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The relationship between graduates and economic growth across countries

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Executive Summary

Higher Education (HE) is recognised as a key economic sector in the UK, having an impact on economic growth and competitiveness. However, producing estimates of the impact of HE on growth and competitiveness is a major challenge. In most countries, there is a dilemma about the amount of public resources that should be devoted to education, which has been amplified by the period of fiscal adjustment faced by many of the advanced economies. In this study we consider the evidence on the impact of HE on economic growth and productivity, drawing conclusions on the longer-term benefits of current investment in degree-level education.

The objectives of this research are to:

- Explore the relationship between graduates and economic growth;
- Assess what should be the key variable (or variables) of interest; and
- Quantify the relationship.

The empirical literature typically finds a positive relationship between education and GDP growth. However, a multitude of indicators are used, particularly to capture measures of education, which makes the studies hard to compare. Most studies focus on GDP growth or the growth in GDP per capita, whilst measures of education fall into one of four types. Most commonly used are average years of schooling, but several studies consider school and university enrolment rates; monetary investment in education; or internationally standardised test scores. Relatively few studies identify different levels of education, so the impact of graduates on growth is not often considered.

A theoretical framework derived from a standard Cobb-Douglas production function indicates that GDP per unit of labour input should be related to the share of labour of a particular type (graduates or workers at different qualification levels) weighted by the average human capital of the type of worker (captured by the relative wages of different types of labour input). Such data has recently been collated for many of the advanced economies through the EUKLEMS project. We exploit this data for 15 countries for the period 1982 to 2005.

Our key findings are:

- **GDP per employment hour increased from 1982-2005 in all countries.** The highest annual average percentage change was in Finland (2.7%); Japan (2.5%) and the UK (2.4%). These countries had the lowest level of GDP per employment hour in 1982, whilst throughout the period considered the Netherlands and the US had the highest GDP per employment hour.

- **The share of employment with tertiary education also increased from 1982-2005 in all countries.** The highest annual average percentage change was in Australia (5.0%) followed by the UK (4.9%). Both of these countries had relatively low shares of employment with tertiary education in 1982 at 6.0%, compared with 22.1% in the US and 18.7% in Finland. The large increase closed the gap, but the US and Finland still had higher employment shares with tertiary education than Australia and the UK in 2005.

- **Growth accounting analysis indicated that graduate skills accumulation contributed to roughly 20% of GDP growth in the UK from 1982-2005.** This approach limits the estimated impact to the productivity enhancement directly accrued to graduates and misses any externalities to HE which may raise the productivity of the rest of the economy. Econometric analysis addresses these issues.

- **Our econometric analysis indicated that a 1% increase in the share of the workforce with a university degree raises the level of long run productivity by 0.2-0.5%.** The long-run adjustment is gradual, with about 5-15% of the correction absorbed per annum. With the UK share of the workforce with a university education having increased by 57% between 1994 and 2005, our estimates suggest this will have raised UK long-run productivity by 11-28%. This means that at least one-third of the 34% increase in labour productivity between 1994 and 2005 can be attributed to the accumulation of graduate skills in the labour force.

1. Introduction

The role of Higher Education (HE) in improving economic growth and competitiveness is widely acknowledged. However, producing estimates of the impact of HE on growth and competitiveness is a major challenge, and in most countries there is a dilemma over the amount of public resources that should be devoted to education. This dilemma has become particularly acute during the difficult period of fiscal adjustment currently faced by many of the advanced economies. The aim of this study is to consider the evidence on the impact of HE on economic growth and productivity, in order to draw conclusions on the longer-term benefits of current investment in university-based education. Within this, the objectives are to:

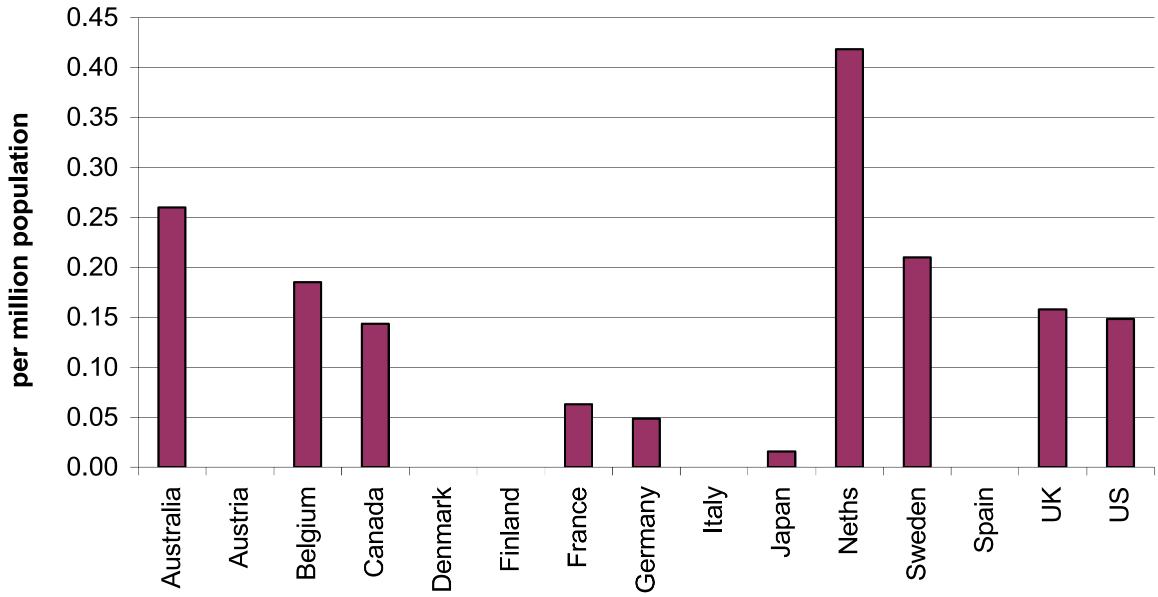
- Explore the relationship between graduates and economic growth;
- Assess what should be the key variables of interest; and,
- Quantify the relationship.

Universities come in many guises. Some are centres for elite education, others for frontier research, whilst the majority may be neither of these. The economic benefits, both to the individual and to the wider economy, of a university degree will clearly depend on the quality and breadth of skills imparted. The set of countries covered by this study contain 90 per cent of the 100 best universities in the world[1]. This suggests that the returns to HE in this subset of countries may be higher, on average, than in many other countries. Barrell et al (2010) found a strong correlation between the number of such institutes per million of population and productivity performance. Figure 1 plots the number of elite universities in each country in our sample per million of population. The US, the largest country in the sample, has 47

[1] We use the 2012-13 version of the Times Higher Education Supplement world university rankings which uses a combination of research, citations and teaching to rank the top 100 universities in the world. See www.timeshighereducation.co.uk/world-university-rankings.

elite universities, whilst the UK has 10[2]. The highest number per million of population are found in the Netherlands and Australia, followed by Sweden and Belgium.

Figure 1. Distribution of the top 100 universities in the world



Source: Times Higher Education Supplement and NiGEM database

UK universities have an outstanding research performance and reputation, which is reflected in international university rankings such as the QS ranking, the Times Higher Education world rankings illustrated above, the Academic Rankings of World Universities and the Shanghai ranking of the world's top 10 universities. After the United States, the UK is the most preferred destination of international students. In the academic year 2010-11, nearly 300,000 foreign non-EU students, mainly from China and India, were willing to pay higher, international tuition fee rates to study in the UK. In addition, 130,000 non-UK students from the EU were enrolled in a full or part-time course at a UK higher education institution. In total, international students constitute about 17 per cent of the student population.

The recent report by the LSE Growth Commission, 'Investing for Prosperity', highlights the importance of maintaining funding for research and an open

[2] There is an English language bias in the evaluation of elite universities, as the core language of science is English, and for instance if universities in France have policies to promote French language journals then their ranking will be affected. This bias does affect our overall conclusion.

environment in which universities can compete for the best minds – both in terms of students and faculty. The report stresses that ‘the knowledge and understanding created in universities play a central role in building a flexible and adaptable economy’. Centres of HE benefit the economy through their role in the education and skill development process as well as providing centres for research that develop productivity enhancing innovations. They also act as an increasingly important source of export revenue, as HE becomes a globalised industry with enormous growth potential.

Below we first review some of the key literature relating graduates and growth. We then review some key measures of productivity and human capital from a descriptive perspective to provide context to interpret the existing literature and introduce the empirical work that follows. This is followed by an analysis of the contribution of HE skills to GDP growth using growth accounting techniques. This provides a useful benchmark for assessing the importance of HE relative to other productivity enhancing factors over the sample period. However, the approach limits the estimated impact to the productivity enhancement directly accrued to the graduates. Given the dual role of universities, which provide centres of education as well as research, this may well underestimate the total macro-economic effects of an expanded HE system. It will also fail to capture other externalities to HE, such as improved management techniques that raise productivity at all skill levels. In the final section we address these issues through a series of econometric estimates that relate the expansion of HE skills to productivity growth.

2. Graduates and growth: a review of the literature

Improvements in educational outcomes have been widely recognised as essential in enhancing growth in both developed and developing countries. In the past few decades an influential macroeconomic literature has emphasised how education, as a measure of human capital, could generate long-term sustained economic growth. On the one hand, as claimed by Stevens and Weale (2003), since education delivers economic benefits to individuals, we should expect to see effects of education on groupings of individuals (nations) too. On the other hand, education acquired by individuals provides social returns at the macroeconomic level, yielding additional indirect benefits to growth (Sianesi and Van Reenen, 2003).

Theories of economic growth have emphasised the role of human capital and the different mechanics through which it may affect economic growth. The main theoretical approaches highlighting the connection between human capital and economic growth are the augmented Solow neo-classical approach and the new growth theories.

The standard growth model developed by Solow (1957) extends the basic production function by adding human capital as an extra input in the aggregate production function, where the output of the macro economy is a direct function of factor inputs: physical capital, labour and human capital, augmented by a term known as the Solow residual, or total factor productivity, which drives technical progress or the productivity of these factor inputs. The endogenous growth models argue that total factor productivity is determined within the model, instead of being driven by exogenous technological progress. Unlike the neoclassical theories, endogenous growth models have explicitly included education by emphasising its role in increasing the innovative capacity of the economy through developing new ideas and technologies.

In the next section of the report we set out the main approaches to modelling economic growth (Section 2.1). In Section 2.2 we discuss the main results from the empirical literature whilst highlighting some of the key measurement issues relating to modelling the influence of graduates on growth.

2.1 Theories of economic growth

The modelling framework that has been adopted in the vast majority of empirical studies that assess the relationship between education and economic growth is constructed around a simple Cobb-Douglas production function such as:

$$(1)\quad Y = AK^{\alpha}H^{1-\alpha}$$

where Y is output, A is total factor productivity, K is the stock of physical capital, and H is the stock of human capital. H can also be disaggregated into the average level of human capital per worker (h) and the amount of labour input (L), so that we can express equation (1) as:

$$(2)\quad Y = AK^{\alpha}(hL)^{1-\alpha}$$

Some authors have treated this as a 3-factor production process, where labour input is disembodied from human capital, as in Mankiw, Romer and Weil's model (1992). The key difference being that the elasticity on *h* is not restricted to be the same as the elasticity on *L or K* (although the three are still constrained to sum to one). Alternatively, L can be disaggregated into different types of labour, where h_l is average human capital of worker type l and L_l is the amount of labour input of type l. In this case equation (1) can be expressed as:

$$(3)\quad Y = AK^{\alpha}\left(\sum_{l=1}^{L} h_l L_l\right)^{1-\alpha}$$

Expressing the variables in terms of per unit of labour input and taking logs, equation (1) can be expressed as:

$$(4)\quad \ln\left(\frac{Y}{L}\right) = \ln A + \alpha \ln\left(\frac{K}{L}\right) + (1-\alpha)\ln\left(\frac{H}{L}\right)$$

Or

(5) $\ln y = \ln A + \alpha \ln k + (1-\alpha)\ln h$

Or

(6) $\ln y = \ln A + \alpha \ln k + (1-\alpha)\ln\left(\frac{\sum_{l=1}^{L} h_l L_l}{L}\right)$

With *y* and *k* being, respectively, output and physical capital stock per unit of labour input and $h_l L_l / L$ is the share of labour input of type l weighted by the average human capital of type l.

In the original model developed by Solow (1957), A is assumed to be exogenous. By contrast endogenous growth models often include variables such as foreign direct investment (FDI) and openness to capture the economy's ability to absorb technology from abroad; and the domestic stock of R&D or government spending on R&D to capture the innovative capacity of the domestic economy. In addition, studies such as Bils and Klenow (2000) look for externalities to education (social returns beyond returns to the individual) by modelling A as a function of measures of human capital/schooling in addition to the direct role expressed in equations (5) or (6) above.

Based on the above derivation, we can describe a full long-run model that underlies the majority of empirical studies of the relationship between education and growth[3] as:

(7) $\ln y = \ln A(h, Z) + \alpha \ln k + (1-\alpha)\ln h + \varepsilon$

where the variables are as defined above, ε is an error term and Z is a vector of control variables such as the degree of openness of economies to trade and foreign investment, R&D spending and various dummy variables to control for country- and time-related influences on economic activity. The fundamental underlying framework is adapted in each study, depending on whether the authors are interested in explaining differences in the levels of productivity across countries, differences in the growth rates of productivity across country, the development of productivity within a

[3] The majority of studies surveyed by Sianesi and Van Reenen (2003) have this framework at their foundation, as do most of the studies reported in Table A1 (Annex).

country or set of countries, or decomposing growth within a country or group of countries.

