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HUMAN CAPITAL FORMATION AND CONTINUOUS TRAINING: EVIDENCE FOR EU COUNTRIES

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This paper links data on continuous training from the EU Labour Force Survey (LFS) to information on skill levels and earnings from the EU KLEMS growth and productivity accounts, to examine the relative magnitudes of continuous workforce training versus human capital formation through the general education system in the European Union. The measurement methodology draws from the literature on measuring intangible investments by firms and sources of growth in an accounting framework. The results suggest that in the EU15 group of countries, intangible investments in continuous training represent just under 2 percent of GDP or about 35 percent of expenditure on general education. The share of GDP accounted for by training is less than a third as large in the new member states. A growth accounting method is employed to show that failure to account for continuous training leads to an underestimate of the impact of human capital on output growth in the EU.

JEL Codes: O47, J24

Keywords: continuous training, human capital, growth accounting

1. Introduction

Human capital has long been seen as an important influence on economic growth (e.g. Lucas, 1988; Galor, 2004; Glaeser *et al.*, 2004). Recent research has highlighted that organizational changes and intangible investments such as workforce training are necessary to gain significant productivity benefits from adopting and diffusing new technology, especially information and communications technology (ICT; e.g. Black and Lynch, 2001; Bresnahan *et al.*, 2002; Bertschek and Kaiser, 2004). In the face of rapidly changing technology it is imperative that skills are appropriate and up to date, and this is often easier to achieve through workplace training than through the general education system. Indeed many studies find a positive association between workplace training and productivity at the firm and industry levels (e.g. Black and Lynch, 1996; Vignoles *et al.*, 2004; Dearden *et al.*, 2006; Zwick, 2006).

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This paper focuses on continuous training and measures of its importance across EU countries and by industry. It draws from a recent literature focusing on unmeasured intangible investments as sources of growth. The pioneering work in this respect is by Corrado *et al.* (2005, 2009), who attempted to measure investments in intangible assets for the U.S. These authors defined a number of types of intangible investments including software, scientific and non-scientific R&D, brand equity, and firm specific expenditures such as on the job training and managing organizational changes. Estimates by the above authors suggest that these investments combined account for about 11 percent of U.S. GDP and have been growing rapidly. Similar studies for the U.K. (Giorgio-Marrano and Haskel, 2006; Giorgio-Marrano *et al.*, 2009), Finland (Jalava *et al.*, 2007), the Netherlands (van Rooijen-Horsten *et al.*, 2008), Japan (Fukao *et al.*, 2009), and EU countries (Jona-Lasinio *et al.*, 2009) suggest also that intangibles are sizeable, although most account for lower proportions of GDP than in the U.S. The above studies on intangible investments mainly refer to the aggregate economy, although a few report results by industry. Nevertheless, comprehensive estimates by country and industry are some way off. This paper adds to the above literature through its focus on one type of intangible investment, workforce training, using harmonized datasets that enable estimates by EU country and a division by industry—these data are described in Section 3.

The methodological approach adopted is similar to that used in the intangible capital literature. It employs information on numbers of workers trained and duration of training from the harmonised labour force surveys, EU LFS, aggregated to industry level and linked to earnings from the EU KLEMS growth and productivity accounts.[1] It extends previous estimates by taking account of the characteristics of those being trained as well as including direct and opportunity costs of individuals who pay for their own training. Investments in workplace training are compared to expenditures on general education. The paper then employs a growth accounting approach to gauge the impact on output growth of a broader measure of human capital than that currently employed in EU KLEMS. The results suggest that in the EU as a whole, intangible investments in continuous training represent about 1.6 percent of GDP compared to about 5 percent for expenditure on general education. The growth accounting results suggest that failure to account for continuous training leads to an underestimate of the impact of human capital on output growth in individual countries and in an aggregate across the large original EU member states.

The next section sets out the general framework on human capital accumulation and its influence on growth. This is followed in Section 3 by a brief overview of training in the EU using data from EU LFS. Section 4 outlines the methodology and assumptions required in constructing investment series for continuous training, and Section 5 presents the growth accounting results. Section 6 concludes.

[1]See Timmer *et al.* (2007) and O'Mahony and Timmer (2009) for details; EU KLEMS data can be downloaded from www.euklems.net.

2. Education, Training, and Growth

Human capital stocks are built up through countries' willingness to invest in educating their early age populations who may use the knowledge acquired subsequently in the workplace. The knowledge obtained through general schooling is topped up through work experience and continuous training but will also depreciate through time. The human capital stock used in production at any point in time will depend on employment rates, which in turn are influenced by demand by firms and willingness of individuals to supply their labor, including retirement decisions. Thus human capital formation depends on expenditure on initial education, continuous education and depreciation rates and its use in production additionally depends on employment and retirement rates.

Letting I_{ED} denote real investments in human capital formation through schooling, I_{CE} real investments in continuous education, and d depreciation rates, human capital stocks (H) can be presented as:

$$H = F(I_{ED}, d_{ED}, I_{CE}, d_{CE}). \tag{1}$$

In this representation, human capital stocks can be seen as one type of asset, similar to tangible fixed capital, and its measurement can be implemented using conventional perpetual inventory models that cumulate investments and specify a form for the depreciation function. Indeed an early literature (e.g. Kendrick, 1976), treats expenditures on education, including the opportunity costs of the time spent in education, as investments and cumulates these to estimate stocks of human capital.

