productivity	-0.137	-0.061	-0.043	-0.035
	(1.01)	(1.77)*	(2.73)**	(3.23)***
Growth in Capital/Labour ratio	-0.082	0.186	-0.138	0.097
	(0.28)	(1.25)	(0.61)	(0.93)
Growth in Total Schooling	0.236	0.06	0.15	0.044
	(0.87)	(0.32)	(0.47)	(0.16)
Business R&D/value added	0.125	0.419	-0.113	-0.081
	(0.15)	(1.30)	(0.74)	(0.56)
Change in Unemployment rate	0.404	0.311	0.394	0.386
	(2.15)**	(2.48)**	(3.58)***	(3.87)***
Log of 50th/10th Wage	-0.283	-0.091	-0.072	-0.046
	(0.70)	(1.17)	(3.00)***	(2.67)**
Log of 90th/50th Wage	0.402	0.232	0.103	0.081
	(1.46)	(1.82)*	(2.41)**	(2.44)**
Constant	0.297	0.094	0.12	0.097
	(0.53)	(0.70)	(2.85)**	(3.37)***
Year dummies	Yes	Yes	Yes	Yes
Observations	31	39	31	39
Number of countries	9	9	9	9
R-squared	0.54	0.63	0.65	0.63
Test of fixed effects (prob)	0.48	0.28	Na	Na
Sign. of year dummies F-test(prob)	0.56	0.63	0.06	0.22
Equality of 90/50 and 50/10 (prob)	0.21	0.07	0.01	0.01

Notes: Absolute value of t statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. The 'test of fixed effects' row shows the probability from an F-test of the null hypothesis of $\eta_i=0$ (i.e. insignificance of fixed effects). The FE and FEIV columns report the 'within' R-squared value. OLS and 2SLS have robust standard errors.

Robustness checks

As discussed in section 3, levels of wage dispersion are correlated with various other political economic characteristics. To further consider the possibility that the results above are being driven by omitted variables correlated with the wage structure, the regressions in both Table 4 and Table 5 were re-estimated adding (severally) a) union density, b) the ratio of social security to GDP, c) hours of work, and d) trade openness (X+M/GDP). In summary, the overall pattern of results for the wage dispersion variables are little changed by the addition of each of these variables; the associations found above are robust.[17]

There might be concern over the inclusion of the change in unemployment variable in the regressions as this is unknown in such analyses, although it is well justified here. Table 4 has shown the implications of the omission of the change in unemployment from the GMM-based estimations. Similarly, omitting the change in unemployment from the regressions shown in Table 5 yields results for wage inequality little different, though those for other variables are affected. A further concern might be the lack of significance of the coefficient on the growth of schooling. However, the poor results on schooling is a feature of the literature.[18]

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[17] There are, however, some insights from these results. Concerning union density, its coefficient is only conventionally (5% level) significant (and positive) in the OLS/IV estimations, and only then when 90/50 and 50/10 are also included as explanators. If trade openness is added to the baseline GMM model in Table 4 it has a negative and significant coefficient, but once the wage dispersion variables are included the coefficient on trade is never significant. For the social security ratio and the hours variables the coefficients are positive but never significant at the 5% level, and the coefficients on the wage dispersion variables are little changed from those in Table 4 and 5. See Rogers and Vernon (2002) for further early results on the relationships between social rights and joint regulation and productivity growth.

[18] Prichett (2001) provides a widely cited study finding no significance for schooling growth in cross sectional analysis. Krueger and Lindahl (2000) discuss the robustness of this finding with respect to OECD, concluding in particular that measurement error may attenuate coefficients. Further regressions were run to investigate robustness, including using 1) secondary schooling 2) using changes in stocks not growth rates and 3) initial levels of schooling. Overall, there was no indication that aggregate schooling stocks can explain manufacturing productivity growth. Equally, exclusion of the growth of schooling had little effect on other coefficients.

Lastly, there is always a concern that a few, influential observations are driving the key results in a regression analysis. To investigate this Figures 5 and 6 below show added variable (or leverage) plots for the fixed effect model (Table 5, column 2) and the OLS (Table 5, column 4). In both cases the plots for (conditional) log 90/50 and log 50/10 are shown. The graphs do show a spread of observations around the regression line. Figure 5 indicates that the United Kingdom has had relatively large (conditional) changes in wage inequality and growth. However, omitting the UK from the FE estimation does, in fact, raise the significance of the 90/50 and 50/10 coefficients (although neither are significant at the 10% level). The plot of E(growth|X) against E(50/10|X) in Figure 5 also indicates that Canada (1970-75) is an influential variable, but omitting this observation, or Canada altogether, does not greatly influence the results reported above. For the OLS results, and the leverage plots shown in Figure 6, there appear to be no strong influential observations. Checking the results by omitting each country in turn and re-estimating the model shows that the coefficients on 90/50 and 50/10 are almost always of the same sign and significant at the 10% level, although the magnitudes of the coefficients do vary (the only exception is the coefficient on 90/50 when Norway is omitted, which is significant at the 13% level). Overall, therefore, there is little indication that a few influential observations are driving the results on wage inequality. In this respect, as in others, the results are remarkably robust.

