The Economic Impact of Capital-Skill Complementarities on Sectoral Productivity Growth

New Evidence from Industrialized Industries during the New Economy *

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Abstract

Recent growth accounting exercises attribute strong productivity growth to increased investments in information and communication technologies (ICT) to be the driving force behind the widening of the US–EU productivity gap over the last 15 years. This paper re-examines the sources of labor productivity (ALP) growth for selected industrialized countries over the period from 1980 to 2005, and shows that ICT was indeed one of the driving factors, although ALP growth was quite heterogeneous within EU countries. Moreover, as both Non-ICT capital deepening and labor quality growth equally affected productivity growth across countries, it was particularly the complementarity of ICT and skilled workers that made the difference. The findings provide new empirical evidence on productivity growth of industrialized countries by combining efficiency gains as derived from the implementation of new technologies embedded in investment goods with countries' differing supply of heterogeneous labor. Econometric industry analysis reveals that the interaction between ICT and skills spurred labor productivity growth of Anglo-Saxon market services and Scandinavian goods-producing industries, while Continental countries are lacking such effects.

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Keywords: *Industry productivity growth, information and communication technology, heterogeneous labor, capital-skill complementarity, skill-biased technological change.*

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1. Introduction

Labor productivity in Europe and the US has experienced a persistent divergence in trend growth since 1990. But also within Europe's member countries growth developments have been quite heterogeneous. While Germany, France, and Italy, for example, exhibited declining productivity growth performances, northern countries like Sweden, Finland, and Denmark but also the UK were on the ascendant. As productivity measurement commenced to allow for effective accounting of information and communication technologies (ICT) in national statistics the origins of the productivity divergence between countries became attributable to a more effective usage of ICT investments, especially during the New Economy starting around the mid–1990s. Detailed country analysis also showed that particularly Scandinavian countries outperformed productivity trends of other European countries. But what was the nature of technological change that occurred during this period? Was technology entirely embedded in new capital goods increasing efficiency by substituting for labor or were productivity gains catalyzed by a skilled workforce equipped with new capital goods? According to recent studies, new and highly productive capital goods, as in case of ICT, induced increased demand for high-skilled labor compared to low-skilled over the last decades, thereby suggesting a complementarity between these two factors (Michaels, Natraj, and Van Reenen, 2010; O'Mahony, Robinson, and Vecchi, 2008).

Immense productivity increases, as seen in the US, may partly stem from the country's large-scale ICT investments, but may also involve its ability to attract high-skilled labor capable of reaping the benefits from these new technologies. This phenomenon is associable with skill-biased technological change (SBTC) that serves as one of the underlying sources of economic growth. Thereby the SBTC concept expands the notion of *factor-neutral* technological change to *factor-biased*, whereas this bias may be determined endogenously by economic incentives innovators are exposed to, such as firm size or market structure, but also by endogenous changes in the long-run demand for skilled workers and international trade.[1]

Resting on the idea that skilled labor is relatively more complementary to capital equipment than unskilled (Griliches, 1969), this paper provides empirical evidence for capital-skill complementarities across selected industrialized countries applying the concept of SBTC to ICT and the New Economy, but furthermore identifies the effect of SBTC on sec-

[1] Skill-biased technological change is determined as a shift in the production technology that especially favors skilled workers, thereby increasing their relative productivity compared to low-skilled workers as well as their relative demand. A variety of economic models of SBTC can be found e.g. in Acemoglu (1998, 2002a, b, 2009), Aghion (2002), and Hornstein et al. (2005).

toral productivity growth.[2] The theoretical underpinning of ICT-skill complementarities and productivity growth mainly follows the idea that industries, which dispose of higher shares of ICT capital or are more ICT intensive are, in turn, more conducive to increase their demand for high-skilled workers. Hence, according to the nature of SBTC increased ICT raises the marginal productivity of highly skilled workers leading to higher sectoral productivity growth. But on the other hand, increased relative supply of a production factor induces endogenous change in technology that is relatively biased toward that factor (Acemoglu, 1998, 2002a, b). Countries with more high-skilled workers available should therefore employ more new technologies and eventually generate higher sectoral productivity again. It will be shown that over the past 25 years this was particularly the case in Anglo-Saxon and Scandinavian countries, although the effects differentiate significantly by sectors.