Many authors have focused on explaining differences in the growth rate of productivity across countries (e.g. Judson (1998), Krueger and Lindahl, 2001 and Benhabib and Spiegel, 1994) and have utilised the difference version of equation (7) in estimation:

$$(8)\quad \Delta \ln y = \beta_1 \Delta \ln A(h, Z) + \beta_2 \Delta \ln k + \beta_3 \Delta \ln h + \eta$$

Finally, many of the cross-country growth regression studies have combined the dynamic and level equations, to include some starting level measures, such as the initial levels of income, physical capital, distance from the technology frontier or schooling (e.g. Levine and Renelt, 1992; Gemmel, 1996; Barro, 1997; Cohen and Soto, 2007):

$$(9)\quad \Delta \ln y = \beta_1 \Delta \ln A(h, Z) + \beta_2 \Delta \ln k + \gamma_1 \ln h_0 + \gamma_2 \ln A(h, Z) + \mu$$

where 0 indicates starting level values. The cross-section growth regression model from equation (9) can be readily adapted to a dynamic framework, and expressed as an error-correction equation, with short-run dynamics around a long-run relationship, as used, for example, by Mason *et al* (2012). A full encompassing model, which allows for the possibility that the relationship is purely dynamic with no long-run relationship (e.g. $\delta_2 = 0$), can be expressed as:

$$(10)\quad \begin{aligned} \Delta \ln y_t &= \delta_1 + \delta_2 \left[\ln y_{t-1} - \delta_{11} \ln k_{t-1} - \delta_{12} \ln h_{t-1} - \sum \delta_{1z} \ln Z_{z,t-1} \right] \\ &+ \sum \delta_{2i} \Delta \ln y_{t-i} + \sum \delta_{3i} \Delta \ln k_{t-i} + \sum \delta_{4i} \Delta \ln h_{t-i} + \sum \delta_{4zi} \Delta \ln Z_{z,t-i} \\ &+ \delta_3 \ln k_{t-1} + \delta_4 \ln h_{t-1} + \sum \delta_{5z} \ln Z_{z,t-1} \end{aligned}$$

All of the modelling frameworks used in the empirical studies that we review can be nested within equation (10), which we will use as the primary framework for our econometric work.

2.2 Existing empirical evidence

Theoretical models, based on derivations similar to that presented above, imply that sustained growth relies on the potential for human capital to grow without bound. As such, policy on education should be prioritised when considering the determinants of growth (Temple, 2003). Empirical studies have been undertaken in order to support this theoretical premise. The most common empirical approach in the literature to study the impact of education on growth has been through cross-country growth regressions, using a framework such as that specified in equation (9) above. These studies relate a measure of the growth rate of productivity to the average level, or growth rate, of education within a country.

Sianesi and Van Reeenen (2003) provide a thorough survey of the empirical evidence on the relationship between human capital and growth. They conclude that there is strong empirical evidence that human capital increases productivity, suggesting that education really is productivity-enhancing, rather than just a device used by individuals to signal their ability to potential employers. The studies surveyed typically suggest that a one-year increase in average education is found to raise the level of output per capita by between three and six percent, or raise the rate of potential growth by just over one percentage point per annum – depending on the type of model adopted.

Table A1 (Annex) summarises the findings of a set of key studies on the relationship between education and growth. This set includes some of the seminal papers surveyed by Sianesi and Van Reenen (2003), but is primarily focused on more recent studies that were not covered by this survey. Most of the papers that we survey typically present multiple model specifications and proxies to capture the key variables. However, the table only displays the main result/model for each paper[4]. The table also includes information on the measures used, time period and country coverage of each study.

[4] Where it is difficult to identify a preferred or main result within a paper, we have selected the model that is most directly comparable to the empirical approach of this study.

As the measures and structure of the models surveyed differ across studies, the empirical results are not strictly comparable. Nonetheless, the key message from Table A1 supports the conclusions of Sianesi and Van Reenen (2003). Irrespective of the proxies and measures used in estimation, almost all the studies found a positive and significant effect of human capital on growth. The only exceptions are the studies by Benhabib and Spiegel (1994) and Pritchett (2001) who found a negative, but not statistically significant relationship between human capital and growth. Holmes (2013) also failed to find a significant relationship between higher education and GDP growth using a range of cross-country regression frameworks, and warns that the results of cross-country regression estimates, such as that used by Gemmell (1996), should be viewed with caution, as the results are sensitive to the sample period and country coverage.

2.2.1 Measurement and data issues in the literature

Empirical studies have adopted a range of different measures and proxies to represent the variables underpinning the theoretical framework presented above. For example, y, which represents output per unit of labour input in equations (5)-(10), has been most commonly proxied by GDP per capita. A preferred measure would reflect developments in employment rather than total population – as demographic and other factors may affect the correlation between the two. However, this variable is difficult to measure for some countries – especially in studies that use a large cross-section of countries that include developing as well as developed economies. If average working time per employee is also non-stationary, output per hour of labour input would be the preferred measure of y. Some studies have modelled total factor productivity (TFP) as the dependent variable, although this is not a directly observable figure and subject to a wide degree of measurement error.

The presumption behind most of the empirical studies is that an educated labour force is better at creating, implementing, and adopting new technologies, thereby generating growth (Benhabib and Spiegel, 1994). One of the issues arising when considering the effect of human capital on economic growth is how human capital should be measured (Hanushek and Kimko, 2000). The primary measures used to capture the average level of human capital per worker include:

- the average number of years of schooling of the workforce or population, which assumes a linear relationship with human capital.
- the share of the workforce/population with specific educational qualifications
- school enrolment rates – especially as a starting value. This flow into education is often used as a proxy for the potential stock of educational qualifications, and is available for a very large cross-section of countries.
- a discounted wage premium of education over unskilled labour (Pritchett, 1999)
- Mincer-style wage equations or Tornqvist relationships that relate human capital to wage returns.
- investment in education – sometimes disaggregated by type (Aghion et al, 2009)
- cognitive skills, usually measured through international test scores such as the PISA and TIMSS.

Over time, data improvements have meant that different, and often more appropriate indicators of human capital have become available for an increasing number of countries. The EUKLEMS database marks a significant improvement over previous datasets, as it allows us to identify both the share of actual employment undertaken by individuals with different levels of educational attainment and also the share of labour compensation that goes to each group. However, the database is only available for a relatively small set of advanced economies. Many studies have shown that splitting cross-section samples according to levels of economic development shows that the relationship between education and growth is sensitive to the stage of development. This suggests that employing more appropriate datasets for smaller groups of countries that are at a similar level of development is likely to lead to more robust results.

Below we review the key literature, differentiating studies by the measure of human capital used as the primary education indicator (stock, flow, investment, and cognitive skills). Finally we discuss studies that specifically consider graduates in their measure of human capital.

2.2.2 The stock of human capital

The first large cross-country dataset on the stock of human capital was compiled by Psacharopoulos and Arriagada (1986), and reflected the average years of schooling of the labour force for 99 countries at a given point in time. Kyriacou (1991) extrapolated this cross-section sample to a time series, using the relationship between these stock measures and school enrolment ratios. This approach has been used by key studies such as Benhabib and Spiegel (1994), who found a negative and statistically insignificant relationship between the growth rate of GDP per capita and the growth rate of human capital, but a positive relationship between the level of human capital and productivity growth.

Kruger and Lindahl (2001) highlight the potential problems arising from measurement errors in education, as the average schooling levels are derived from enrolment flows. They adopt more reliable country-level education micro data, and find a positive association between the growth rate of education and economic growth. However, they note the strong correlation between physical and human capital measures – both of which are subject to severe measurement error – which makes it difficult to separately identify the effects of the different types of capital.

Cohen and Soto (2007) make further advancements in improving the quality of human capital measures, and present a new dataset for years of schooling across countries from 1960 to 2000 that accounts for the age structure of the population and for three educational categories (primary, secondary, and tertiary). They also find a significant impact of schooling on growth.

Barro and Lee (2010) provide an improved data set on educational attainment from 1950 to 2010 for 146 countries, which is disaggregated by sex and age. Using these new education measures they provide further evidence of a significant and positive effect of education on output.

Mason *et al.* (2012) differentiate between qualifications gained through academic study and qualifications gained through vocational education and training. The key findings are that vocational skills made positive contributions to growth in average labour productivity (ALP) in six of the seven countries considered. The approach to measuring human capital is broadly in line with the one used in the analysis presented in this report, although we focus exclusively on qualifications gained through academic study.

2.2.3 Human capital flows

Human capital flows – most commonly proxied by school enrolment rates – have been widely used in empirical studies of the relationship between human capital and growth. This is largely due to the availability of long time series of data for a large cross-section of countries rather than because it is viewed as preferable to the stock measures. As improved stock measures continue to be developed, it is likely that this approach will gradually be phased out in preference for stock measures.

Among the first studies to adopt enrolment rates as a proxy for human capital is the contribution of Barro (1991). This study analyses the relationship between growth and human capital for 98 countries from 1960 to 1985, using 1960 primary and secondary-school enrolment rates as a determinant. Barro shows that enrolment rates are positively correlated with growth in real per capita GDP.

Mankiw, Romer and Weil (1992), focusing on the same time period (1960-1985), use the percentage of the working-age population in secondary school as a proxy for the rate of human-capital accumulation. Their results show that including human capital lowers the estimated effects of saving and population growth; with the augmented models accounting for 80 percent of the cross country variation in income.

Bils and Klenow (2000) question the studies of both Barro (1991) and Benhabib and Spiegel (1994) in that the empirical relationship they document does not exclusively reflect the impact of schooling on growth, due to omitted factors that are related to both schooling rates and growth rates. They conclude that the direct channel from schooling to growth can explain less than one-third of the empirically observed relationship between schooling and growth.

Based on the motivation that school enrolment rates conflate human capital stock and accumulation effects, and lead to misinterpretations of the role of labour force growth, Gemmell (1996) constructed an alternative measure of human capital based on both school enrolment rates and labour force data. He used 1960 school enrolment rates as a proxy for the proportion of the 1960 labour force with the relevant level of education (primary, secondary, and tertiary), combining it with data on the working age population in 1960 to estimate initial stocks of human capital.

This measure has the advantage of providing a consistent dataset on education stocks based on school enrolment rates and also provides a closer approximation to educated labour being more relevant for growth than the educated population. Estimates based on both developed and less developed countries over the period 1960-1985 support the hypothesis that both initial stocks and subsequent growth of human capital are important in fostering faster income growth.

2.2.4 Investment in human capital

School enrolment rates have also been interpreted as a measure of the flow of investment in human capital rather than a proxy for the stock of human capital. A recent strand of research considers alternative measures of investment in human capital as a determinant of growth. Keller (2006) examines three measures of education investment: enrolment rates, public education expenditures as a share of GDP, and public education expenditures per student as a share of GDP per capita. She does so by estimating individual effects of primary, secondary, and tertiary education. Her estimates suggest that the public expenditure per student and enrolment models explained 69 percent of GDP per capita growth, with secondary education being highly significant.

In a similar vein to Keller (2006), Aghion *et al* (2009) focus on the role of investment in education (measured in actual dollars spent per person by cohorts) across states in the US. They use a series of political instruments for different types of education spending. Their analysis supports the existing evidence that investment in education raises growth.

2.2.5 Human capital measured by cognitive skills

While the most frequently employed measure to capture human capital is the primary or secondary-school enrolment rates, Hanushek and Kimko (2000) argue that these measures do not accurately represent either the relevant stock of human capital embodied in the labour force or changes in this stock during periods of educational and demographic transition. A few studies have addressed this short-coming through introducing measures of cognitive skills into the models, rather than enrolment rates or average years of schooling. As pointed out by Hanushek and Woessmann (2010) measuring years of schooling assumes that one year of schooling delivers the same increase in knowledge and skills, regardless of the education system; and education systems in different countries can be very different.

Hanushek and Kimko (2000) address this by constructing new measures of educational quality based on students' performance on various international tests of academic achievement in mathematics and science. In so doing they measure the quality of the labour force by aggregating different test scores into a single measure for each country. Using these new measures they show that labour-force quality differences are very strongly related to growth rates for 31 countries between 1960 and 1990. Moreover, they claim that these quality measures are important for explaining which countries are at the top and at the bottom of the distribution of economic growth rates.

Hanushek and Woessmann (2010) also consider cognitive skills as a proxy for education quality[5]. They focus on the long-run growth differences among OECD countries, and show that educational outcomes have a crucial role for developed countries. The empirical analysis is built on a series of cross-country growth regressions for 24 OECD countries between 1960 and 2000. They measure human capital using international math and science tests, and show that those tests dramatically increase the ability of the statistical models to explain growth differences across OECD countries.

2.2.6 The impact of higher education and skills

To a large extent, long-run changes in average educational attainment are driven by government policies. However it is possible that as output and tax revenues increase, governments will allocate more resources to education, and educational enrolment rates may not be stationary over time. In this context, the human capital stock measures described above have an advantage over the human capital flow measures. New entrants are usually a small fraction of the labour force, and a

[5] Hanushek and Woessmann (2010) outline that the advantages of cognitive skills are that they capture variations in knowledge and ability that schools strive to produce; they incorporate skills from any sources (families, schools, and ability); they allow for investigation of important different policies designed to affect the quality aspects of schools, and finally they are practical to use given the extensive development of consistent and reliable cross-country assessments.

change in the flow of educational provision will affect the stock of skills only very gradually. Measures that take into account differences in the quality of education across countries, such as students' performance on various international tests of academic achievement, may have further advantages. However, these measures are less relevant for assessing the impact of tertiary education on growth, as these internationally comparable tests tend to be carried out at earlier stages in education.

In recent years the contribution of tertiary education to countries' economic success has become the focus of greater attention, since tertiary education is expected to support the supply of skilled workers and enhance the conditions for innovation, bringing substantial social and economic benefits (McNeil and Silim, 2012). However, amongst the empirical evidence analysing the effect of education on growth across countries, only a few papers explicitly analyse the role of tertiary education. For example, Barro and Lee (2010) provide evidence that, for developed countries, the estimated rate-of-return to an additional year of schooling is higher at secondary and tertiary levels than at primary level. Similarly, Gemmell (1996) highlights how the role of different levels of education varies across countries at different stage of growth. Specifically, he shows that the primary level appears to be important in the poorest low developed countries; secondary level effects dominate in 'intermediate' LDCs, while tertiary effects are strongest in OECD countries. Holmes (2013), using a sample that pools countries across different levels of development, finds a significant relationship between secondary education and GDP growth, but not between tertiary education and growth. Keller (2006) identifies a positive relationship between enrolment in tertiary education rates and economic growth, while Hanushek and Woessmann (2010) find that the role of tertiary schooling in OECD countries increased after controlling for cognitive skills, based on educational attainment tests at the primary and secondary levels of schooling.

In the wake of diffusion of Information and Communications Technologies (ICTs) in recent decades, an extensive literature has developed around the concept of skill-biased technical change, i.e. skilled labour is more complementary to the introduction and/or effective utilisation of new technologies than is unskilled labour (Autor, Katz and Krueger, 1998; Machin and van Reenen, 1998). US evidence suggests that skills play a key role in facilitating the effective utilisation of ICTs (Bresnahan, Brynjolfsson and Hitt (2002), and that over several decades ICTs have enhanced the ability of educated labour required to perform non-routine tasks (Autor, Levy and Murnane, 2003).