Figure 5 Added variable plots for fixed effect regression

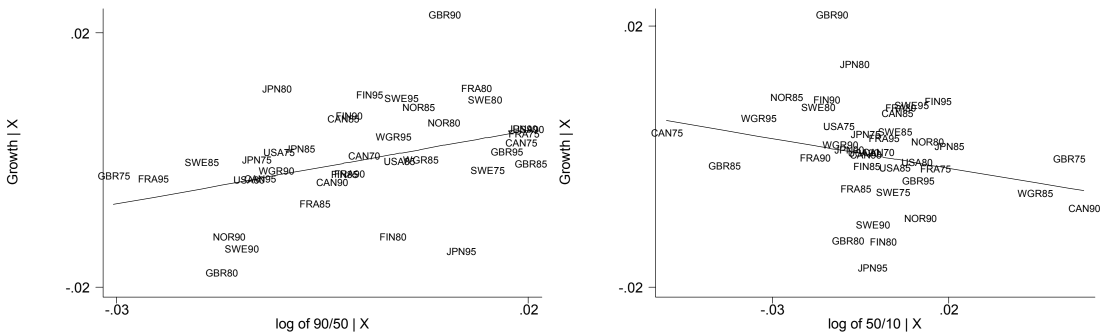
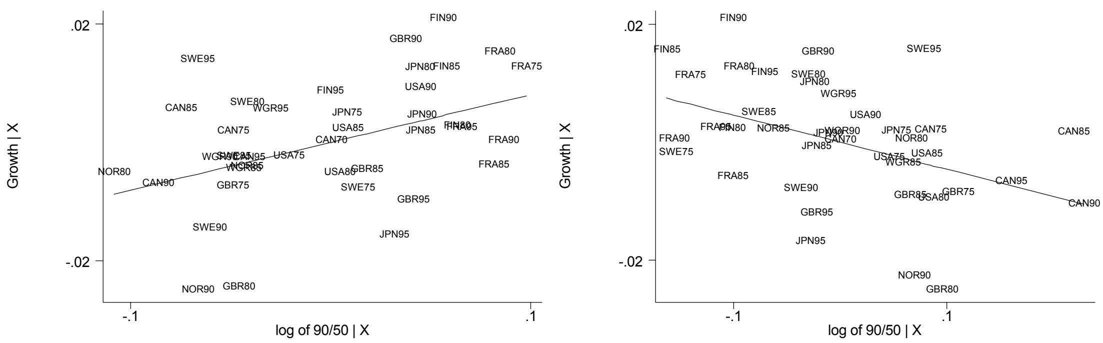


Figure 6 Added variable plots for OLS regression



7. Discussion

The basic thrust of the empirical results is as follows. The 90/10 wage dispersion ratio has no significant association with productivity growth. In contrast, higher wage inequality above the median is associated with a higher productivity growth rate, while higher wage inequality below the median is associated with a lower productivity growth rate. This pattern of results is common to the GMM-first differenced and OLS/2SLS estimators, but is weaker in the fixed effects estimations. Furthermore, the results were checked for robustness by a) included variables for union density, social security, trade openness and hours of work as explanatory variables, b) omitting the change in unemployment as an explanatory variable and c) an analysis of influential observations.

A further issue concerns the economic significance, or size, of the coefficients. The magnitude of the coefficient on the log 90/50 ratio is around 0.25 (in GMM regressions), hence a one standard deviation increase in log 90/50 (equal to 0.09) is associated with a 2.3% increase in the productivity growth rate. The magnitude of the coefficient on the log 50/10 ratio (say around -0.1) suggests a one standard deviation (0.17) fall in inequality below the median is associated with a 1.7% rise in productivity growth. These are remarkable magnitudes.

There is, therefore, evidence of significant and important associations between the shape of the wage structure and productivity growth. What might explain this remarkable association? Section 2 provided three potential mechanisms whereby the distribution of wages could influence productivity growth: human capital accumulation, pressure on managers and structural change. A discriminating test of the relevance of each of these mechanisms would require a great deal of further analysis using a wider variety of data. However, it is illuminating to consider the correspondence of these mechanisms with the above results.