In a recent study on ICT and skill demand Michaels, Natraj, and Van Reenen (2010) suggest that ICT has been the main driver of demand for high skills in OECD countries during 1980–2004 and found supporting evidence for an ICT-induced skill polarization (Autor, Levy, and Murnane, 2003). Latter is accompanied by a falling demand for middle-skilled workers relative to those at the top of the skill distribution. Low-skilled workers are relatively unaffected by ICT and experienced an increase in more recent numbers. Another study by O'Mahony, Robinson, and Vecchi (2008) examining the link between ICT and skills, provide empirical cross-country evidence on the demand effect for skilled labor stemming from ICT in the US, the UK, and France during the 1980s and 1990s, especially with respect to highly skilled workers with IT-specific occupations. Thereby their findings suggest that the impact of information technology has been more transitory in nature as it is more and more slowing down, at least in the US.

Despite both studies employ detailed country-sector data, they do not explicitly account for parameter heterogeneity in complementarities of ICT and high skills by sector and country. The subsequent analysis will revisit the complementary between ICT and high-skilled workers for three different country samples, particularly accounting for sectoral parameter heterogeneity by goods-producing sectors and market services. Unique is also the determination of differing effects stemming from ICT-skill complementarities on sectoral productivity growth under explicit accounting for sectoral differences in production functions and growth in factor proportions. The findings provide new heterogeneous evidence on the sources of productivity growth and the nature of technology change.

[2] Previous papers that provide empirical evidence for capital-skill complementarities are e.g. Bartel and Lichtenberg (1987), and with respect to ICT Autor, Katz, and Krueger (1998); Autor, Levy, and Murnane (2003); and Autor, Lawrence, Katz, and Kearney (2006).

Therefore the paper analyzes three sets of OECD countries comprising of Germany and France (Continentals), the United Kingdom and the United States (Anglo Saxon), and Sweden and Finland (Scandinavians) using 2-digit NACE industry-level data as provided by the *EU KLEMS Growth and Productivity Accounts* (see Table A1 in the Appendix for a detailed list of all industries provided and employed in the analysis). The data employed is in line with the data used by Michaels, Natraj, and Van Reenen (2010) and covers the period from 1980 to 2005 including the emergence phase and apex of the New Economy in 2000. As an important extension the analysis will be applied for goods-producing sectors and market services separately, as both sectors are assumed to differ in their rates of technological progress as well as their production functions. Significant differences in factor proportions and capital deepening across sectors are important premises in explaining differing sectoral growth rates and nonbalanced growth (Acemoglu and Guerrieri, 2008; Acemoglu, 2009).[3]

The empirical investigation reveals that there are robust and weakly robust econometric results on ICT-skill complementarities during the period 1980–2005, which generated strong sectoral productivity growth. In particular, Scandinavian goods-producing sectors show robust productivity growth effects from ICT-skill complementarities, while the effect for Anglo-Saxons market services depends to some extent on the employed estimator. Nevertheless, only Anglo-Saxon market services experienced robust positive effects from increasing ICT capital deepening over the period of coverage. Interestingly, ICT-skill complementarities are not detected either for Continental goods-producing sectors or market services. Besides lacking positive effects from ICT capital deepening across sectoral groups, Continentals' productivity growth stagnation compared to Anglo-Saxon and Scandinavian countries is *inter alia* attributed to non-directed technological change towards high-skilled labor.

The paper is organized as follows: Section 2 provides the theoretical underpinning for the empirical models to test the effect of capital-skill complementarities on sectoral productivity growth. Section 3 and 4 introduces the employed data and shows descriptive statistics on labor productivity growth, ICT capital deepening, and labor composition by goods-producing industries and market services and by country clusters, respectively. The econometric estimation of productivity effects from ICT-skill complementarities is provided in Section 5, while Section 6 concludes.

[3] These assumptions provide further differentiation in explaining sectoral growth instead of imposing differing exogenous rates of technological progress (Baumol, 1967).