A number of studies in European countries have supported the US evidence of a positive relationship between workforce education or skills and the adoption of new technologies. Examples include firms in Spain (Bayo-Moriones and Lera-López, 2007), Switzerland (Hollenstein, 2004), Portugal (Barbosa and Faria, 2008) and Ireland (Haller and Siedschlag, 2008). The principal mechanisms involved are that high skilled workers can contribute more than low skilled workers to the selection, installation, operation and maintenance of ICTs and also to the adaptation of ICTs to firm-specific requirements. This positive relationship between education or skill levels and ICT adoption also holds in cross-country studies involving European and other industrial nations (Hargittai, 1999; Gust and Marquez, 2004).

Assessment of the types of skills best suited to ICTs is complicated by the fact that the level of skills required for rapid adoption of ICTs may differ from the skills required for their subsequent utilisation. O'Mahony, Robinson and Vecchi (2008) report that ICT-related demand for university graduates in the US was particularly strong in the 1980s, suggesting that early adoption of ICT in the US was facilitated by the greater availability of university-educated workers in the US at that time compared to European countries such as Britain, France and Germany. However, O'Mahony *et al*. (2008) also find that, during the following decade, ICT-related demand for workers with sub-graduate (intermediate) qualifications increased in the US.

Chun (2003), in a study of the relationship between ICTs and the demand for educated workers at industry level in the US, distinguished carefully between the adoption and use effects of information technology and found that both had contributed substantially to the increased relative demand for university graduates. However, his evidence also suggested that while adoption is positively related to highly skilled workers; as the new technology becomes fully implemented, firms may be able to replace highly skilled workers with lower-paid less-skilled workers. In a similar vein, Ruiz-Arranz (2004) notes that as new technologies become more established and ICT equipment becomes more user-friendly over time, fewer graduates are likely to be needed as ICTs become more complementary to workers with skills below graduate level.

A vast microeconomics literature has focused on identifying the returns to schooling using regressions methods, where the estimated return is based on the coefficient on a variable measuring years of education in an equation that controls for work experience and other individual characteristics (the standard Mincer equation). Mincer's derivation of these empirical models is based on the schooling measure being exogenous, which is open to question as to some degree, education level is a choice variable for individuals (Harmon, Oosterbeek and Walker, 2003). When it comes to tertiary education the role of choice is clearly more relevant. While few of the studies separately identify the role of tertiary education, they nonetheless provide a useful backdrop to the analysis.

Martins and Pereira (2004) analyse the returns to education at the first and ninth deciles using micro-data for 16 developed countries during the mid-1990s. They provide evidence of a common pattern for most of the countries, in that the returns to education are higher at higher points of the conditional wages.

Using comparable micro-data for 28 countries from 1985 to 1995, Trostel, Walker and Woolley (2002) estimate the rate of return and find considerable variation in rates of return across countries, although this variation declined slightly over the sample period. They document that the highest returns to education are found in countries with incomes that are relatively high (USA and Japan) and relatively low (Philippines), as well as in-between (Northern Ireland, GB, Slovenia and Poland). Moreover, they provide evidence that the rate of return declines with average educational attainment, per capita income, and relative spending on education.

The empirical evidence clearly supports the assertion that the human capital embodied in higher education strengthens economic growth prospects. This role has been particularly prominent during the ICT revolution of recent decades. While ICT may have evolved to a stage where tertiary skills are less important for absorbing productivity enhancements, it does not necessarily follow that HE skills are likely to become less relevant over time. Freeman and Soete (1997) describe the growth process over the last two centuries as a sequence of product innovation cycles where new products are developed, followed by process innovation cycles where those products are improved. Recent product innovations have been closely linked to university level research and innovation. It is of course impossible to know where the next wave of scientific innovation might come from, but a strong research base, supported by top quality universities, is clearly conducive to leading product innovation. The diffusion of innovations is also more likely to be accelerated by a highly-skilled labour force, as observed in the case of the ICT wave of innovation.

3. Data sources and descriptive statistics

In this section of the report we introduce the data to be used in our analysis and provide a brief description of key measures of labour productivity and human capital.

3.1 Countries included, time period and sources of data

Most of the required data for analysis is downloadable from our National Institute Global Econometric Model (NIGEM) database. This includes data on:

- GDP
- GDP per capita
- GDP per employment hour
- Investment
- Size of the Labour Force
- A measure of country openness – the sum of exports and imports as percentage of GDP

We also have added data on Research and Development (available from the OECD) and data on Foreign Direct Investment (available from UNCTAD).

The main data required from other sources is the share of employment by education level and the share of labour compensation by education level. We have considered a number of different sources for this information and conclude that the best available data comes from EUKLEMS. This provides data from 1982-2005 for most EU as well as some large non-EU countries. More recent data is available for a smaller number of countries, but given that one of the key aims of the analysis is to establish the long run relationship between graduates and growth across countries we decided to limit the period of analysis to 1982-2005 to allow a broader coverage of countries.

A comprehensive data set is then available for the following 15 countries covering the period 1982-2005:

- Australia
- Austria
- Belgium
- Canada
- Denmark
- Finland
- France
- Germany
- Italy
- Japan
- Netherlands
- Spain
- Sweden
- UK
- US

3.2 Measures of labour productivity

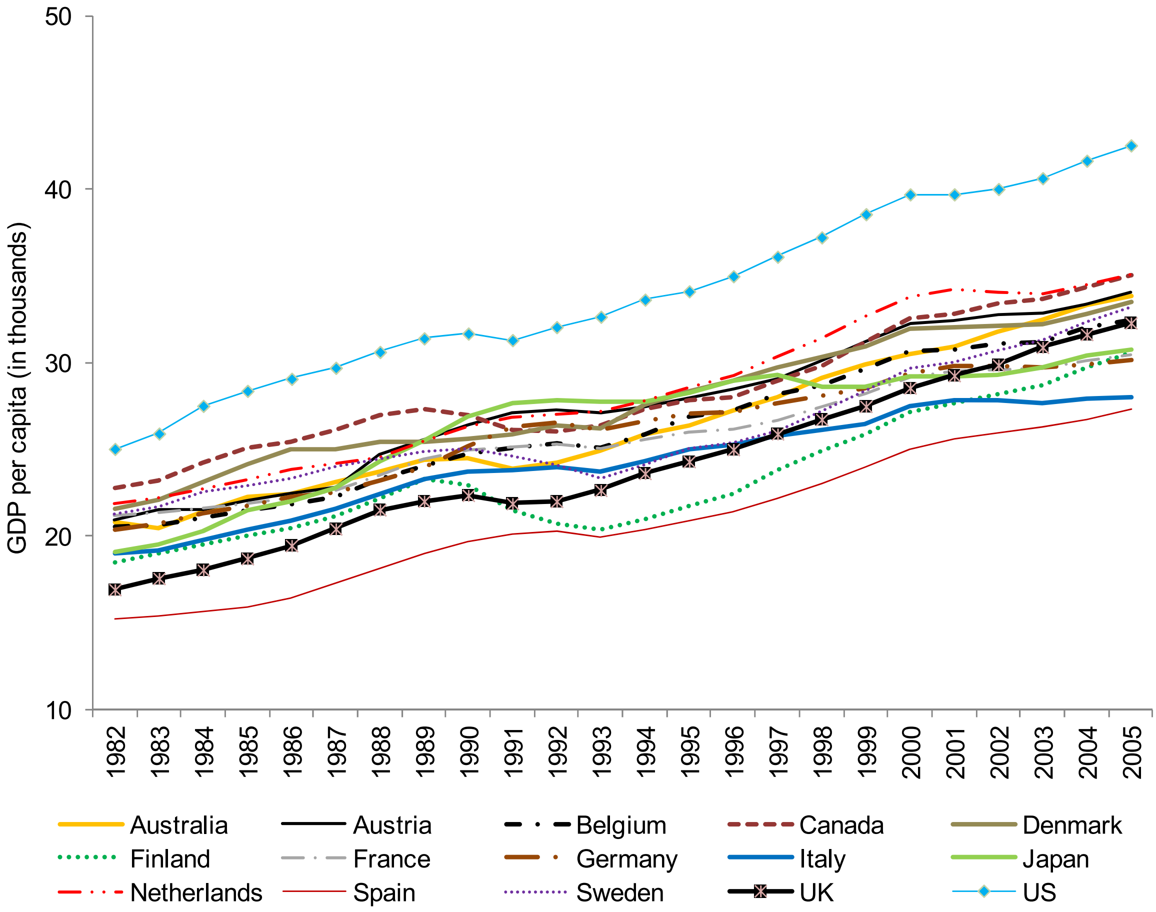
Figures 2 and 3 and Table 1 report descriptive statistics for indexes of labour productivity measured by GDP per capita and GDP per employment hour for our 15 countries from 1982-2005.

Figure 2 plots for each country the GDP (in Purchasing Power Parity, PPP) per capita, showing that on average between 1982 and 2005 the level of GDP per capita has been increasing in all countries, though at a different speed.

- The US stands out with the highest level of GDP per capita in both the initial and final year of the analysis.

- Even though the UK had the second lowest GDP per capita in 1982, by the end of 2005 its GDP per capita became the 9th largest amongst the countries in our sample.

Figure 2. GDP (PPP) per capita by country, 1982-2005



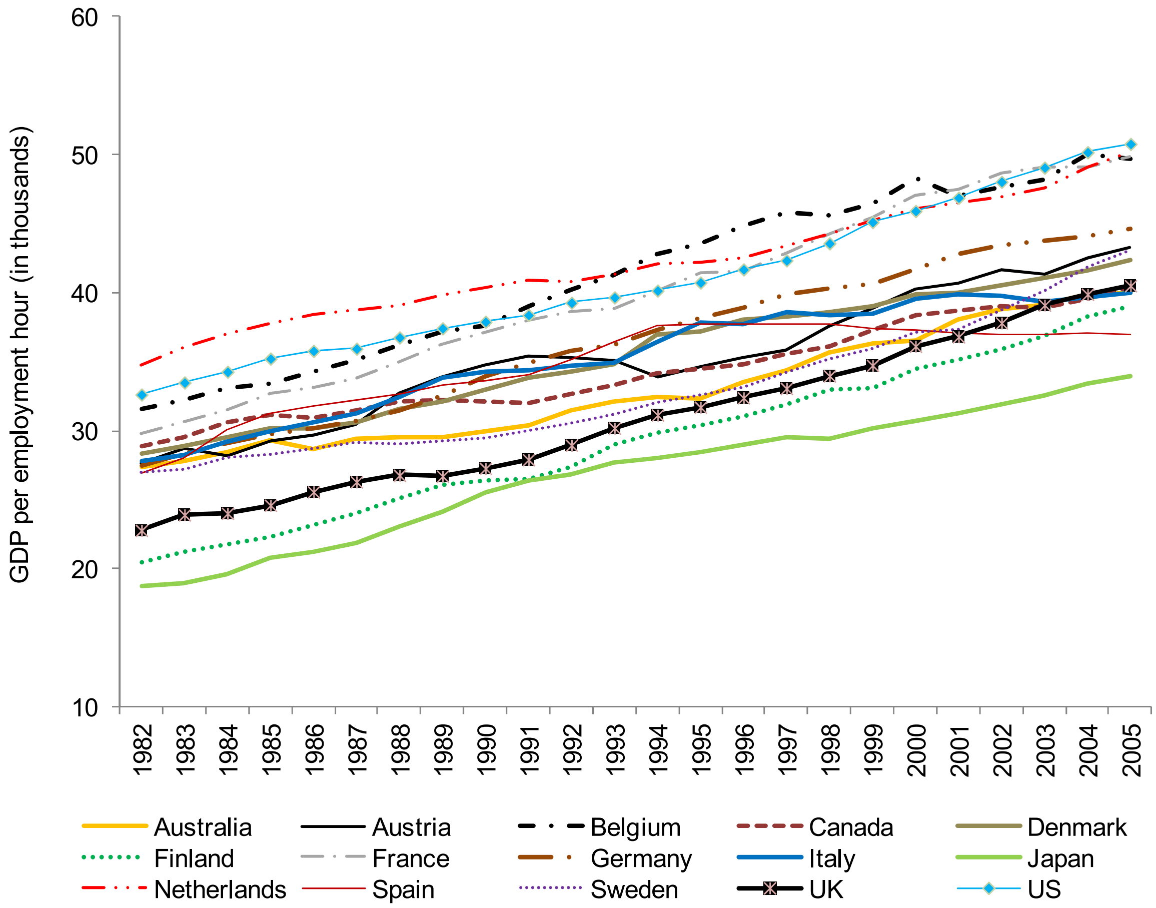
Source: NiGEM database

The majority of cross-country regression studies that have assessed the relationship between growth and educational attainment have relied on GDP per capita as the measure of productivity. This is due to data limitations, especially when expanding the sample to include developing and emerging economies. However, the preferred measure of labour productivity is GDP per employment hour (Figure 3). According to this measure, differences in growth rates are more marked across countries.

- The experiences of Italy and Spain stand out, as in both countries GDP per employment hour essentially stopped growing from the middle of the 1990s.

- Between 1982 and 2005, the rate of change in output per employment hour for the UK was amongst the top three highest in our sample of countries.

Figure 3. GDP (PPP) per employment hour, by country 1982-2005



Source: NiGEM database

Table 1 shows GDP per capita and GDP per employment hour in 1982 and 2005 and the annual average growth rate of the two measures between 1982 and 2005.

- Spain had the lowest GDP per capita in 1982, followed by the UK.

- These countries had the highest growth in GDP per capita over the whole period (UK 2.7% p.a. and Spain 2.5% p.a.). However, this still leaves Spain with the lowest GDP per capita in 2005, along with Italy.

- The US, followed by Canada, had the highest level of GDP per capita in both 1982 and 2005.
- Despite being the two countries with the lowest share of the workforce with tertiary level of education, Netherlands and Denmark are the countries with respectively the third and fourth highest level of GDP per capita in 1982.