There are aspects of human capital formation, however, that are different from other assets. Human capital is embodied in individuals and cannot be transferred to others, so do not appear on balance sheets. Therefore "education assets" are difficult to value and hence have not appeared in countries national accounts (SNA, 2009). An alternative approach to that employed by Kendrick is to measure human capital stocks based on the stream of future earnings, viewing lifetime earnings as the monetary returns to investments in human capital (e.g. Jorgenson and Fraumeni, 1992; Wei, 2004). This method is applied to all gender, age, and education cohorts as well as students in education. Many countries are currently experimenting with producing such measures as satellite accounts.

An important assumption in the Jorgenson–Fraumeni (JF) approach is that returns to education and training are captured by workers in their wage payments. However this will not take account of returns to firms in the cases where they provide and pay for the training. This is recognized in the SNA 2008 where it is stated that "When training is given by an employer to enhance the effectiveness of staff, the costs are treated as intermediate consumption" (SNA, 2009). The important contribution of Corrado *et al*. (2005) and subsequent studies referred to above is to question this approach of treating intangibles in general, including training provided by firms, as intermediate consumption and instead arguing that they should be classified as investments. This literature, which began with the seminal paper by Corrado *et al*. (2005), treats training as an activity largely undertaken by firms who pay the direct costs of training programs and indirect costs in terms of production output foregone. The issue then becomes one of separating human capital formation where returns go to workers from those where firms enjoy the benefits. If this can be achieved then human capital formation arising from activities of firms can be added to those measured using the JF approach.

One way forward is to make a distinction between general and specific training. Investment in formal education, I_{ED}, can be assumed to be mostly general as it occurs usually before individuals join the workforce and is paid for by individuals or taxpayers.[2] Investments in continuous education, I_{CE}, will have both general and firm specific components. In what follows we use the term continuous training (CT) to denote that part of the continuous education that is paid for by firms and assume the firms reap the full benefits from this activity. Therefore we construct intangible capital stocks for CT, assuming geometric decay as:

$$(2) \qquad R_{CT,t} = R_{CT,t-1}(1-d_{CT}) + I_{CT,t}$$

where R is capital, I is investment, and d is depreciation.

Section 4 discusses how we estimate these investments and stocks in practice. Before turning to this it is worth setting out the growth accounting method that will be used to estimate the impact of CT on output growth. Here we outline the methodology employed in EU KLEMS and then add continuous training as a separate input, drawing on the discussion in Giorgio-Marrano *et al.* (2009).

For each country we begin by assuming the existence of a value added production function for industry j given by:

$$(3) \qquad Y_j = f_j\left(K_j, L_j, T\right)$$

where Y is real output (value added), K is an index of capital service flows from k types of tangible assets, L is an index of labor service flows from l types of labor, and T denotes time. Under the assumptions of competitive factor markets, full input utilization, and constant returns to scale, the growth of output can be expressed as the cost-share weighted growth of inputs and Hicks neutral technological change, A, using the translog functional form common in such analyses:

$$(4) \qquad \Delta \ln Y_{jt} = \bar{v}_{jt}^{K} \Delta \ln K_{jt} + \bar{v}_{jt}^{L} \Delta \ln L_{jt} + \Delta \ln A_{jt}$$

where $\bar{v}_{jt}^{K}$ and $\bar{v}_{jt}^{L}$ denote the two-period average share of the aggregate inputs in nominal output defined as follows:

$$(5) \qquad v_{jt}^{L} = \frac{P_{jt}^{L} L_{jt}}{P_{jt}^{Y} Y_{jt}}; \quad v_{jt}^{K} = \frac{P_{jt}^{K} K_{jt}}{P_{jt}^{Y} Y_{jt}}$$

where P denotes prices of output and inputs. Constant returns to scale implies $\bar{v}^{L} + \bar{v}^{K} = 1$. Each element on the right-hand side of (4) indicates the proportion of output growth accounted for by growth in capital services, labor services, and technical change as measured by multifactor productivity (MFP), respectively. In

[2]An exception is apprenticeships which are likely to include some specific training.

EU KLEMS aggregate labor input is defined as a Törnqvist quantity index of individual labor types as follows:

$$\Delta \ln L_{jt} = \sum_{l} \overline{w}^{L}_{l,jt} \Delta \ln L_{l,jt} \tag{6}$$

where $\Delta \ln L_{i,t}$ indicates the growth of hours worked by labor type l and weights are given by the two period average shares of each type in the value of labor compensation. The types of labor distinguished are gender, three education/qualification groups to capture human capital embodied in the workforce, and three age groups to capture experience. Thus the services rather than the stock of human capital are included in the growth accounting equation; this method is consistent with the JF approach to human capital stock estimation for persons in work at time t as earnings are employed as weights.

In EU KLEMS capital input is also measured as services at time t, through distinguishing k different types of capital assets, mostly tangible but also including software. As with labor, a Törnqvist quantity index of capital services is given by:

$$\Delta \ln K_{jt} = \sum_{k} \varpi^{K}_{k,jt} \Delta \ln K_{k,jt}. \tag{7}$$

Capital stocks, K, for each asset are estimated using the perpetual inventory model with geometric depreciation as set out in equation (2).

The weights, ϖ, are the value of each asset in capital compensation and are calculated using the rental price of capital services, $p^{K}_{k,t}$, which reflects the price at which the investor is indifferent between buying or renting the capital good for a one-year lease in the rental market. This gives the familiar cost-of-capital equation:

$$p^{K}_{k,t} = p^{I}_{k,t-1} r_t + \delta_k p^{I}_{k,t} - \left[p^{I}_{k,t} - p^{I}_{k,t-1} \right] \tag{8}$$

with r_t representing the nominal rate of return, δ_k the depreciation rate of asset type k, and $p^{I}_{k,t}$, the investment price of asset type k.