2. Empirical Models of Labor Productivity Growth

For the examination of productivity growth effects from interaction of ICT and high-skilled workers, I commence by employing a standard neo-classical production function for industry i

$$Y_i = F_i\left(K_i, L_i, A_i\right) , \tag{1}$$

where output Y is generated from the two input factors capital, K, and labor, L, and a disembodied technology parameter, A. K and L are measured in terms of capital and labor services, which account for quality differences in assets and labor types, respectively (Jorgenson et al., 2005). In the following industry notation i is omitted due to simplicity. Assuming that disembodied technological change is hicks neutral and capital can be separated by ICT and Non-ICT, labor productivity (measured as output per hour worked, where H resembles total hours worked) is derived as

$$\frac{Y}{H} = A\,F\left(\frac{K^{ICT}}{H}, \frac{K^{NICT}}{H}, \frac{L}{H}\right) . \tag{2}$$

Assigning lower-case letters to per-hour factors the output generating process can be rewritten according to

$$y = A\,F\left(k^{ICT}, k^{NICT}, q\right) \tag{3}$$

with y being labor productivity, k^{ICT} is ICT capital deepening, k^{NICT} is Non-ICT capital deepening, and q reflects an index of labor quality. In particular, as this index intends to capture the effects from SBTC it incorporates shifts in labor composition from a low to a more skilled workforce. These shifts are traced by introducing productivity adjusted hours worked, whereas the numbers of hours worked for three different worker types (low, medium, and high skills, henceforth denoted by l) are weighted with their marginal productivities. Therefore the weights resemble the share in labor compensation by type of worker. This is condensed in the following composite indicator of labor quality

$$q = \frac{\sum_l w_l H_l}{H} , \tag{4}$$

where w_l and H_l are labor compensation shares and hours worked for different labor types l, respectively, while H is the sum over total hours worked by different labor types. This composite indicator, q, differs from other quality indicators that additionally adjust for other characteristics of the labor force as e. g. gender and age (see therefore Jorgensen et al., 2005 or Jorgenson and Timmer, 2011). Its purpose is to isolate the productivity effects that entirely originate from education levels and thus workers cognitive abilities, and less from other potential productivity sources. The implementation of this indicator is so far unique in econometric analysis of capital-skill complementarities. The nominator in equation (4), which employs the sum of hours worked adjusted by labor compensation for different skill types, is a simple labor services indicator reflecting the production factor L in equation (2) and (3).

As this indicator seeks to identify capital-skill complementarities and the impact of SBTC, it may be helpful to give a short distinction of the concept of biased-technological change and the concept of factor-augmenting technological change. In the latter, technological progress enhances the output-generating possibility of the factor that is augmented by the technology, so that more output can be produced from the same unit of factor input. Biased-technological change differs in so far as technological progress increases the marginal productivity of the one factor toward which it is biased in comparison to the other factor that is available. Hence, SBTC increases the marginal productivity of high-skilled compared to lower-skilled workers measured as an increase in relative prices at given factor proportions. This, in turn, increases the relative demand for high skills at a given supply level of skill proportions. In constructing the quality indicator by utilizing labor compensation shares, which reflect marginal skill-type productivities, it allows for explicit accounting of the effect of SBTC on labor productivity growth.[4]

Under the assumption that the production function is Cobb Douglas, log-linearizing ends up in the subsequent estimable specification

$$\ln y = \ln A + \alpha_1 \ln k^{ICT} + \alpha_2 \ln k^{NICT} + \beta \ln q \ . \quad (5)$$

The final econometric specification, which is specified in terms of growth rates, takes on the form

$$\Delta \ln y_{it} = \Delta \ln A_{it} + \alpha_1 \Delta \ln k^{ICT}_{it} + \alpha_2 \Delta \ln k^{NICT}_{it} + \beta \Delta \ln q + \delta_1 t + \Delta \ln \varepsilon_{it} \quad (6)$$

for industry i and time t, including a linear time trend t and an assumed error-term structure of

$$\Delta \ln \varepsilon_{it} = \Delta \ln a_{it} + \Delta \ln d_t + \Delta \ln \upsilon_{it} \quad (7)$$

where a_{it} are time-variant unobserved industry effects, d_t common time effects, and υ_{it} a stochastic i.i.d. component. Since A_{it} is not observed in the data, the implementation of time-variant industry effects a_{it} capture different average growth rates in sectoral disembodied technological change, while the time trend captures overall technology.

[4] For detailed discussion on the concept of SBTC, see e. g. Acemoglu (2009).

