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**Title:** **GROWTH, INEQUALITY AND TRAINING**

**(GRIT)**

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# ABSTRACT

Numerous factors have been widely proposed to account for the recent shift in the distribution of skills and wages that has been observed in many developed countries. The research project undertaken under the acronym GRIT reflects on the causes and effects of such changes as well as investigates the substantial variation in patterns across countries. Our research has focused on the role played by institutions in providing a trained and educated workforce and their impact on the way the distribution of wages responds to shocks. This has led us to investigate the way these institutions enhance or constrain the performance of an economy in terms of its capacity to produce innovations underlying growth and its implications towards inequality.

This research has extended the on-going discussion on these issues by examining both demand and supply side factors in the determination of an equilibrium in the market for skills. New time series databases were constructed with information on the distribution and the returns to skills for a number of European countries. Additional information has been compiled on the provision of training and the incidence of innovation. Given the comparable nature of the data constructed, comparative studies were undertaken, with special emphasis on the changing patterns in the supply and demand of skills in Europe.

Strong econometric evidence was found supporting a number of theoretical hypothesis developed in GRIT. Three key findings emerge particularly strongly from this study. Skill biased technical change is present in most countries although it manifests itself in radically different ways depending on the relative strength of labour market institutions. In this context, technological innovation within a firm appears to require a process of organisational change, in order to exploit complementarities between highly skilled labour and new technologies. Investment in training by employers and the government can be justified on pure efficiency grounds. The relative importance of alternative reasons such as trainee's contribution to productivity and investment reasons depends on factors such as the size of a firm and the type of sector. Additionally, our research also concludes the supply of educated workforce should be considered as endogenous, as it appears to be highly responsive to relative prices of skills and cost variables such as tuition fees and credit constraints.

These empirical results justify the modelling efforts undertaken to explain in a unified manner investments in human capital, investment in R&D and subsequent economic growth and also inequality. The theories developed in GRIT indicate that the latter should be considered both as an incentive mechanism for investment as well as an outcome of some population groups taking the lead in making the most of new economic opportunities. These considerations have major implications towards the design and implementation of economic policies. Our models show that fostering human capital can marginally enhance growth without increasing inequality, but the opportunity cost of such win-win policies implies giving up on other policies such as R&D subsidies which promote faster growth with increased inequality.

# SECTION 1.

# EXECUTIVE SUMMARY.

The primary objective of this research was to bring together the expertise of a number of European economists from diverse methodological backgrounds in order to provide a better understanding of the mechanisms underlying the changing distribution of earnings and processes driving technical progress and skill accumulation. The research project under the name "Growth, Inequality and Training" (GRIT) has sought to explore the links between these different concepts: The incidence of human capital formation through training as well as standard forms of education and its effects on aggregate growth and earnings premia. The stated aims were the following.

- Extend the current discussion on the changing distribution of skills and wages in the workforce by incorporating demand and supply-side factors in a unified framework.

- On the supply side, a detailed analysis was to be undertaken examining both the evolving distributions of the supply of skills in different countries and the factors determining the production and acquisition of skills, and hence the responsiveness of skill supply to technology changes.

- This analysis would proceed in the context of an explicitly comparative study of the links between growth and inequality across different countries. The primary aim is to provide a single coherent framework that can help understand the complex cross-country evidence.

- Provide a coherent intellectual framework to address the links between growth and inequality, in which the pace of technological change and the distribution of wages are determined endogenously. This is intended to shed light on the effectiveness of institutions and policies in providing incentives and opportunities to acquire skills.

- The empirical and theoretical insights are intended to provide the basis for a systematic analysis of policies that can enhance long-run economic performance, where the concept of performance will encompass both sustained growth and distributional considerations.

This report consists of a summary of the results found in a series of papers that were presented in workshops and seminars within and outside the "GRIT" project environment from January 1999 until March 2001.

**Comparative study of available evidence of skill bias and human capital-related inequality patterns in developed countries.**

This strand of research reviews the available empirical literature on the evolution of the educational premium and the earnings distribution in the US, UK, Germany, France, Italy and Greece. Particular attention was paid to the existing evidence on the incidence of skilled biased technical change in these countries. Substantial differences were found across these countries in terms of earnings and unemployment patterns of inequality, suggesting that idiosyncratic features of each country's educational and labour market institutions have had a major effect in shaping the effects of technical progress and increased supply of skilled labour.

**Comparative study of patterns in inequality and skill endowment in a few selected European countries.**

The goal pursued here was to elaborate a comprehensive time series dataset which allowed to describe changes in the supply of skills over the last decades for a number of European countries. This work provides some clues on the role played by returns to education (in terms of wages and unemployment risk) in fostering an enhanced distribution of educated workforce across Europe.

**New econometric evidence on skill-biased demand shifts.**

Our research has found that the increased demand for a better qualified workforce is highly responsive to the existing supply of skills, measured by a number of proxy variables. Such an increase in demand appears to require a number of simultaneous organisational changes that allow firms to exploit the synergies between human capital and new technologies. Broadly speaking, the intensity of training appears associated to this type of changes and the overall picture seems to suggest that it is the service sector and very specific industries within the manufacturing sector those explaining most of the changes.

In conclusion, we found strong evidence in support of the view that organisational change, technology and human capital are complementary assets of the modern enterprise.

The econometric evidence does also suggest that the trade induced skill bias hypothesis requires further attention, as the available evidence denying any significant effect assumes certain features of international trade which are contradicted by the facts, with most trade taking place in terms of intermediate products within and not between industries. Evidence from France indicates that although the trade hypothesis does not completely explain changes in unemployment and earnings premia, its effect is far from negligible.

**Econometric investigations on the individual incentives to invest in skills.**

This strand of research attempts to understand better what are the supply responses to current and expected differences in the fortunes associated to different levels of education and other sources of human capital. The findings on this issue can be separated in two different groups.

First, we have found strong indications of increasing incentives for firms to either train their workers and/or demand an apprenticeship scheme. Hiring apprentices appears to be justified from the firm's point of view on the basis of their pure current productivity. This is particularly relevant for small firms, as found for France and Germany. This means that apprentices can substantially contribute to the productivity of the firm where they are training. Besides, there is an additional argument in terms of apprentices having an investment value for a firm as a result of their privileged information on their trainee's productivity and the trainee's learning of firm-specific skills.

Second, the decision to stay on in education after the compulsory schooling age was also investigated. The evidence supports the view that the staying on decision is at the margin highly influenced by current labour market conditions, particularly unemployment. Besides, individuals appear to be responsive to the existing wage premium, which in the case of countries with short higher education courses is a good approximation to their own expected wage premium. This responsiveness is also shaped by the direct cost of additional education as embedded in tuition fees and availability of student loans. In this context, a model based on human capital investment incentives (without dismissing other considerations) does seem to do a good job in explaining UK data.

**Empirical studies of innovation.**

This research has analysed innovativeness patterns across industries and countries. We have learnt from innovation data that the micro-aggregation procedure followed by the Community Innovation Surveys in order to protect confidentiality does not bias results compared to using the original data. Innovation indexes have been constructed in order to ease comparisons and distinguish between innovation types.

An important finding is that governments should be cautious in choosing the instruments to encourage innovation as it may well be the case that public subsidies to innovations can crowd out privately undertaken research and development activities. Both theory and evidence suggest the convenience of targeting separately R&D activities that lead to innovations which are new to the market (new marketable products) and innovations which are just new to the firm (implementing new processes)

**Theoretical developments.**

Before exploring new theoretical explanations of the links between growth, inequality and training, a comprehensive exercise reviewing the existing literature was undertaken. Particular attention was paid to economic models that took into account the observed changes in inequality, supply of skills and the impact of new technologies.

The theoretical work undertaken in GRIT has been characterised by the willingness to learn from and develop models consistent with the empirical evidence. Besides, theories have always established testable implications for further validation and policy considerations have been discussed.

Theory has provided a useful tool to understand the role played by educational and labour market institutions in explaining why technical change has not affect developed countries in identical ways. This is not a mere and almost tautological acknowledgement that country differences accounting for other differences, but also helps evaluate the potential impacts of institutional changes that aim at reproducing the experience of other countries.

For example, it has been explained how a decrease in educational standards required to enter higher education may lead to a higher degree of crowding out in the labour market for less skilled workers. This highlights the importance of first targeting credit constrained individuals when subsidising access to higher levels of education. It has been found too that overeducation at the individual level can be consistent with a socially suboptimal level of educational attainment.

Restrictions on the free flow of information regarding quality of skills and job's productivity, effort, etc. across participants in the labour market can lead to market failures which are impossible to reconcile with classical assumptions in economic theory. The concept of multiplicity of equilibria has been explored in a number of papers and the main conclusion from our research is that there is room for successful government intervention and institution design in order to lead the economy to the most preferable equilibrium.

Besides, the rationale for certain labour market institutions can be justified on pure efficiency-related grounds. For instance, unions help wage compression by discouraging independent investment in human capital and encouraging firm-sponsored training. In this context it is found that a period in which economic growth rates accelerates might endogenously lead to a reduction in the unionisation rates and thus increase inequality. Minimum wages can lead to an overall improvement in the quality of jobs offered by firms without leading to a significant unemployment increase. Publicly supported apprenticeship schemes can contribute to an improved market efficiency on a number of dimensions. It is important to note that the beneficial effect of these policies has to be traded off against their opportunity cost and the distortions they might generate in other sectors of the economy. Most of the

theoretical contributions in GRIT suggest numerous lines of empirical research that examine recent policy changes and evaluate simultaneously the associated costs and benefits.

## POLICY IMPLICATIONS

All aspects referred to in the GRIT acronym were finally combined in a single model. This model provides a very simple framework which for the first time, allows to look at links between R&D/growth, skill/inequality and training. The framework is rich enough to explore these linkages in both a cross sectional manner by looking across different firms, and in a time-series cross sectional fashion by looking across different economics.

Some important points emerge from the model. Firstly, the links between education/skills and training that one might observe at the micro level do not carry across to the macro level. Thus at the micro-level education and skills are substitutes in the sense that the more education a person has the less training they need. However at the macro level policies that generate a higher proportion of educated people can increase the amount of training that takes place since they make the economy more innovative and raise the demand for training.

Secondly on the macro level one faces a policy dilemma between policies that are effective in promoting growth –through directly promoting R&D- which come at a cost of increased inequality- and policies that may involve no such trade-off but are less effective, such as those aimed at reducing the costs of access to education and lowering training costs to firms.

# SECTION 2.

# BACKGROUND AND OBJECTIVES.

The main feature of the background for the GRIT project is the changing distribution of skills and wages in the workforce across developed countries. Virtually, every advanced country has seen a significant increase in the proportion of employment which is accounted for skilled workers, and a decrease in the share of employment accounted for by unskilled workers. Simultaneously, some countries such as the USA and UK have been affected by a sharp and pervasive increase in wage inequality whereas in other countries such as Japan and many European there has been hardly any increase in wage inequality although unemployment has risen especially amongst the less skilled.

Skilled biased technical change and globalisation and the associated enhanced competition from low wage countries has been presented in the literature as competing explanations for the phenomena described above, with especial emphasis on their implications on the demand for skills. Far less attention has been paid to the processes affecting the supply of skills. This is important, for , while skill biased technical change may help explain why all countries have seen a shift in the composition of employment, it cannot explain why, if all countries have been subject to common technological shocks, the change in the pattern of wages has been so varied across different countries. Indeed what one might expect is that if a country has a relatively large fraction of low skilled workers in its working population and a small proportion of high skilled workers then skill-biased technical change would produce an acute shortage of high-skilled workers and an acute surplus of low-skilled workers resulting in a sharp increase in wage inequality. This suggests that bringing the supply of skills into the analysis is an essential component of a coherent explanation of the observed changes.

It is probably more crucial to understand why the sensitivity of the distribution of skills with respect to the distribution of wages might differ across countries. The effectiveness of various institutions for providing a trained and educated workforce and its relationship with the way in which the distribution of wages responds to shocks needs to be taken into account. This would provide the basis for assessing the impact of such institutions on the performance of an economy in a number of ways:

1. For a given pace of discovery of basic innovations, it will affect the rate at which new these get translated into new products, processes and individual productivity.

2. It may affect the incentives of firms to spend on innovation and R&D. If firms anticipate problems in the availability of required skills, they might be more reluctant to undertake growth-enhancing activities.

The original objectives of the research project can be summarised in six points:

1. Extend the current discussion on the changing distribution of skills and wages in the workforce by incorporating demand and supply-side factors in a unified framework.

2. On the supply side, a detailed analysis was to be undertaken examining both the evolving distributions of the supply of skills in different countries and the factors determining the production and acquisition of skills, and hence the responsiveness of skill supply to technology changes.

3. This analysis would proceed in the context of an explicitly comparative study of the links between growth and inequality across different countries. The primary aim is to provide a single coherent framework that can help understand the varied experience.

4. Provide a coherent intellectual framework to address the links between growth and inequality, in which the pace of technological change and the distribution of wages are determined endogenously. This is intended to shed light on the effectiveness of institutions and policies in providing incentives and opportunities to acquire skills.

5. The empirical and theoretical insights are intended to provide the basis for a systematic analysis of policies that can enhance long-run economic performance, whether the measure of performance will encompass both growth and distributional considerations.

6. From a methodological point of view, these objectives will be pursued by means of a combination of state of-the-art theoretical models and applied econometric techniques.

# SECTION 3.

# SCIENTIFIC DESCRIPTION OF THE PROJECT RESULTS AND METHODOLOGY.

**Descriptive comparative studies.**

The Growth, Inequality and Training project has focused primarily on the analysis of factors related to the supply of skills and the way they can account for different inequality patterns in the UK, Germany, France, Greece and Italy, in response to common technological shocks and patterns such as recent globalisation trends. Much of the existing research on Growth and Inequality has in fact mainly considered the links between growth and the changing demand for skills. This report considers the results of the empirical research advanced in Stage 1 of the project. In this Stage, the linkages between technology, growth and training had to be investigated treating both technological progress and the distribution of skills as exogenous.

To consider the interactions between technological change, growth, inequality and training, the different teams carried out a preliminary investigation of the existing empirical literature for each of the countries involved, to be compared with similar investigations for Japan and the US. This preliminary study is part fulfilment of the tasks the research team had to carry out under Work Package 1, task1.2.

To bring into the analysis the supply side we have looked at the evolving distributions of skills for each of the countries involved. As agreed under Work Package 3 (task 3.1) time series of skill distribution were compiled. This data were pooled together for the countries involved and analysed in order to stress differences in skill endowment across countries that explain differences in wage inequality.

The existing empirical studies for the countries involved show a clear pattern of increasing wage inequality in the UK and the US, while the level of inequality stayed almost constant if not decreased in France, Germany and Italy. The employment composition in all the countries considered has shifted to an intensification in the use of more skilled labour. The cause of this shift is debated though there is strong evidence in favour of technological change. Other explanations have been proposed, such as the increased trade with developing countries, where unskilled labour is cheaper, and the observation of recent organisational changes within firms. The competing explanations are considered for each of the countries involved.

Changes in Inequality and Employment Structure and impact of Technological Change in UK, France, Germany, Italy and Greece

There exists exhaustive empirical evidence on the pattern of wage inequality for the UK and the US. In Germany, Italy, France and Greece, wage inequality seems to be a subordinate problem because in these countries wage dispersion has stayed almost constant over the last two decades. This section briefly reports the stylised facts for each of the countries involved in the project.

In the UK, income and wage inequality remained relatively constant from the post war period to the beginning of the 70s', when the distance between the rich and poor started to rise. The 80s' are characterised by increases in earnings dispersion with large gains at the top and essentially no wage growth at the bottom deciles of the distribution.

The pattern of earnings between 1990 and 1996 reveals that, during the 90's, inequality is still rising though at a slower rate compared to the 80's.

These trends in inequality are revealed from several data sources such as the *Family Expenditure Survey* (FES), the *General Household Survey* (GHS) and the *New Earnings Survey*, (NES)[1]. Irrespective of whether one looks at weekly or hourly earnings it appears that aggregate wage inequality has substantially risen from mid 70's, and the pattern is similar by gender. Between 1979 and 1990 Gini coefficient rose from .242 to .312, which correspond to an increase of some 30 percent. During the 90's, although inequality continues to rise, the rate of change in Gini coefficient for male wages is slightly lower, growing from .312 in 1990 to .335 by 1996. The slowdown for women is even more evident with aggregate inequality falling from .320 in 1990 to .312 in 1996.

Part of the change in overall inequality in Britain was due to the decline and subsequent recovery of financial returns to labour markets skills: education levels and years of experience. The wage educational differential has increased in the last 15 years and so has the age differential. In the UK, inequality has increased not only between groups but also within group of individuals with same observable characteristics.

A quantile regression approach was adopted in order to account for the effect on human capital accumulation of changes in education policies, in the role of labour market institutions. The chosen quantiles are an additive function of cohort, life cycle and time effects. If quantiles evolve in the same way over time, then changes in inequality might be summarised by changes in the median wage, that is,

[1] While FES and NES reports hourly wages GHS contains data on weekly earnings.

changes in the observable. Else, differences across quantiles can be interpreted as an estimate of the changing importance of the unobserved component in wages within predefined groups.

The dispersion in individual earnings contains a highly permanent element. The proportion of earnings variation within cohort is mainly accounted for by the permanent component.

The effect of technology on the employment structure and wages has been analysed for the UK using industry and establishment level data. It appears that over the post war period the nature of employment has considerably shifted away from manual to non-manual labour, with the non manual employment share rising from 16% in 1948 to 33% in 1990. The share of non-manual wages in total wages rose from 23% in 1948 to 42% in 1990. A similar pattern emerges using more disaggregated data, 3-digit industry level, for the period between 1979-1990[2]. Between 1979 and 1990, the employment share of non-manual workers has increased by .37 points per annum. The "within component" accounts for almost the entire shift in employment composition between 1979 and 1990. This finding may be interpreted as evidence in favour of the technological change hypothesis.

With respect to more direct evidence of the effects of technology on wages and employment structure, the main constraint comes from the data available to proxy technology. The measures of technology which have been used to date are R&D intensity, the impact of computers as derived from WIRS data and the stocks of innovations produced and used between 1970 and 1979 in the relevant industry, as drawn from the Science and Policy Research Unit data base. Overall, it seems that the increase in employment of non manual labour in UK, during the 80's, was driven mostly by within establishment changes in skill composition. The reduced demand for unskilled labour is significantly explained by an increase in computer-based technologies.