Incorporating intangible assets in the above growth accounting framework involves a number of modifications, including adding intangible assets, adjusting both nominal and real output to reflect the fact that investments in these assets were previously allocated to intermediates, and modification to the user cost of capital to reflect changes in the internal rate of return. Giorgio-Marrano *et al.* (2009) set out in full the implications of these adjustments for the growth accounting framework—here we just sketch the main modifications.

In the context of this paper the first adjustment involves incorporating an additional input, intangible capital denoted by R, in the production function (3). This intangible investment good in turn requires capital and labor inputs in its production so that including intangible investments raises both the value of output on the production side and the payments to inputs. Both involve adjustments to the growth accounting equation to yield a modified model given by:

$$\Delta \ln Y^{*}_{jt} = \overline{v}^{*K}_{jt} \Delta \ln K_{jt} + \overline{v}^{*R}_{jt} \Delta \ln R_{CT,jt} + \overline{v}^{*L}_{jt} \Delta \ln L_{jt} + \Delta \ln A^{*}_{jt} \tag{9}$$

where the modified real output Y^* and input shares v^* are adjusted to include intangible inputs:

$$(10) \qquad v_{jt}^{*L} = \frac{P_{jt}^{L} L_{jt}}{P_{jt}^{Y} Y_{jt}^{*}}; \quad v_{jt}^{*K} = \frac{P_{jt}^{K} K_{jt}}{P_{jt}^{Y} Y_{jt}^{*}} \quad v_{jt}^{*R} = \frac{P_{jt}^{X} R_{jt}}{P_{jt}^{Y} Y_{jt}^{*}};$$

and $\bar{v}^{L} + \bar{v}^{K} + \bar{v}^{R} = 1$.

An added complication is the need to adjust the nominal rate of return if it is determined ex-post through the endogenous approach (Jorgenson *et al.*, 1987), as employed in EU KLEMS. This assumes that the total value of capital services for each industry equals its compensation for all assets. This procedure yields an internal rate of return that exhausts capital income which, due to constant returns to scale, equals value added minus the compensation of labor. Therefore including intangible assets requires both that capital compensation is spread over both tangible and intangible assets and the rate of return in the user cost formula (8) is adjusted to ensure rates are equalized across the expanded set of assets. Note also that technical change ($\Delta \ln A^*$) in (9) may be higher or lower than $\Delta \ln A$ in equation (4) as both output and inputs have changed.

Although in theory adding investments in continuous training to output and capitalizing it in a growth accounting framework is relatively straightforward, in practice a number of assumptions are required to implement the methods. Before turning to this we first present a brief overview of training in the EU.

3. Continuous Training in the EU

This section examines the prevalence of workforce training across EU countries, using data from EU LFS. It presents an overview for the EU, both the quantity and quality of training provided, and information on the characteristics of those trained. The estimates are derived from aggregating microdata from the quarterly surveys.[3]

Since 2003 the EU LFS has asked respondents if they "attended any courses, seminars, etc. outside the regular education system."[4] In 2007 in the EU as a whole, approximately 10 percent of employees received some training in the four weeks prior to the quarterly survey (Table 1). Training proportions are significantly higher in the EU15 than in the group of new member states (EU9).[5] The training proportion has been rising over time in the EU as a whole, but as Table 1 shows, this growth occurs mainly in the EU15 group of countries.

The figures for the EU aggregates hide large variation across countries. The proportions are very high in the Scandinavian countries, the Netherlands, and the

[3]Use of the microdata has the advantage that it allows cleaning of the data to remove outliers that appear to be reporting errors; an example is the question on duration of education where some individuals report more hours than available in a four week period.

[4]Prior to 2003 the question was more general and included both regular education and continuous training. By restricting the sample to persons in employment, we exclude all full time students. Apprenticeships are included in regular education and not continuous training. The growth in the broader measure is used to estimate growth over time in proportions of the workforce trained to derive a longer time series and so enable calculation of capital stocks.

[5]The list of countries included in these two groups is given in the Appendix tables.

TABLE 1
Percentage of the Workforce Receiving Training in the Past Four Weeks[a]

	EU24[b]	EU15	EU9[b]
1995	7.8	8.5	3.6
1996	8.0	8.7	3.6
1997	8.1	8.9	3.7
1998	8.1	8.9	3.7
1999	8.3	9.1	3.7
2000	8.6	9.3	3.7
2001	8.7	9.5	3.7
2002	8.7	9.4	4.1
2003	10.0	10.9	4.0
2004	11.3	12.3	4.3
2005	11.1	12.2	3.8
2006	11.0	12.1	3.8
2007	10.2	11.2	3.9

Notes:
[a]From 2003 this is based on the variable "COURATT," which asks respondents "did you attend any courses, seminars, conferences or received private lessons or instructions outside the regular education system in the past four weeks?" Time series are constructed by linking in an overlapping year to the variable "EDUC4WN"—education or training received during the previous four weeks.
[b]The EU member states up to 2006, excluding Malta.
Source: EU LFS, Eurostat.