Explicit formal testing of the ICT-skill complementarity effect on labor productivity growth requires estimation of a Translog production function, which is provided in addition to the Cobb-Douglas specification. This leads to the introduction of further interaction terms

$$\begin{aligned}\Delta \ln y_{it} = {} & \Delta \ln A_{it} + \alpha_1 \Delta \ln k_{it}^{ICT} + \alpha_2 \Delta \ln k_{it}^{NICT} + \beta \Delta \ln q + \delta_1 t \\ & + 0.5\gamma_{11} \left(\Delta \ln k_{it}^{ICT}\right)^2 + \gamma_{12} \Delta \ln k_{it}^{ICT} \Delta \ln k_{it}^{NICT} + \gamma_{13} \Delta \ln k_{it}^{ICT} \Delta \ln q \\ & + 0.5\gamma_{21} \left(\Delta \ln k_{it}^{NICT}\right)^2 + \gamma_{22} \Delta \ln k_{it}^{NICT} \Delta \ln q \\ & + 0.5\gamma_3 \left(\Delta \ln q\right)^2 + \delta_{11} t^2 + \Delta \ln \varepsilon_{it}\end{aligned} \tag{8}$$

with the same error-term structure as assumed in equation (7).

Moreover, as countries exhibit strong differences in institutional settings of labor and capital markets and may be located at different growth paths during the period of estimation, pooling of countries is conducted for three groups of similar institutional settings: Germany and France, UK and US, and Sweden and Finland. Also, instead of imposing the same function specification across all industries, the tested specifications will allow for parameter heterogeneity in goods-producing sectors and market services.

For estimation of a well-behaved production function of homogeneity of degree 1 in input elasticities, the constant-returns-to-scale property is imposed to both the Cobb-Douglas and the Translog specification, respectively:

$$\alpha_1 + \alpha_2 + \beta = 1 \tag{9}$$

and in case of the Translog specification also

$$\gamma_{11} + \gamma_{12} + \gamma_{13} = 0 \tag{10}$$

$$\gamma_{12} + \gamma_{21} + \gamma_{22} = 0 \tag{11}$$

$$\gamma_{13} + \gamma_{22} + \gamma_3 = 0 \tag{12}$$

Since the equality constraints are linear in the parameters, a restricted estimator can be solved analytically. Therefore the constraints are rewritten as

$$\alpha_1 = 1 - \alpha_2 - \beta \tag{13}$$

$$\gamma_{11} = -\gamma_{12} - \gamma_{13} \tag{14}$$

$$\gamma_{21} = -\gamma_{12} - \gamma_{22} \tag{15}$$

$$\gamma_3 = -\gamma_{13} - \gamma_{22} \tag{16}$$

and substituted into equation (6) and (8). In case of the Cobb-Douglas production function this yields the estimable regression specification

$$\left(\Delta \ln y_{it} - \Delta \ln k_{it}^{ICT}\right) = \Delta \ln A_{it} + \alpha_2 \left(\Delta \ln k_{it}^{NICT} - \Delta \ln k_{it}^{ICT}\right) + \beta \left(\Delta \ln q - \Delta \ln k_{it}^{ICT}\right) + \delta_1 t + \Delta \ln \varepsilon_{it} \tag{17}$$

and for the Translog production function

$$
\begin{aligned}
\left(\Delta \ln y_{it} - \Delta \ln k_{it}^{ICT}\right) = {} & \Delta \ln A_{it} + \alpha_2 \left(\Delta \ln k_{it}^{NICT} - \Delta \ln k_{it}^{ICT}\right) + \beta \left(\Delta \ln q - \Delta \ln k_{it}^{ICT}\right) + \delta_1 t \\
& + \gamma_{12} \left(\Delta \ln k_{it}^{ICT} \Delta \ln k_{it}^{NICT} - 0.5\Delta\left(\ln k_{it}^{ICT}\right)^2 - 0.5\Delta\left(\ln k_{it}^{NICT}\right)^2\right) \\
& + \gamma_{13} \left(\Delta \ln k_{it}^{NICT} \Delta \ln q - 0.5\Delta\left(\ln k_{it}^{NICT}\right)^2 - 0.5\Delta\left(\ln q\right)^2\right) \\
& + \gamma_{22} \left(\Delta \ln k_{it}^{ICT} \Delta \ln q - 0.5\Delta\left(\ln k_{it}^{ICT}\right)^2 - 0.5\Delta\left(\ln q\right)^2\right) \\
& + \delta_{11} t^2 + \Delta \ln \varepsilon_{it}
\end{aligned}
\qquad (18)
$$