Table 1. GDP (PPP) per capi ta and G DP per employ ment hour and annual average change, (index: USA=100 in 1982), by country, 1982-2005

Countries	GDP per capita			GDP per employment-hours		
Year	1982	2005	1982-2005 Annual average change, percent	1982	2005	1982-2005 Annual average change, percent
Australia	83.2	135.2	2.0	83.8	122.4	1.6
Austria	83.6	136.4	2.1	84.7	132.5	1.9
Belgium	82.0	129.6	1.9	96.7	152.3	1.9
Canada	91.2	140.0	1.8	88.4	123.8	1.4
Denmark	86.4	134.0	1.9	86.8	129.8	1.7
Finland	74.0	122.0	2.1	62.9	119.4	2.7
France	84.8	122.0	1.5	91.3	152.7	2.2
Germany	81.2	120.4	1.6	84.2	136.6	2.0
Italy	76.0	112.0	1.6	85.3	122.4	1.5
Japan	76.4	123.2	2.0	57.4	104.0	2.5
Netherlands	87.6	140.4	2.0	106.4	153.6	1.5
Spain	60.8	109.2	2.5	82.5	113.3	1.3
Sweden	85.2	132.8	1.9	82.7	132.0	2.0
United Kingdom	67.6	129.2	2.7	69.8	124.1	2.4
United States	100.0	170.0	2.2	100.0	155.6	1.9

Source: NiGEM database

The pictures change slightly when looking at GDP per employment hour.

- In 1982 the three countries with the lowest level are Japan, Finland and the UK, with Netherlands having the highest level of GDP per employment hour followed by the US.

- By 2005 the US and the Netherlands swapped positions.

- The growth rate of GDP per employment hour was highest in Finland at 2.7% per annum followed by Japan and the UK (2.5% and 2.4% p.a. respectively). Despite this, Japan still had the lowest level of GDP per employment hour in 2005.

- Spain had the lowest growth in GDP per employment hour (1.3% p.a.), as productivity stagnated in the second half of the sample period, leaving it next to bottom of the countries (only above Japan) in terms of GDP per employment hour in 2005.

Turning to comparisons of GDP per employment hour, or average labour productivity (ALP) levels (Figure 4).

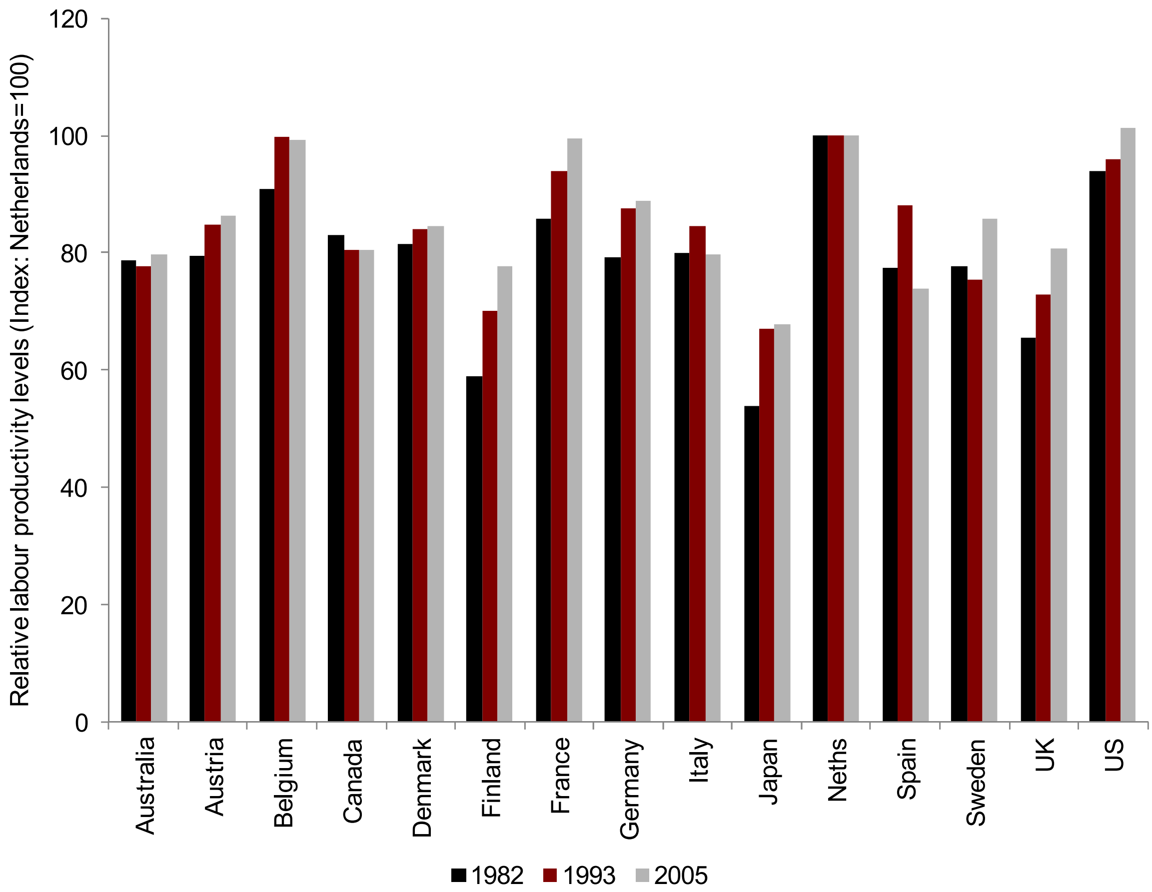
- The productivity leader from 1982 to 2000 was the Netherlands overtaken by the US since 2001.

- Although the Netherlands was ahead of all the countries in the sample (except for the US) throughout this time period, several countries significantly reduced the ALP gap between themselves and the Netherlands: Belgium, France and Germany narrowed the ALP gaps substantially such that by 2005 ALP in Belgium and France was about 99% of the Dutch level while German ALP was 89% of the Dutch level[6].

- The ALP gap for the UK reduced from 66% of the Netherlands in 1982 to 73% in 1993 and 81% in 2005.

[6] These estimates of ALP levels across countries are based on conversion of output values from domestic currencies to a common currency (US$) using 2005 purchasing power parity (PPP) exchange rates.

Figure 4. Relative labour productivity levels, 1982, 1993 and 2005

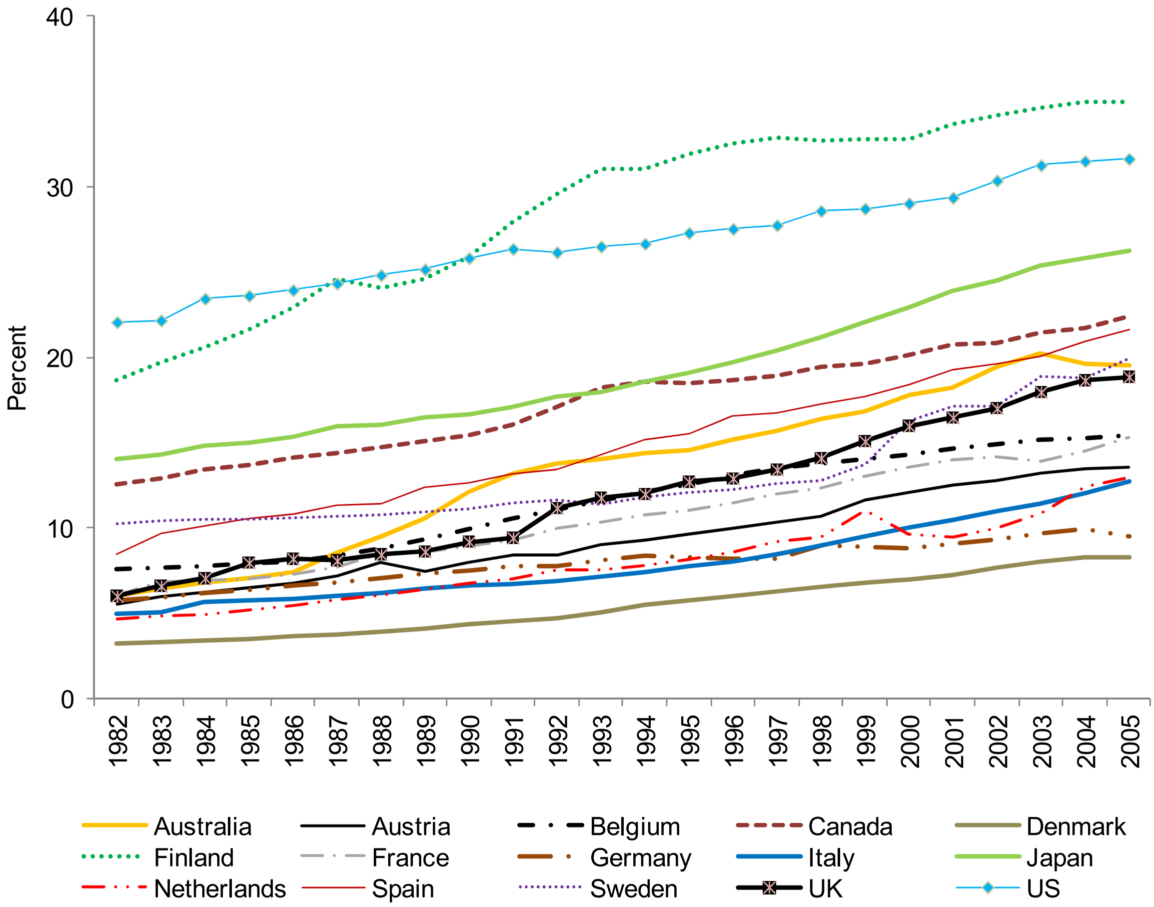


Source: NiGEM database

3.3 Measures of human capital

Figure 5 and Table 2 provide some descriptive statistics for the share of employment with tertiary education in the 15 countries from 1982 to 2005. Figure 5 shows that between 1982 and 2005 the share of workers with a tertiary level of education increased in all countries, although the rate of increase and the starting level vary significantly across the countries.

Figure 5. Tertiary education employment shares (percentage), by country 1982-2005



Source: EUKLEMS

This is better seen from Table 2, which shows the share of workers with tertiary education in 1982 and 2005, and the corresponding average annual growth rate of these shares.

- In 1982 Denmark was the country with the lowest share of workers with a tertiary level of education (3.2%), although during the time period analysed its average annual percentage change is amongst the highest (4.0%).
- In 2005 Denmark and Germany are the only two countries with less than 10% of workers with a tertiary level of education.

- In 1982 United States and Finland had the highest share of the workforce with tertiary education. They remain the countries with the highest share of tertiary educated workers in 2005, although growth rates in these employment shares in other countries have been considerably higher.
- Australia had the highest (5.0%) average annual percentage change in the share of workers with a tertiary level of education followed by the UK (4.9%).

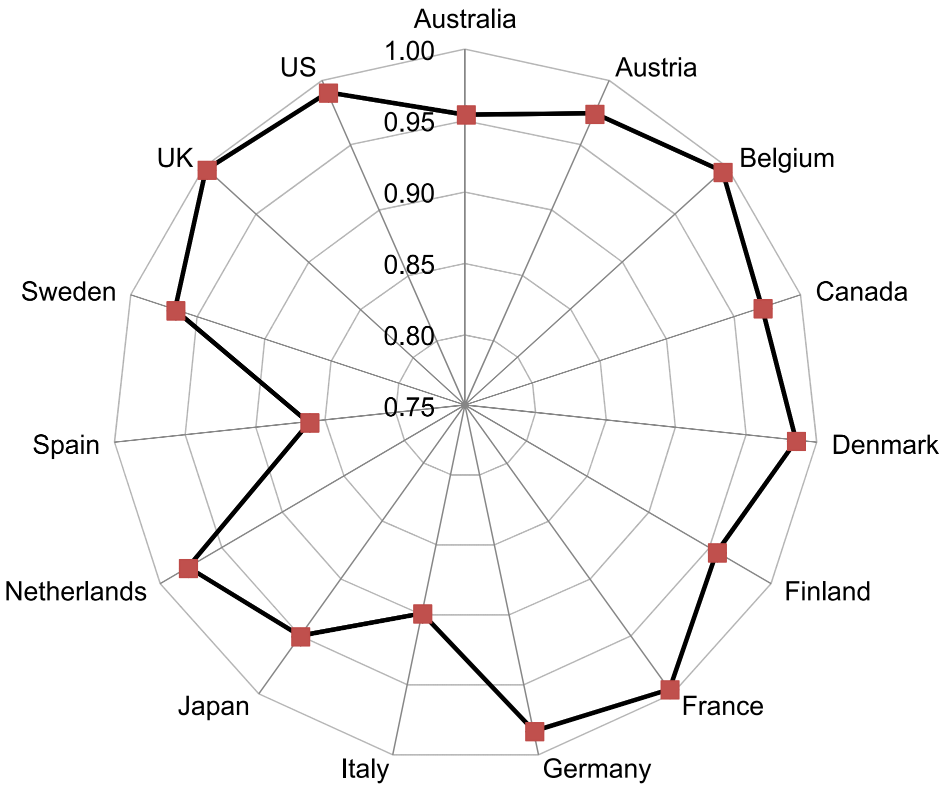
Table 2. Tertiary education employment shares and annual average change b y country, 1982-2005

Country	1982	2005	1982-2005 Annual average change, percent
Australia	6.0	19.6	5.0
Austria	5.5	13.5	3.8
Belgium	7.6	15.4	3.0
Canada	12.6	22.5	2.4
Denmark	3.2	8.3	4.0
Finland	18.7	35.0	2.6
France	6.1	15.3	3.9
Germany	5.8	9.5	2.1
Italy	5.0	12.8	4.0
Japan	14.0	26.3	2.7
Netherlands	4.6	12.9	4.3
Spain	8.4	21.6	4.0
Sweden	10.3	19.9	2.8
United Kingdom	6.0	18.9	4.9
United States	22.1	31.7	1.5

Source: EUKLEMS

Figure 6 plots correlations between output per employee hour and the average share of the workforce holding tertiary education qualifications over 1982-2005 for each country. It can be seen that there is a strong correlation between these variables in all countries. However, correlation coefficients vary. They are very high in thirteen out of fifteen countries, ranging from 0.95 for Japan to 0.997 for the UK. The lowest coefficients are observed in Spain (0.862) and Italy (0.899). However, finding a correlation is not sufficient to establish a causal relationship between the variables. We address this point in econometric analysis section, when we test for the existence of a long-term relationship between the variables.