An attempt to determine the impact on earnings of microelectronic technologies in the workplace is made, for the UK, by matching individual (GHS) and industry level data (WIRS). The interesting result is that roughly half (54%) of the within groups increase in individual earnings variance is within plants. This implies that part of the increase in wage inequality is due to plant specific characteristics and therefore the effect of technological change is somehow different, for the same type of workers in the same industry, depending either on the pace of technological change itself (firms may well happen to be in different stage of implementation of a new technology) or on how the firm structure itself affects wages.

In Germany, the wage inequality situation is substantially different from that in the UK. The main finding is that wage inequality in Germany remained constant over the 80's. Different data sources have been used to study the pattern of wage inequality. For the period 1978 to 1983 the analysis is drawn from the IABS while the GSOEP is used for the period 1983 to 1989. The earnings ratio as measured by the ratio of 90/10 percentile has remained nearly constant between 1978 and 1983.

Between 1983 and 1989 the 90/10 wage ratio for *full time* workers (GSOEP) decreased slightly. Real earnings at the bottom of the wage distribution are rising over the period, with the worse paid workers relatively catching up with the rest of the workforce. Absolute wage differentials between those with a polytechnic degree and those with no qualification fell slightly between 1977 and 1983 and a similar pattern is observed between employees with occupational qualifications and those with no qualification.

The changes in the employment structure and the factors behind the shift in demand for skills have been fully examined in empirical studies. Skill biased technical change (SBTC) is suspected to be the main contributor to the growing demand for skills. This is concluded from studies attributing indirectly the time trend to SBTC and from studies estimating elasticities between different skill groups or between capital and heterogeneous labour. In particular, using data by the Bundesinstitut fur Berugsbildung (BIBB) and Institut fur Arbeitsmarkt, SBTC is found to be responsible for the employment restructuring of –1.2 per-cent of unskilled manual workers per year for the period 1964-1991. Further IT – investment was estimated to have a significant positive impact on universities graduates and is negatively significant for skilled labour. The trade hypothesis seems less conclusive than the SBTC the skills ratio fell less in industries with the lowest import share than in industries with the highest import share.

In France, the pattern of earnings has been analysed drawing from the following datasets: INSEE DADS, *Declarations Annuelles des Donnes Sociales,* for the period 1951-1976, which conveys information on net mean wages and minimum wages of full time workers in the private and semi public sector; and from the INSEE survey on employment *Enquete d'Emploi* for the period between 1976 and 1995; ACEMO survey, *Activité et Condition de la Main d'Ouvre*; ESE, *Enquete sur la Structure de Emploi.*.

Wage inequality decreased between 1970 and 1996 as the ratio between the 90 to 10 percentile fell over this period. The wage gap between mean and minimum wage increases over the period. Wage returns to different qualifications decrease with factory workers wages increasing relatively to managers' wages between 1989 and 1995. A slight increase in wage inequality is evident if part-time workers are considered.

As far as changes in the employment structure are concerned, there exists evidence of reallocation of labour from unskilled to skilled. The share of high skilled increases between 1976 and 1996. There exists exhaustive evidence on the effect of technological change on employment structure.

In Italy, the wage distribution has been compressed in the 70's and for the first half of the 80s' to increase thereafter. Various studies come to this conclusion drawing from different data sources. At an individual level, Bank of Italy *National Survey on Income and Wealth of Italian Household* conveys good information on

[2] The reason for limiting the analysis to this time period is the change in the Standard Industrial Classification in 1980 which makes it

education level, experience, sector of employment and type of occupation number of hours worked in a year; earnings variable is derived from annual labour income net of taxes and social contribution, period of observation 1977 1992. The Gini coefficient falls between 1977 and 1982. During the 80s'income dispersion remained stable while it increased quite rapidly between 1991 and 1993. When controlling for individual characteristics average returns to an extra year of education decreased between 1977 and 1985 by approximately 0.4% and increased later on by only 0.6% points in 6 years.

Evidence on wage dispersion at firm level is drawn form INPS firm data and from Company Accounts Data Services for the years 1986 and 1990. These data show a small increase in earnings dispersion, between white and blue collars, both across firms and within firms. Between 1986 and 1988 the variance of earnings increases both across firms and within firms to fall thereafter, with the within firms share of total variance being larger than the between firms one.

The same data set allows a more careful analysis of the pattern of earnings dispersion across different groups of workers: by decomposing the variance of earnings it is found that the *within* groups variance accounts for more than the *between* group component. Attempts to explain the determinants of wages throughout the period 1974-1994 show that firm variables result positively strongly correlated to wages of individual workers, after controlling in the wage equation for both individual and firm characteristics. Positive shifts in labour demand (firm size) have positive effect on outsiders' wages and less significant effect on insiders' wages. Furthermore, average wages appear to be larger in large firms than in small ones. Wage differentials across firms reflect the effect of differences in individual characteristics and of a selection mechanism that in turn is the result of unobserved characteristics (turnover behaviour, social mobility, household related variables) and demand (e.g. provincial unemployment rates). Besides, modelling the wage distribution as an ARMA process it appears that the permanent component accounts for large part of the increase in wage inequality.

Patterns of regional differences in inequality are found between the North and the South of the country with wage inequality increasing faster in the South than in the North between 1989 and 1993. Considering the incidence of observed characteristics, the different industrial and occupation compositions explain jointly almost half of the 8% increase in the difference between the North and the South of the country. In particular, the inclusion of individual characteristics such as human capital, age and gender explains 96 % of the variance between the regions. Wage returns to skills increase more in the North than in the South. More precisely, the higher premium for instruction in the South 1977 declines over the period, to converge to that observed in the North in 1993.

Technologically advanced firms –those with a larger share of R&D expenditure- employ a comparatively higher and increasing share of white collar staff. From the ISTAT – CNR survey on innovation for the period 1985-1991 in 30 industrial sectors, it appears that the share of white collar workers is higher in firms with larger average innovation cost per employee. The net employment effect of innovation is unclear in the Italian case. Overall positive effects of innovation on the use of labour are concentrated in high tech sectors.

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impossible to accurately consider disaggregated data in comparable industries prior to 1980.

The Italian labour market shows in general a rather different patterns of wage dispersion and, to some extent, of employment structure when compared to the UK and the US. Institutional factors are responsible for the different inequality patterns as shown in several studies. The labour market in Italy is by no doubt one of the most regulated in OECD countries. Union density is equal 38.8%; the percentage of workers affected by collective contracts is 85%; and bargaining is highly centralised. Union density in Italy has a strong negative effect on wage dispersion mainly at the bottom end of the distribution, whereas the centralisation of bargaining instead affects negatively wage dispersion at the top. In particular, most of the recent changes in the skill premium are due to changes in the national bargaining system rather than to labour market forces.

In particular, the *Scala Mobile* (an indexation mechanism granting the same nominal increase to both low and high-wage workers) was responsible for compression in returns to education between the late 1970s' and mid 1980s'. As the *Scala Mobile* mechanism was curbed the returns to one extra year of education rose. One difficulty in concluding that Institutional factors have been responsible for wage compression in Italy may be that wages would have evolved in the same direction had the institutional factor not been in force.

Evidence on the evolution of labour demand comes for the period 1986-1990 Social Security Data (INPS) and *Centrale dei Bilanci* (Company Accounts). The proportion of white collar workers increases over the period. The percentage of blue collars falls 75.8 to 63.5 in the period 1976-91.

In Greece the analysis of inequality draws from data on income and consumption expenditure from the *Household Expenditure Survey* from the National Statistical Service of Greece. It appears that aggregate inequality declines between 1974 and 1982 with the Gini coefficient falling from 0.35 to 0.30. Inequality appears to rise slightly between 1982 and 1987 to fall again below the 1974 level in 1993. When the Theil index is computed for various economic subgroups with reference to region, locality, age of household and level of education, the change in inequality can be decomposed in *between* and *within* groups. Since the contribution of most "between groups" components is rather low, the reduction in aggregate inequality is attributable to the "within group" component. Only when the population is grouped according to the educational level does the decrease in the "between group" component appears to contribute to the reduction in overall inequality. This reveals the impact of educational opportunities upon the equalisation of the distribution of income.

With respect to the changes in labour demand in the Greek labour market, no systematic study of shifts in the employment structure exists either at firm level or industry level. This is in part due to data problems.

As far as technological change is concerned, Greece appears to be characterised by a double handicap related to a low level of research expenditures combined with a low commercially oriented research effort, which is partially due to the absence of mechanisms and institutions promoting technological innovation and diffusion . The bulk of technology took the form of foreign direct investment or licensing with foreign firms. This often led to transfer of specific technologies more than to the development of their own local laboratories. The decomposition of the gross R&D expenditure data according to the source funding reveals that the sector with by far the higher expenditure in R&D is the State, while the share of R&D expenditure undertaken by private firms is small but increasing over

time. In the late 1970's, the Greek Government set the basis for a Science and technology policy. Research Institutes became quickly involved in European R&D programs and sector technology transfer firms grew rapidly during the first year of their operations at the end of the 1980's.

The introduction of new technologies in the production process dictates the need for the endowment of the workforce with a minimum of technical knowledge and experience. Although the number of researchers in Greece is amongst the highest in OECD countries the percentage of researchers per 1000 employees in both the public and the private sector is amongst the lowest. Further employment composition has stayed almost unchanged in manufacturing sector has stayed almost unchanged over the last 20 years. Furthermore, the management of Greek industry is estimated to be undereducated, since it has been estimated that that 27% of those occupied with the administration of the firm are only graduates of lower education. This finding in part explains the unwillingness of the domestic industry to plan and direct corporate strategies to technology-intensive sectors.

Interactions between Supply and Demand

"Some of the problems in the labour market performance of OECD countries have their roots on shifts in the relative demand for skilled workers". In order to ascertain the plausibility of this claim it is necessary to look at relative fortunes of high, mid and low skilled workers and see how they have evolved over time and across countries. If the demand for skills changes faster than the supply, the position of those at the top of skill distribution will improve.

In the UK, the interactions between supply and demand are analysed within a simple demand and supply framework. Changes in the relative demand of skilled to unskilled labour are explained by changes in the relative supply and changes in relative wages given an estimate of the elasticity of substitution between supply and demand. The eighties and the nineties must have seen demand shifts in favour of more educated workers as the effects both for the relative supply and relative wages are positive. Continuous demand shifts must have occurred since wages of the more educated do not respond enough to the large increases in relative supply during the 80's and the 90's.

In Italy, the supply/demand skill-mismatch can be in part inferred using Bank of Italy Data. The relative demand for skilled workers is approximated by the wage bill share of skilled workers (college graduates) and the supply of unskilled workers (less than high school diploma) is simply calculated as the share of the population between 18 and 65 years in each cell (skilled/unskilled). The analysis shows a positive difference between the growth rate of demand and supply of skilled between the North and the South. The skill mismatch between the net demand for skilled and unskilled labour is significantly larger in the North than in the South. In the North, the net demand growth is of some +1.12 while in the South it remains stable. On the contrary, the growth of the net demand for unskilled workers was significantly negative both in the North and in the South. The difference in the evolution of the net demand between the two regions is explained in part by different industrial and occupational structures, as

the service sector which typically absorbs a large share of "white collars" expanded faster in the North than in the South. The skill mismatch in the North explains higher skills in the North relative to the South.

For Greece, no study exists on the supply-demand mismatch. What is found is that the unemployment rate of PhD graduate has increased from 4% to 6% in just five years in the first half of the 1980's. The finding might be interpreted as *prima facie* evidence of no mismatch. It is nonetheless true that college graduate have a better chance of finding employment than individuals at lower education levels, secondary and post secondary education and graduates from vocational schools.

The hypothesis that employment by skills group in Germany is mainly determined by labour demand has been tested. Econometric models have been estimated relating relative demand for unskilled and skilled labour to their relative earnings, with a time trend and a set of other variables affecting the relative demand of labour.

Training

Apart from the schooling system, there exist other sources of skill accumulation that contribute to meet the increasing skills requirements in developed countries. Each team involved has briefly examined the incidence of training schemes in shaping skill distribution over time.

In the UK, work related training has undergone a number of changes over the last 15 years, moving towards a nationally recognised system of vocational qualifications. The percentage of employees receiving a four week training period has risen from 8.4% in 1984 to 13.5% in 1992. These courses have generally a short duration (generally just a few days). Compared to countries like Germany (in which young workers participate in apprenticeships schemes lasting two to three and a half year) and the US (which has a more decentralised college based and learning by doing system of training), Britain still places high reliance on employer development of employee skills. There exists in fact the «Investors in People» provision of loans to firms to support investment into training. It operates alongside NVQ system which provides a set of Nationally recognised Vocational Qualifications for individuals undertaking work-related training.

The existing literature has mainly focused on the impact of government training schemes or formal educational qualifications. In these studies training is defined in terms of courses designed to help individuals to develop skills that might be useful in the workplace.

In Italy, training is mainly publicly financed in particular in the form of training courses, special labour contracts with training content and firm sponsored training. Data on publicly provided training come from ISTAT survey on professional training. Most publicly supported training is organised at regional level and over 68% of the financial support between 1996 and 1997 come from the EU. With respect to the effectiveness of training schemes, the importance of regional training varies considerably across sectors with agriculture counting for only 4% of total

training courses, while services and manufacturing accounts respectively for 71% and 25% of total training. In the agricultural sector, most training activities are targeted to retrain unemployed workers, while in manufacturing and services training courses are aimed at the attainment of a second qualification for employed workers. Regional differences do also arise between the North and the South of the country with 53.6% of training courses provided in the North of the country.

To strengthen the linkages between the school system and the labour market, special labour contracts, the "Trainee contracts" and "Apprenticeship contracts", have been introduced. The aim is to assist young people in their transition from schooling to the labour market. In particular, training contracts imply reduced social contributions for firms that hire first job seekers and provide training to workers between 21 and 29. Apprenticeship contracts attempt to improve the skills and reduce unemployment of unskilled workers below the age of 24. Apprenticeship contracts have declined between 1991 and 1997 mainly because of the recession, with a downward trend in employment levels for manufacturing, the demographic decline that affects most recent cohorts and the increase in school participation.

There are few studies that have tried to assess the incidence of firm provided training in Italy. The existing evidence points towards different training strategies adopted by Italian firms. The bulk of firm sponsored training is financed by internal resources. Continuous training- aimed at updating the capabilities of labour force- is most frequent in firms undertaking organisational changes and in firms operating in the energy sector, chemicals and machinery. The majority of firms rely on training activities oriented to update workers' capabilities and to favour the entry in the new working environment. Other objectives of training strategies are the implementation of special projects and retraining. The empirical studies lack an exhaustive analysis of firm sponsored training, specially on the incentives to provide training in conjunction with innovative activities within the firm.

Training is provided in Greece in the form of v*ocational, post – obligatory vocational, technical and continuous training*, which is resumed by a number of public services and private institutions. In particular, the vocational *lykeio* was established as the official means to rehabilitate the value of vocational training and supply industries with qualified practitioners and technicians. However, the effectiveness of vocational training is limited by the perception of "second class" education. In 1998 the Educational reform has replaced the multiple lykeio with one integrated lykeio. The *technical vocational schools* constitute a form of "middle" post-obligatory secondary education. The aim is to provide pupils who do not intend to complete post secondary education.

*Post – obligatory vocational training* at the post secondary and tertiary level is informal and is offered by different seminars and in housing programs. The aim of the post – obligatory vocational training is to provide occupation specific skills but also information technology and language skills.

*Continuous Training* in Greece has been greatly affected by the intervention of the Community structural funds and by the European Social Funds. The effectiveness of continuous training is though reduced, as it is perceived as a supplement to insufficient initial education, and thus called to perform operations beyond its specialised role.

Finally, empirical evidence on the relationship between training and innovation activities is severely limited by problems of data availability.

In France firms are compelled to provide a certain amount of training to their workers if not a fee is due. Returns to continuous training have a negative impact on labour mobility.

Work Package 3 principally involved (1) the compilation of time series of data on supply of skills in working age population as indicated under task 3.1 and (2) data on innovation, training and productivity at firm level.

In order to shed some light into the relevant differences in the trends and the levels in supply of skills between UK and European Countries time series of data on supply of skills and wages have been compiled for UK, Germany and Italy. For France and Greece only time series of supply of skills became available to us.

Time series of cross sections on firm level training, innovation and productivity were compiled for Germany and Italy. For the UK, data on innovation and productivity are available at firm level and have been widely used in previous studies while data on training can be found only at industry level.

The data on the supply of skills in UK, France, Germany, Greece and Italy are derived from microdata. The use of microdata has allowed to consider changes in supply of skills not only in labour force but as well in the whole population.

When measuring the supply of skills, the main issue concerns the relevant measure of skills to identify the existence of a mismatch. There will be always problems in tracking the differences across countries in the supply of skills. In fact, in the same "skill category" the contents of the education attained might considerably vary either if years of schooling or education levels are used.

In order to construct measures of skills comparable across countries, three skill groups have been delimited: (1) High: for those individuals with a completed college degree or more; (2 ) Middle: all those that do not follow either in 1 or 3; (3) Low no formal schooling degree attained. The evolution of supply of skills was analysed for the whole population (inactive plus active), for the inactive population and by employment status.

For each education cell the study was performed for two main age groups that were delimited in the following way: Young (individuals between 15 and 30 years old) and Old (between 30 and 64).

In the UK, the General Household Survey was used for the period 1974-1996. Vocational qualifications A-levels O-levels Voc Mid Voc, Other; the Low all those with no formal schooling. Data are in levels and the evolution of supply of skills is analysed by age and gender for each education cell

defined. Time series of data on wages by skill have been derived as well from the GHS, for the same time period.

For Germany, the *German Socio-Economic Panel* was used to analyse the evolution of the supply of skills for 1976, 1980, 1982, 1985, 1987, 1990, 1991, 1993, 1995. The High category encompasses Completed College (Universitat) or Polytechnics (Fachhochschule); the Mid category is defined as those graduating from Technical College (Fachhochschule), Pratica and Apprenticeship training; the Low category is defined as those with no qualifications. Frequencies for each of the education cells defined are available by age, gender for both total population and active population.

For Italy, the ISTAT Labour Force Survey was used for the years 1980, 1985, 1990, 1993, 1998. The High category includes all those with a degree, the Mid Students of Higher Education, Graduates of post Secondary education, Low category includes those with no formal schooling and graduates from Primary Education. Frequencies for each of the education cells defined are available by age, gender for both total population and active population. Data on wages are derived from Bank of Italy Survey on Household Income and Wealth. The wage variable is estimated from annual labour earnings net of taxes and social contributions.