Ultimately, the parameters α_1 , γ_{11} , γ_{21}, and γ_3 can be computed by substituting the estimates of α_2 , β, γ_{12}, γ_{13} , and γ_{22} into the equations (13) to (16).[5]

3. Data

For the subsequent analysis of formally testing the complementarity effects between new technologies (as embedded in ICT investment) and skilled labor on sectoral labor productivity growth, I employ growth accounting data for the three sets of industrialized economies: Continental (Germany and France), Anglo-Saxon (United Kingdom and United States), and Scandinavian (Sweden and Finland).

For implementation of the specified production functions, I employ real value-added for output, and capital and labor services for the input factors capital and labor. To derive variables in per-hour terms total hours worked by persons engaged are used. Data for output and input factors are mainly provided by the 2009 release of the EU KLEMS database (EU KLEMS, 2009) on a 30 industry level, while skill composition data for hours worked and labor compensation are provided by the 2008 release (EU KLEMS, 2009).[6] The country-industry panel is unbalanced by nature as it exhibits different periods of coverage by country, however, most of the variables are available for the period 1980–2005.[7]

When comparing different skill types by countries, one should be aware of differences in educational systems across the EU and the US. Comparability of single skill types is best across the high-skilled level, which contains above bachelor degrees, but it is less appropriate for the medium- and low-skilled levels (Timmer et al., 2007a). For this purpose country groupings are employed according to similarities in educational and institutional settings.

Importantly, since the period of analysis coincides with the launching phase of the New Economy during the second half of the 1990s, the data accounts for productivity effects stemming from new technologies in ICT capital services. Moreover, the sectoral nature of the data enables disaggregation of all economies into 30 industries (see Table A1, Appendix) and

[5] The parameter estimates and their significance levels are derived via the delta method.

[6] Regarding skill types, see Table A2 in the Appendix for a detailed definition by country. For a detailed description of the data, see Timmer et al. (2007a, b).

[7] See Table A3 for a detailed coverage of variables by time and country.

accounting for industry-specific trends in labor productivity growth.[8] Jorgenson (2005), for example, argues that the magnitude of the US growth resurgence outpaced all but the most optimistic expectations. After advances in productivity measurement allowed for effective accounting of information technology in national statistics (Schreyer, 2001), it became clear that recent productivity increases in the US originated to a great extent with ICT investments.

4. Descriptive Statistics by Country Clusters and Sectoral Type

4.1 Labor Productivity Growth, Capital and Labor Services

Beginning with juxtaposing period average labor productivity (ALP) growth for the the three country clusters suggests significant differences in growth rates by goods-producing industries and market services (Figure 1). Firstly, in most cases goods-producing sectors exhibit stronger ALP growth compared to market services, except for Anglo-Saxon countries during the period 1996–2000. While Continental and Anglo-Saxon countries show comparable growth rates in goods-producing sectors ranging from 2 to 4 percent, Scandinavian countries depict outstanding productivity increases of around 6 percent on average at the beginning of the 1990s. But also, on average, Scandinavian goods-producing industries experienced higher ALP growth compared to Continental and Anglo-Saxon countries ranging close to 4 percent. Regarding market services reveals a somewhat different picture; especially Continental ALP growth exhibits a substantial productivity weakness. While post–1990 ALP growth in Scandinavian market services is on the decline, they still outperform those of Continental countries. On contrary, Anglo-Saxon market services show a significant upward trend in productivity gains until the end of 2000, but suffered a productivity setback in the following period to roughly the pre–1995 level.