Figure 6. Correlation between output per employee hour and tertiary education employment share (1982-2005)



Source: NiGEM database, EUKLEMS

4. Growth accounting estimates

4.1 Measuring the wage and productivity premia of graduates

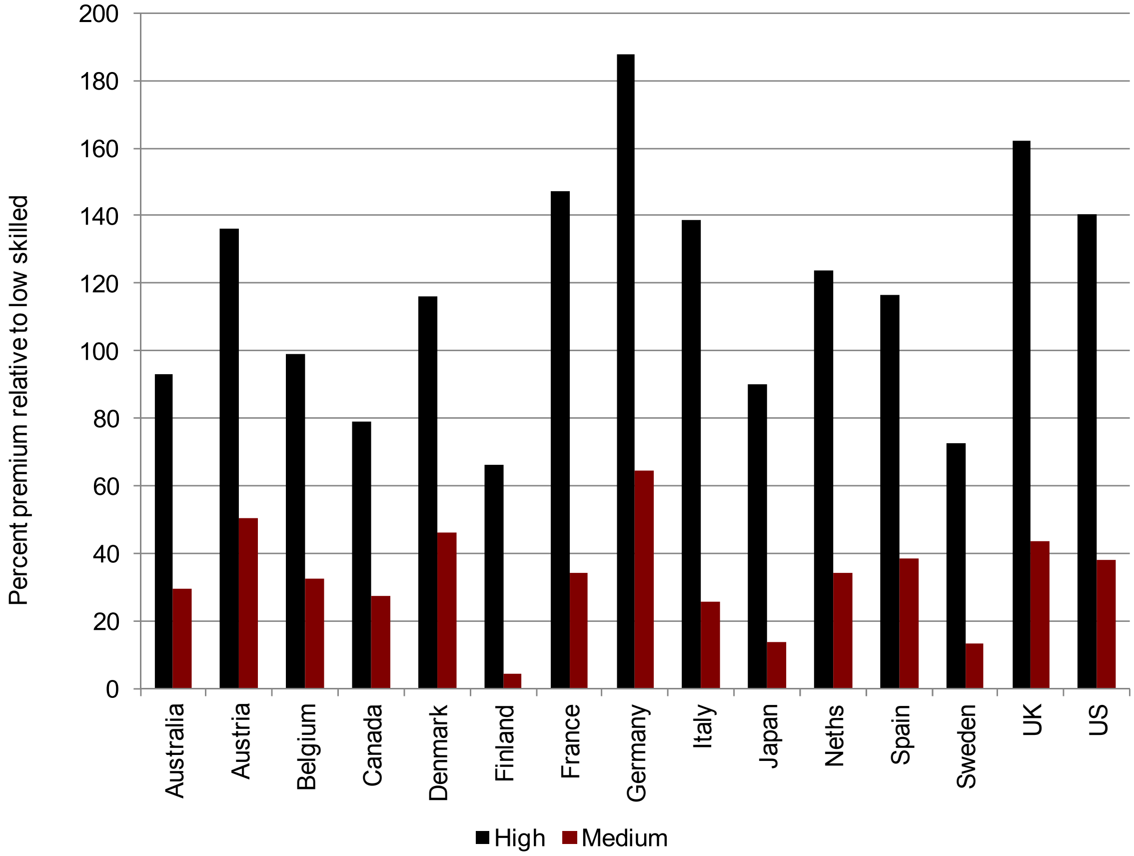
An individual's expected economic returns to education can be clearly identified through a comparison of the average wages of individuals with different levels of educational attainment. The EUKLEMS database allows us to calculate average wages for workers with different levels of educational attainment. The workforce is disaggregated into those with "low skills", which is defined as primary education, "medium skills", which includes secondary education and some types of vocational education, and "high skills", which is defined as holding a university degree. While the definitions are not strictly comparable across countries at lower levels of educational attainment, at the higher level (high skills) there is a high degree of comparability[7]. They can also provide insight into within country returns to education and the evolution of these returns over time.

Figure 7 illustrates the average wage of graduates and those with secondary education relative to low skilled workers over the sample period 1982-2005.

- Within the sample of countries, graduates, on average, are paid 70-180 per cent more than workers without formal educational qualifications.
- There is also a significant wage premium over those with secondary qualifications below a university degree.
- Average wage premium of graduates in our sample is highest in Germany, followed by the UK.

[7] Definitions of "high", "medium" and "low" skilled categories are given in table 5.3 in the EUKLEMS Methodology of the March 2007 Release (http://www.euklems.net/data/EUKLEMS_Growth_and_Productivity_Accounts_Part_I_Methodology.pdf).

Figure 7. Average wage premia for high and medium levels of educational attainment, 1982-2005



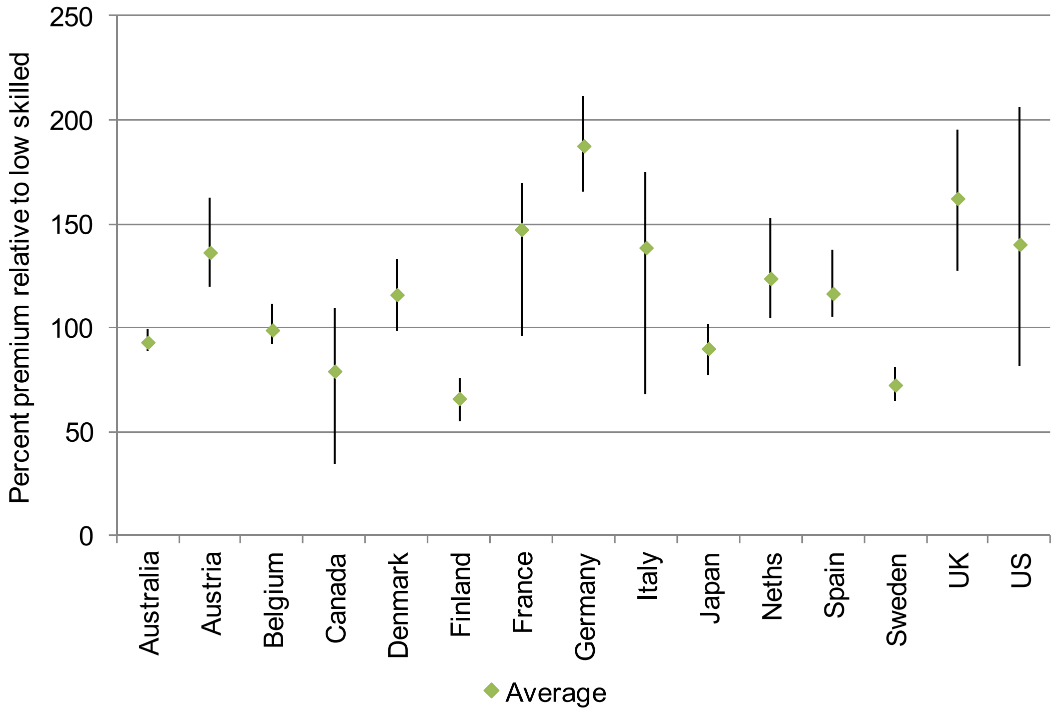
Source: Derived from EUKLEMS

The wage premia have been relatively stable across most countries over the course of our sample period, although we have seen a tendency for the wage premia of graduates to rise in the US and to a lesser extent in Germany and Canada, while they have tended to become more compressed in Italy, France and Austria. Figure 8 illustrates the average wage premia for high skilled workers over the full sample period of 1982-2005, compared to the high and low observations within the sample period to give an indication of the variance over the sample period.

- US, Italy, and Canada show the highest variation in the wage premium for high skill workers, while Australia, Sweden and Finland the lowest.

- The UK experiences some variation in the wage premium, however it is not amongst the highest in the sample.

Figure 8. Wage premia for high skilled workers 1982-2005, high and low observations



Source: Derived from EUKLEMS

While it is clear that individuals with a university degree tend to have a significantly higher wage rate than those without, what is of more interest from a policy perspective is how this reflects on the overall productive capacity and competitiveness of the economy as a whole. If some individuals are paid a higher wage without having a higher productive capacity, when the share of these individuals increases there would be a loss of competiveness and adverse effects at the macro-economic level. However, under market principles, there should be a strong correlation between wage differentials and productivity differentials. Under the extreme assumption of perfectly competitive markets, a firm will hire an additional hour of labour up to the point where that person's marginal product equals his/her marginal cost. Under this assumption, the wage premium of graduates should reflect their productivity premium relative to low-skilled workers. Since relative wages are determined to a large extent by employer demand, relative productivity is likely to be at least partly explained by wage differentials. However, employee wages may deviate from their marginal products due to imperfect labour market conditions and other factors. Furthermore, the extent of divergence between wages and marginal products may vary systematically between countries due to the operations of country-specific labour market institutions such as collective bargaining procedures and minimum wage legislation, and may also vary over time if the incidence of skill shortages is time varying.

In the growth accounting work below we employ the assumption that workers are on average paid their marginal product in order to estimate the contribution of graduate skills to GDP growth over the sample period. We make the simple assumption of a constant wage premium over time, reflecting a constant productivity premium of individuals with a university degree over those without educational qualifications, using the average premia illustrated in Figure 7 above. We then consider some of the sensitivities around this assumption.

4.2 Growth accounting framework

Robert Solow (1957) is generally attributed with the introduction of the theoretical framework for growth accounting. Solow's framework specifies an explicit model of potential output as a function of factor inputs, such as capital and labour, and an efficiency indicator termed total factor productivity (TFP)[8]. This approach assumes a general underlying production function that maps the factor inputs to final output, thereby representing the productive capacity of an economy. With two factors of production this can be expressed as:

$$Y = f\left(K_t, L_t, T_t\right) \tag{11}$$

where Y is the final output good, K is the capital stock, L is labour input and T indicates the state of technology, or TFP. Totally differentiating this equation with respect to time, and assuming perfect competition in factor markets and a homothetic production function, the partial derivatives of the production function may be rearranged to obtain a decomposition of the growth rate of output into the sum of

[8] Other terms for the indicator are Solow residual, measure of ignorance, or rate of technical change.

the growth rates of each input, weighted by their relative factor share, plus the growth in TFP.

$$d\ln(Y_t) = \theta_{K_t} d\ln(K_t) + \theta_{L_t} d\ln(L_t) + dA_t \quad (12)$$

Where θ_{K_t} is the share of output accruing to capital, θ_{L_t} is the labour share and dA_t is the growth rate of TFP, defined as:

$$dA_t = \frac{f_{T_t} T_t}{Y_t} d\ln(T_t) \quad (13)$$

We have assumed constant returns to scale, and hence θ_{L_t} = (1- θ_{K_t}). Growth accounting exercises based on measures of physical units of capital and labour do not allow us to say whether changes in TFP capture efficiency gains in the production process achieved thanks to the implementation of technological innovations or whether they reflect changes in the quality of capital or labour. More can be learned from growth accounting using measures of the quality of the capital and labour input. Skills-adjusted labour input (*L*) can be expressed as:

$$L = E * Hours * S \quad (14)$$

where *E* is total employment, *Hours* is average hours worked and *S* is a measure of workforce skills or human capital. The basic growth accounting decomposition can then be expressed as:

$$d\ln(Y_t) = \theta_{K_t} d\ln(K_t) + (1-\theta_{K_t}) d\ln(E_t * Hours_t) + (1-\theta_{K_t}) d\ln(S_t) + dA_t \quad (15)$$

The skill measure that we use in this study is based on the wage premia and change in shares of the workforce high, medium and low skills, as measured by their educational attainment. As discussed above, we estimate S_j using a single set of benchmark qualifications-wage ratios averaged over the full sample period (1982-2005) for each country.

We integrate the aggregate skills index into the growth accounting framework specified in equation (15) above, and disaggregate this into the contribution from each of the three skill categories.

A common growth accounting practice is to subtract the growth rate of (unadjusted) labour input from both sides of equation (15), to derive a decomposition of labour productivity into its components:

$$d\ln\left(\frac{Y_t}{E_t * Hours_t}\right) = \theta_{K_t} d\ln\left(\frac{K_t}{E_t * Hours_t}\right) + (1-\theta_{K_t}) d\ln(S_t) + dA_t \quad (16)$$

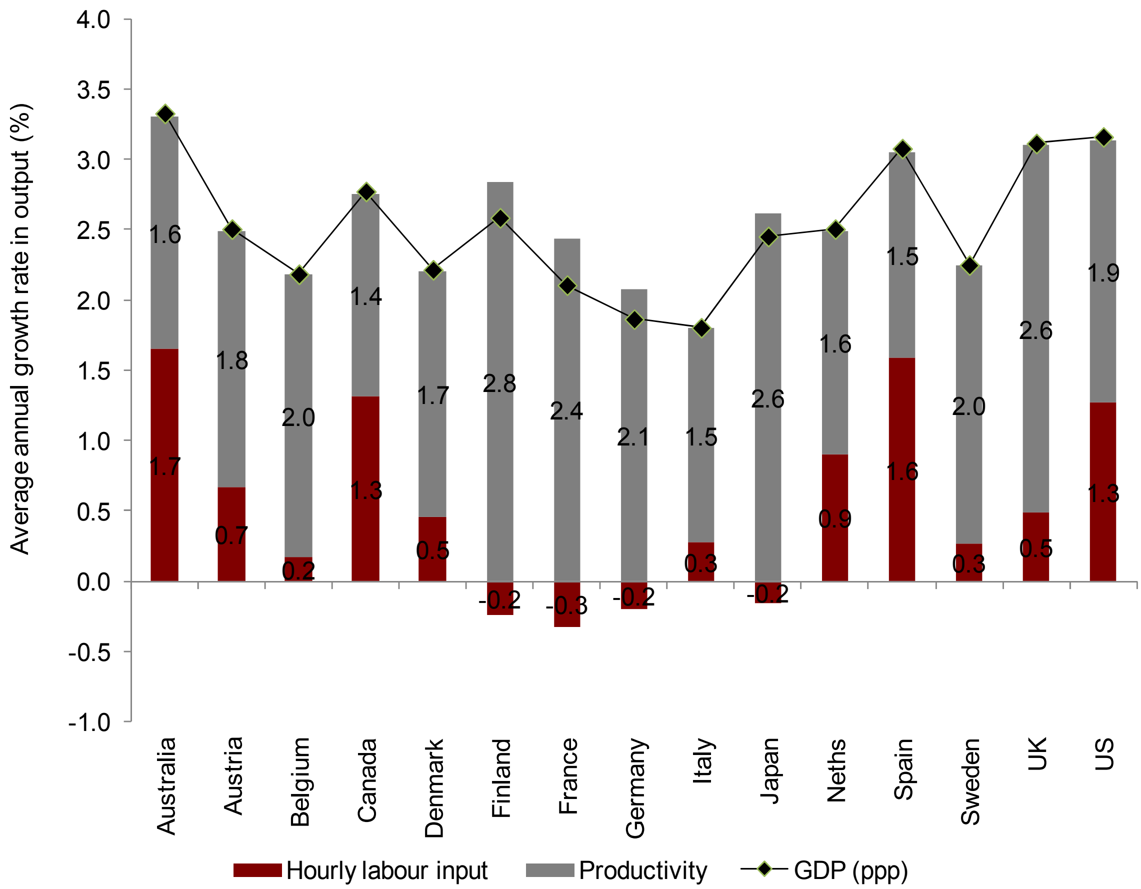
Equation (16) indicates that output per person hour can be decomposed into the contribution from skills accumulation, a contribution from capital deepening, which is the units of capital per hour worked, and the residual category, total factor productivity. In Figure 9 we use the simple relationship between output, labour input and labour productivity:

$$Y = (E * Hours) * \frac{Y}{(E * Hours)} \quad (17)$$

in order to decompose GDP growth in to the contribution from labour input (E*Hours) and labour productivity, defined as output per person hour.