For Greece, the National Statistical Office's Workforce Survey was used for the period 1987-1994. Data in frequencies are available for each education cell by employment status but not by gender and age. Data on wages and salaries by education are not available for Greece. The High category includes all those with a degree, the Mid Students of Higher Education, Graduates of post Secondary education, Low secondary school graduates Primary school graduates. The Low category includes those with no formal schooling and graduates from Primary Education.

For France, *Enquete Emploi* data were used for 1975, 1977, 1980,1985,1990,1995. Frequencies are available for each education cell by age, gender and employment status. Data on wages by education cells are not available. The High category is defined as those graduated from Universities and Grand Ecoles; Mid category as those Baccalaureat general CAP or BEP; Low those No diploma or initial education level.

The analysis of differences in the supply of skills in Europe and UK shows that the accumulation of human capital in UK has been faster starting from the mid 80s' relative to the other countries considered. UK, which shows a clear increase in earnings dispersion, is the country that counts in 1974 the lowest proportion of high skilled workers. The upward pressure in wages of high skilled relative to low skilled might in part be due to the shortage of skills relative to the other European countries.

**Applied econometric studies.**

The empirical work undertaken in the GRIT project has not been restricted to purely descriptive analysis of the relevant variables. All partners have made an extensive and intensive use of econometric methods to test a wide range of hypothesis. This section provides a summarised descriptions of the methodology followed and the results obtained.

Before doing so, it might be worth highlighting the results from the survey by Chennells and van Reenen. There is a growing concern in advanced countries that the position of less skilled workers has deteriorated, either through their ability to secure jobs and /or their ability to earn a decent wage. Some have linked this decline to modern computing technologies. This paper surveys the evidence on the effects of technical change on skills, wages and employment by examining the microeconometric evidence (taking into account studies at the industry, firm, plant and individual levels). The main focus is on studies which use direct measures of technology rather than associating technology with a residual time trend. There are three basic methodological problems relating to endogeneity, fixed effects and measurement, namely. The survey comes to the following tentative conclusions:
There is a strong effect of technology on skills in the cross section which appears reasonably robust to various econometric problems.
There is a strong effect of diffusion of technologies on wages in the cross section which is not robust to either endogeneity or fixed effects.
At the firm level, product innovations appear to raise employment growth, but there is no clear evidence of a robust effect (either positive or negative) of process innovations or R&D on jobs.

The paper by Audric, Givord and Prost assesses the on-going continuous decrease in unskilled employment in France by building time series of employment and costs of skills. The authors use a definition of skills based on the precise nomenclature of professions. Using two separate data sources, namely the “Enquete Emploi” and the “Declarations Annuelles de Donnees Sociales” (DADS), they confirm this continuous decrease up until 1992, when it stabilises. Since 1992, the contributions of employers have been sizeably reduced for those workers paid lowest salaries. They use a stylised model to assess the effect of this reduction in contributions on unskilled unemployment. Assuming that unskilled employment is substitutable with both capital and skilled employment, the impact of a fall in social contributions is quantified. The authors find evidence of a considerable effect, with the cost of such a measure becoming attenuated in the long run.

The dominant explanation for the rise in wage inequality in the US and UK and unemployment in continental Europe is that technological progress is skilled biased. However, a large body of informal literature stresses the importance of firm organisation on the demand for skills, and witnesses in the past two decades firms move toward a more flexible form of organisation, involving more skilled workers. In this paper, the authors aim at disentangling the effects of potential technological bias and organisational change onto the skilled labour demand. This analysis is made possible by means of a

tremendously rich panel of firms, with details on their employment structure according to functions (R&D, logistics, administration, production and sales) and skills (skilled, unskilled). The authors find that the share of skilled workers in employment has increased over the 1984-1995 period and that this aggregate skill upgrading cannot be explained by inter-firm nor by intersectoral job reallocations, as in the OECD countries surveyed by Berman, Bound and Machin (1998). These pieces of evidence are often interpreted as evidence of skill biased technical change. It is shown that such a reasoning implicitly assumes a large degree of substitutability between skilled and unskilled workers in all sectors and neglects within-firm functional heterogeneity and the dynamics for labour demand by function. It is found that these two hypothesis are highly problematic, at least in the French case: firms have indeed experienced a very large change in their functional mix, with a decline in the share of production related jobs and a rise in the share of jobs related to trade, development and customisation of new products. From a purely statistical point of view, this functional reallocation explains half of the within-labour shifts. At the same time, the share of skilled workers has remained highly stable within most of the functions.

A model is also developed in order to take functions into account, allowing to estimate the biases toward skilled labour without any assumption on the various elasticities of substitution. Once these functions are accounted for, technical change appears to be directly biased toward the unskilled, but indirectly biased toward skilled labour, since it promotes organisations emphasising skill intensive activities such as trade, development, customisation and other administration-related jobs, all at the expense of unskilled labour-intensive occupations such as transportation, production, etc.

Another paper investigates evidence for the 'skill bias' of organisational change. Caroli and Van Reenen use several sources of data on British and French establishments, including a panel. Three main findings emerge: (i) organisational change tends to reduce the demand for unskilled workers in both countries; (ii) organisational change is retarded by increases in regional skill price differentials (a measure of the relative supply of skill); (iii) it also leads to greater productivity increases in establishments with larger initial skill endowments. It is argued that organisational change, technology and human capital are complementary assets of the modern enterprise. The widespread introduction of new organisational forms may be an important factor in the declining demand for less skilled workers in OECD countries.

As it has been repeatedly argued above, skilled biased technical change is said to be the most important cause for increasing wage inequality or increasing unemployment risks for the unskilled in most European countries. Since the needs for skills and knowledge change quickly in economies with high technology growth and wage differentials apparently depend on skills differentials, it is obvious the need to investigate the role of private sector further training for inequality and productivity.

The paper by Ludsteck tries to explain private sector further training in the German manufacturing and service sector by technical progress (innovation proxies), firms' qualification structures and other firm

characteristics ( for example firm size). Their data only allow to investigate the role of firm-financed private sector training, i.e. we cannot say anything about the role of public subsidies or the interaction of private sector training and government training programmes.

The descriptive part of the paper reveals significant differences between the manufacturing and service sector. Whereas almost all manufacturing firms provide training (92%), the corresponding share in the service sector is only 63%. On the other hand, training intensity (measured as the share of training expenditures over total labour costs) is higher in the services sector (2.3%) than in manufacturing (1.5%). Furthermore, the manufacturing sectors appear much more homogeneous than the service sectors with respect to training intensity. For example, the largest difference in training intensity between manufacturing sectors is about 0.15%, the largest difference for the services is 0.5%.

An econometric model explaining training intensity by firm size, innovation proxies, the qualification structure of the firm and other control variables shows that the qualification structure is the most important determinant of a firm's training expenditure. The share of training expenditure over total costs is significantly higher in firms with higher shares of high qualified personnel (technicians, masters and employees with completed apprenticeship training) has no significant impact on training expenditures. The econometric model also shows that the impact of the qualification structure on training intensity is about twice as high in the service sector as in manufacturing.

As regards innovative activity, the model shows that firms which undertook both product and process innovations have a significantly higher share of training expenditures in total labour costs. Again, innovation impacts are higher in the service sector. Data on expenditures for information technology (IT) investment, which appear as a very direct indicator for technical progress, were available only in the service sector. Here the econometric model shows that firms investing in IT have significantly higher training expenditures, but the functional relationship between It investment and training expenditures is not conclusive. Finally, the authors do not detect any clear pattern for the interrelation between firm size and training expenditures in their model.

To summarise, it can be said that technical progress raises private sector further training expenditure. As regards wage inequality, they find that private sector training is likely to increase the skill gap, since firms with a large stock of human capital tend to train more. Likewise, training expenditures are higher in skill intensive sectors.

Whereas most of the literature concentrates on highly skilled and unskilled employees while skills are frequently measured rather crudely. The impact of innovation and IT activities on the majority of the labour force –those employees with an apprenticeship certification- is unknown, however. In addition, the results of most studies depend on the kind of innovation, the definition of skill and the period under consideration. The focus of this paper therefore is on the correlation between medium skilled workers with a degree from the German Dual Apprenticeship System and innovative activities. Besides,

estimation and data problems usually occurring in the skilled biased technology literature are addressed on the basis of a topical and rich data set. The paper shows that innovation expenditures and investments in IT lead to lower medium skilled worker shares, whereas non IT investments lead to higher shares.

Estimation techniques which take into account the double censoring of the medium skilled worker shares have to employed. As the consistency of the Tobit model depends on the normality and homoscedasticity assumptions on the error term, a heteroscedastic Tobit model and tow semiparametric methods (censored least absolute deviation and symmetrically censored least squares estimations) are employed to check the robustness of the results. All estimations lead to similar results and therefore the potential violation of the assumptions does not have an impact on the conclusions.

The negative correlation between innovation and IT intensity and medium skilled labour demand indicates that job opportunities for the majority of the employees in Germany in the most promising sectors are decreasing. It is unclear at this stage, however, which are the reasons for the low demand of employees with an apprenticeship degree in these firms. Additional research seems necessary to derive adequate policies affecting the attractiveness of medium skilled workers for innovative and IT intensive firms.

An additional paper by Salvatore Torrisi examines the same issues for Italy. This paper analyses a sample of 3,525 Italian manufacturing firms with the aim of assessing the impact of Information & Communication Technology (ICT) on productivity and employment. The work draws on a data set provided by Mediocredito Centrale. This dataset provides quantitative and qualitative data at the firm level, part of which are collected by Mediocredito Centrale through periodical surveys of representative manufacturing firms in Italy. Balance sheet data for the sampled firms were also provided. The sample excludes firms with less than 11 employees.

The analysis shows that ICT have a significant impact on the productivity of firms in several sectors. These effects are insignificant within high-tech sectors most probably because productivity gains arising from ICT have mostly occurred before the sampling period for these firms. The results indicate that there are remarkable intra-industry differences across firms in terms of ICT intensity. For example, there are firms in traditional sectors like textiles, clothing and furniture which invest more than the median firms in all the other sectors. This suggests that firm-specific factors tend to play a much more important role than industry-specific ones. It also suggests that the traditional distinction between high and low tech sectors becomes blurred in the “new economy”. Finally, it stresses the importance of growth and competition policies centred on enterprises rather than industries or “technolocial filiere”.

Contemplating the less well explored hypothesis on the skill bias induced by trade, the paper by David Thesmar, “Trade Induced Skill Bias”, assesses the known hypothesis according to which increased exposure to trade with countries with a more intensive use of less skilled workforce will tend to

increase the skill premium. Using a more sophisticated theoretical model of trade and French customs data, it is found that the contribution of trade to the skill bias has been underestimated in the past.

Parallel to the appearance of the so called "skill-bias", there is a growing concern about the joblessness risk in most Western countries. It is especially important to assess whether the risk of losing one's job actually changes over time and whether this is mainly due to variations in the macro-economic environment, to changes in the labour market institutions or even linked to the effect of technological changes on the organisation of the workforce within and across firms. To address these issues, the paper develops a model for hiring and layoffs that makes it possible to separate these effects with firms continually adapting their job structure to different shocks. This model is used to analyse and interpret the evolution of job stability in France between 1982 and 2000. The data from the French Labour Force surveys highlights a structural increase in the risk of job loss in France for both high and low-seniority workers, which cannot be explained by changes in the macroeconomic environment itself. By comparing the recession periods in the 1980's with those in the 19990's, the latter are found to be bigger, the same applying for expansion periods. In the context of the theoretical model used in this paper, such an overall decline in job stability can hardly be explained by the kind of labour market institutions that were introduced in France at the end of the 1980's to make the labour market more flexible. In particular, the increase in risk of losing one's job is pervasive to workers with different seniority levels, whereas labour market reforms made layoff procedures substantially cheaper for firms dismissing low seniority workers. On the contrary, the estimated increase in the risks of job loss are consistent with a persistent drop in the relative productivity of high-seniority workers relative to that of low-seniority ones.

It is important to note that not all the econometric contributions have been constrained to the analysis of the demand for skills. The following series of papers address the factors explaining why individuals decide to improve their own skills and why firms choose to invest in their workers human capital.

The recent economic literature on the participation of firms in apprenticeship training underlines the fact that firms may gain from this participation. Asides from firm-specific human capital in the sense of Becker, 1964, and Hashimoto, 1981, which may be included in the training, returns may come from a direct production value of the apprentices during their training. Other returns may come from wage compression, due to asymmetric information between the training firm and other firms in the market concerning apprentices' ability. The informational asymmetry may result from a screening process during or before training as well as from other firms' uncertainty about the post training production value of apprenticeship graduates changing firms, which limits the transferability of the training contents.

If the combined returns described above net off the training costs within a given firm there is a sufficient condition to observe that particular firms train apprentices. However, the returns due to

asymmetric information are future returns from the point of view of a firm which decides whether the apprentices stay after training: As a role, it is not possible for firms to conclude binding contracts with their apprentices that would oblige them to stay. A firm which trained a given apprentice has to compete for this apprentice with all other firms in the market as well as with non-market opportunities of this apprenticeship graduate. At the time of the investment in apprenticeship training, firms will therefore calculate expected values for these future returns based upon their previous experience with the post-training behaviour of former apprenticeship graduates. The relevant measure here is the so called retention rate, defined as the percentage of apprentices who stay with their training firm after training, because only with those  a training firm may gain future returns to training. This is why, in order to infer on potentially training firms' expectations about the future returns from training it is of interest to analyse the transition of apprenticeship graduates to the labour market with respect to their motivational background, i.e. their responsiveness to various sorts of incentives.

The paper by Bender and Schwerdt first analyses the interaction of possible incentives during this transition; The training firm's wage offer, outside wage opportunities as well as other economic or non economic incentives individual apprenticeship graduates face at the end of their training. A model is presented, based on the assumption of utility maximising agents, incorporating the various motivational factors, and then estimated using a matched German employer-employee data set. Because the emphasis is made on the interaction of competing opportunities, a reduced form model is chosen where wage offers are considered explicitly as explanatory variables. In order to avoid a possible endogeneity problem, the training firm's wage offers and the apprentices' market opportunities are instrumented. By calculating expected utilities apprentices receive from different options faced, it is possible to obtain an insight into the relative bargaining power of training firms, which will also influence their calculation of expected future returns from training.

There has also been a substantial development in the theoretical literature concerning the motivation of firms to invest in human capital of not a purely firm-specific type and especially to invest in apprenticeship training. The usual reasons for this type of behaviour may basically be divided into two arguments: The first motivation may come from a reduction of costs of non-qualified work: Apprentices in this case are hired because they are cheaper than unskilled workers while accomplishing the same tasks. Additionally, by hiring apprentices firms may more easily and at a lower price adapt their unskilled workforce to business cycle needs. This motivation is called the current production argument. A second argument proposes that firms may want to invest in human qualified capital, especially if they face shortages on the labour market for skilled work. In this case their motivation will depend on the expected composition of the qualifications offered in the open labour market as well as their level firm-specific human capital employed in the production process. This argument will be referred to as the investment argument.

Whereas the investment argument is related to an expected profit, the current production argument is based on the comparison of the production value of apprentices during their training period with the

direct costs of training. Recent results show that in France, the current production argument seems to be more relevant because of relatively costly unskilled labour. The same may be true for Germany where for small and medium sized firms the current production argument may be a sufficient condition to train apprentices. However, for the time being there is no reliable evaluation of the actual productivity of apprentices during their training that may give a mean test the relevance of this argument. This is mainly the task which is accomplished in the paper by Fougere and Schwerdt. Two data sets are employed. The first contains about 10,000 French firms observed in 1992 from the Survey on the Cost of the Workforce and the Wage Structure (ECMOSS) which is matched to the Survey on Industrial and Trade Profits (BIC), both surveys of the INSEE. The second data set is an extraction of the German firm panel of the Institute for the Research on the Labour Market and Firms. This allows to observe 4,500 firms of all industrial sectors.

Estimations are made based on Cobb-Douglas and Translog production functions. As only apprentices in a subgroup of firms are observed, a probit selection equation is used resulting in a switching regression model with endogenous selection. This allows to control for the process determining why some firms decide to train workers and some others not.

A profound structural difference between small and large firms is found. For small firms in France and Germany, negative net costs during the training period may be a sufficient condition for training to take place. Especially with small German firms, there is evidence of a strong involvement of apprentices in the production process. For larger firms, the observed behaviour does not seem to be consistent with the current production argument.

Second, the decision to stay on in education after the compulsory schooling age was also investigated. Houillier and Machin have looked at the aggregate enrolment decisions by UK cohorts in order to estimate a time series based higher education supply equation. The evidence supports the view that the staying on decision is at the margin highly influenced by current labour market conditions, particularly unemployment. Besides, individuals appear to be responsive to the existing wage premium, which in the case of countries with short higher education courses is a good approximation to their own expected wage premium. This responsiveness is also shaped by the direct cost of additional education as embedded in tuition fees and availability of student loans. In this context, a model based on human capital investment incentives (without dismissing other considerations) does seem to do a good job in explaining UK data.

The GRIT project has also undertaken econometric research on the process driving innovations by firms which are at the heart of any sustainable process of economic growth.

Duguet has assessed the issue of whether subsidies crowd out privately funded R&D using firm-level data from French research surveys. The critical issue is to identify how much subsidised firms would have invested in R&D had they not been subsidises. The absence of this counterfactual imposes the use

of non experimental methods to control for the fact that unobservable factors affecting the reception of subsidies are expected to be associated to the process that determines a firm's choice of innovative activities.

Out of a growing concern that inputs into the innovation process were insufficiently covered by the mere notion of R&D expenditures as defined in the Frascati Manual (OECD, 1963) that the input of that process ought to be better measured than indirectly by patent grants or applicatons, and, last but not least, that some quantitative information was lacking on the organisation of innovation and the flows of knowledge, statistical experts of the OECD sat down to formulate the Oslo Manual (OECD, 1992) which set out the guidelines for the formulation and the design of innovation surveys. A number of countries have launched by now at least two or three innovation surveys.

In Europe, these surveys are known as CIS (Community Innovation Surveys). They are conducted in more or less the same fashion in all countries, although in the first round of surveys (CIS1) major differences existed for instance in terms of coverage, sampling, question asked, reporting unit, and organisation of the survey. Eurostat assembles the country data, fills in some missing values, and harmonises the data to make them as much as possible suitable for international comparisons. To protect the confidentiality of the data, the CIS data are made available to a limited number of researchers in microaggregated form.