U.K., but are considerably lower in some large continental EU15 countries such as Italy and Germany. Some EU15 countries (Portugal, Greece) have as low training densities as many of the smaller new member states—see Appendix Table A1. Dividing by industry group shows that the percentage of workers receiving training is generally higher in service sectors than in production industries and is highest for non-market services (Table 2). The underlying data suggest that training proportions are very high in financial services. The distribution across industries is similar in the EU15 and the new member states, except perhaps in financial services where the EU9 proportion is closer to the EU15 than is the case for other sectors (see Carmichael *et al.*, 2009, for training proportions by detailed industry).

Training is also likely to vary by worker characteristic. The figures in Table 2 suggest that females are more likely to receive training than males, and the training proportion declines with age and rises with skill level. The division by skill group is particularly pronounced—in fact in the EU15 the share of all workers receiving training who have "high" qualification levels was much higher (44 percent) than this group's share of the total workforce (15 percent).

The EU LFS also asks a number of questions that yield additional information on aspects of training received. These include purpose of training, duration of training, and whether training occurs during working hours. These questions were only asked since 2003 or 2004, depending on the country; the response rate was relatively low in some cases so the numbers presented below are all based on average values over the period 2003–07. EU LFS respondents were asked if the purpose of the training was mainly professional or mainly personal/social. In the

TABLE 2

Percentage of the Workforce Receiving Training in the Past Four Weeks

	EU24[a]	EU15	EU9[a]
By industry group (2007)			
Production[b]	6.0	7.0	2.3
Market services[c]	9.3	10.1	3.9
Non-market services[d]	14.9	16.2	6.7
By skill group (2007)			
High[e]	17.0	18.3	9.0
Intermediate[f]	7.9	9.5	2.9
Low[g]	5.0	5.2	1.0
By gender (2007)			
Male	8.7	9.7	3.2
Female	11.5	12.8	4.7
By age group (2007)			
15–29	11.7	13.1	4.3
30–49	9.9	11.0	4.1
50+	8.4	9.4	3.1

Notes:
[a]Excluding Malta.
[b]Agriculture, forestry and fishing; mining; manufacturing; electricity, gas and water; construction.
[c]Distribution; hotels and catering; transport and communications; financial services; business services; other personal services.
[d]Public administration; education; health and social services.
[e]Educational attainment at ISCED levels 5–6; university degree or equivalent.
[f]Educational attainment at ISCED levels 3–4; academic and vocational qualifications above intermediate secondary.
[g]Educational attainment at ISCED levels 1–2; secondary qualifications at age 16 or below.
Source: EU LFS.

EU as a whole, 84 percent said the training was mainly professional. There was some small variation by type of worker—the most salient being that the low skilled were more likely to say the training was for personal reasons, 25 percent, against only 14 percent for the highest skill group. The percentage of workers saying training was for professional reasons was similar across gender and across age groups. There were also some differences across country and industry, but in general the response rate on this question was quite low so these differences are unlikely to be significant.

A more revealing dimension is the average length of training, shown in Table 3. On average workers who have received training in the past four weeks are trained for about 15 hours in the EU as a whole. This is a significant length of time, indicating that workplace training is not overly concentrated in short duration courses. Table 3 shows that the number of hours is highest in the production industries and lowest in non-market services, the reverse of the pattern for training proportions. There is also variation across countries, with hours generally larger in new member states than in the EU15, and high in some countries where training propensities are relatively low, e.g. France and Greece (see Appendix Table A2).

TABLE 3

Average Duration of Training (Hours), Average 2003–07

	Total	Production	Market Services	Non-Market Services
EU24[a]	15.3	25.6	14.5	11.6
EU15	15.2	25.9	14.5	11.6
EU9[a]	15.3	21.7	15.5	11.7

Note: [a]Excluding Malta.
Source: EU LFS.

Examination of figures on duration of training by worker characteristic suggests that females receive less hours training on average than males, and that duration of training falls marginally with skill level for the youngest age group, compensating to some extent for the reverse findings for proportions of workers trained in these two dimensions. However duration of training falls with age, reinforcing the findings above on relatively low training proportions for this group.

Another interesting dimension is the extent to which training occurs during normal working hours. In the EU countries for which data were available, about 67 percent of respondents said training occurred wholly or mostly during working hours. In Finland, France, and the U.K. more than 75 percent of training occurred during working hours; in Belgium, Ireland, Italy, the Netherlands, and Poland the proportion was about 50 percent, whereas in many new member states and Greece the proportion was under 40 percent. However, it should be noted that this variable was not reported for many countries, including Germany and Spain.

These results on both amount and types of training are consistent with findings in the literature. Blundell *et al.* (1996) find that more educated people have higher chances of receiving training. Vignoles *et al.* (2004) find that male workers in their mid career (age 33–42) are more likely to receive training and experience the highest wage growth from training and that firms often train the workers who are more able in the first place. Carmichael and Ercolani (2010), also employing the EU LFS microdata, argue that older persons (age 50+) receive less training, which is of shorter duration, and are more likely to engage in types of training less clearly related to employability.

In estimating intangible investments in continuous training we include all training regardless of whether it occurs during working hours or not, including the opportunity costs to individuals. However, in the growth accounting analysis, to avoid double counting, we employ the information on whether training occurred during working hours to adjust the estimates of intangible investments in continuous training to those paid for by firms. This adjustment is discussed further below.

4. Training Investments

This section analyses continuous training as an intangible investment, using the information on proportions of workers trained and the duration of training.[6] It first sets out a description of the methodology employed. This is followed by a discussion of the importance of investments in continuous training as shares of GDP and compares them with expenditures on general education.