There is a strong presumption in economics that human capital accumulation is central to productivity growth, although there is a great deal of controversy about the specific mechanisms and the measurement of human capital. While the regression finds no significant results for the growth of secondary schooling, this variable is defined at the economy level and might thus and otherwise be thought a poor proxy for actual human capital in the work force. We have also argued that wage inequality cannot be viewed as an expression of the prevailing inequality of human capital or of machine embodied technology. Yet the nature of wage inequality may be an important factor influencing individual and firm-level investments in skills.

The discussion in section 2 noted that wage dispersion could affect the incentives to accumulate human capital. First, higher wage inequality may increase the incentives of employees to invest in skills; a simple incentive effect. Second, there is an opposing effect if (risk averse) employees perceive lower wage inequality as reducing the uncertainty over the return to skills, or regard a compression of wage inequality below the median as increasing the probability of unemployment without training. These mechanisms can offer an account of the results reported above. The role of lower uncertainty and fear of unemployment may dominate workers' actions facing below median wages, whereas the incentive effect may dominate for workers' facing above median wages.

Yet the relevance to the results of individual human capital accumulation is subject to important caveats. Although some training episodes of relevance to productivity growth may be of short duration, and deliver rapid results, generally the implications for productivity growth of educational and training decisions might be expected to occur over rather longer time periods than the five year periods under consideration here. There must also be some doubt about why the human capital investment reactions of those earning above and below the median to wage inequality should be so different. Moreover, all these arguments are presented in terms of the (actual or potential) employee's decisions, neglecting the role of the employer.

Might the results then be interpreted in terms of the pressure on managers to reorganise work? It is quite possible that when managers are (relatively) free to pay low wages, they need pay less attention to upgrading not only training but work organisation. In other words, assuming that organisational change requires effort that managers wish to avoid, greater wage inequality across lower paid jobs allows greater managerial slack. This is consistent with the notion that relatively cheap skills promote productivity. Conversely, it is also possible that higher wage inequality above the median also places more pressure on managers to reorganise. Thus, greater 90/50 inequality prevents managers paying (relatively) low wages to better paid and qualified employees, forcing managers to upgrade the organisation of their work.

The central economic justification for wage compression in Sweden in the 1940s was the Rehn-Meidner argument that wage compression from the bottom up could increase the rate of structural change. Poorly performing establishments, firms and industrial branches would have to exit more rapidly if not able to survive by paying low wages. Whilst this argument suggests the level of productivity should make a step increase, during the transition to the new productivity level growth rates would also be higher, and this transition period could of course last many years.[19] In addition, if there are positive (growth) externalities from having more resources in better performing, perhaps sunrise, firms and industries, the growth rate of productivity may increase indefinitely. The results on the 50/10 wage inequality measure are quite consistent with such a view.

The results demonstrate the importance of change in unemployment as an explanatory variable in growth regressions, something new to the empirical literature. The positive coefficient on the change in unemployment indicates that severe recessions are associated with an immediate rise in productivity growth. Such a phenomenon is not confined to the UK in the early 1980s, but occurred also in Sweden and, most dramatically, Finland in the early 1990s. This can be seen as the result of a combination of a batting average effect and the productive results of pressure applied to the remaining establishments. Given the results on bottom end wage inequality, this latter possibility seems best interpreted as relating to the productive pressure applied

[19] Hibss and Locking (2000) feature evidence for post-war Sweden on levels of productivity and inter- and within- firm and industry variation in wages.

to remaining organisational coalitions in their entirety in such difficult operating conditions, rather than simply to a disciplining effect on non-managerial or manual employees alone.

Lastly, the results for R&D are also of interest. Overall, the coefficient on R&D intensity is only positive and significant in the first difference (GMM) regressions and when both the 90/50 and 50/10 wage inequality measures are included as explanatory variables. This suggests that the effectiveness of R&D may be interlinked with the economy-wide structure of employee relations, human capital accumulation, managerial incentives and structural change.[20] Similarly, Machin and Van Reenen (1998) note how R&D intensity and skills are complementary, with the strength of this association varying across countries. It seems that more attention should be given to R&D and labour markets.

8. Conclusions

This paper analyses whether wage dispersion has an influence on manufacturing productivity growth in 9 OECD countries over the period 1970-1995. This represents a new direction for productivity studies of advanced countries. Given that wage dispersion varies dramatically across countries and also through time, and that the core of neoclassical economics concerns the role of relative prices, some investigation is warranted. Though there are no clear predictions in this context from the conventional body of economic theory, there exist a range of theoretical arguments as to how wage dispersion may affect the organisation of work and thus productivity growth. These relate variously to the rate of structural change, managerial slack, the nature of the employment relationship, the relative cost of skills and human capital investment.