To compare innovativeness across industries or countries, Mairesse and Mohnen authors have proposed a predicted innovation indicator. This indicator uses various pieces of information retrieved from the innovation surveys to construct an expected percentage of innovative sales controlling for a number of exogenous variables influencing innovation. The purpose is twofold. First, check the robustness of the indicator to the use of microaggregated data. The second object of the paper is to illustrate the use of this predcited innovation indicator. It is applied to the French CIS2 data to compare innovation across French manufacturing sectors and to CIS1 data of seven European countries to compare innovation across countries.

**Theoretical contributions.**

The survey by Galindo-Rueda provides a review of the state of the art of the literature on growth, inequality and human capital accumulation through training. On the link between inequality and growth, redistribution frequently appears as a burden on the overall performance of an economy because of the distortions that affect negatively private incentives to invest. However, inequality is also shown to perpetuate inefficient outcomes arising as a result of market failures that restrict individuals' ability to maximise their potential welfare. These market failures are bound to have a particularly strong impact on the accumulation of human capital is concerned because of its immaterial nature. The problem of identifying individual and group capacities is likely to introduce significant externalities and credit constraints which limit the effectiveness of the market to implement optimal allocations in the economy.

The interaction between human capital and growth has been analysed from two different perspectives. Some authors insist on changes in human capital as the engine behind growth. A more recent approach suggests that it is not only human capital accumulation, but also its level, what determine the extent to which an economy can grow. This is shown to have important implications for inequality within and between countries, as initial inequalities may tend to persist under the second interpretation.

The survey also attempts to distinguish conceptually the role of training with respect to growth and inequality from other sources of human capital, such as formal education. Besides, training has been subject to a multiple characterisation depending on the type of skill that it provides (general vs specific) and who pays for it (worker or firm). Relationships of complementarity and substitutability arise between all these alternatives, producing a rather complex image of the meaning of human capital. This problem becomes more acute when we consider alternative theories such as the screening hypothesis of education, whereby the rationale for these investments is not so much to increase skills but to provide evidence of one's ability in a world where information is not symmetric.

Another source of concern in the theoretical literature is the interaction between the process through which workers become more skilled and investment decisions faced by firms. It is acknowledged that if we depart from the conventional Walrasian description of markets, strategic interactions will take place between both decisions, thus originating multiple equilibria with different properties. In many occasions, these equilibria can be Pareto ranked, showing how the economy can find itself anchored in poverty traps or vicious cycles of poor investments in R&D, low innovations and shortage of skills in the labour force. In such a situation, there will be a case for active policies that allow the economy to move to *better* equilibria.

The survey also reports on recently published papers that challenge conventional wisdom about the link between types of human capital and firms' incentives to contribute to their acquisition by workers. The traditional beckerian argument is broken as firms develop a considerable degree of monopsonistic

power by realising their incumbent informational advantage with respect to other firms and the progressive but endogenous specificity of the human capital acquired through training.

It is at this point when it becomes clear the importance of institutional aspects for disentangling the links between innovation, training and inequality. Therefore, it is explored the theoretical significance of trade unions, minimum wage and flexibilisation policies in the labour market. The literature has only recently started paying attention to these issues, as globalisation and technical and organisational changes cannot explain the rich variety of stylised facts which are being currently observed in developed economies. More than competing explanations, institutional factors seem to shape the effect of such global trends on the performance of modern economies.

A number of contributions within the GRIT project address the theoretical significance of the "skill-bias" phenomenon from a wide range of perspectives. These contributions assess the relative plausibility of competing interpretations in the light of the available empirical evidence, addressing a series of apparent logical inconsistencies.

For example, Decreuse echoes from previous work by Nickell and Bell, who show that unemployment differentials have followed non-monotonic trajectories over the period 1970-1992. From the 1970's to mid 1980's, the ratio of low to high educated unemployment rates has risen. Then, for a vast majority of OECD countries, the ratio has fallen. According to Nickell and Bell, the economy is hit by productivity shocks, which could either be biased against unskilled labour or neutral. They discuss theoretical mechanisms supporting the view that neutral shocks have a greater impact on the skilled unemployment rate than on the uskilled one. They conclude that biased shocks must have dominated during the 1970s, then neutral shocks have occurred. Obviously, this conclusion is in contradiction with the existing literature on the rising disparity of earnings.

The paper by Decreuse provides an alternative interpretation. Non-monotonic paths in relative unemployment rates can be caused by the (optimal) supply responses to a permanent or only temporary productivity shock biased against the least skilled workers. Namely, in response to a shift in demand against unskilled labour, households alter their schooling choices and a larger proportion acquires skills. If the unskilled labour force is immediately affected by these changes, the proportion of skilled in the labour force is not modified until new cohorts of students have completed their schooling. This delay alone can cause the empirically observed dynamics of unemployment differentials. The authors highlight demographic dynamics that are endogenously driven by the optimal response of schooling to changes in the economic environment.

This paper relates demographic effects from technological change to inequality in the distribution of wealth. It is suggested that the most unequal economies are those where the rise in the global unemployment rate is the sharpest. It is also those where unemployment differentials are the most

likely to exhibit non-monotonic patterns. The more dispersed the distribution of wealth, the lower the demographic impact of skill-biased technological change.

The model also shows that unemployment differentials eventually increase. This property is due to the permanence of the productivity shock. However, a temporary shock induces no structural change in the composition of the labour force, i.e. no modification in the relative proportion of skilled. To obtain structural changes, a social externality of education is considered. The higher the proportion of skilled, the easier the access to higher education. Multiple equilibria naturally emerge in that setting. A temporary shock allows the economy to reach an equilibrium with a larger number of skilled, generates a bell pattern in unemployment differentials and does not have an impact on long-run unemployment differentials.

Another paper by Decreuse tries to reconcile human capital theory with the observed simultaneous increases in unemployment, education attainment and over-education indexes. Previous papers have stressed two main predictions. First, unemployment is detrimental to education. Unemployment means that human capital remains idle over long/frequent unemployment spells; this tends to discourage education investments. Second, workers invest too little in general skills. Due to matching frictions, there is room for rent-sharing and wage bargaining. As workers bear the full cost of education and only get a share of the reward, they under invest in skills.

However, these predictions are challenged by the evidence. Firs, most European countries have witnessed a simultaneous rise in education levels and in the incidence of unemployment. This suggests that unemployment and education may well be positively correlated. Second, empirical studies present some evidence on over-education, such as falling returns to schooling, mismatch by education and rising wage dispersion within workers of a given educational attainment.

In this paper, a simple argument is explored, based on workers' heterogeneity and employers' recruitment practices. In a situation where unemployment is high, heterogeneous individuals have different incentives to invest in human capital. High ability workers acquire general skills to achieve higher earnings; unemployment is detrimental to their educational effort. Low ability workers are compelled to schooling to improve their employability. Unemployment raises their incentives to undergo extra schooling.

In the model, workers have heterogeneous returns to schooling and bear the risk of unemployment because of a random matching process. To account for non-trivial hiring strategies, firms are required to buy a unit of scarce resource prior to the opening of a new vacancy. The quantity of this non-reproducible input is thus complementary to labour in the production process and determines the size of the market. Consequently, firms intend to allocate their vacancies at best and discriminate among the applicants. The existence of a hiring standard implies that workers are sorted in three different groups: for the least able of them, it is not profitable to invest in education. Since they cannot reach the

reservation productivity, their skills will not be marketable. For the ablest, the existence of the hiring standard has no influence on their education behaviour since their productivity is naturally above the standard. An intermediate class of workers is constrained to raise its education effort in order to reach the reservation productivity and compensate its initial disadvantage in terms of ability. These workers overinvest in education, in the sense that the marginal return from their investment is lower than its cost. However, it is nevertheless profitable for them to undertake such an effort, since they would otherwise be excluded from the labour market: the private return to their participation is positive.

The results are twofold. First, unlike standard models with human capital, the relationship between education and unemployment is not necessarily negative. Consider a rise in unemployment. If that increase is primarily due to an increase in short-term unemployment, then education levels must fall. Conversely, if it is mainly caused by a rise in long-term unemployment, then education efforts must increase. Importantly, an increase in the strictness of employers translates into both an increase in long-term unemployment, and a decrease in short-term unemployment; consequently, schooling efforts rise.

Second, the fact that some workers are obliged to over-invest in skills at the microeconomic level is in line with the empirical evidence. Typically, overeducated workers get lower wages than their coworkers with a natural education; returns to overeducation are nevertheless positive –a typical result. But private overeducation is a poor index to assess whether over or under-education takes place at the macroeconomic level. The main reason for this is that workers misperceive the returns to schooling. Due to non-competitive wage determination, the private returns to natural education are lower than the social returns. Private overeducation is thus compatible with undereducation from a social perspective. In addition, there are two other externalities; the first one is a standard congestion externality. If the number of firms were too high, private returns to schooling might exceed social returns. The second is directly related to microeconomic overeducation. For a given hiring standard, workers choose to enter the labour market as long as the reward of education is greater than its cost. Since the marktet size is limited, any increase in the participation rate translates into both higher employment –more participants means more contacts between unemployed and vacancies – and unemployment – due to the congestion externality, the individual probability to find a job decreases in the number of unemployed. This may result in an output loss (net of schooling costs). Therefore, a policy aimed at rising natural educational attainments must also deter the least able from pursuing extra education.

Another study investigates the result of the various incentives to invest in general human capital on the labour market performance when workers face unemployment risks. One of the most striking features of the European labour markets it that unemployment has remained persistently high over the past decades, while education levels have soared. In this paper, Charlot, Decreuse and Granier argue that a potential explanation is that in a situation where unemployment is high, workers have more incentives to undertake longer studies when education increases their probability of finding a job. From an empirical point of view, employment opportunities are clearly related to education levels.

However, the predictions of standard models are not in line with this evidence: in these models, unemployment is detrimental to investment in human capital. The reason is twofold. First, the only incentive to invest in education considered is an increase in productivity. As a consequence, a high unemployment rate implies human capital remaining idle for longer fraction of time, which lowers the effective return to education. Second, the cost of education is generally independent of the state of the labour market.

This study differs from the previous in two aspects: first, education increases both productivity and adaptability. Second, education takes time. By "adaptability" it is not meant that workers have a different ability to adapt to technological change, but that education determines the range of technologies a worker can operate and, therefore, the number of jobs she can apply for. When education makes the labour force more adaptable, the higher the overall educational attainment becomes and so the number of workers able to apply for the same type of jobs. The latter aspect implied is the concept of education as a time consuming activity. Then the private cost of education corresponds to the value of foregone earnings during the studies. Decreuse assumes away any direct private costs of education such as transportation or tuition fees: in most European countries, the education system is public and its direct cost mainly subsidised by the State. Consequently, in a situation where unemployment is high, the reward to an additional year of study is low but unemployment also reduces the opportunity cost of education.

The results under this setting are the following: (i) when education increases workers' adaptability, the education attainment is positively related to the job destruction rate and negatively related to the labour market tightness. Unemployment therefore increases the incentive to invest in education. As a result of this, two countries with different unemployment rates can be characterised by similar educational attainment of the population provided their job destruction rates differ. (ii) Because of its effect on educational efforts, a rise of in the job destruction rate can lead to a higher exit rate from unemployment and short unemployment spells on average. This feature also sheds some light on the puzzling example provided by the case study of Australia vs Canada. In Australia there is less job destruction and fewer unemployed, but the incidence of long-term unemployment is significantly higher too. This cannot be explained by a standard matching model with exogenous job destruction where an increase in the job destruction rate reduces job creation and increases both standard and long-term unemployment. This phenomenon is accounted for by this model, since Canadian workers facing a higher risk of being unemployed undertake long studies (see OECD, 1995). (iii) The market outcome is generally inefficient: both over- and undereducation are possible outcomes. If the only incentive to invest in human capital were an increase in productivity, the duration of studies would be too short. But if the only incentive to invest in human capital were a larger probability of finding a job, the duration of studies would be too long. (iv) The Hosios condition is not sufficient to ensure the outcome is efficient, but if it is met, the first best of the economy can be decentralised by means of a voucher to students (tuition fee) when under (over) education takes place.

Over the past decades, European countries have witnessed major changes in the labour market. One of the most striking evolution is probably the deterioration in employment opportunities for both high and low educated workers. It is usually argued that the demand has shifted away from the low educated towards the high educated. But this does not explain why the employment perspectives of the latter did not improve since changes in the economic environment (such as the emergence of new technologies, or international competition) seemed to favour them. In another paper, Charlot and Decreuse suggest that education policy may be held responsible for this.

It is showed that when the mean productivity of each education group is negatively correlated to the share for high educated in the population, a less stringent education policy aimed at increasing the number of high educated in the population may generate simultaneously: (i) a rise in educational attainment, (ii) a rise in all unemployment rates by education groups, (iii) a fall in the returns to schooling, (iv) overeducation in the labour market.

The basic argument is the following: a subsidy meant to increase the incentives to schooling leads to a rise in education attainment, thus the ablest among the former low educated now become high educated. As a result of this, the mean productivity of the whole population rises, but the mean productivity of each education group falls. This depresses the demand for each kind of labour and reduces employment opportunities for all. This raises questions about the optimality of the decentralised equilibrium.

The model is based on two main assumptions: first, the existence of two sectors is assumed, on for the high educated and one for the low educated. Thus schooling choices become equivalent to occupational choices. Second, workers are heterogeneous and their productivity can be divided into two components. The first component is worker specific and denoted “ability”. The other one is sector specific and can be related to education. The main difference between the two components is that the access to the most efficient technology can be purchased (via education) whereas ability is innate. Both have an impact on individuals’ performance on the labour market. The result is that a rise in the number of high educated workers increases the global productivity but decreases the mean productivity of the two groups in the workforce, since the ablest among the formerly low educated now become high educated. This allows to account for the changes in unemployment that have been depicted. Additionally, it is empirically plausible that considerable changes in the composition of education groups have occurred during the past twenty years.

Overeducation takes place because of the alteration in the skill structure of the workforce, leading not only to a change in the mean productivity of both skill types, but also to a change in the amount of search expenditure incurred by firms. Conventional wisdom argues that the cost to recruit an applicant is at least compensated by the expected output value generated by the applicant. However, this might not be the case in a decentralised economy with heterogeneous workers. Employers never turn off the applicants, not even those whose productivity is below the average search cost. Therefore, the workers

are not driven to take into account the impact of their schooling on decisions on recruitment expenditures. From this perspective, education policy is a tool that might compensate this inefficiency by controlling the ability level required to become educated. This argues in favour of more stringent standards in education.

The institutional hypothesis of differences in wage inequality patterns in the presence of skill bias has been assessed from a theoretical point of view by Galindo-Rueda. This paper argues that depending on the distribution of skills in the population and on the relative productivity of skilled workers, firms will decide whether to create jobs strictly designed for specific skill types by choosing extreme levels of investment or to create jobs for which no skill discrimination would (optimally) take place. The notion of irreversibility is crucial for this result. On the one hand, if firms have to commit to a certain match-specific investment plan, it will not always be optimal to accept less skilled workers, as wage bargaining will not incorporate the investment cost. Thus, a firm might prefer to keep on waiting for a better match. Nevertheless, if a firm cannot prevent the total sum of such cost by refusing to engage in production with a worker, such type of equilibrium will be far less likely, as this refusal will not be plausible ex post. Therefore, in the presence of irreversible costs such as screening costs, tight firing and hiring regulations, etc, firms would have incentives to design jobs with lower levels of match specific capital and discriminate less on the basis of skills.

This theoretical benchmark is consistent with observed inequality patterns. In the presence of a similar type of skill bias, whereby skilled workers' relative productivity increases, across countries, we would observe a change in regime towards more discrimination only in those countries whose institutional framework implies a lower degree of irreversibility, as explained above. For a given magnitude of skill biased technical change, the response across countries is not identical: less rigid countries experience a larger degree of inequality following the creation of jobs where more capital is invested, whereas firms in more rigid countries do not find optimal to risk creating such type of jobs, discriminate less and therefore inequality will not increase to the same extent.

Another contribution which considers institutional factors as crucial for understanding differences between the wage distribution across countries has been made by Galindo-Rueda. In his model, he explores potential incentives on individuals to invest in a type of education which allow to signal themselves as high ability workers. The paper provides a conceptual framework for signalling behaviour in a frictional dynamic labour market. It is highlighted the fact that an equilibrium with education signals is only possible in a labour market where firms are somehow constrained in their ability to dismiss workers. Besides, identical conditions can give rise to multiple steady-state equilibria that differ in the proportion of the population educated and firms' willingness to screen any type of worker.

The theoretical results provide a framework where to assess the relative importance of education as an institution enhancing human capital or as a signalling tool. Exogenous policies affecting the flexibility

in the labour market predict opposite effects in the occurrence of observed overeducation, thus suggesting a way to characterise educational systems across Europe. The need for such type of evidence is not spurious at all, as previous empirical works dismiss the screening hypothesis on the basis of stylised facts on mobility, training and wages that are easily replicated by the pure education-signalling model.

Wage and income inequality has become a common phenomenon in many advanced countries. Existing studies have focused on two explanations –the effects of international trade, and skill biased technical change. In the former explanation, growing international trade implies increasing demand of goods that are unskilled labour intensive in the less advanced countries. This reduces the demand for unskilled labour in the advanced countries, and hence their wage. By contrast, advanced countries specialise in goods that are skilled labour intensive, which increases the demand for that type of labour, and their wage. The skill biased technical change hypothesis explains inequality from the rising demand for skilled labour due to the skill bias of technical progress.

The paper by Gambardella and Ulph examines this issue from a slightly different perspective. Specifically, it suggests a new but rather simple reason inequality. Most notably, inequality may stem from the fact that skilled and unskilled labour have been complementary in industrial production. The complementarity is apparent if one thinks of the classical manufacturing industries which employ both engineers and manufacturing workers, or marketing strategists and simple salesmen. Many new industries nowadays, and particularly new services like those created by under the auspices of the information technologies, are typically skilled labour intensive. Thus, factors that increase the demand for skilled labour by such new industries shift skilled workers away from the "old" sectors. Because of the complementarity with unskilled workers, this reduces the productivity of the latter. Hence, their wages are reduced. By contrast, the growth of the new industries implies that skilled workers move towards the new industries up to the point where their productivities in new and old sectors are equal. This implies that their productivity increases as new opportunities arise in the new sector, and this is true of the skilled workers employed in both the old and the new sector. Ultimately, this means that with shocks that favour the growth of new industries that are skilled labour intensive, the productivity, and hence the wage, of the unskilled workers declines, while that of the skilled workers increases, leading to more wage inequality. The culprits are then simply the complementarity between skilled and unskilled workers in the traditional manufacturing industries, and the skill intensity of the newly rising sectors.