- For the fifteen countries in our sample, the fastest average annual rate of growth in GDP between 1982 and 2005 was in Australia (3.3%), followed by the US (3.2%), UK and Spain (both 3.1%).
- However, as shown in Figure 9, only about half of the Australian growth in output (1.6 percentage points) reflected average labour productivity growth, the remainder coming from an expansion in hours worked.
- By contrast, average labour productivity (ALP) grew by an average 2.8% per year in Finland closely followed by Japan and the UK (both 2.6%).

Figure 9. Average annual growth rates in GDP, hours worked and labour productivity, 1982-2005



Source: NiGEM database

4.3 Decomposing productivity growth

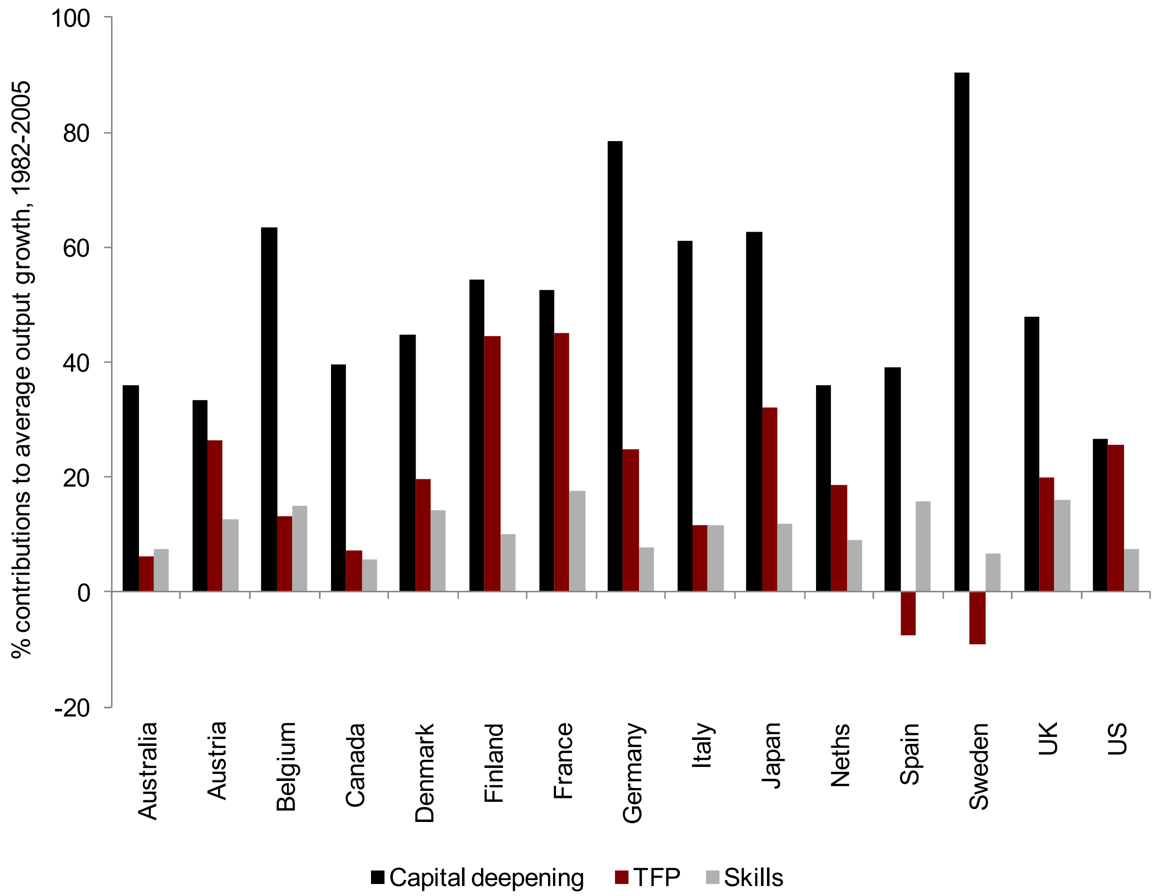
In this section we use growth accounting techniques to decompose labour productivity growth into the contribution from capital deepening, the contribution from skills accumulation and the residual component, total factor productivity growth. Finally we decompose the contribution from skills accumulation into the contribution from each of the three qualification groups. The growth accounting approach typically splits up the sample period to assess whether the contributions of various components have shifted over time. It is also typical to consider time periods corresponding to a single business cycle. Here we split the sample period in half, in order to consider 1982-1993 and 1994-2005 separately.

Figure 10 shows that over the whole 1982-2005 period, the contribution of growth in aggregate skills to output growth in all countries was substantially smaller than the contributions made by growth in capital per hour worked (capital deepening).

- The contribution made by skills was also smaller than the contribution made by TFP growth in ten out of the fifteen countries.
- Out of the five remaining Australia, Belgium and Italy had comparable contributions made by TFP and skills growth. TFP growth was negative in Spain and Sweden[9]. In Spain this probably reflects relatively inefficient use of capital and labour resources, since the TFP measure is strongly influenced by the efficiency with which existing resources are combined (Hulten, 2001).
- Similarly to other countries, capital deepening in the UK is the main contributor to growth, while TFP and skills together account for just above 40 percent.

[9]Stronger contribution made by capital deepening to output growth in Sweden may reflect the unavailability of data on capital services for the years 1980-1992, as missing years were filled in by applying moving average of the growth in previous three years to the latest available observation.

Figure 10. Average contribut ions of grow th in c apital per hour w orked, TFP and skills to growth in output, 1982-2005



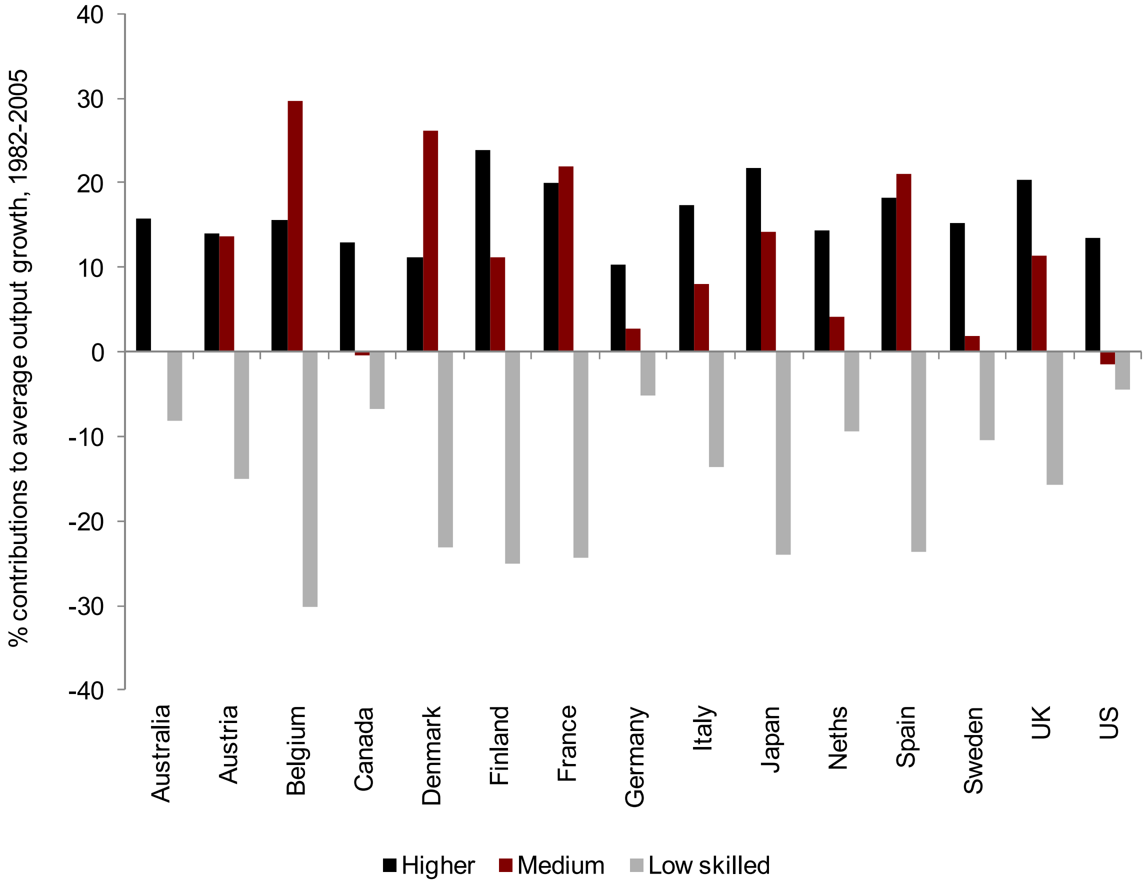
Source: NiGEM database and EUKLEMS

Table 3 below shows details of these decompositions over the two time periods 1982-1993 and 1994-2005.

- Skills accumulation made small but positive contributions to output growth in all countries in each of these time periods.
- A contribution of growth in high skills to output growth was positive across the 1982-2005 period in all countries (Figure 11).
- In Finland, Germany, Italy, Japan, Netherlands, Sweden and the UK a positive contribution made by growth in high-level skills across the whole 1982-2005 period exceeded positive contributions of growth of medium skills.

- In Austria, Belgium, Denmark, France and Spain a contribution of growth in medium skills exceeded a contribution from high skills.
- The contribution of low skills to GDP growth is negative, which is a reflection of the declining share of low-skilled workers in the workforce, and does not suggest that low skilled workers detract from growth.

Figure 11. Contributions of higher, me dium and low skills grow th to output growth, 1982-2005



Source: NiGEM database and EUKLEMS

Table 3. Decomposition of average annual growth rates in output, 1982-2005

		Australia	Austria	Belgium	Canada	Denmark	Finland	France	Germany	Italy	Japan	Neths	Spain	Sweden	UK	US
GDP (ppp) (% change)	1982-1993	2.9	2.7	1.9	2.1	2.0	1.5	2.1	2.4	2.0	3.9	2.3	2.7	1.3	2.9	3.0
	1994-2005	3.8	2.3	2.5	3.4	2.4	3.7	2.2	1.4	1.6	1.1	2.7	3.5	3.2	3.4	3.3
of which		*Percentage point contribution to average annual GDP growth*														
Hourly (unadjusted)	1982-1993	1.4	0.8	-0.6	0.9	0.2	-1.7	-0.7	0.0	0.1	0.3	0.7	-0.2	0.0	0.1	1.3
	1994-2005	1.9	0.6	0.9	1.7	0.7	1.2	0.1	-0.4	0.5	-0.6	1.1	3.4	0.5	0.9	1.2
Output per person hour	1982-1993	1.5	1.9	2.5	1.2	1.8	3.2	2.8	2.4	1.9	3.5	1.6	2.8	1.2	2.7	1.7
	1994-2005	1.8	1.8	1.6	1.6	1.7	2.5	2.1	1.7	1.1	1.7	1.6	0.1	2.7	2.5	2.1
of which		*Percentage point contribution to average annual growth in output per person-hour*														
Capital deepening	1982-1993	1.1	0.9	1.5	1.4	1.0	2.2	1.2	1.4	1.2	1.8	1.0	1.8	2.3	1.5	0.8
	1994-2005	1.3	0.8	1.2	0.8	1.0	0.6	1.0	1.5	1.0	1.3	0.8	0.6	1.8	1.4	0.9
TFP (excluding skills)	1982-1993	0.1	0.6	0.6	-0.3	0.4	0.5	1.1	0.7	0.5	1.5	0.3	0.5	-1.1	0.6	0.6
	1994-2005	0.3	0.7	0.0	0.7	0.4	1.8	0.7	0.2	-0.1	0.1	0.6	-1.0	0.7	0.6	1.0
Skills accumulation	1982-1993	0.3	0.4	0.3	0.2	0.4	0.4	0.4	0.3	0.2	0.3	0.2	0.5	0.0	0.6	0.3
	1994-2005	0.2	0.3	0.3	0.1	0.2	0.1	0.3	0.0	0.3	0.3	0.2	0.5	0.3	0.4	0.2
of which		*Percentage point contribution to average annual growth in skills accumulation*														
Higher	1982-1993	0.7	0.3	0.4	0.4	0.2	1.0	0.4	0.3	0.2	0.4	0.3	0.6	0.1	0.6	0.5
	1994-2005	0.4	0.4	0.3	0.3	0.3	0.2	0.4	0.1	0.4	0.7	0.4	0.6	0.6	0.6	0.4
Medium	1982-1993	-0.2	0.6	0.6	0.0	0.9	0.3	0.7	0.3	0.1	0.6	0.3	0.7	0.0	0.5	0.1
	1994-2005	0.2	0.1	0.7	-0.1	0.3	0.2	0.3	-0.2	0.2	0.1	-0.1	0.6	0.1	0.2	-0.2
Low skilled	1982-1993	-0.2	-0.5	-0.7	-0.3	-0.7	-0.9	-0.7	-0.2	-0.2	-0.8	-0.4	-0.8	-0.1	-0.6	-0.3
	1994-2005	-0.4	-0.2	-0.6	-0.1	-0.3	-0.4	-0.4	0.1	-0.3	-0.4	-0.1	-0.7	-0.4	-0.4	0.0

4.4 Sensitivity analysis for wage premia

The growth accounting estimates of the contribution of graduate skills accumulation to GDP growth relies on two sets of information. The first is the change in the share of the workforce with graduate qualifications over the sample period, and the second is the average productivity differential between workforce members with graduate degrees and those with no or lesser qualifications. The first is straightforward. Figure 5 in Section 3.3 illustrates the share of the workforce holding a graduate qualification over the sample period from 1982-2005. There has been a clear upward trend in the prevalence of graduate qualifications across all countries in our sample over this period, although there are significant discrepancies in the shares across countries.