Of course, the wage inequality characteristic of a nation at a particular time is not exogenous to the larger political economy. It is an element of the societal organisation

[20] Although there is no existing empirical literature directly on this issue, there is empirical work that stresses the effectiveness of R&D varies across firm size, funding source and ownership structure (see Symeonidis, 1995, for a summary), and a more case study-based literature on the role of management, culture and employee skills (see Nijhof et al, 2002, for a recent discussion).

of work. This paper has, however, shown that the available evidence does not justify the views that comparative wage inequality can be accounted for by skill biased technical change or by inequality in the distribution of human capital. Wage inequality is, however, strongly related to simple gauges of the social regulation of employment such as union density. Yet wage inequality is not reducible to a single, or even small number, of simple well-defined variables and is in this sense a proper focus for causal econometric analysis.

The paper's central finding is that higher wage dispersion above the median (90/50 ratio) is associated with *higher* rates of productivity growth whilst, in contrast, higher wage dispersion below the median (50/10) is associated with *lower* rates of productivity growth. It is clear that although some simple, plausible, mechanisms do not appear consistent with the above results, this leaves a range of mechanisms which are. Wage inequality in the top half of the distribution promotes productivity, apparently not only by encouraging better paid, or more ambitious, employees and potential employees, to invest in vocational education and training, but also by encouraging them to meet the more immediate demands of their employers. In contrast, lower wage inequality in the bottom half of the distribution nurtures productivity growth, apparently not only by (conversely) encouraging investment in vocational education and training within this range of ambition, but through its implications of upgrading in the organisation of work, and its facilitation of structural change.

Considering the immediate policy implications of these results in isolation, the suggestion is that the 'optimal' wage structure would feature half the employed at the median wage, and half at a wage tending to infinity. This is an obvious absurdity as a policy prescription. No econometric investigation should be used so crudely as a guide to, even generalised, policy. Moreover, at least with regard to wage inequality there are particular considerations of the means by which policy might be pursued. The likely implications of policy to reshape the wage structure for other aspects of social regulation which may have implications for productivity growth require attention (see Rogers and Vernon, 2002). Superficially, though, it appears that a minimum wage provides one means by which government may seek to reduce bottom end inequality without reducing that at the top. It appears more difficult to extend top end inequality without this bringing an extension also at the bottom.

Data Appendix

Further description of variables

Variable	Definition, Source
Initial GDP per hour, manufacturing	GDP in 1990 constant PPP US dollars. Employment collated from OECD (1997) sources, and average annual hours from various sources, including national (see Vernon, 2000).
Growth in capital to labour ratio	Data on gross capital stock (1990, constant US$ PPP). Gross capital stock refers to the cumulative flow of volume investments, corrected for retirement. In the gross stock, assets are treated as new until they are retired: it is assumed that they retain their full productive capacity until removed from the stock. Employment and hours data as above. Source: OECD (International Sectoral Database).
Growth in total schooling	Average years of schooling in population (age 25 plus). Source: Barro and Lee (2001). http://www.cid.harvard.edu/ciddata/ciddata.html
Change in unemployment	Change in ratio of unemployed to labour force (standardised rate) from average in one five year period to the next. Source: OECD (1997)
R&D Intensity	Business R&D in manufacturing to value added in manufacturing, averaged over five year period. Source: OECD, Basic Science Indicators (1997)
Union density	Active union density averaged over five year period; membership from various sources (see Vernon, 2000).
Social security	Share of social spending in GDP, OECD sources (see Vernon, 2000).
Wage inequality	Data used by Rueda and Pontusson (2000), supplied to them by OECD. Based on gross (net for France) earnings of full-time employees (all employees for Norway). No adjustments for unearned income, taxation, transfers or household size.

Summary statistics

Country	Code	Obs	Initial Year	Last year	growth	Means 90/10	90/50	50/10	Time
Canada	CAN	5	1965	1995	0.030	4.13	1.81	2.28	A
Finland	FIN	4	1975	1995	0.057	2.48	1.68	1.47	A
France	FRA	5	1970	1995	0.036	3.29	1.97	1.67	A
UK	GBR	5	1970	1995	0.032	3.22	1.78	1.82	W
Japan	JPN	5	1970	1995	0.039	3.08	1.80	1.71	M
Norway	NOR	3	1975	1990	0.026	2.10	1.48	1.41	H
Sweden	SWE	5	1970	1995	0.034	2.10	1.57	1.34	A
USA	USA	4	1970	1990	0.021	3.93	2.00	1.96	W
W. Germany	WGR	3	1980	1995	0.025	2.84	1.72	1.65	M
		39							

Notes: the 'Time' column indicates over which period wage inequality data are based on (A=annual earnings, M=monthly, W=weekly, H=hourly)

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