If one assumes, as in this paper, that new sectors are characterised by increasing returns, an even move interesting phenomenon arises. Specifically, it is assumed that, unlike the old sectors, the new ones exhibit increasing returns to high skills. A typical example would be the new software based industries, wherein a longer history of software production (vs more skilled workers employed by the industry in the past) implies that new software can be developed by selecting from a wider pool of previously developed re-usable codes. Under these conditions, the rise of the new industries depends on the

critical mass of skilled workers that choose to move on to the new sector. In particular, there is a threshold level of skilled workers that has to move onto the new sector for the latter to arise. Using a more technical language, there are two equilibria. In one equilibrium a threshold number of skilled workers moves to the new sector, and the economy will exhibit two industries, new and old. The effect of the presence of the new industry is to raise inequality because of the lower complementarity of the unskilled workers with skilled ones in the old sector. In the other equilibrium no skilled worker would move to new sector. The latter does not arise, and inequality is less marked because the skilled workers keep exerting their higher externality on the unskilled ones in the traditional manufacturing industries.

The model developed in this paper appears to explain a number of interesting facts occurring in the advanced industrial economies recently. First, it explains the rise of new industries that look very much like the newly arising sectors that stem today from the growth of the information technologies. Second, it suggests that such new sectors can give rise to potential inequality because they shift away complementary assets to the unskilled workers. Put differently, it suggests that the traditional manufacturing industries, typically organised around large firms, were inherently consistent with lower inequality. Third, it explains why the growing inequality appears to be different in different countries or industries. Most notably, it is lower in industries or countries where the traditional industries are quite efficient. This limits the outflow of the skilled workers to the new sectors, and hence prevents inequality from arising. Relatedly, this model shows that for the new industry to arise, a critical mass of skilled workers has to move to the new sector. In short, for such a new sector to arise, some coordination (hence policy) is required.

Finally, the model developed in this paper is not inconsistent with explanations based on skill biased technical change. However, one interesting implication of the model is that under the two equilibria, skilled biased technical change can give rise to two profoundly different types of inequality. In particular, the equilibrium with new industries implies more inequality through larger wages for skilled workers and vice versa. By contrast, in the other equilibrium inequality follows from larger increases in the wages for skilled workers compared to the unskilled. Wages for the latter also increase because of the complementarity between both skill types, and hence skill biased technical change is Pareto-improving, whereas in the former equilibrium it is not.

Over the past 25 years, the US and the UK experienced sharp increases in wage inequality and rapid deunionisation. Acemoglu, Aghion and Violante argue that these two phenomena are related, and that skill-biased technical change is at the root of deunionisation as well as the rise in inequality. Skill-biased technical change causes deunionisation because it increases the outside option of skilled workers, undermining the coalition among skilled and unskilled worker supporting unions. This approach implies that although deunionisation is not the direct cause of the increase in inequality, it simply amplifies the direct effect of skill-biased technical change by removing the wage compression imposed by unions. This research also shows that deunionisation may happen inefficiently.

It has been observed that firms which are apparently similar make rather distinct offers for workers with identical characteristics as far as their productivity is concerned. It has been suggested that unobservable characteristics can indeed account for some, but certainly not all, of the observed wage heterogeneity and, in particular, recent increases in wage dispersion in the United States and in the United Kingdom.

The paper by Galindo-Rueda reflects on the rational for endogenous wage dispersion (and hence inequality) in a labour market where employed individuals are aware to some extent of offers made by other firms. Incentives to offer higher wages that some minimum value (flow value of unemployment) do exist in this economy because firms can substantially increase the likelihood of receiving applications and, simultaneously, reduce the probability that incumbent employees, whose hiring process has been costly for the firm, find better offers and decide to quit.

This paper presents a model of endogenous wage and technological dispersion where heterogeneity is driven by search on the job and matching frictions. Microfoundations for these frictions are introduced by means of an urn-ball matching technology. The most striking result is the existence of a continuum of atomless disperse equilibria, in contrast with similar models with wage posting that choose to adopt conventional aggregate matching functions. This extreme type of multiciplicity can be understood as the result of the changing degree of competition for a job faced by an unemployed individual, which depends on the distribution of offers and the distribution of wages for currently employed individuals. Unlike with aggregate matching functions, market tightness does not uniquely define the probability of leaving unemployment.

Additionally, by considering simultaneous decisions on wages and match-specific capital, it is possible to derive positively skewed distributions for wages and capital. Because of the multiplicity result, it is impossible to conduct clearcut comparative statics exercises. Nevertheless, an increase in the minimum wage is shown to be potentially welfare-improving by not increasing unemployment substantially and enhancing wage and capital decisions by firms.

Over the past decades, the rise in European unemployment has been associated to a massive increase in long-term unemployment: in 1996, over 60% of the nine millions of long-term unemployed in the European Union had been out of work for over two years. Long-term unemployment seems to have a very weak tendency to correct itself: workers lose some of their skills during unemployment, this making them less attractive to firms, reducing their change of getting a job and discouraging search activities. Thus, long-term unemployment gives rise to a vicious circle and there is room for public intervention. Active labour market policies (ALMP) has been repeatedly undertaken in most OECD countries as an attempt to counter the effects of skill decay. In 1996, a typicial European country spent on average 1.2% of it s GDP in active labour market programmes, according to the OECD. It seems that these policies have achieved a large success: cross country studies do not systematively highlight a robust econometric relationship between key macroeconomic aggregates such as real wages or the

natural reate of unemployment and various measures of the size of ALMP. Panel data investigations are generally led to the conclusion that that some programmes may effectively improve individual earnings and employment perspectives, but that gains from these are not sufficiently large to cut unemployment nor to significantly reduce poverty. It is nevertheless generally recognised that retraining the unemployed generally proves to be a better strategy rather than other schemes aimed at improving the employability of workers, both in terms of the individual probability to leave unemployment and gains in expected earnings.

The lack of concrete effectiveness of ALMPs is often attributed to the fact that they may only displace the problems: positive discrimination towards the long-term unemployed may well be beneficial to them but could also induce a diminished hiring of short-term unemployed. Firms accept hiring subsidies but would might have hired workers anyway. It is also often argued that ALMPs weaken workers' incentives to search or even to maintain their skills.

In the study by Charlot and Decreuse, skill decay introduces two different kinds of distorsions: on the one hand, job seekers progressively become discouraged during their unemployment spells, their search intensity is reduced and they finally give up search altogether. On the other hand, employers facing the low productivity of those who have experienced long unemployment spells discriminate against the long-term unemployed. In this setting, two alternative ways to fight long-term unemployment are considered: The first consists in retraining the unemployed, the second implies a subsidy mean to reduce employer's reluctance to hire the long-term unemployed (positive discrimination). It is argued that ALMPs have mixed results because of their adverse effects on workers' search effort and firms' hiring behaviour. Even when ALMPs raise workers incentives to search, they may nevertheless fail to be met with a large degree of success because with a higher average quality of the workforce, employers might be more reluctant to hire those workers worst ranked. It is argued that retraining programmes have better performance than hiring subsidies targeted towards the long-term unemployed since they tend to increase search efforts, have a positive impact on the reduction of unemployment and raise the average productivity, yet their impact on workers' employability is generally ambiguous.

Another very much debated option of economic policy against long-term unemployment is the introduction of measures promoting work-sharing. The paper by Moutos evaluates two approaches to work-sharing by examining both within the same macro model. The standard approach involves imposing a quantity constraint on labour market participants (a maximum number of standard hours for each worker). This approach is compared to a revenue-neutral employment subsidy financed by a tax on overtime hours –an initiative intended to harness market incentives. The paper shows that the second approach brings much preferred results –it involves lower unemployment, higher investment and no reduction in the wage earnings of those already employed. The analysis suggests that policy makers should not reject work sharing just because they are (justifiably) sceptical of mandated reductions in hours.

The model involves the following features: (i) It is optimisation-based (so there is a well-defined reason for labour market failures); (ii) it facilitates the investigation of trade-offs (so it can be determined whether improvements in unemployment must be accompanied by reductions in productivity, investments, average hours or wage rates); (iii) it involves a small open economy (so concerns about the limits to independent policy in this setting are respected); and (iv) it can be readily calibrated (so empirically relevant quantitative results are derived).

Concerned with the validity of the widespread argument of skill biased technical change as the main reason for increasing wage gap between skilled and unskilled workers, Moutos (1999) develops a static general equilibrium model with two sectors. He shows that the skill premium can indeed increase with a uniform across sectors and Hicks neutral technological change. The basic argument is that such productivity shock is translated into an increasing demand of higher quality versions of the vertically differentiated product. The result follows as this good's productivity shows an imperfect substitutability between skilled and unskilled labour.

By considering economic growth as exogenous, we are not considering the effect that skill accumulation has on an economy's ability to be more innovative and therefore grow at a higher sustainable rate. This also implies that the assessment of economic policies intended to reduce inequality will not account for additional implications, either positive or negative, on growth.

Eicher and García-Peñalosa (1999) discuss the effects of human capital accumulation on a country's growth rate and income inequality. In their model, differences in abilities to learn determine that not all individuals invest in human capital. Besides, positive externalities in education determine a U-shaped relationship between wage and supply of skilled labour. On the demand side, productivity differentials between skilled and unskilled labour are endogenised by postulating different degrees of complementarity with new technologies, which arise as result of countries switching from pure learning by doing to directed R&D. Both purposeful R&D and serendipitous learning by doing allow the economy to grow in a sustained fashion, although the rates will crucially depend on the type and amount of innovative effort.

The combination between relative supply and demand of skills determines different and in some cases multiple steady state equilibria. The outcome is crucially dependent on the magnitude of the externality, the cost of education and the elasticity of substitution, which highlights the crucial role to be played by the product mix in growth and inequality empirical, since it will not always be optimal for a country to conduct R&D, the interplay between supply and demand can lead to works. Additionally poverty traps where a critical amount of skilled labour force cannot be reached. This will leave the economy in a vicious circle of low growth. Many of these conclusions seem to be validated by cross country data on inequality and skill premia.

Park and Philippopoulos (1999) also explore the connections between inequality and growth but without explicitly modelling the accumulation of human capital. They set up a dynamic general equilibrium model where the government designs its fiscal policy in order to maximise aggregate intertemporal welfare. The existence of redistributive transfers has the effect of reducing growth but it is in the interest of society that this transfers actually take place as the government can provide public production services. Besides the negative relationship between growth and inequality, the model emphasises the need to examine the transitional dynamic properties of such an economy. Since the government also provides public consumption services, the optimal tax rate should in general change over time if the economy moved away from its balanced growth path.

The paper by Aghion, Howitt and Violante develops a theoretical model to analyse how a General Purpose Technology (GPT) shapes within-group wage inequality when workers are ex-ante equal, but their adaptability to new technologies is subject to stochastic factors that are history dependent. It is argued that the diffusion of a GPT leverages the importance of these stochastic factors in three ways. First, a rise in the speed of embodied technological progress raises the market premium to workers adaptable to the leading-edge technology. Second, the generality of the technology raises the ability of adaptable workers to transfer recently acquired knowledge to new machines. Third, the generality of the technology reduces the cost of retooling old machines, which increases the demand for adaptable workers. In the model the rise in within-group inequality is mainly transitory, and is mirrored by a rise in wage instability. The key predictions of the model are shown to be in line with some of the existing empirical evidence.

Turrini and Gabszewicz develop a model of a vertically differentiated industry where the production of higher quality good needs a higher fraction of specialised labour. In the first stage, firms choose the quality of their products, in the second, both good prices and skilled workers' wages are determined. They show that in duopoly, though supplying different variants of the product, firms tend to cluster either at the bottom or at the top of the quality ladder, depending on skilled labour availability. This switch in equilibrium qualities creates a discontinuous behaviour for the wage rate of skilled workers. When the supply of skilled labour is made endogenous, two equilibria are simultaneously possible: one with low-skill, low-quality, the other with high-skill, high-quality.

Apart from the analysis of long run growth, it is also interesting to understand the implications of strategic investment behaviour by firms, which can focus on workers' human capital or on R&D, towards the cyclical behaviour of an economy. The paper by Gerard-Varet, d'Aspremont and Dos-Santos Ferreira studies an endogenous business cycle model with Cournotian monopolistic competition and an endogenous number of firms in each sector. This model is a simple general equilibrium macroeconomic model introducing overlapping generations both of consumers and firms. Firms strategically decide on investment in the first period of their life, and compete a la Cournot in the second period. Investment is taken to be in human capital or technological know-how, to have spillover effects and to be formed from simple labour supplied by young consumers in anticipation of the profit

share they get when old. It is Cournot competition that allows to analyse the variation of monopoly power along the cycle, since the number of firms is endogenised. As this number increases, firms behave more and more competitively. The properties along the cycle are generated by business formation (or destruction). They will include the counter-cyclicality of markups and prices, the pro-cyclicality of the number of firms and, in a lesser way, of real wages.

Additionally, Ulph has explored a number of endogenous growth models which have led to the elaboration of a model which renders itself useful for the evaluation of a number of policies concerning incentives to growth, inequality, education and training. This paper is included as an annex and its major policy implications are described in the following section of this report.

# SECTION 4.

# POLICY CONCLUSIONS.

The phenomena being studied in this project are complex both individually and in their interactions. It was therefore decided to develop a formal analytical framework in which to draw together many of the elements of the nexus of issues surrounding growth, inequality and training, and to use this framework to consider some policy issues.

The elements that are required in such a model are as follows:

1. an account of the factors responsible for growth – in this case R&D generated productivity and/or product quality improvement;
2. an account of the nature of different types of skills in the economy, and why they would get paid at different rates;
3. an explanation of the link between the nature of the technology that firms use and/or the product they produce and their demand for different types of skill – in particular it is important to investigate how the demand for skills may vary across different firms depending on their relative success in R&D and hence the quality of their product and/or technology;
4. from the following one can then understand how changes in technology/product quality gives rise to changes in the demands for different types of skills;
5. an understanding of the link between technology, skills and training provided by firms;
6. an endogenous supply of skills.

It is important to stress that within such a model there are complex interactions. Thus the training requirements of different types of workers will be one factor that enters into their relative costs and hence the employment decision – conditional on technology/product. This in turn will affect the profitability of companies conditional on technology/product and hence the incentives of firms to do R&D. Once we determine the incentives of firms to do R&D this, and the employment decision will determine the demand for skilled versus unskilled workers, and hence, knowing how the composition of skill supply in the labour force responds, via the education system, the skill premium. But this then becomes another factor that firms take into account in deciding what types of workers to employ.

While many aspects of this agenda have been investigated individually, to our knowledge there is no model that brings all these issues together in a single framework.

The details of the model are set out in the accompanying paper. Here we just summarise the main policy conclusions of the model.

Given the complexity of the model it was necessary to calibrate it to some data and then carry out numerical simulations.

The particular features to which the model was calibrated were:

50% of the population should be receiving education and becoming high skilled. This is the target figure for higher education enrolment in UK based on similar figures for other OECD countries.
Growth rate of 4%.
Skilled workers get 50% premium over unskilled workers.
Most advanced firms spend on training an amount equal to 30% of wage bill.

This generates what the base case which is used to investigate some microeconomic cross-section correlations between, R&D, skills training, profitability firm size etc.

Having fitted the model to the data, it was then possible to undertake four pieces of comparative static analysis – each of which can be thought of as corresponding indirectly to a particular policy initiative.

These comparative static changes are:

An increase the amount of quality improvement obtained when firms innovate. This can be thought of as corresponding to a policy that generates more innovation per unit spend on R&D and so is the analogue of and R&D subsidy or tax credit.

An increase the costs of obtaining education. This can be thought of a straightforward analogue of policies such as the introduction of student loans that raise the cost to students of obtaining education.

An equi- proportionate increase in the costs of training all types of skills in all types of jobs. This can be thought of as a policy such as a uniform subsidy or tax credit for training.

A more targeted training policy that is aimed particularly at making it relatively easier to train skilled workers.

The discussions of the main policy conclusions are organised into three sets of comparisons. The first is to look at the cross section results in the base case. The second is to look at the comparative static effects of changes in parameters/policies on the broad aggregates like growth, inequality and training, while the third set of comparisons looks at how the cross section results in the base case change with the comparative static policy/parameter changes. This is a test of how robust any cross section predictions are.

## A Cross Section Results in Base Case

Start by looking at the size distribution of firms in the base case.

8% of firms produce the most basic product that is not technologically advanced, while 51% produce the most advanced product, leaving 41% producing a medium quality product. If we look at the relative sizes of firms, we see that it is the medium quality firms that are the largest; the basic quality firms that are the smallest and the high quality firms that are of intermediate size – though close in size to small companies.

There are a number of factors explaining this size distribution. The fact that top quality goods are of such high quality tends to increase demand for them as a group, while the fact that they sell at a very high price tends to lower the share of the market taken by them as a group. But, more importantly, the fact that there is so many of these firms lowers the amount of the market for high quality goods that each of them can take.

We know from the theoretical work that there is a positive correlation between the quality of product that a firm is producing and the proportion of its workforce that is skilled, and this of course is confirmed in the simulation results where we see that top quality firms employ only skilled workers, whereas the other two types of firm employ only unskilled workers. However, product quality is not often observable in the data, so we have to look for other links between firm type and the proportion of workforce that is skilled.

We see from Table 2 that in this base case there is a positive link between profitability and quality, so one would see a positive correlation between profitability and skill composition of the workforce.

One such link is between firm size and skill composition. Putting together the previous observations we see that if we looked at the cross section link between skills and firm size, we would see no obvious pattern – both the largest and smallest firms employ only unskilled workers while intermediate sized firms employed only skilled workers. If we fitted a function with quadratic terms we would find an inverse U-shape between firm size and the percentage of workforce that is skilled.

Looking at the link between training and firm characteristics we see that there is a positive association between:

- percentage of workforce trained and percentage skilled;
- firm size and the percentage of workforce trained;
- firm size and training costs as a percentage of wage costs;
- profitability and percentage of workforce trained.

For those firms that do any training, there is a negative association between:

- percentage of workforce skilled and percentage of wage bill spent on training;
- profitability and percentage of wage bill spent on training.

Turning to links between R&D skills and training, notice that the amount of R&D that a firm does in any period is determined by its past innovative success, while this, plus its current R&D success determine its product quality and hence its current output, profits, skill composition and training decisions.

Notice that in the base case, firms who were previously successful in innovating spend a little less on R&D than firms that were previously unsuccessful – there is creative destruction taking place.

This immediately implies a negative correlation between R&D and operating profits.