Higher productivity growth generated by increased capital intensity reveals striking differences across country clusters when capital is separated by ICT and Non-ICT capital services. ICT capital services constituted high growth rates in Anglo-Saxon and Scandinavian countries during the per–1990 period, while Continental countries lagged behind substantially (Figure 2). Despite lower growth rates in ICT capital services post 1990, Anglo-Saxon goods-producing industries and markets services continued to have strong growth in ICT investments until 2000, before growth started to fade. Nevertheless, ICT services in Anglo-Saxon market services still show sizable growth rates post 2000. On contrary, enormous ICT growth in Scandinavian goods-producing sectors and market services prior to 1990 collapsed during the following periods and ultimately converged to Continental growth levels. During

[8] Because of measurement issues in the output of non-market services, the analysis focuses on goods-producing industries and market services.

their path of convergence both sectors, in particular goods-producing industries, still exhibit substantially higher ICT growth rates as in Continentals.

Regarding Non-ICT capital services, growth appears to be significantly lower across all three country clusters (Figure 3). While Continental countries show declining Non-ICT growth in both goods-producing and market services sectors, Anglo-Saxon countries suggest increasing Non-ICT investments prior to 2000 in goods-producing sectors and slowing Non-ICT growth in market services, which was interrupted by a surge in growth rates during 1995–2000. A similar picture becomes apparent when Scandinavian goods-producing sectors are considered. These sectors also exhibit slowing Non-ICT investments during the period of coverage interrupted by surging post–1995 Non-ICT investments, before they ultimately stabilized on low growth levels. In contrast, Scandinavian market services show a secular decline in Non-ICT services.

An interesting development is depicted in labor services, which mostly experienced increasing growth in goods-producing sectors for all three country clusters (Figure 4). These positive growth rates suggest that labor composition either shifted towards a more skilled workforce (i.e. more hours worked by skilled workers) or labor compensation for higher skilled workers increased. Interestingly, labor services growth in goods-producing sectors declined dramatically post 2000 in Anglo-Saxon countries, while the strongest surge happened in Scandinavian goods-producing sectors post 1990. Regarding labor services growth in market services, Continental countries generated low positive growth rates at the beginning and then negative growth rates post 1995. But the most impressive collapse occurred in Anglo-Saxon market services post 1995. In contrast, Scandinavian market services once again managed to steadily increase their post–1990 labor services growth.

4.2 ICT-Skill Complementarities

A first impression of ICT-skill complementarities across different country regimes is provided by Figures 5a and b, which scatter growth in ICT capital deepening and labor quality by sectoral type. Figure 5a suggests a positive relationship between ICT capital deepening and a more educated workforce in goods-producing sectors for all three country clusters, whereas this relationship is most pronounced in Scandinavian countries. For Continental and Anglo-Saxon goods-producing sectors the scatter plots also display positive correlations, but indicate a much higher dispersion. Such a relationship is less clear in market services (Figure 5b). While Continental and Scandinavian market services exhibit strong dispersion in ICT capital deepening and labor quality growth, suggesting no significant correlation between the two factors, dispersion in Anglo-Saxon markets services is reduced. In particular, Anglo-

Saxon market services suggest such a weakly positive relationship between growth in ICT capital deepening and labor quality from some of the observations, but do not indicate general acceptance.

Taking stock on the statistical exploration of the relationship between ICT capital deepening and skills by sectoral type, the scatter plots indicate a more pronounced complementarity between these two factors in goods-producing sectors than in market services. Especially complementarities in Scandinavian goods-producing sectors become apparent, while for market services the picture is much more ambiguous. Investigating the origins of this difference asks for the nature of technological change. According to figures 6a and b, which show the development of the labor compensation shares by skill and sectoral types, the overall increasing shares of high-skilled compensation and thus their increasing marginal productivities suggest to be driven by SBTC. However, it is not yet clear whether technological progress as assumed to be embedded in ICT goods is actually responsible for this increase. As depicted by the previous scatter plots, this does not necessarily seem to be the case as the plots suggest a lower bias of ICT toward more skilled workers across countries' market services. Hence, increasing the intensity of ICT capital goods does not inevitably increase high-skilled workers marginal productivity the same way as in goods-producing sectors. More be it other types of technological progress that could have been responsible for the skill-upgrading in market services. Eventually, this difference makes clear that separating between the two sectoral types is necessary to avoid misspecifications in the production function estimates.

5. Econometric Estimations

5.1 LSDV Estimates

According to equation (17), I start the econometric estimation by implementing a least-square dummy-variable (LSDV) approach, in which the relation between labor productivity growth and its input factors is estimated for the Cobb-Douglas case. Thereby sectoral heterogeneity in labor productivity growth rates is explicitly accounted for (see Table 1).