Estimating investments in continuous training requires a monetary valuation of the number of hours of training received by workers. To achieve this, hours trained, calculated as numbers of workers trained times average duration of training, are multiplied by the average hourly cost of this training. Hence investments in continuous training in industry i, country j, and time period t are calculated by:

$$TI_{i,j,t} = HTR_{i,j,t} C_{i,j,t} \tag{11}$$

where TI = nominal expenditures on investments in training, HTR = total hours spent training per worker, and C is the cost of an hour's training. Since average durations are reported for the previous four weeks, this is converted to an annual basis, allowing for time lost due to holidays and other forms of absence.

Hourly costs C will have two elements, the direct costs of training (costs of running courses or external fees) and the opportunity costs of the production or leisure time foregone due to time spent on training. Both time away from production and leisure are valued at the market wage, as in Jorgenson and Fraumeni (1992). In this analysis hourly costs were estimated as:

$$C_{i,j,t} = DR + \bar{w}adj \tag{12}$$

where w denotes average wages and adj is a composition adjustment described below.

Information on hourly direct costs (DR) was taken from the Eurostat Continuous Vocational Training (CVT) surveys, which were carried out in 1999 and 2005. We used the variable "the ratio of direct to opportunity costs (wages)" in these surveys. Examination of the data suggests that these ratios vary significantly across time and industry, possibly due to small sample sizes. Therefore we average across the two survey years, using the same number for all time periods, and calculate just two ratios for each country, dividing into production industries (NACE C–F) and market services (NACE G–K and O). Non-market services are not covered by the CVT survey, so we assume the ratios for these sectors are equal to those for market services. In the total EU direct costs are estimated to be about 30 percent higher than wage costs in production industries and 26 percent higher in services, but there is large variation across countries, e.g. in the U.K. the ratio for the whole economy is close to two. The first component in (12) was estimated as the average labor compensation of employees, taken from EU KLEMS, multiplied by the ratio of direct to opportunity costs.

The second term in the hourly costs equation is the opportunity cost. This is set equal to the average wage but adjusted for the composition of those being

[6] In these calculations we restrict attention to training of those in employment and do not take account of training of the unemployed or inactive persons. This is due to problems with the underlying data that only allow us to distinguish continuous from formal education by restricting the sample to those in work. Ideally human capital calculations would include all persons and not just those currently in employment.

TABLE 4

Investments in Continuous Training as a Percentage of Value Added,[a] Average 2003–07

	Total	Production Industries	Market Services	Non-Market Services
EU24[b]	1.62	1.06	1.51	2.76
EU15	1.80	1.21	1.67	2.95
EU9[b]	0.52	0.27	0.46	1.26

Notes:
[a]Adjusted to include investments in continuous training.
[b]Excluding Malta.

trained; data on average wages by labor type are again taken from EU KLEMS.[7] Due to small samples we estimate proportions trained by skill, age, and gender groups for just three industry groups—production industries, market services, and non-market services—and apply the average proportion for 2003–07 to all years. In most countries the proportions of workers with university degrees or equivalent is higher for those trained than for employment so this adjustment is positive. The one exception appears to be Italy. When dividing by broad industry, however, the adjustments are positive for production industries and market services, but allowing for composition lowers the average wage in non-market services due to a predominance of females in those sectors. On average wages are adjusted upwards by 10–15 percent for EU15 countries and by closer to 25 percent for new member states.

Table 4 presents investments in continuous training as a share of adjusted value added, Y^*, averaged across the years 2003–07. In the EU15 investments in continuous training account for 1.8 percent of GDP but the share of GDP is less than a third as large in the new member states. These investments represent a lower share of production industry value added than in the total economy and are highest in the non-market sectors, where the much higher training propensity more than compensates for the lower duration and lower opportunity cost.

Results for individual countries are shown in Appendix Table A1, alongside the country values for proportion of the workforce trained. This shows the U.K. as the country most willing to spend on training followed by Denmark and Finland. The shares in Table A1 are somewhat higher than those of other authors: e.g. for the U.K., 2.45 percent in 2004 estimated by Giorgio-Marrano and Haskel (2006); and Finland, 1.5 percent in 2005 estimated by Jalava *et al.* (2007). These differences largely reflect the higher opportunity costs calculated in this paper arising from the composition adjustment, but also reflect some differences in source data. In general this table shows that investment in continuous training

[7]In theory we should use wages for the individual workers who receive training, but such information is not available systematically across countries. The research in Vignoles *et al.* (2004) suggests that, at least for the U.K., firms train their most able workers and so individual specific wage rates would likely raise the value of investments above those presented here.

TABLE 5
Expenditure on Education as Percentage of GDP, Average 2003–07

	Total[a]	Primary	Secondary	Tertiary
EU24	5.05	1.29	2.14	1.04
EU15	5.07	1.16	2.28	1.14
EU9	5.07	1.15	2.29	1.15

Notes: [a]Includes pre-primary education.
Note the denominator is the GDP, so is not directly comparable with the shares in Table 4.
Source: Eurostat.

constitutes a lower share of GDP in countries with low populations and in new member states. However the share is much smaller for Italy than for other major EU15 countries, and the figure for Slovenia, a small new member state, is larger than in Germany or Spain.

It is useful to compare these figures with expenditure on general education as a percentage of adjusted value added. Table 5 summarizes this information for the EU—country values are shown in Appendix Table A3. Comparing Tables 4 and 5 shows that continuous training is about a third as large as spending on general education in the EU15, with the difference much smaller for some individual countries such as the U.K. and Denmark. In the EU15, continuous training represents a higher share of GDP than either primary or tertiary education individually, although to be strictly comparable the latter should also account for the time students spend on their studies. In contrast, continuous training is only about one tenth of expenditure on general education in the new member states.