Only firms that were previously successful have a chance of becoming top quality producers and so employ skilled workers. So there is a negative correlation between R&D spending and percentage of workforce skilled.

Firms that were previously successful in doing R&D will end up training all their current workforce whatever the outcome of current R&D success, whereas firms that were previously unsuccessful at innovating will train all their workforce if they are currently successful in innovating but none if they are again unsuccessful. So we would see a negative correlation between R&D and percentage of workforce trained.

The link between training costs as percentage of wage bill and R&D is less clear cut. Firms that were previously successful at innovating will spend less on R&D but can end up either as top quality companies hiring only skilled workers and spending a lower faction of the wage bill on training than if they fail to innovate, remain medium quality companies, hire only unskilled workers and consequently have to spend a lot on training. On the other hand previously unsuccessful companies will spend a lot on R&D and can end up either being medium quality firms spending a very high fraction of wage bill on training, or base quality companies hiring unskilled workers and spending nothing on training.

B Comparative Static Macro Predictions

Consider in turn now the effects of each of the comparative static changes in parameters/policies set out above. In undertaking this exercise, each of the relevant parameters was increased by 20%.

B.(i) Effects of an increase in $q$ – the product quality improvement obtained when firms innovate

Not surprisingly this increases the rate of growth. What is a bit more surprising is just the extent of the increase – from 4% to 5.1% - an increase of over 25% in the growth rate. There are three factors giving rise to this:

The first is the *direct effect* – the increase in $q$ means a great amount of progress is made for any discovery. By itself this would account for 10% of the increase in growth.

Secondly the fact that R&D has a bigger payoff obviously raises the rate of return to R&D and increases the amount of R&D by all firms.

Thirdly the *composition* of R&D changes, with previously unsuccessful firms increasing their R&D faster than successful firms. This reduces the share of unsuccessful firms in the economy.

These latter two effect account for the remaining increase in the growth rate.

The reason for this compositional shift comes about from the second major effect of the increase in $q$, which is to raise the demand for skilled workers and hence their skill premium – which rises by 14%. The effect of this is that the gap between the profits of the top quality firms and the medium quality firms increases by less than the gap between the profits of the medium quality firms and the bottom quality firms. This is why R&D increases less for previously successful firms than for previously unsuccessful firms.

This increase in the skill premium induces more people into higher education – an increase from 50% of the population to 54%.

Overall this brings about a sharp increase in the Atkinson measure of inequality.

Turning to training, we see that since there are fewer firms that are producing just the basic good, the proportion of the working population receiving training increases slightly, as do training costs as a percentage of the overall wage bill. This latter effect is a pure compositional effect, since training costs as a percentage of the wage bill are unaffected across the different types of company – it is just that there are more companies of the type that need and want to provide training.

So policies, such as R&D tax credits, that directly raise the rate of return to R&D will certainly increase growth- but at the expense of rising inequality. They also induce more training. Notice however that an R&D tax credit would not have the immediate direct effect on growth that the increase in $q$ brings about, but otherwise would operate in precisely the same way as this parameter shift. In other words a 10% R&D tax credit would raise growth from 4% to 4.7%.

B.(ii) Effects of an increase in $E$ – the costs of education

This will contract the supply of skills, and, as we can see, this leads to a fairly sharp reduction in the percentage of people going into higher education – from 50% to 45% - a 10% fall, but a relatively small increase in the skill premium – from 50% to 52%.

The reason that the skill premium increases very little is that, in this model, the demand for skills can be very elastic over quite wide range since what is driving the change in the percentage of skilled workers employed are changes in the composition of different types of firm rather than changes in the demand for skilled workers at the individual firm level.

This rise in the skill premium has two effects:

it *increases* inequality – the Atkinson index rises from 4.0 to 4.2;

it reduces the incentive to do R&D by previously successful firms but has no effect on R&D done by previously unsuccessful firms – since they employ only unskilled workers whether they succeed or fail in their current innovation efforts. This reduction in R&D by previously successful firms causes a slight *reduction* in the growth rate from 4% to 3.8%.

These results are very important for they indicate that growth and inequality need not always be positively correlated. *Policies that promote access to education can simultaneously raise growth and reduce inequality*.

However the magnitudes of these effects are pretty small.

A further consequence of the reduction in R&D by successful firms is that the number of successful firms producing the top quality good falls while the percentage of firms producing the lowest and medium quality goods rises. This reduces the percentage of the workforce getting training but has no effect on the percentage of the wage bill going on training, since the fall in numbers getting trained is offset by the increase in training costs required to cater for the fact that a lower percentage of the workforce is skilled.

B.(iii) Effects of an increase in $b$ – an equi-proportionate increase in training costs for all types of workers in all jobs.

This has a very dramatic effect on the pattern of R&D in the economy. The increase in training costs lowers profits for all firms engaged in training, but it lowers profits most for firms producing medium quality goods who employ unskilled workers and incur high training costs. This raises the rate of return to R&D for previously successful firms but lowers it dramatically for previously unsuccessful firms.

The effects on relative R&D rates are such that now previously successful firms do more R&D than previously unsuccessful firms. Thus R&D races are characterised by an outcome of *persistent dominance* - firms that are successful tend to be successful, while firms that are unsuccessful remain unsuccessful. We have vicious circles and virtuous circles.

On balance these effects slightly reduce the growth rate, but this depends entirely on the particular numerical example. The arithmetic could have worked out differently and increased the rate of growth. So we see that *policies that increase training costs in an equi-proportionate fashion may either raise or lower the growth rate.*

We see that the there is no effect on the skill premium and consequently no effect on the percentage of workers getting higher education – because the equilibrium remains on the elastic portion of the demand curve. There is therefore no effect on inequality.

Finally the percentage of the labour force getting trained falls, since there is a significant increase in the percentage of firms producing the lowest quality good who undertake no training. As we would expect, the percentage of the wage bill that goes on training rises significantly.

So overall this policy has a small but negative effect on growth but no effect on inequality.

B.(iv) The effect of an increase in $a$ – a policy that raises the costs of training unskilled workers relative to skilled workers.

This increases the demand for skilled relative to unskilled workers at any wage. It has a similar qualitative effect on the relative profits of companies producing different quality goods, and so increases R&D done by previously successful companies, while reducing R&D by previously unsuccessful companies.

As in the previous case this now means that we now have *persistent dominance*. However, the negative effect on R&D by unsuccessful firms is now somewhat smaller than in the previous case and, as a result, there is no overall effect of this policy on growth.

However the shift in demand towards skilled workers raises the skill premium, and attracts more people into higher education. As a result the overall Atkinson measure of inequality increases.

Slightly fewer people get trained, and training costs rise as a percentage of the wage bill.

Taking all these comparative static effects together we see the following:

Policies targeted directly at raising the rate of return to R&D have the strongest effect on growth, but at the cost of increasing inequality.

Policies targeted at reducing the costs of access to education will have the win-win effect of raising growth and reducing inequality - however the effects are rather small.

Policies that lower training costs across the board will have an ambiguous effect on growth and could have a mild positive or negative effect, but seem to have little effect on inequality.

Policies that differentially reduce the training costs of the least skilled have little effect on growth and a small effect on reducing inequality.

C. Comparative Static Cross Section Predictions

This final sub-section briefly considers how the cross section results reported in sub-section 3A are affected by the comparative static changes considered in Section 3B.

The two main conclusions are as follows.

Under all the policy changes, the firms producing the medium quality good remain the largest firms. However the relative sizes of the firms producing the top quality goods and the lowest quality good will change around. This will affect some of the predictions about the links between firm size and other variables. For example it is no longer true that there is a positive association between firm size and the percentage of the wage bill that goes on training.

Secondly, as we have seen policies that increase training costs can dramatically reverse a situation of creative destruction – previously unsuccessful firms spend more on R&D that previously successful ones – into an outcome of persistent dominance - previously unsuccessful firms spend more on R&D that previously successful ones.

This will turn around a lot of the cross section predictions on the links between R&D, skills and training.

The main conclusion here is that:

Cross –section links between profitability and skills; profitability and training; and consequently between skills and training are robust and unaffected by policy changes.

However cross section correlations between firm size and either skill composition and training or between R&D , skill and training are unstable and sensitive to the precise policies in force.

## Conclusions

In the accompanying paper we have developed a very simple framework within which, for the first time, one can look at links between R&D/ growth, skill/inequality and training. The framework is rich enough to explore these linkages in both a cross sectional manner by looking across different firms, and in a time-series cross sectional fashion by looking across different economies.

Given the rather special nature of the model and the very specific nature of the numerical simulations it is difficult to draw very general conclusions. However some important points emerge.

Firstly the links between education/skills and training that one might observe at the micro-level do not carry across to the macro level. Thus at the micro-level education and skills are substitutes in the sense that the more education a person has the less training they need. However at the macro level policies that generate a higher proportion of educated people can increase the amount of training that takes place since they make the economy more innovative and raise the demand for training.

Secondly on the macro level one faces a policy dilemma between policies that are effective in promoting growth – through directly promoting R&D – which come at a cost of increased inequality - and policies that may involve no such trade-off but are less effective.

Finally there are very few robust comparative static predictions particularly between

- firm size and: skill composition, training;
- R&D and: skill composition, training.

This is clearly an area for further research.

# SECTION 5.

# DISSEMINATION AND/OR EXPLOITATION OF RESULTS.

Most of the individual theoretical papers have already been submitted for publication to individual journals, with some of them having been published already in refereed journals and as discussion papers.

New datasets with time series information on the supply of skills have been produced. These are available from the authors upon request for further research.

It has also been discussed the possibility of bringing the country studies together in a book. Publishers have been approached and details are being discussed at the moment.

The project has held seven meetings/workshops in:

1. London (Dec 98)
2. Milan (March 99),
3. Mannheim (July 99)
4. Paris (Dec 99).
5. London (April 00).
6. Crete (July 00).
7. Paris (January 01).

These have been actively attended by all groups.

There have been significant bilateral exchanges between individual groups:

David Ulph met with Louis Andre Gerard-Varet and David Encaoua in Paris to discuss possible collaborative theoretical work. This has led to joint research by Encaoua and Ulph.

There have also been meetings between Ulph and Moutos in Athens and between Ulph and Gambardella in London.

Anna Maria Grimaldi visited Eric Maurin in CREST, Paris, to discuss work on the econometric modelling of staying on education decisions.

# SECTION 6.

# ANNEXES.

## ANNEX 1. CONFERENCE PRESENTATIONS.

**MILAN, 16TH –17TH APRIL 1999**

Pauline Givord: "A description of unskilled labor in France"

Bruno Decreuse: "Unemployment Responses to Structural Shocks in the Skilled Workforce"

Anna Maria Grimaldi: "A Survey of the Empirical Studies on Wage Inequality in the UK"

Fernando Galindo-Rueda: "Growth, Inequality and Training: A Survey of the Theoretical Literature"

Alfonso Gambardella: "Entrepreneurship and the formation of Skills: Silicon Valley vs Cambridge"

Eric Maurin and Dominique Goux: "Reuturns to Continuous Training. Evidence from French Worker-Firm Matched Data". "Change in the Demand for Skilled Labor: Technological vs Organisational Factors"

Asimina Christoforou: "Growth, Inequality and Training: The Case of Greece"

Salvatore Torrisi: "Wage Inequality, Skillsand Technical Change. The Empirical Evidence in Italy"

John Van Reenen: "The TSER Network 'Innovation, R&D and Productivity': Overview of the Main Results"

Giovani Luca Violante: "Deunionization, Technical Change and Inequality"

Louis André Gerard-Varet: "Endogenous Business Cycles and Business Formation in an Oligopolistic OLG Model with Strategic R&D"

Alessandro Turrini: "Workers' Skills, Product Quality and Industry Equilibrium"

**MANNHEIM, 9th –10th JULY 1999**

Anna Maria Grimaldi: “The Supply of Skills in the UK”

Valerie Molkhou: Country report on the state of work. “Growth, Inequalities and Training in France”

Ashimina Chistoforou: “The Demand and Supply of Skills in Greece”

Johannes Ludsteck: Country report for Germany.

Wolfgang Schwerdt: “Explaining The Supply of Apprenticeships in Germany”

Thomas Moutos: “Neutral Technological Change and the Skill Premium”

Apostolis Philippopoulos: “On the Dynamics of Growth and Fiscal Policy with Redistributive Transfers”

David Ulph: “Training Costs, Differential Firm Performance and Economic Growth”

**PARIS, 17TH-18TH DECEMBER 1999**

Johannes Ludsteck: “Innovative Activity and Private Sector Training. Empirical Evidence from Firm Data”

Alfonso Gambardella: “Technology, Entrepreneurship and Inequality: An Interpretative Model”

Wolfgang Schwerdt: “Who supplies Apprenticeships? A Detailed Analysis of German Firms in 1995”

Valérie Molkhou: CORE-CREST-EUREQUA-GREQAM Report

Fernando Galindo-Rueda: “Education Signalling in a Frictional Labour Market”

Cecilia García-Peñalosa: “Inequality and Growth: The Dual Role of Human Capital in Development”

David Encaoua and David Ulph: “Catching-Up or Leapfrogging? The Effects of Competition on Innovation and Growth"

Philippe Aghion: “Notes on Innovation and Market Structure”

Eric Maurin: “Labour Market Institutions and Job Stability” (co-author: Dominique Goux).

Alfonso Gambardella and Salvatore Torrisi: “Skill Biased Technical Change and Training. Evidence from a Panel of Italian Manufacturing Firms”

David Thesmar: “Trade Induced Skill Bias”

Thomas Moutos: “Work Sharing: An Efficiency Wage Analysis”

Johannes Ludsteck: “The Impact of Innovations on Private Sector Further Training: Empirical Evidence from the German Service Sector”

Pauline Givord: “Layoff Costs, Job Security and Seniority: Evidence from France”

David Ulph: “Notes on Growth, Inequality and Training”

Anna Maria Grimaldi and Stephen Machin: “Estimating a Model of School Enrolment”

**Chania (Crete): 3d and 4th July, 2000, hosted by CERES.**

David Ulph: “Growth, inequality and training”.

Rodrigue Mendez: “ Inequality and the product cycle”.

Jacques Mairesse and Pierre Mohnen: “R&D, innovation and productivity: A first look at the Second Community Innovation Survey”.

Bruno Decreuse: “Can skill-biased technological change compress unemployment rate differentials across education groups?”.

Fernando Galindo-Rueda: “Simultaneous innovation and learning efforts by firms and workers”.

Asimina Christoforou: “Skill upgrading and R&D intensity in Greece: Testing the hypothesis of skill-biased technical change”.

George Liagouras: “The absortion of NTUA engineers in the labour market”.

Alfonso Gambardella and David Ulph: “Technology, industry structure and inequality”.

Olivier Charlot and Bruno Decreuse: “Public policy in a matching model of long-term unemployment with endogenous search effort”.

Peter Jakobebbinghaus and Thomas Zwick: “The impact of innovations and information technologies on medium qualified labour demand”.

**Paris: 27th and 28th January, 2000, hosted by INSEE-CREST.**

Wolfgang Scherdt and D. Fougere: “What is the marginal productivity of apprentices?”

Anne-Claire Houillier: “High education enrolment in Britain”

Bruno Decreuse: “Over-education, wage inequality and long-term unemployment”

Fernando Galindo-Rueda: “Irreversible investments, inequality and the changing composition of jobs”

Patrick Waelbroeck: “Nature and effects of information sources on innovation”

Emmanuel Duguet: “Do R&D subsidies increase R&D expenditures?: An econometric study on the firm level using French manufacturing data”

Jacques Mairesse and Pierre Mohnen: “Innovation indicators from innovation survey data”

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# GROWTH, INEQUALITY AND TRAINING - **A POLICY FRAMEWORK***

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November 2001

*** This paper was written as part of the TSER project "Growth Inequality and Training". A preliminary version was presented at a workshop in Crete in July 2000. I am grateful to participants at that workshop for helpful comments.**

**Growth Inequality and Training – A Policy Model**

The aim of this paper is to provide an analytical framework in which we can draw together many of the elements of the nexus of issues surrounding growth, inequality and training, and to use this framework to consider some policy issues.

The elements that are required in such a model are as follows:

- an account of the factors responsible for growth – in this case R&D generated productivity and/or product quality improvement;
- an account of the nature of different types of skills in the economy, and why they would get paid at different rates;
- an explanation of the link between the nature of the technology that firms use and/or the product they produce and their demand for different types of skill – in particular it is important to investigate how the demand for skills may vary across different firms depending on their relative success in R&D and hence the quality of their product and/or technology;
- from the following one can then understand how changes in technology/product quality gives rise to changes in the demands for different types of skills;
- an understanding of the link between technology, skills and training provided by firms;
- an endogenous supply of skills.

**It is important to stress that within such a model there are complex interactions. Thus the training requirements of different types of workers will be one factor that enters into their relative costs and hence the employment decision – conditional on technology/product. This in turn will affect the profitability of companies conditional on technology/product and hence the incentives of firms to do R&D. Once we determine the incentives of firms to do R&D this, and the employment decision will determine the demand for skilled versus unskilled workers, and hence, knowing how the composition of skill supply in the labour force responds, via the education system, the skill premium. But this then becomes another factor that firms take into account in deciding what types of workers to employ.**

While many aspects of this agenda have been investigated individually, to my knowledge there is no model that brings all these issues together in a single framework.

The aim of this paper is to fill this gap.

The plan of the paper is as follows. Section 1 sets out the model. Section 2 spells out all the potential predictions of the model. Section 3 presents some numerical simulations.
Section 4 concludes.

## Section 1. The Model

The basic model considered here was originally developed by Ulph (1991), and has subsequently been used in Owen and Ulph (1994). These models considered only product market competition. An extension by Ulph (1996), introduced some of the labour market considerations considered here, particularly the nature of skills and the relation to training. However, that model treated the supply of skills as fixed. The major extension in this model is to endogenise the supply of skills by modelling workers' education decisions.

### 1. The Product Market

The model is one in which firms are engaged in ongoing R&D competition to improve the quality of the product they are producing. At any given time there is a basic product that incorporates the level of each characteristic that each and every firm can incorporate in their product. Firms then specialise by producing products that are potentially better in just one dimension. At any given time a firm's price, output and hence profits depend solely on the "quality gap" that it has opened up over this basic good in its specialised dimension. See also recent papers by Aghion Harris and Vickers (1997) Encaoua and Ulph (2000), where a similar modelling assumption is used.

A crucial assumption is that patents last just two periods. This means that all firms can incorporate in their product the highest quality of any given dimension that was available 2 periods ago. Suppose that if a firm improves its good through innovation then its quality goes up by the exogenously given amount $q > 0$. Given the above assumptions, the maximum gap that any firm can open up over the basic good is $2q$.