If the average productivity of individuals holding a graduate degree and those with no educational qualification is the same, then the change in these shares over time make no net contribution to GDP growth. However, based on the reasonable assumption that wage differentials at least partly capture productivity differentials between the skill groups, the average productivity level of the workforce will increase when the share of higher skilled workers increases. The question is then how to approximate the productivity differentials across skill groups. Wage premia provide a useful guide, as discussed above, but it is important to keep in mind that employee wages may deviate from their marginal products for a number of reasons. Labour market institutions, such as collective bargaining procedures and minimum wage legislation may affect wage dispersion, without necessarily bearing a relationship with productivity differentials. This is particularly important when comparing wage premia across countries, as these institutions may vary systematically between countries. There may also be volatility in wage premia over time that reflects shifting patterns of skill shortages or other factors.

Some genuine shifts in average productivity of a particular skill group may evolve over time. For example, more widespread access to computers during university and/or secondary education may well have allowed graduates to enter the workforce with a higher level of skills than previous cohorts over our sample period.

Alternatively, as the incidence of HE increases, and is no longer limited to the most able pupils, the average skill level of graduates may well have declined over time.

The productivity premium of graduates may also differ systematically across countries. This could reflect the quality of university education across countries, the subjects studied, or the industrial structure of the economy, which may rely to a greater or lesser degree on HE skills. Mason *et al* (2012) argue that it may be more appropriate to apply common wage premia across countries, as the differences in labour market institutions are likely to outweigh genuine differences in the productivity of similar skill groups across countries.

In the central growth accounting work presented above, we abstracted from volatility in wage premia over time, and applied a constant wage premium within each country for high and medium skilled workers. We did, however, allow for differences in the levels of productivity across countries. We now reassess the potential contribution of graduate skills growth to productivity in the second half of the sample, based on a series of different assumptions on wage premia, in order to assess the sensitivity of the results to this assumption. Figure 12 illustrates the differences in the wage premia applied to higher skills in each of the alternative models, using the UK as an example.

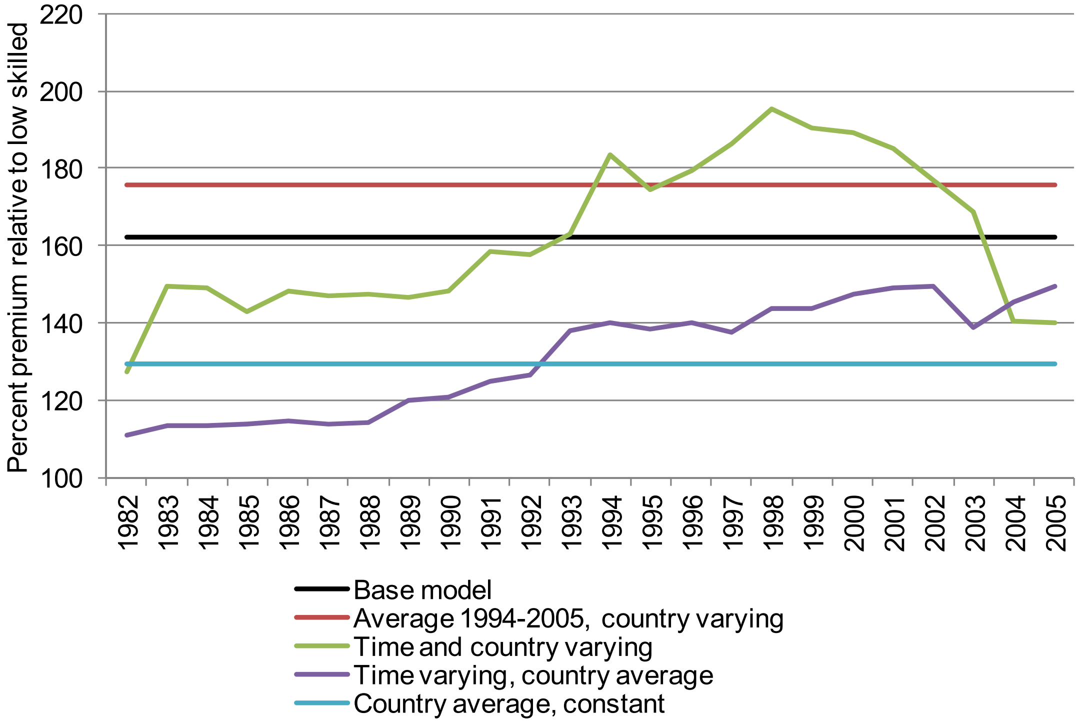
- The base model assumed a constant premium for each country separately over the full sample period of 1982-2005;
- The first alternative (“average 1994-2005, country varying”) splits the sample period, and applies a constant premium within each country for the sample period 1994-2005[10] (in line with the split in Table 3 above).
- The next approach (“time and country varying”) allows for time varying premia within each country.

[10] The first two columns of Table 4 showing the contribution of graduate skills accumulation to growth based on the base model and the average wage premia for 1994-2005 are almost identical – highlighting that splitting the sample is this way does not influence the results. Given this, taking the average wage premia for the earlier period (1982-1993) produces similar results.

- The fourth approach ("time varying, country average") allows the premia to vary across time, but takes a weighted average across all countries, so a common trend is applied to each country.

- The final approach ("country average, constant") takes the average wage premia for all countries for the whole period.

Figure 12. Models for wage premia of higher skills, UK



Source: Derived from EUKLEMS

Table 4 compares the estimated contribution of higher skills accumulation to average labour productivity growth based on the different wage/productivity premia assumptions.

- Allowing for time variation in the premia has the most significant impact on the estimated contribution of graduate skills to productivity growth, especially in countries such as the US and France where there is a significant trend in the wage premia over time.

- But on the whole the estimated contributions are relatively insensitive to the assumptions made regarding the magnitude of the premia.

Table 4. Contribution of graduate skills accumulation to average productivity growth under different assumptions, 1994-2005

	Base model	Average 1994-2005, country varying	Time and country varying	Time varying, country average	Country average, constant
Australia	0.40	0.40	0.46	0.54	0.45
Austria	0.37	0.36	0.31	0.45	0.39
Belgium	0.31	0.31	0.38	0.42	0.34
Canada	0.28	0.29	0.36	0.43	0.33
Denmark	0.29	0.28	0.29	0.37	0.32
Finland	0.25	0.24	0.43	0.40	0.27
France	0.40	0.40	0.12	0.44	0.38
Germany	0.13	0.13	0.21	0.16	0.12
Italy	0.40	0.39	0.31	0.45	0.38
Japan	0.65	0.65	0.51	0.79	0.68
Netherlands	0.43	0.42	0.51	0.50	0.44
Spain	0.56	0.57	0.67	0.70	0.60
Sweden	0.59	0.59	0.53	0.75	0.67
UK	0.62	0.62	0.48	0.68	0.59
US	0.38	0.39	0.80	0.50	0.38

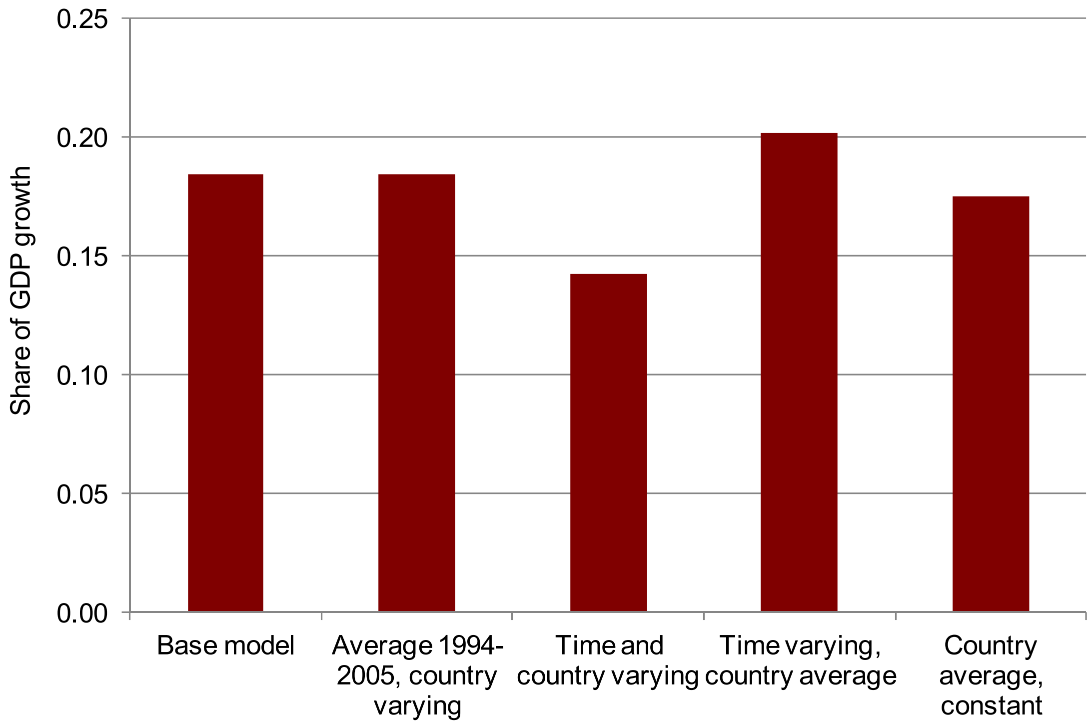
Note: Percentage point contribution. Source: derived from EUKLEMS

Figure 13 again uses the UK as an example, and illustrates the share of GDP growth over the period 1994-2005 that can be attributed to graduate skills accumulation.

- Based on this set of sensitivity studies, we can attribute somewhere between 14-20 per cent of GDP growth in the UK over this period to the accumulation of graduate skills.

- This is roughly in line with the other countries in the sample.

Figure 13. Contribution of graduate skills accumulation to GDP growth in the UK under different assumptions, 1994-2005



While this analysis provides a useful benchmark for assessing the importance of HE relative to other productivity enhancing factors over the sample period, the approach limits the estimated impact to the productivity enhancement directly accrued to the graduates. Given the dual role of universities, which provide centres of education as well as research, this may well underestimate the total macro-economic effects of an expanded HE system. It will also fail to capture other externalities to HE, such as improved management techniques that raise productivity at all skill levels. In the next section we address these issues through a series of econometric estimates that relate the expansion of HE skills to productivity growth.

5. Regression-based estimates

In this section we present the results from our econometric analysis. First we replicate the Gemmell (1996) model for our 15 countries covering the period from 1982 and 2005. Here we also explore the sensitivity of the results to considering different time periods, noting that 1982-2005 is the longest period for which data is available for all 15 countries.

Next we present the results of our error correction models. Again we focus on the 1982-2005 period and again discuss the sensitivity of the results to the time period considered.

5.1 GDP Growth Models

In replicating the Gemmell (1996) model we follow his specification as closely as possible estimating models for GDP growth whilst including the log of the initial share of employment with a tertiary level qualification and the log of the change in the employment share with a tertiary level qualification as control variables. Our main estimation period covers 1982 to 2005 (the longest available time period for which we have full data for all 15 countries), but we also estimate models for different time periods to assess the robustness of our findings.

It is important to note that the dependent variable is the annual average growth rate over the whole period under consideration, so for each model there is just a single observation for each country.

The model we estimate can be written as:

$$\Delta \ln y = b_0 + b_1 \ln y_{1982j} + b_2 \ln INV_j + b_3 \ln \Delta L_j + b_4 \Delta h_j + b_5 h_{1982,j} + b_6 \ln L_{1982,j} \qquad (18)$$

j=1,..15 countries

Where Δlny is the annual average growth rate of GDP per employment hour (over 1982-2005), $lny_{1982,j}$ is GDP per employment hour at the beginning of the estimation period (1982 in our preferred models), $lnINV_j$ is the average private business investment/GDP ratio over the whole period, $ln\Delta L_j$ is an annual change in the size of a labour force, Δh_j captures the effect of the change in the tertiary education (measured by shares), $h_{1982,j}$ is the stock of the tertiary education in 1982 (measured by shares), and $L_{1982,j}$ is the size of a labour force in 1982. The results from our estimation are reported in Table 5.

Table 5. Growth Regression Results: Ordinary Least Squares

	Coefficient	P-Value
Ln GDP in 1982	-0.00698	(0.338)
Ln Private business investment/GDP	0.00310	(0.593)
Ln Change in labour force	-0.00352*	(0.068)
Annual change in log share of employment with tertiary education	0.0690	(0.677)
Ln Share of employment with tertiary education in 1982	0.00168	(0.426)
Ln Labour Force 1982	0.00110	(0.360)
Constant	0.0336	(0.430)
Observations	15	
F	16.06	
R2	0.739	

Notes: Results are estimated pooling data for the 15 OECD countries, from 1982-2005, and using Robust Standard errors. * p<0.10 ** p<0.05 *** p<0.01

The coefficient on the change in the log of the share of employment with tertiary education has a positive sign but is it not significantly different from zero. Although the signs of most variables are in line with Gemmell's (1996) findings they are not statistically significant even at 10 percent level (apart from the annual change in the size of the labour force).

The results do not change much when we estimate the models for different time periods[11]. We varied both the first and last year of our estimation period, but the tertiary education variables were never statistically significant.

[11] In the sensitivity analysis we have used different time periods, specifically 1980-2005, 1983-2005, and 1985-2005. EUKLEMS data for employment shares by the level of qualification is missing prior to

Overall these results do not suggest a strong relationship between the growth in GDP per employment hour and the growth in the share of employment with tertiary level education between the early 1980s and mid 2000s for the 15 countries considered. In contrast Gemmell (1996) found a positive significant relationship between tertiary education and growth.