The results for Continentals indicate that with respect to capital Non-ICT capital deepening has been the main driver of labor productivity growth over the period 1980–2005 (column I-CD and III-CD). Goods-producing sectors experienced higher estimates in Non-ICT elasticities compared to market services, indicating that substitution of capital for labor generated higher productivity gains in goods-producing sectors. Higher impacts from increased Non-ICT capital deepening in goods-producing sectors is validated for Anglo-Saxon as well (column I-CD and III-CD). However, in case of Scandinavians, Non-ICT capital deepening shows markedly lower elasticities in goods-producing sectors (column I-CD) and an even statistically insignificant effect for market services (column III-CD). In case of ICT capital deepening, neither goods-producing nor market services sectors exhibit statistically significant labor productivity growth effects in Continental and Scandinavians countries. On contrary, positive ICT effects are generated in both Anglo-Saxon goods-producing and market service sectors (column I-CD and III-CD), where both effects are of similar magnitude.

Growth in labor quality apparently had a strong impact on labor productivity growth across all tree country samples, whereas its impact was highest in market services throughout all country clusters (column III-CD, respectively). These positive effects suggest SBTC to increase productivity of more educated workers and, in turn, the aggregate productivity of the entire workforce employed in the sectors. As the elasticities are all estimated at a high statistical significance, the Cobb-Douglas specifications suggest SBTC to be one of the major productivity drivers in these selected industrialized countries.

Considering the Translog specification estimated via the LSDV approach, most of the capital deepening effects are qualitatively supported (Table 1). For Continentals the elasticity of Non-ICT capital deepening appears to be the main driver of productivity growth, whereas in particular the Non-ICT elasticity for market services increased compared to the Cobb-Douglas estimates (column IV-TL). The effect of growth in labor quality is only significant for goods-producing industries (column II-TL), while it turns insignificant for market services. These findings indicate that SBTC and quality growth in labor composition did not impact productivity growth of Continental market services comparably as in case of goods-producing sectors. Similar findings are provided for substitution elasticities of the production factors, which show insignificant effects in the LSDV approach for both sectoral types.

For the UK and the US the Translog specifications provide some interesting findings with regard to capital deepening. The previously determined marginal products of Non-ICT capital deepening in goods-producing sectors and market services qualitatively remain the same, but now the effect from ICT capital deepening is estimated as statistically insignificant in good-producing sectors (column II-TL). The effects of changes in labor quality still generate strong productivity growth in Anglo-Saxon countries independent of goods-producing or market services sectors (column II-TL and IV-TL). The estimates of substitution elasticities only show significant effects for market services and support typical economic assumptions about diminishing returns on capital and labor (column IV-TL). For all there production factors, i.e. ICT capital, Non-ICT capital and labor, increases generate diminishing returns.

In Scandinavian countries the Translog production functions supports the positive marginal product for Non-ICT capital deepening in the goods-producing sectors and also shows positive effects from Non-ICT in market services, although these effects are very low (column IV-TL). The positive effects from labor quality growth are again estimated with high statistical significance and constitute by far the highest marginal product of all three production factors. The most interesting findings are with respect to substitution elasticities, where increases in ICT capital deepening are associated to generate higher labor productivity growth only in combination of increases in labor quality. Thereby the highly statistically significant interaction effect constitutes strong complementarity between ICT and a more skilled workforce in Scandinavian goods-producing sectors.

5.2 First-Difference Estimates

Because of potential endogeneity issues stemming from interrelating incentives between productivity growth, ICT investment, and the demand for skilled workers, I rerun the regressions with GMM estimators (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998; Roodman, 2006). The employment of GMM mitigates the inadequacy of the LSDV approach to control for endogeneity issues beyond purging fixed effects from the regressions. Problems of endogeneity may originate from simultaneity, for example, which affects all input factors as they are chosen on the basis of economic incentives. Thus, all input factors are unlikely to be fully independent of shocks that affect the production function relations. Also, omitted variables that influence investment incentives, thereby allowing firms to differentiate themselves with respect to their competitors and enhance their profitability prospects, lead to increased investment outlays and dependent on firms' productivity. Latter may be of particular importance along business or product cycles or/and developments in the market size. Hence, assuming predetermination of input variables renders lagged values as valid instruments and helps to alleviate endogeneity problems, as well as the problem of reverse causality.[9]