It is interesting to examine the cross country correlation between expenditures on continuous training and on education. It might be argued that countries that spend more on general education may have less need for continuous training. Continuous training (CT) might be a substitute for general education (GE), for example, where education systems have a more vocational training orientation. Cross country correlations were calculated using the full annual panel of CT and GE shares of value added from 2003 to 2007. Looking at the EU as a whole, this correlation for the average shares of CT with GE turned out to be significantly positive at 0.53, and larger in the EU15 (0.61) than in the new member states (0.33). These numbers do not change much if average shares across the years 2003–07 are employed or if the U.K. is removed, as that country could be seen as an outlier in terms of CT. These results suggest that CT and GE are complements rather than substitutes. A more complete analysis would control for other forms of capital and other factors. This is beyond the scope of this paper but is an interesting avenue for future research.

The figures in Tables 4 and 5 suggest that failure to take account of continuous training is likely to seriously understate the magnitude of human capital accumulation and its impact on growth. We now turn to an analysis of the sources of growth, to gain additional insight into the extent of this understatement.

5. Training Capital and Growth Accounting

As outlined in Section 2, this paper combines the division into worker type common in the growth accounting literature to take account of general human capital (see, e.g. Jorgenson *et al.*, 1987; Inklaar *et al.*, 2005) with the intangible capital stocks arising from investments in continuous training calculated in the previous section of this paper. Here we need to take care that we are not double counting the impacts of continuous training since relative wages of different types of workers will in part reflect their propensities to engage in training. As noted above, training is far more prevalent among highly skilled workers and will be reflected in their relative wages. In order to address this issue we would like to separate returns to individuals from returns to firms. We do so by seeking to remove expenditures by individuals on their own training, since workers are unlikely to spend on activities that are firm specific and where the benefits go directly to firms. Instead workers who pay for their own training will expect compensation in the form of higher wages. Expenditure on training by individuals is not directly observable, so we use as a proxy the measure of whether training occurs during working hours described above. Therefore equation (10) is adjusted downwards by the proportion of training that occurred wholly or mainly during working hours. Although not ideal we believe this should remove most of the double counting bias. The effect of this assumption is discussed further below.

In order to estimate the impact of these investments on productivity, it is necessary to convert investment values to volumes and construct capital stocks. The convention in the literature set by Corrado *et al.* (2009) is to use the GDP deflator to construct volume measures. However, in this paper we employed an earnings deflator instead, to ensure that cross country differences are not driven by changes in real earnings; sensitivity of the estimates to this assumption is considered further below.

In all such exercises the perpetual inventory method that cumulates investments and deducts depreciation is employed to convert to stocks. The most common assumption employed in the literature on the form of the depreciation function is geometric decay as in equation (2)—this is the method employed in the EU KLEMS data used in the analysis below. Geometric decay implies that proportionally more of the asset is depreciated early in its use.

The intangibles literature assumes relatively high depreciation rates to take account of the idea that many of these investments are associated with new technologies that change rapidly. Hence Corrado *et al.* (2009) assume a 40 percent depreciation rate for their measure of firm specific organizational investments, which includes on the job training. However, this is an arbitrary assumption and deserves some scrutiny. The literature on depreciation rates for general human capital yields rates that are much lower, ranging from about 4 percent in the U.S. to 11–17 percent for EU countries (Groot, 1998). De Grip and van Loo (2002) discuss reasons for human capital depreciation, distinguishing physical deterioration (due, for example, to a worker's physical deterioration or insufficient use of their skills) from economic depreciation, which lowers the market value of skills due to technical change and shifts in employment structures between sectors. Both are likely to be influenced by the degree of worker turnover and the extent to which training is firm specific or more general in nature. Training paid for by firms is often assumed to be firm specific (Becker, 1975), and so high degrees of worker mobility would imply a high depreciation rate as skills acquired through training would not be transferable between firms. Against this there are many models where firms and workers share the cost of general training (see the discussion in Pichler, 1993), especially in times of rapid technical progress, with workers better off staying with firms who provide continuous training. Examination of the field of study in the EU LFS suggests that training is often general rather than specific. If there is a high element of general training, then depreciation rates should be closer to those for broad measures of human capital.

While there are many papers on the theoretical arguments for and against high depreciation rates, empirical evidence is very sparse, with many authors resorting to "best guesses"—e.g. Conti (2005) assumes 15 percent for training in Italy, citing Groot (1998) as support. Some evidence on service lives for training is provided in Awano *et al.* (2010) for the U.K.; it suggests a relatively short service life equivalent to about a 35 percent depreciation rate, but this is based on a very small sample. Goerzig *et al.* (2010) argue that for organizational capital in general a 25 percent depreciation rate is more reasonable as it accords with company valuations. In this study we employ a 25 percent depreciation rate consistent with the assumptions in the latter study as this feeds into studies arising from the INNODRIVE project of intangible organizational capital that has a cross Europe focus and so is the research most comparable to this paper.[8] However, sensitivity of the estimates to the depreciation rate is discussed further below.[9]

The estimates of capital stocks can be combined in a growth accounting equation to estimate the impact of intangible continuous training capital on output growth, as outlined in Section 2. In particular that part of investment in training that adds to the returns to workers is captured by the labor composition term, whereas the part that corresponds to expenditure by firms is estimated by the contribution of R in equation (9). Therefore in the estimates below we compare an expanded measure of human capital that accounts for continuous training with one that only partially accounts for this element of human capital accumulation.