There are some obvious differences between our results and Gemmell's estimates. The time period and countries considered are different. Gemmell focussed on 1965-1985 for 21 countries, while our analysis is based on smaller number of countries and for a later time period.

The lack of a significant relationship between human capital and growth is not new to the literature. As discussed in section 2.3.2, studies carried out by Benhabib and Spiegel (1994) and Pritchett (2001) even if focusing on a similar time period to Gemmell and for a large number of countries, did not find a statistical significant relationship between human capital and growth.

Furthermore, cross-country growth regressions of this type are known to suffer from certain deficiencies (Durlaf, 2009). The approach assumes homogeneous parameter estimates across countries, which may be a strong assumption even in a sample of OECD countries at similar stages of development. As the skill-biased technological change literature indicates, the contributions of graduates to growth may be evolving over time, and a dynamic panel framework may offer additional insights. This is supported by the analysis by Holmes (2013), who demonstrates that the results of cross-country growth regressions of this sort are not robust to changes in the sample period and country coverage and should always be viewed with caution.

We therefore explore relationships further using dynamic panel models based on the approach used by Mason *et al* (2012) and Barrell, Holland and Liadze (2011) in the next section.

1981 for Sweden and prior to 1982 for Australia. Missing observations are filled in by applying three year moving averages of the rate of change to the last available observation.

5.2 Error Correction Models

In order to allow for the possibility that the relationship between growth and human capital is dynamic and that there is a long-run relationship as well, we estimate an Error Correction Model (ECM) as expressed in equation (10).

We use the Pooled Mean Group estimator (PMG), first introduced by Pesaran, Shin, and Smith (1997, 1999). This allows us to estimate non-stationary dynamic panels in which the parameters can be heterogeneous across groups. The approach has the advantage that the short-run dynamics can be determined for each country, whilst we can also formally test for whether a pooled long run relationship is valid.

When dealing with long time-series, we need to be concerned about the variables of interest being non-stationary[12] which may lead to spurious regression results if the model is estimated in levels.

An alternative to the PMG is the mean group estimator (MG) which allows the intercepts, slope coefficients, and error variances to differ across groups. Here the long-run coefficients are unrestricted. Here we use a Hausman test to assess whether the PMG restriction of long-run coefficients being the same for all countries is valid. The results indicate that imposing the same long-run coefficients across all countries is valid.

Table 6 reports the PMG estimates for our 15 countries. The error correction parameter, corresponding to δ_2 in equation 10, captures the speed of adjustment. If $\delta_2=0$ then there would be no evidence for a long-run relationship. Under the prior assumption that the variables show a return to a long-run equilibrium, the error correction parameter is expected to be significantly negative.

Table 6 indicates the existence of both a short-run dynamic and long-run relationship. The existence of the short-run dynamic is captured by the statistical significance of the coefficient of the lag of the dependent variable. The long-run

[12] In order to investigate non-stationarity of the variables we used the Augmented Dickey-Fuller unit root test and the results indicate acceptance of the null hypothesis of non-stationarity for the overwhelming majority of variables. Additionally, tests on differenced variables were performed with similar results. The Johansen test indicated the existence of a long-run cointegrating relationship between dependent and independent variables.

relationship is indicated by the negative and significant coefficient of the error correction parameter.

The final specification is given in the first column of Table 6. Our indicators for openness, investment, and research and development[13] were also not statistically significant in our models and are not reported, whilst foreign direct investment as a share of GDP was significant in all model specifications.

- The share of employment with tertiary education variable is positive and statistically significant with a coefficient of 0.468.
- The remaining columns report the same model specifications for different time periods and here we can see that the coefficient on the tertiary education variable varies from around 0.2 to 0.5, and it is always statistically significant.
- Results were similar for country sensitivity analysis[14].

[13] In most countries there was a high correlation between the share of employment with tertiary education and Research and Development, so it is not surprising that when we control for the share of employment with tertiary education the Research and Development indicator is not statistically significant in the models.

[14] In the country sensitivity analysis we run the models excluding, one at a time, the largest countries with the highest correlation coefficients between high skill employment share and productivity: US, UK, France, and Germany. In addition, we have also tested for exclusion of non EU countries. All models have been tested, and passed, Hausman test for pooling estimation.

Table 6. Error Correction Regression Results: Pooled Mean Group Estimates

	1982-2005	1982-2004	1983-2005	1984-2005
Long-run				
Lag ln(Foreign Direct Investment/GDP)	0.0244** (0.017)	0.0514*** (0.000)	0.0630*** (0.000)	0.0180** (0.019)
Lag ln(share of employment with tertiary education)	0.468*** (0.000)	0.215*** (0.000)	0.185*** (0.000)	0.502*** (0.000)
Short-run				
Error Correction	-0.101** (0.015)	-0.0576* (0.075)	-0.0770* (0.072)	-0.146** (0.016)
Lag difference ln(GDP)	0.158** (0.021)	0.126* (0.081)	0.108 (0.130)	0.159** (0.018)
Constant	0.627** (0.015)	0.343* (0.057)	0.449* (0.060)	0.901** (0.016)
Observations	360	345	345	330
Hausman tests, Prob>chi2	0.786	0.157	0.548	0.679

Note: Dependent variable: Change in Log of GDP; p-values in parenthesis; * - p<0.10, ** - p<0.05, *** - p<0.01

When the dependent and independent variables are log-transformed, a coefficient on the independent variable is referred to as an ‘elasticity’. This indicates the per cent change in the dependent variable, when the independent variable increases by one per cent.

- A long-run coefficient of between 0.2 and 0.5 on the tertiary education employment share means in the long-run a 0.2 to 0.5 per cent increase in output per employee hour when tertiary education employment share increases by one percent.

6. Summary and conclusions

The role of Higher Education (HE) in improving economic growth and competitiveness is widely acknowledged and supported by the literature, although many of the existing studies are based on outdated datasets and proxy variables for productivity and workforce skills that are subject to a significant degree of measurement error. Nonetheless, policy makers face a dilemma over the amount of public resources that should be devoted to education, especially at present as they try to regain control over public finances in the wake of the financial crisis.

It is clear that individuals with a university degree tend to have a significantly higher wage rate than those without. Within our sample, graduates, on average, are paid 70-180 per cent more than workers without formal educational qualifications. Within the UK, the wage premium for graduates is higher than average, at about 160 per cent relative to workers without formal educational qualifications. Wage differentials should be closely correlated with productivity differentials, since firms face a hard budget constraint and relative wages are determined to a large extent by employer demand.

Our growth accounting analysis relies on information contained in wage differentials to approximate productivity differentials, exploiting both the observed variation in premia across time and across countries. This analysis suggests that the accumulation of graduate skills contributed on average 0.1-0.7 percentage points per annum to average labour productivity growth over the period 1994-2005. The lowest contributions were found in Germany, with relatively high contributions in Japan, the UK, Sweden and Spain. In the case of the UK this reflects both the strong expansion of graduate qualifications over the sample period and the relatively high premium paid to graduates. The UK has a world-class system of higher education, and is home to 10% of the world's top 100 universities. While higher education has expanded significantly between 1982 and 2005 and has continued to expand since 2005, the share of the workforce holding a university degree in the UK remains below that in Finland, the US, Japan and Canada in 2005, suggesting that there may still be room for further expansion.

While the growth accounting analysis provides a useful benchmark for assessing the importance of HE relative to other productivity enhancing factors over the sample period, the approach limits the estimated impact to the productivity enhancement directly accrued to the graduates. Given the dual role of universities, which provide centres of education as well as research, this may well underestimate the total macro-economic effects of an expanded HE system. It will also fail to capture other externalities to HE, such as improved management techniques that raise productivity at all skill levels. The econometric analysis addresses these issues.

The econometric work starts by replicating a cross-country growth regression, similar to that Gemmell (1996), Benhabib and Speigel (1994), Pritchett (2001) and others. Overall these results do not suggest a strong relationship between the growth in GDP per employment hour and the growth in the share of employment with tertiary level education between the early 1980s and mid 2000s for the 15 countries considered. Cross-country growth regressions of this type are known to suffer from certain deficiencies (Durlaf, 2009). The approach assumes homogeneous parameter estimates across countries, which may be a strong assumption even in a sample of OECD countries at similar stages of development. The sample size is also very small, with only a single observation for each of 15 countries.

Our preferred econometric model is based around a dynamic panel framework, which allows us to uncover the longer-term relationship between graduate skills and productivity. This analysis suggests that, for example, a 1 per cent rise in the share of the workforce with a university education raises the level of productivity by 0.2-0.5 per cent in the long-run. The speed of adjustment towards this long-run is gradual, with about 5-15 per cent of the correction absorbed per annum.

Over the sample period 1994-2005, the share of the workforce with a university education in the UK rose from 12-18.9 per cent, or increased by 57 per cent. Our estimates suggest that this will have raised the level of productivity in the UK by 11-28 per cent in the long-run. Over the same period, average labour productivity in the

UK increased by about 34 per cent, suggesting that at least 1/3 of this can be attributed to the accumulation of graduate skills in the labour force. By contrast, the growth accounting exercise found that the direct contribution of graduate skills accounted for closer to 20 per cent of labour productivity growth over the sample period. This suggests that there are indeed externalities to education that have wider macroeconomic benefits over and above what can be directly observed through wage premia. If the HE sector in the UK were to expand towards the size in the US, this could be expected to raise the level of productivity in the UK by 15-30 per cent in the long-run.

A single equation study of this sort is not sufficient to estimate the net economic returns to a marginal increase in spending on HE. This would require in the first instance an estimate of the cost of increasing the number of university places by 1 per cent. We would also want to consider the general equilibrium effects of expanding HE. An approach such as that adopted by Barrell and Kirby (2007) to study the impact of the Lisbon Process within the EU could be employed. This would involve integrating the estimated econometric relationship into a full macro-economic model and running a series of model simulations. This would allow us to address specific issues such as the impact of a rise in government spending on education policies on the economy in the short, medium and long-term; the net impact on the government budget in the short, medium and long-term; and the length of time it will take for the rise in spending to be recovered through higher government revenue if the productive capacity of the economy is enhanced.

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Annex

Table A1. Cross-study comparison

	Authors, date of publication	**Main estimates**	**Dependent variable**	**Data used**	**Time period analysed**	**Countries covered**	**Variable used to measure human capital**	**Main effect**
Panel A. Human capital measured as stock								
1	Mason et al (2012)	Positive and significant	Growth of output per worker hour	EUKLEMS	1980-2007	7 EU countries	Shares in Education level	One percentage point rise in the vocational-skilled share of employment is associated with a 0.143 percentage point rise in average labour productivity.

2	Cohen and Soto (2007)	Positive and significant	Annualized change in GDP per worker	OECD UNESCO National Statistics	1960-1990	59 countries	Average years of schooling	The coefficient ranges between 0.616 and 0.516.
3	Kruger and Lindahl (2001)	Positive and significant	Annualized growth rate of GDP per capita	World values survey	1965-1985 1960-1990	78 countries 110 countries	Average years of schooling	The estimate is 0.614.
4	Pritchett (2001)	Negative and insignificant	Growth of GDP per worker	Barro and lee (1993) data, Penn World tables	1960-1982	91 countries	Wage premium ratio	The estimate is -0.049.
5	Benhabib and Spiegel (1994)	Negative and Insignificant	Differences in per capita income	Based on Kyriacou data (1991) and Summers-Heston data (1991)	1960-85	78 countries	Average years of schooling	The coefficient is negative and ranges between -0.043 and -0.080.
6	Barro and Lee (2010)	Positive and significant	Income per worker	UNESCO Eurostat	1950-2010	157 countries	Average years of schooling by primary,	Output for the world economy as a whole would increase by around 2% for every additional year of

							secondary, and tertiary.	schooling.
		Panel B. Human capital measured as flow						
7	Bils and Klenow (2000)	Positive and significant	GDP per capita	Summers-Heston (1991) and UNESCO	1960 -1990	93 countries	Enrolment rates	An increase in enrolment rates corresponding to one more year of attainment is associated with 0.30 percent year faster growth.
8	Gemmel (1996)	Positive and significant	Growth of GDP per capita	UNESCO ILO	1960-1985	21 OECD countries	Enrolment rates at primary, secondary and tertiary levels.	The coefficient of change in tertiary education is 5.89, while initial stock equals 1.10.
9	Barro (1991)	Positive and significant	Annual average growth rates of real per capita GDP	Summers and Heston (1988), UN, World Bank, Banks's (1989)	1960-1985	98 countries	Enrolment rates	Coefficient of enrolment rates ranges around 0.03.
10	Mankiw, Romer and Weal (1992)	Positive and significant	Income per capita	Real national Accounts (Summers and Heston, 1998) and	1960-1985	98 countries	Enrolment rates of secondary school	Coefficient equals to 0.66 for all countries; while it equals to 0.76 for 22 OECD countries.

				UNESCO				
		Panel C.	Human capital measured as investment					
11	Aghion et al (2009)	Positive and significant	GDP Growth and level of real per capita income.	US data: (Department of Commerce; Digest of Education Statistics; CASPAR; et others).	1947 -1972 birth cohorts	US	Dollars Investment in education.	For a state at the technological frontier, a thousand dollars of research education-type spending per person in the cohort raises growth by 0.04 percentage points and per capita income by $360.
12	Keller (2006)	Positive and significant	Growth of GDP per capita	World Bank	1971-2000	Up to 88 countries	Investment flow: public education expenditures per student as a share of GDP per capita; enrolment rates; public	Public expenditure per (secondary education) student coefficient equals 0.024. Coefficient for secondary and tertiary enrolment rates equals to 0.086 and 0.075 respectively.

							education expenditures as a share of GDP,-for primary, secondary, and higher education.	
		Panel D. Human capital measured as cognitive skills						
13	Hanushek and Woessmann (2010)	Positive and significant	Average annual growth rate in real per capita GDP	Penn World tables; PISA, Barro and Lee (2010)	1960-2000	24 OECD	Test scores for primary and secondary level of schooling.	An increase in one standard deviation in educational achievement yields an average annual growth rate over 40 years that is 1.86 percentage points higher.
14	Hanushek and Kimko (2000)	Positive and significant	Average annual growth rate in real per capita GDP	TIMSS NAEP Barro and Lee (1993), UNESCO	1960-1990	31 countries	Test scores	An increase of one standard deviation labour-force quality enhances the real per capita growth rate by over 1.4 percentage points a year.

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