A further implication of this assumption is the fact that at the start of any period there are two *ex-ante* types of firm characterised by their history of innovative success in the previous period. Index firms by $h = 0,1$, where $h = 0$ means a firm failed to innovate in previous period, $h = 1$ means a firm succeeded in innovating.

If a firm enters a period with a history of $h$ then, if it succeeds in innovating in that period it will be able to produce a good with quality gap over the basic good of $Q = (h + 1).q$. If it fails to innovate it will produce a good of quality gap $Q = h.q$ Thus $Q$ takes the values $0, q, 2q$. Say that in a particular period a firm is of *ex-post* type $k$, $k = 0,1,2$ if, after innovation, it has a quality gap $Q = k.q$.

The good with quality gap 0 in any period is the *basic* good.

Goods are produced using labour alone. There are two types of worker – skilled and unskilled. Each supplies 1 unit of labour and each has **exactly the same productivity**. As we will see below, the skill

differential shows up in the amount of training that workers require in order to learn how to produce new products – see Ulph (1996).

For simplicity it is assumed that 1 unit of labour of either type produces 1 unit of output. Assume also that the wage rate is normalised to 1 so that the unit cost of production for each good is 1.

From Ulph (1991) three things now follow.

1. The price of a good of *ex-post* type $k$ is $1 + k.q$.

2. Denote the fraction of firms that are of *ex-post* type $k$ by $f_k \geq 0, \qquad \text{where} \sum_{k=0}^{2} f_k = 1.$

   Later on we will see that these fractions are functions of the skill premium $S$.

   Then the equilibrium output of a firm of *ex-post* type $k$ is:

$$D_k(S) = \frac{M}{1+k}\psi(kq)\left\{1 - \sum_{\substack{j=0 \\ j\neq k}}^{2} \frac{f_j(S)}{j-k}\psi(jq) + \frac{f_k(S)}{2}\psi(kq)\right\} \quad (1)$$

   where $M$ is a parameter that measures the size of the market,

$$\psi(z) = \left(\frac{1}{1+z}\right)^{\frac{1}{z}}, \quad z>0, \quad \text{and} \quad \psi(0) = \frac{1}{e}.$$

3. The equilibrium operating profits of a firm of *ex-post* type $k$ are

$$\pi_k(S) = kq.D_k(S). \quad (2)$$

***Notice that there is very little that we can say at this level of generality about the relative size of firms of different* ex-post *types. There are three factors at work in determining the relative sizes of these different firms.***

(a) Firms producing higher quality goods charge higher prices and so, ceteris paribus get a lower output;

(b) Firms producing a higher quality good attract a higher fraction of consumers.

(c) The demand for any given firm will depend on the number of firms producing a good of similar quality level – the degree of competition.

## 2. The Labour Market

As indicated there are two types of worker – skilled and unskilled. They have exactly the same labour productivity. Workers live for just a single period. At the start of a period a certain number of workers are born. They are born unskilled but can choose to acquire an education and become skilled workers. All workers can produce the *basic good* – that of *ex-post* type 0 (i.e. that with *ex-post* quality gap 0). However, in order to produce goods of *ex-post* type 1 or 2 workers need to be trained. The following assumptions are made about training.

(a) For either *ex-post* type of good skilled workers require less training than unskilled workers. That is skilled workers have an absolute advantage over unskilled workers.
(b) Workers require more training to produce a good of *ex-post* type 2 than a good of *ex-npost* type 1.
(c) Skilled workers have a comparative advantage over unskilled workers in the production of the highest quality good – that of *ex-post* type 2. Thus the relative cost of training a skilled worker to produce a good of type 2 to a good of type 1 is less than the relative cost for an unskilled worker.

It is assumed that, in recognition of the fact that skilled workers are cheaper to train than unskilled workers they command a skill premium $S > 0$. Since this has nothing to do with their underlying productivity, this premium does not enter into the wage rate that is paid to skilled workers, but is paid as a bonus on top of the wage payments. Thus the total gross income of an unskilled worker will be 1 while that of a skilled worker is $1+S$.

Let us now formalise these ideas.

### 2.1 Education and the Relative Supply of Skilled Workers

Let the fraction of workers who choose to become skilled be given by the strictly increasing *relative skill supply function* $R^s(S)$, which satisfies the following assumptions:

$$R^s(i): R^s(0) = 0;$$
$$R^s(ii): 0 < R^s(S) < 1 \quad \forall S > 0;$$
$$R^s(iii): \frac{dR^s}{dS} > 0.$$

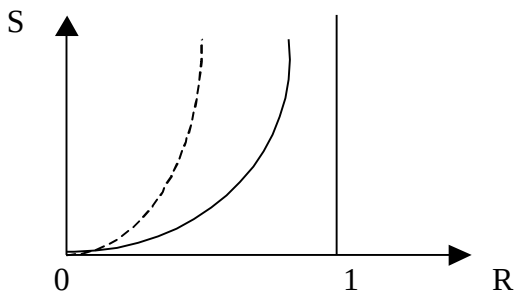
These are very standard assumption.

Such a supply function can be derived as follows. Suppose that workers differ in their educational ability. This is measured by the variable $n > 0$. For a worker of ability $n$ the cost of becoming skilled is $\frac{E}{n}$, where $E > 0$ is a parameter of the model reflecting the costs of education. Given the skill premium $S$ a worker will choose to be come educated/skilled iff $S - \frac{E}{n} \geq 0$ i.e. iff $n \geq \frac{E}{S}$.

Assume now that the distribution of *n* in the population is given by the density function $\nu(n)$, where $\nu(n)>0$ for all $n$ and $\int_0^\infty \nu(n)\,dn=1$. Then $R^s(S)=\int_{\frac{E}{S}}^\infty \nu(n)\,dn$. This satisfies all the assumptions that are made above.

Later on, in numerical simulations we will use the particular distribution $\nu(n)=e^{-n}$, in which case $R^s(S)=e^{-\frac{E}{S}}$.

This is shown in the following diagram.




The solid line shows the supply curve for a given level of educational costs, E. The dotted line shows the supply curve for a higher level of E.

Notice that the distribution of income **net of education costs** of workers is given as follows:

$$y(n;S,E)=\begin{cases}1\ ,\ 0<n\le\dfrac{E}{S}\\[2ex] 1+S\ \dfrac{E}{n},\quad n\ge\dfrac{E}{S}\end{cases} \tag{3}$$

*2.2 The Relative Demand for Skilled Workers*

Having determined the relative supply of different types of skill, we now need to determine the relative demand for skilled workers. In order to do this we need to be clear about the precise sequence of decisions that a firm makes in any given period.

Right at outset firms choose how much R&D to do. This determines the probability that a firm will succeed in innovating. The success of this innovation is also determined right at outset of period. Also at outset of period workers decide whether or not to acquire education. Once firms know the outcome of the innovation process – and hence both the quality of the good they will produce and the number of workers they will need to produce it - firms then choose what workers to hire. They will make this decision so as to minimise training costs.

Thus in order to determine the relative demand for skilled workers for any given skill premium, we have to proceed as follows. We first of all have to specify the nature of training costs that different ex-post types of firms have to incur if they employ the two different types of worker. For any given level of the skill premium, we can then calculate the total hiring costs – training costs plus skill premium – for each type of worker in each ex-post type of firm. This determines the hiring decision by each type of firm and hence the profits, net of hiring costs that each ex-post type of firm will make. This will enable us to determine the amount of R&D that each ex-ante type of firm will undertake, and hence the proportion of each ex-post type of firm in the population of firms. Combined with the hiring decision we can now determine the relative demand for skilled workers for any given skill premium.

Lying behind this description of how we determine the relative demand for skills is the following sequence of decisions that firms take in any given period.

### *2.2.1 Training Costs*

Let $c_{tk} \geq 0$ be the cost of training a worker of type $t = s, u$ to produce a good of *ex-post* type $k = 0,1,2$.

Assume:

TC(i) $c_{s0} = c_{u0} = 0$;

TC(ii) $0 < c_{s,k} < c_{u,k}$ $k = 1, 2$;

TC(iii) $c_{t2} > c_{t1}, t = s, u$

TC(iv) $\frac{c_{u2}}{c_{s2}} > \frac{c_{u2}}{c_{s2}} > 0$.

So, from (i) the technology for producing the basic good is common knowledge and neither type of workers needs any training to produce this. From (ii) skilled workers have both an absolute advantage over unskilled workers, in the sense that they need less training than unskilled workers for any type of advanced good. From (iii) we see that the production of a higher quality is intrinsically more complex and therefore requires more training than the production of lower quality goods. Finally, from (iv) skilled workers have a comparative advantage in the production of high quality goods.

For future purposes, it will help to parameterise these training costs in the following way.

The lowest of these training costs is $c_{s1}$, so let $c_{s1} = b$, where $b$ now stands for the *base level* of training costs. Let $c_{u1} = b.(1+a)$ where $a$ is a parameter that controls the degree of *absolute advantage* that skilled workers enjoy over unskilled workers in economising on training costs. Let $c_{s2} = b.(1+d)$ where $d$ is the factor that controls the extent to which training costs rise because of the increased *difficulty* of producing more complex goods. Finally we have $c_{u2} = b(1+a).(1+d).(1+c)$ where the parameter $c$ reflects the degree of *comparative advantage* that skilled workers enjoy over unskilled workers in producing the more advanced good.

### 2.2.2 The Hiring Decision

Let $\phi_k$, $0 \le \phi_k \le 1$ be the fraction of the workforce of a firm of *ex-post* type *k* that is skilled.

Let

$$\eta_k(S) \equiv \min_{0 \le \phi_k \le 1} \{(1-\phi_k)N_k + \phi_k N_k(c_{u2}, c_{s2}) : c_k \quad k = 1, 2$$

be the **minimum** hiring/employment costs associated with producing good of *ex-post* type *k*, and let

$$\hat{\phi}_k(S) \equiv \arg\min_{0 \le \phi_k \le 1} \{(1-\phi_k)N_k + \phi_k N_k(c_{u2}, c_{s2}) : c_k \quad k = 1, 2$$

be the equilibrium hiring decision.

Define $\bar{S} = c_{u2} - c_{s2}$; $\underline{S} = c_{u1} - c_{s1}$. Assume that comparative advantage of skilled workers shows up not just is the relative form TC(iv) but also in the additive form:

TC(v) $\bar{S} = c_{u2} - c_{s2} > c_{u1} - c_{s1} = \underline{S}$.

Notice the following:

1. If $S > \bar{S} = c_{u2} - c_{s2}$ then no firms will want to hire skilled workers, so

$$\hat{\phi}_k(S) = 0 \quad \text{for all } \eta_u = c(\ )_k, \ 0 \ k = 1, 2.$$

2. If $c_{u2} - c_{s2} > S > c_{u1} - c_{s1}$ then only firms producing a good of *ex-post* type 2 hire skilled workers, all others hire unskilled workers. Hence

$$\hat{\phi}_2(S) = 1 \; ; \hat{\phi}_k(S) = 0 \;, \; k = 0, 1 \text{ and so } \eta_2(S) = S; \; c_{s2} + \eta_k(S) = c_{uk} \; k = 0, 1$$

3. If $c_{u1} - c_{s1} > S > 0$ then firms producing goods with gaps 1 and 2 hire skilled workers, and only those producing the lowest quality good with gap 0 hire unskilled workers. Hence

$$\hat{\phi}_k(S) = 1 \;, \; k = 1, 2 \; \hat{\phi}_0(S) = 0 \text{ and so } \eta_k(S) = S, \; c_{s1} + \eta_k(S) = c_{u0} \; k = 1, 2$$

Notice that $\forall S > 0 \; \eta_0(S) = c_{u0}$.

Given our assumption of comparative advantage we have the following result.

**Result 1** The proportion of skilled workers hired by firms producing a more advanced product is at least as great as that of a firm producing a lest advanced product.

### 2.2.3. The R&D Decision

We can now calculate the profits– net of training costs – that each *ex-post* type of firm will make. These are

$$\begin{aligned} &\Pi_0(S) = 0 \; ; \\ &\Pi_k(S) = S(1 - \phi_k) - \eta_k(S)[1 - (1 - \phi_k)], \; k = 1, 2 \end{aligned} \tag{4}$$

Let $V_h(S)$, $h = 0, 1$ be expected present value of profits of a firm that enters period with history *h* when the skill premium is *S*.

We have

$$V_h(S) = \max_{0 \le p_h \le 1} \{\Pi_h(S) - [\gamma(p_h) + \delta(1 - p_h)V_1(S)] + \delta[p_h V_1(S) + (1 - p_h)V_0(S)]\} \tag{5}$$

where $\delta = \dfrac{1}{1+r} < 1$ is the discount factor; $r > 0$ is the interest rate, and $\gamma(p)$ is the R&D cost function. This is assumed to have the following properties:

$$\gamma(0) = 0, \quad \gamma'(p) > 0 \;\forall\, p, \quad \gamma'(0) > 0, \quad \gamma''(p) > 0$$
$$\gamma'(p) \to \infty \text{ as } p \to 1$$

These assumptions guarantee that firms will do some R&D as long as the return is positive, but no firm will innovate for sure.

In numerical examples I will use the particular functional form

$\gamma(p) = \log(1-p)$ for which $\gamma'(p) = \dfrac{p}{1-p}$ and so satisfies all the above assumptions.

Let $p_h(S)$ be the value of $p_h$ that solves the above maximisation problem (5). These are define by the condition

$$[\Pi_{h+1}(S) + \delta V_1(S)] - [\Pi_h(S) + \delta V_0(S)] = \gamma'[p_h(S)] \qquad (6)$$

Now once we know these underlying probabilities, we can calculate the steady-state fraction of firms that are *ex-ante* successful at the start of any period – i.e. those that enter the period with *h* =1. Denote this by $H(S)$, where $H(S) \le 1$. This satisfies the equation:

$$H(S) = (H)S + (1-H)S[1-H(S)]p_0(S),$$

and so

$$H(S) = \frac{p_0(S)}{p_0(S) + [1-p_1(S)]}. \qquad (7)$$

Similarly we can now determine the steady-state fractions of firms of each *ex-post* type by

$$f_2(S) = \frac{p_0(S)\,p_1(S)}{p_0(S) + [1-p_1(S)]}$$
$$f_1(S) = \frac{2\,p_0(S)[1-p_1(S)]}{p_0(S) + [1-p_1(S)]} \qquad (8)$$
$$f_0(S) = \frac{[1-p_0(S)][1-p_1(S)]}{p_0(S) + [1-p_1(S)]}$$

By substituting (7) back into (1) and (2) and the resulting expressions into (5) and (6), we end up with a system of 4 simultaneous equations in 4 unknowns - $V_0(S)$ $V_1(S)$ $p_0(S)$ $p_1(S)$.

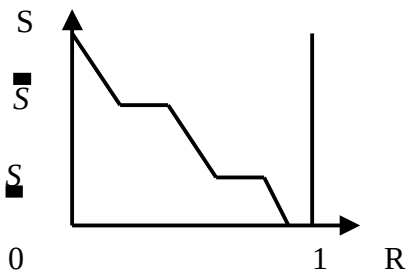
In principle we can solve these and substitute the resulting solution into (8) to determine the equilibrium fraction of firms of each ex-post type conditional on any S.

### 2.2.4 The Relative Demand for Skilled Workers

From this we can now determine the proportion of the work-force that the firms would choose to employ as skilled workers - the *relative skill demand function* $R^d(S)$. This is defined by

$$R^d(S) = \frac{\sum_{k=0}^{2} f_k(S)\,\hat{\phi}_k(S)\,D_k(S)}{\sum_{k=0}^{2} f_k(S)\,D_k(S)}$$

The relative demand for skills is shown in the following diagram:




### 2.3 Full Labour Market Equilibrium

To complete the model we now determine the equilibrium value of $S$ for which

$$R^s(S) = R^d(S). \qquad (9)$$

Denote this equilibrium value by $S^e$

## Section 2 Model Predictions

By plugging the value of $S^e$ determined by (9) back into the model we can determine the following variables.

(i) In addition to the equilibrium skill premium, $S^e$ ,solving (9) will also determine the equilibrium fraction of the population that choose to acquire education, $R^e$. Obviously these two variables are crucially important in determining the degree of inequality in the economy. Indeed many studies on the link between growth and inequality concentrate on the link between the growth rate and S.

(ii) In this model, once we know $S^e$ then, from (3), we know the entire equilibrium distribution of income $y^e(n) = y(n; S^e, E)$, and so can calculate a more precise measure of inequality. Here I will calculate an Atkinson measure of inequality when the inequality aversion parameter is *2* . I denote this by $I_2$. The comparative static results I obtain below on the link between growth and inequality are not very sensitive to the precise inequality measure that is used.

(iii) Once we know the equilibrium skill premium, we can determine the equilibrium hiring decision of each ex-post type of firm, $\hat{\phi}_k^e = \hat{\phi}_k\left(S^e\right)$, and hence the amount of training costs that each advanced ex-post type of firm will incur - $c_k^e = c_{\phi_k^e k}$, $k = 1, 2$. We can also determine the equilibrium hiring costs of each firm: $\eta_k^e = \eta_k\left(S^e\right)$.

(iv) We can now use (4) to calculate the equilibrium operating profits –net of training costs – of firms with different quality gaps. Denote these by $\Pi_k^e = \Pi_k\left(S^e\right)$.

(v) Once we know these equilibrium hiring costs we can use the solution to (5) and (5) to determine the equilibrium probabilities of discovery of each ex-post type of firm: $p_h^e = p_h\left(S^e\right)$, $h = 0, 1$.

(vi) From (6) we can now determine the equilibrium fraction of firms that are successful in innovating $H^e = H\left(S^e\right)$, while from (7) we can calculate the equilibrium fractions of firms of various ex-post types: $f_k^e = f_k\left(S^e\right)$, $k = 1, 2$.

(vii) From (1) we can now calculate the equilibrium size of each ex-post type of firm $D_k^e = D_k\left(S^e\right)$. In particular we will be interested in the relative size of firms, so that we can see whether there is any tendency for larger firms to do more training than smaller firms. We can completely describe the relative size of the three *ex-post* types of firm by considering the two ratios $D_2/D_0$ and $D_1/D_0$.

(viii) We are now in a position to calculate some macro-level measures of the amount of training that takes place in an economy. Thus we can calculate the percentage of the workforce that gets trained: $T^e = 1 - f_0^e$, and training costs as a percentage of the wage bill: $TC^e = \frac{\sum_{k=0}^{2} c_k^e . D_k^e . f_k^e}{\sum_{k=0}^{2} D_k^e . f_k^e}$.