The analysis in this section makes use of the EU KLEMS database, which provides a breakdown of output into conventional capital inputs (with a division into ICT and non-ICT assets), labor input (divided into labor hours and labor composition), and derived variables such as MFP at industry level (O'Mahony and Timmer, 2009). Continuous training capital is included as an additional input, using the method outlined in Section 2 and employing user costs to calculate shares in value added. The rate of return is set equal to the internal rate employed in EU

[8]INNODRIVE: Intangible Capital and Innovations: Drivers of Growth and Location in EU, www.innodrive.org

[9]In addition, depreciation rates are likely to vary across country, e.g. due to greater worker mobility in some countries than others which would lead to earlier retirement of firm specific training. Data constraints preclude using country (or industry) specific depreciation rates but this is an issue that deserves further work.

TABLE 6

Growth in Continuous Training Capital and its Contribution to Growth in Corrected Value Added, 2001–07

	Growth in Continuous Training Capital (% p.a.)				Contribution of Continuous Training Capital to Corrected Value Added Growth[a]			
	Total	Production Industries	Market Services	Non-Market Services	Total	Production Industries	Market Services	Non-Market Services
EU24	4.57	3.06	5.43	4.60	0.051	0.027	0.052	0.079
EU15	4.63	3.13	5.49	4.65	0.063	0.035	0.063	0.094
EU9	1.10	–0.79	1.71	1.73	0.002	–0.001	0.002	0.005

Note: [a]Growth in continuous training capital times its share in value added.

KLEMS[10] and the capital stock estimation begins in 1995.[11] Estimates are presented from 2001 to ensure the results are not sensitive to the starting stock assumption.

EU KLEMS presents full growth accounts only for a few countries. It is useful first to gauge the magnitude of the impact of continuous training capital on output growth for all countries and across a broad sector, shown in Table 6. The first panel showing growth rates in continuous training capital stocks suggest that these were relatively high in the period since 2001 in the EU15. To place this in perspective, the growth rate of real tangible physical capital in the EU15 was only 2.6 percent per annum in the same period, with ICT capital growing at 7.3 percent per annum.[12] In a number of countries, namely, Denmark, Spain, Finland, France, the Netherlands, Sweden, Slovenia, and the U.K., these high growth rates translate into small but significant contributions to value added growth—see Appendix Table A4. The results by broad sector indicate that training capital is most important in non-market sectors—in the EU aggregates and almost all individual countries the contributions are greater in non-market services than in the total economies. The tables also show that contributions are generally significantly higher in market services than in production industries, with the latter negative in many new member states and some small EU15 countries such as Ireland and Portugal. Growth rates of continuous training capital and contributions to value added in individual sectors (not shown) indicate that the contributions are highest in the health sector, with continuous training capital also important in financial services, business services, and wholesale and retail trade.

[10]In theory the internal rate of return should also be adjusted to use the revised gross operating surplus (value added minus payments to labor), but this would require a full revision of EU KLEMS which is not feasible. The estimates were not very sensitive to the magnitudes of revisions in the internal rate of return that would arise from this adjustment as CT investments are small relative to gross operating surplus. Also average EU15 or EU9 estimates of the internal rate are employed where no capital data are available.

[11]The equilibrium starting stock in a perpetual inventory model with depreciation rate d and geometric decay if real investment were constant prior to the start date is $1/d$ times investment in the start date. The starting stock estimates include a small adjustment to allow for growth over time in CT investments.

[12]This number, derived from EU KLEMS data, includes some intangible capital in the form of software; see O'Mahony and Timmer (2009) for more details of capital growth rates in the EU.

TABLE 7

Growth in Continuous Training Capital and Contributions to Value Added: Sensitivity to Assumptions, Total Economy (2001–07)

	Growth in Continuous Training Capital (% p.a.)			Contribution of Continuous Training Capital to Value Added Growth[a]		
	EU24	EU15	EU9	EU24	EU15	EU9
25% depreciation, wage deflator	4.57	4.63	1.10	0.051	0.063	0.002
40% depreciation, wage deflator	4.41	4.47	1.11	0.049	0.060	0.002
25% depreciation, GDP deflator	5.64	5.78	4.23	0.070	0.082	0.008
40% depreciation, GDP deflator	4.90	4.92	3.97	0.061	0.074	0.007

Note: [a]Growth in continuous training capital times its share in value added.

The estimates above may be sensitive to the assumptions underlying the calculation methods including measuring real investments and on the assumptions employed to capitalize these assets. Table 7 shows how the growth in training capital varies according to assumptions on deflators and depreciation rates. The assumption of a 40 percent depreciation rate leads to a small reduction in CT capital growth, with a larger impact on its contribution to value added growth—with this assumption capital levels are lower, leading to a reduction in their share of value added. Nevertheless the impact of changing the depreciation assumption is relatively minor. The assumption on which deflator to employ has greater impact in the group of new member states, with the use of the GDP deflator raising the contribution of continuous training capital from 0.002 to 0.008 percentage points, as wages have been rising quite rapidly in these countries. However, since the training costs to firms are related more to wage payments than prices in general, it seems preferable to employ an earning based deflator. Finally the adjustment to remove costs of training borne by employees has little impact on growth rates but lowers the percentage point contributions of continuous training capital by about 40 percent. This assumption is necessary, however, to avoid double counting.

The contributions of CT capital to value added in Table 6 may at first sight seem small. This is partly because CT is only one of a number of intangible investments undertaken by firms. However, the magnitude of the impact of CT capital can only be judged relative to contributions from other inputs. Table 8 presents output growth and contributions of inputs for the EU15ex group of countries for which full growth accounts are available in EU KLEMS, contrasting the original estimates with the expanded growth accounts including CT capital. When looking at the contributions of the components of output growth, the impact of labor composition is generally relatively small and lower than other "knowledge" inputs such as ICT capital. Table 8 shows that the contribution of continuous training capital in the EU15ex at 0.06 is about 40 percent of the contribution from labor composition, 0.15, which in turn is mainly driven by up-skilling of the workforce arising from general education. The results suggest that the combined contribution of labor composition and training is much closer to that for ICT capital. For some individual countries the expanded human capital measure (CT plus labor composition) contributes as much or more than ICT

TABLE 8
Contributions of Inputs to Output Growth, EU15ex, 2001–07

	Value Added Growth	Percentage Point Contributions from					
		Hours Worked	Non-ICT Capital	ICT Capital	Labor Composition	Training	MFP
EU15ex[a]	1.93	0.48	0.63	0.33	0.15		0.35
Austria (AT)	2.11	0.50	0.31	0.32	0.14		0.85
Belgium (BE)[b]	1.78	0.42	0.69	0.61	0.17		–0.11
Germany (DE)	1.35	–0.15	0.47	0.30	0.07		0.66
Denmark (DK)	1.28	0.61	0.35	0.68	–0.05		–0.30
Spain (ES)	3.27	1.51	1.50	0.40	0.49		–0.62
Finland (FI)	2.86	0.54	0.39	0.41	0.25		1.26
France (FR)	1.78	0.28	0.62	0.21	0.22		0.45
Italy (IT)	1.17	0.64	0.71	0.15	0.08		–0.41
Netherlands (NL)	1.91	0.28	0.28	0.33	0.35		0.67
United Kingdom (UK)	2.40	0.55	0.51	0.47	0.38		0.50
EU15ex[a]	1.91	0.47	0.61	0.32	0.15	0.06	0.29
Austria (AT)	2.09	0.50	0.30	0.31	0.14	0.02	0.82
Belgium (BE)[b]	1.76	0.42	0.69	0.61	0.17	0.01	–0.13
Germany (DE)	1.33	–0.14	0.46	0.30	0.06	0.04	0.61
Denmark (DK)	1.26	0.60	0.34	0.66	–0.05	0.09	–0.38
Spain (ES)	3.23	1.50	1.48	0.39	0.48	0.10	–0.73
Finland (FI)	2.82	0.53	0.38	0.40	0.25	0.09	1.17
France (FR)	1.75	0.28	0.61	0.21	0.22	0.07	0.37
Italy (IT)	1.16	0.64	0.71	0.15	0.08	0.01	–0.43
Netherlands (NL)	1.89	0.28	0.27	0.33	0.35	0.13	0.53
United Kingdom (UK)	2.37	0.54	0.48	0.45	0.37	0.06	0.47

Notes:
[a]The aggregate across the countries included in the table.
[b]2001–06.
Source: EU KLEMS with adjustments to value added to include investments in continuous training.

capital—these include Spain, the Netherlands, and the U.K. Therefore these results suggest that failure to include training investments underestimates the impact of changes to the average skill level of the labor force. Note also that for the EU15ex and all individual countries, MFP growth is slightly lower in the expanded than in the original growth accounts. As discussed in Section 2, this may not be the case in theory but occurs in the time period considered in this paper and is consistent with the results in the previous literature referred to above.

6. Conclusions

This paper linked the microdata underlying the EU LFS to industry data from EU KLEMS to estimate investment in continuous training and their importance as sources of growth in the European Union. Modeling continuous training activities as intangible investments allows comparison of the extent of these investments across countries and with expenditures on human capital formation through the general education system. The comparison suggests that CT investments are not negligible compared to investment in general education and the two types of investment in human capital appear to be positively correlated.

In the EU15 and a number of individual countries, intangible capital from investing in continuous training is an important contributor to output growth. The results suggest that ignoring continuous training leads to an understatement of the contribution of human capital to growth. Van Ark *et al.* (2008) define knowledge economy contributions to output growth as the sum of the contributions of ICT capital, labor composition (mostly due to up-skilling of the labor force), and MFP. The inclusion of training capital suggests that about 21 percent of the contributions of knowledge inputs are directly related to increases in the level of human capital in the workforce. Therefore understanding the knowledge economy requires more attention to human capital than earlier growth accounting estimates suggest.

Growth accounting typically leads to a relatively low contribution from human capital as it only takes account of benefits to individuals in the form of wage payments and so precludes both the direct benefits to the firm estimated in this paper and any complementarities between human capital and other inputs as well as any spillovers. In a recent paper, O'Mahony and Peng (2011) provide econometric evidence that benefits from CT capital are linked to investment in ICT capital, especially in market service sectors. Further work is required to gauge if CT and other forms of intangible capital complement other inputs and if there is any evidence of external benefits from these investments.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table A1: Proportions of the Workforce Receiving Training (TR) and Investments in Continuous Training as a Percentage of GDP (ITRG), Average 2003–07
Table A2: Average Duration of Training (Hours), Average 2003–07
Table A3: Education Expenditures as a Percentage of GDP
Table A4: Continuous Training Capital and Output Growth, 2001–07, Sector

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