(ix) Finally we can determine the equilibrium growth rate $g^e = q . H^e$

Notice that the model has eight parameters:

$M$ – the size of the market;

$q$ - the size of the quality gap that a firm obtains when it innovates;

$E$ – the costs of acquiring education;

$r$ - the rate of interest (and hence the discount factor δ);

$(b, a, d, c)$ - the four parameters that determine the costs of training the different skills of worker to produce the two different advanced goods, namely $c_{tk}$, $t = s; u$ $1 k = 2$

From all these outputs we can derive a number of different predictions, which can be grouped into two categories.

*Cross-Section Micro-Economic Predictions*

**For any given set of parameter values, we can determine various aspects of the microeconomic performance of individual firms.**

- The first aspect is the firm's size, $D_k^e$ - which is measured equivalently in output or employment.
- The second is the employment decision of firms, which we measure as the proportion of skilled workers that they employ - $\hat{\phi}_k^e$.
- The third is the amount of training that firms do. The main measure that we have is the expenditure on training as a proportion of the wage bill, $c_k^e$. Notice that we could alternatively measure the proportion of its workforce that a firm trains. However, by construction, this will be 100% for any firm that is producing and advanced good – with quality gap of 1 or 2 – and 0% for firms producing the basic good, so, in terms of this model, this is not a very interesting variable to consider.

- The final aspect is a firm's innovative performance, which we can measure in terms of R&D input – essentially $p_h^e$ - or by patenting behaviour – which will be determined whether or not a firm innovated. However this is not easily identified in our model[3], so we will focus on R&D.

We can then look at correlations between these variables, to see what restrictions, if any this theoretical model might place on these.

*Comparative Static (Cross-Country) Macro-Economic Predictions*

For any given set of parameters we can calculate the following macroeconomic indicators of various aspects of performance;

- The first is innovative performance which we can measure by the growth rate - $g^e$.
- The second is inequality which can measure in a rough and ready way through the skill premium, $S^e$, or, more precisely through the Atkinson measure of inequality, $I_2$.
- The third is the educational performance of countries, which we can measure through the proportion of the population who are skilled, $R^e$.
- Finally there is training performance which we can measure through the proportion of the workforce getting training, $T^e$, or training costs as a proportion of the wage bill, $TC^e$

**Given the complexity of the model it is hard to make progress on these issues analytically. Therefore I have had to resort to numerical simulations. The results are presented in the following section.**

[3] All firms of *ex-post* type 2 have clearly innovated, while all those of ex-post type 0 have clearly failed to innovate. Those of *ex-post* type 1 will contain a mixture of innovators and non-innovators.

## Section 3 Numerical Simulations

In this section I present some numerical simulations of the model. What I have done is to calibrate in a very rough and ready way to some broad stylised facts. Since this involves searching an 8-dimensional space, this is a non-trivial exercise, and for this reason I have not at this stage undertaken a more systematic calibration exercise.

The particular features to which the model was calibrated were:

- 50% of the population should be receiving education and becoming high skilled. This is the target figure for higher education enrolment in UK based on similar figures for other OECD countries.
- Growth rate of 4%.
- Skilled workers get 50% premium over unskilled workers.
- Most advanced firms spend on training an amount equal to 30% of wage bill.

This generates what I call the base case. Within this base case we can investigate some microeconomic cross-section correlations.

Having fitted the model to the data I then undertake four pieces of comparative static analysis – each of which can be thought of as corresponding indirectly to a particular policy initiative.

These comparative static changes are:

(i) An increase in $q$ the amount of quality improvement obtained when firms innovate.

This can be thought of as corresponding to a policy that generates more innovation per unit spend on R&D and so is the analogue of and R&D subsidy or tax credit.

(ii) An increase in $E$ the costs of obtaining education.

This can be thought of a straightforward analogue of policies such as the introduction of student loans that raise the cost to students of obtaining education.

(iii) An increase in $b$ – the costs of training a skilled worker to produce the most advanced product.

Given the way training costs are modelled, an increase in $b$ will raise proportionately the costs of training all kinds of worker. So this can be thought of as a policy that reduces a subsidy to training.

(iv) An increase in $a$ – the factor of absolute advantage of training unskilled workers relative to skilled workers.

This can be thought of as a more targeted training policy that is aimed particularly at making it relatively easier to train skilled workers.

The results of the numerical simulations are presented in Tables 1 and 2 below. Table 1 presents all of the output data that are measured in percentages – virtually all. Table 2 presents separate figures for the equilibrium operating profits of firms since these are measured in absolute figures.

I will organise the discussion of the results into three sets of comparisons. The first is to look at the cross section results in the base case. The second is to look at the comparative static effects of changes in parameters/policies on the broad aggregates like growth, inequality and training, while the third set of comparisons looks at how the cross section results in the base case change with the comparative static policy/parameter changes. This is a test of how robust any cross section predictions are.

**3A Cross Section Results in Base Case**

I start by looking at the size distribution of firms in the base case.

8% of firms produce the most basic product that is not technologically advanced, while 51% produce the most advanced product, leaving 41% producing a medium quality product. If we look at the relative sizes of firms, we see that it is the medium quality firms that are the largest; the basic quality firms that are the smallest and the high quality firms that are of intermediate size – though close in size to small companies.

There are a number of factors explaining this size distribution. The fact that top quality goods are of such high quality tends to increase demand for them as a group, while the fact that they sell at a very high price tends to lower the share of the market taken by them as a group. But, more importantly, the fact that there is so many of these firms lowers the amount of the market for high quality goods that each of them can take.

We know from the theoretical work that there is a positive correlation between the quality of product that a firm is producing and the proportion of its workforce that is skilled, and this of course is confirmed in the simulation results where we see that top quality firms employ only skilled workers, whereas the other two types of firm employ only unskilled workers. However, product quality is not often observable in the data, so we have to look for other links between firm type and the proportion of workforce that is skilled.

We see from Table 2 that in this base case there is a positive link between profitability and quality, so one would see a positive correlation between profitability and skill composition of the workforce.

One such link is between firm size and skill composition. Putting together the previous observations we see that if we looked at the cross section link between skills and firm size, we would see no obvious pattern – both the largest and smallest firms employ only unskilled workers while intermediate sized firms employed only skilled workers. If we fitted a function with quadratic terms we would find an inverse U-shape between firm size and the percentage of workforce that is skilled.

Looking at the link between training and firm characteristics we see that there is a positive association between:

- percentage of workforce trained and percentage skilled;
- firm size and the percentage of workforce trained;
- firm size and training costs as a percentage of wage costs;
- profitability and percentage of workforce trained.

For those firms that do any training, there is a negative association between

- percentage of workforce skilled and percentage of wage bill spent on training;
- profitability and percentage of wage bill spent on training.

Turning to links between R&D skills and training, notice that the amount of R&D that a firm does in any period is determined by its past innovative success, while this, plus its current R&D success determine its product quality and hence its current output, profits, skill composition and training decisions.

Notice that in the base case, firms who were previously successful in innovating spend a little less on R&D than firms that were previously unsuccessful – there is creative destruction taking place.

This immediately implies a negative correlation between R&D and operating profits.

Only firms that were previously successful have a chance of becoming top quality producers and so employ skilled workers. So there is a negative correlation between R&D spending and percentage of workforce skilled.

Firms that were previously successful in doing R&D will end up training all their current workforce whatever the outcome of current R&D success, whereas firms that were previously unsuccessful at innovating will train all their workforce if they are currently successful in innovating but none if they are again unsuccessful. So we would see a negative correlation between R&D and percentage of workforce trained.

The link between training costs as percentage of wage bill and R&D is less clear cut. Firms that were previously successful at innovating will spend less on R&D but can end up either as top quality companies hiring only skilled workers and spending a lower faction of the wage bill on training than if they fail to innovate, remain medium quality companies, hire only unskilled workers and consequently have to spend a lot on training. On the other hand previously unsuccessful companies will spend a lot on R&D and can end up either being medium quality firms spending a very high fraction of wage bill on training, or base quality companies hiring unskilled workers and spending nothing on training.

**3B Comparative Static Macro Predictions**

Consider in turn now the effects of each of the comparative static changes in parameters/policies set out above. In undertaking this exercise, each of the relevant parameters was increased by 20%.

B.(i) Effects of an increase in $q$

Not surprisingly this increases the rate of growth. What is a bit more surprising is just the extent of the increase – from 4% to 5.1% - an increase of over 25% in the growth rate. There are three factors giving rise to this:

- The first is the *direct effect* – the increase in $q$ means a great amount of progress is made for any discovery. By itself this would account for 10% of the increase in growth.
- Secondly the fact that R&D has a bigger payoff obviously raises the rate of return to R&D and increases the amount of R&D by all firms.
- Thirdly the *composition* of R&D changes, with previously unsuccessful firms increasing their R&D faster than successful firms. This reduces the share of unsuccessful firms in the economy.

These latter two effect account for the remaining increase in the growth rate.

The reason for this compositional shift comes about from the second major effect of the increase in $q$, which is to raise the demand for skilled workers and hence their skill premium – which rises by 14%. The effect of this is that the gap between the profits of the top quality firms and the medium quality firms increases by less than the gap between the profits of the medium quality firms and the bottom quality firms. This is why R&D increases less for previously successful firms than for previously unsuccessful firms.

This increase in the skill premium induces more people into higher education – an increase from 50% of the population to 54%.

Overall this brings about a sharp increase in the Atkinson measure of inequality.

Turning to training, we see that since there are fewer firms that are producing just the basic good, the proportion of the working population receiving training increases slightly, as do training costs as a percentage of the overall wage bill. This latter effect is a pure compositional effect, since training costs as a percentage of the wage bill are unaffected across the different types of company – it is just that there are more companies of the type that need and want to provide training.

So policies, such as R&D tax credits, that directly raise the rate of return to R&D will certainly increase growth- but at the expense of rising inequality. They also induce more training. Notice however that an R&D tax credit would not have the immediate direct effect on growth that the increase in *q* brings about, but otherwise would operate in precisely the same way as this parameter shift. In other words a 10% R&D tax credit would raise growth from 4% to 4.7%.

B.(ii) Effects of an increase in *E* – the costs of education

This will contract the supply of skills, and, as we can see, this leads to a fairly sharp reduction in the percentage of people going into higher education – from 50% to 45% - a 10% fall, but a relatively small increase in the skill premium – from 50% to 52%.

The reason that the skill premium increases very little is that, in this model, the demand for skills can be very elastic over quite wide range since what is driving the change in the percentage of skilled workers employed are changes in the composition of different types of firm rather than changes in the demand for skilled workers at the individual firm level.

This rise in the skill premium has two effects:

(i) it *increases* inequality – the Atkinson index rises from 4.0 to 4.2;

(ii) it reduces the incentive to do R&D by previously successful firms but has no effect on R&D done by previously unsuccessful firms – since they employ only unskilled workers whether they succeed or fail in their current innovation efforts. This reduction in R&D by previously successful firms causes a slight *reduction* in the growth rate from 4% to 3.8%.

These results are very important for they indicate that growth and inequality need not always be positively correlated. *Policies that promote access to education can simultaneously **raise** growth and **reduce** inequality*.

However the magnitudes of these effects are pretty small.

A further consequence of the reduction in R&D by successful firms is that the number of successful firms producing the top quality good falls while the percentage of firms producing the lowest and medium quality goods rises. This reduces the percentage of the workforce getting training but has no

effect on the percentage of the wage bill going on training, since the fall in numbers getting trained is offset by the increase in training costs required to cater for the fact that a lower percentage of the workforce is skilled.

B.(iii) Effects of an increase in *b* – an equi-proportionate increase in training costs for all types of workers in all jobs.

This has a very dramatic effect on the pattern of R&D in the economy. The increase in training costs lowers profits for all firms engaged in training, but it lowers profits most for firms producing medium quality goods who employ unskilled workers and incur high training costs. This raises the rate of return to R&D for previously successful firms but lowers it dramatically for previously unsuccessful firms.

The effects on relative R&D rates are such that now previously successful firms do more R&D than previously unsuccessful firms. Thus R&D races are characterised by an outcome of *persistent dominance* - firms that are successful tend to be successful, while firms that are unsuccessful remain unsuccessful. We have vicious circles and virtuous circles.

On balance these effects slightly reduce the growth rate, but this depends entirely on the particular numerical example. The arithmetic could have worked out differently and increased the rate of growth. So we see that *policies that increase training costs in an equi-proportionate fashion may either raise or lower the growth rate.*

We see that the there is no effect on the skill premium and consequently no effect on the percentage of workers getting higher education – because the equilibrium remains on the elastic portion of the demand curve. There is therefore no effect on inequality.

Finally the percentage of the labour force getting trained falls, since there is a significant increase in the percentage of firms producing the lowest quality good who undertake no training. As we would expect, the percentage of the wage bill that goes on training rises significantly.

So overall this policy has a small but negative effect on growth but no effect on inequality.

B.(iv) The effect of an increase in *a* – a policy that raises the costs of training unskilled workers relative to skilled workers.

This increases the demand for skilled relative to unskilled workers at any wage. It has a similar qualitative effect on the relative profits of companies producing different quality goods, and so

increases R&D done by previously successful companies, while reducing R&D by previously unsuccessful companies.

As in the previous case this now means that we now have *persistent dominance*. However, the negative effect on R&D by unsuccessful firms is now somewhat smaller than in the previous case and, as a result, there is no overall effect of this policy on growth.

However the shift in demand towards skilled workers raises the skill premium, and attracts more people into higher education. As a result the overall Atkinson measure of inequality increases.

Slightly fewer people get trained, and training costs rise as a percentage of the wage bill.

Taking all these comparative static effects together we see the following:

A) Policies targeted directly at raising the rate of return to R&D have the strongest effect on growth, but at the cost of increasing inequality.

B) Policies targeted at reducing the costs of access to education will have the win-win effect of raising growth and reducing inequality - however the effects are rather small.

C) Policies that lower training costs across the board will have an ambiguous effect on growth and could have a mild positive or negative effect, but seem to have little effect on inequality.

D) Policies that differentially reduce the training costs of the least skilled have little effect on growth and a small effect on reducing inequality.

### 3C. Comparative Static Cross Section Predictions

In this final sub-section I briefly consider how the cross section results reported in sub-section 3A are affected by the comparative static changes considered in Section 3B.

The two main conclusions I wish to draw are these.

Under all the policy changes, the firms producing the medium quality good remain the largest firms. However the relative sizes of the firms producing the top quality goods and the lowest quality good will change around. This will affect some of the predictions about the links between firm size and other variables. For example it is no longer true that there is a positive association between firm size and the percentage of the wage bill that goes on training.

**Secondly, as we have seen policies that increase training costs can dramatically reverse a situation of creative destruction – previously unsuccessful firms spend more on R&D that**

**previously successful ones – into an outcome of persistent dominance - previously unsuccessful firms spend more on R&D that previously successful ones.**

This will turn around a lot of the cross section predictions on the links between R&D, skills and training.

The main conclusion here is that:

Cross –section links between profitability and skills; profitability and training; and consequently between skills and training are robust and unaffected by policy changes.

However cross section correlations between firm size and either skill composition and training or between R&D , skill and training are unstable and sensitive to the precise policies in force.

**TABLE 1 Numerical Simulation Results**

BASE CASE PARAMETERS:

M = 80; q = 0.5; r = 0.05; E = 0.35;

a = 1; b = 0.2; c = 0.5; d = 0.5.

| Outputs | Base Case | $q = 0.6$ | $E = 0.42$ | $b = 0.24$ | $a = 1.2$ |
|---|---|---|---|---|---|
| $g^e$ | 4.0 | 5.1 | 3.8 | 3.8 | 4.0 |
| $R^e$ | 50 | 54 | 45 | 50 | 51 |
| $I_2$ | 4.0 | 4.9 | 4.2 | 4.0 | 4.3 |
| $S^e$ | 50 | 57 | 52 | 50 | 53 |
| $T^e$ | 93 | 96 | 92 | 87 | 91 |
| $TC^e$ | 32 | 33 | 32 | 36 | 33 |
| $p_0^e$ | 73 | 82 | 73 | 56 | 67 |
| $p_1^e$ | 71 | 74 | 67 | 74 | 74 |
| $f_0^e$ | 8 | 4 | 9 | 14 | 9 |
| $f_1^e$ | 41 | 40 | 45 | 35 | 38 |
| $f_2^e$ | 51 | 56 | 46 | 51 | 53 |
| $D_2^e / D_0^e$ | 101 | 98 | 101 | 99 | 100 |
| $D_1^e / D_0^e$ | 109 | 107 | 109 | 108 | 108 |
| $\hat{\phi}_2^e$ | 100 | 100 | 100 | 100 | 100 |
| $\hat{\phi}_1^e$ | 0 | 0 | 0 | 0 | 0 |
| $c_2^e$ | 30 | 30 | 30 | 36 | 30 |
| $c_1^e$ | 40 | 40 | 40 | 48 | 44 |

Note: Figures in Table represent percentages.

**Table 2 Profitability Figures**

| Outputs | Base Case | $q = 0.6$ | $E = 0.42$ | $b = 0.24$ | $a = 1.2$ |
|---|---|---|---|---|---|
| $\Pi_2^e$ | 20 | 33 | 18 | 14 | 17 |
| $\Pi_1^e$ | 10 | 20 | 10 | 2 | 6 |
| $\Pi_0^e$ | 0 | 0 | 0 | 0 | 0 |

**Conclusions**

**In this paper I have developed a very simple framework within which, for the first time, one can look at links between R&D/ growth, skill/inequality and training. The framework is rich enough to explore these linkages in both a cross sectional manner by looking across different firms, and in a time-series cross sectional fashion by looking across different economies.**

**Given the rather special nature of the model and the very specific nature of the numerical simulations it is difficult to draw very general conclusions. However some important points emerge.**

**Firstly the links between education/skills and training that one might observe at the micro-level do not carry across to the macro level. Thus at the micro-level education and skills are substitutes in the sense that the more education a person has the less training they need. However at the macro level policies that generate a higher proportion of educated people can increase the amount of training that takes place since they make the economy more innovative and raise the demand for training.**

**Secondly on the macro level one faces a policy dilemma between policies that are effective in promoting growth – through directly promoting R&D – which come at a cost of increased inequality - and policies that may involve no such trade-off but are less effective.**

Finally there are very few robust comparative static predictions particularly between

- firm size and: skill composition, training;
- R&D and: skill composition, training.

This is clearly an area for further research.

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