Both GMM estimators, first-difference and system-GMM, are employed but eventually I will consider system-GMM superior over first-difference GMM because of its increased efficiency in short panels (Blundell and Bond, 1998). In general, the GMM estimators will be the preferred over LSDV because of the above mentioned features to mitigate endogeneity problems. Since each country-group panel is relatively small with a maximum of 728 observations, instrument proliferation may overfit endogenous variables. Coping with the problem

[9] Under the assumption that all input variables are predetermined, they enter the regressions in growth rates and I employ longer lags in input variables as instruments, i.e. t-3 and longer. Time dummies are assumed to be strictly exogenous and are implemented as instruments as well.

of employing too many instruments Roodman's (2008) way of "collapsing" the employed instrument matrix to reduce its dimension is employed.

Continuing the analysis of testing labor productivity growth effects from ICT-skill complementarities, the first-difference GMM estimates in the Cobb-Douglas specification mainly support the findings of the LSDV estimates, in particular for Non-ICT capital deepening and labor quality growth (Table 2). First-difference GMM shows the most dramatic changes in Cobb-Douglas estimates for Anglo-Saxon countries. While Non-ICT capital deepening and labor quality growth are mainly estimated with high statistical significance in both sectors (column I-CD and III-CD), the impact of ICT capital deepening becomes insignificant. Moreover, Non-ICT capital deepening also turns statistically insignificant in Anglo-Saxon market services (column III-CD), while labor quality growth remains significant in these sectors. For Scandinavians the productivity enhancing effect from Non-ICT capital deepening in goods-producing sectors also turns statistically insignificant (column I-CD), in addition to market services.

Turning to the Translog specifications the first-difference GMM estimates reveal some interesting new results, especially with regard to ICT capital deepening and its complementarity effects with other production factors (Table 2). In Continental countries the estimation results suggest that ICT capital deepening exhibits a negative marginal product and even more diminishing returns on this production factor in goods-producing industries (column II-TL). These findings conjecture that Continental goods-producing sectors had severe problems to exploit ICT-induced productivity gains during the pre-period of and during the New Economy. Instead, Non-ICT capital deepening constitutes a high positive elasticity and even shows increasing returns (column II-TL). Labor quality positively affects labor productivity growth and shows the expected diminishing returns (column II-TL). In case of Continental market services Non-ICT capital deepening exhibits strong positive contributions to labor productivity growth and interestingly shows complementarity to an increasingly educated labor force (column IV-TL). Hence, these findings conjecture that instead of an ICT-skill complementarity, there was an Non-ICT-skill complementarity that spurred Continental market services' productivity growth. In contrast, but in accordance with the strong impact of Non-ICT capital deepening, ICT and Non-ICT capital are estimated to be substitutes in Continental market services as their substitution elasticity is estimated with a negative sign (column IV-TL).

The Translog specification for Anglo-Saxon goods-producing sectors estimated via first-difference GMM resembles those estimates of the LSDV approach, but with an inter-change in the magnitude of the impact from Non-ICT and labor quality (column II-TL). Interestingly, for Anglo-Saxon market services the estimated elasticities for the three production factors are still statistically significant, but with a more pronounced effect on Non-ICT capital deepening (column IV-TL). Hence, ICT is confirmed to play an essential role in productivity growth of Anglo-Saxon market services. The Translog results for market services also support the diminishing returns on the three production factors, but provide new insight on the complementarity between ICT and skills (column IV-TL). In particular, the interaction term of both factors turns out to be statistically significant, suggesting a productivity enhancing effect from increasing ICT combined with a shift in labor composition toward a more educated workforce. Such a complementarity effect in Anglo-Saxon market services is not provided by the LSDV estimates of Table 1.

Scandinavian countries see a confirmation of their LSDV Translog results for goods-producing sectors via the first-different GMM approach (column II-TL). Although there are some minor changes in the magnitude of elasticities of Non-ICT capital deepening and labor quality growth, the complementarity effect for ICT and skills is still estimated as statistically significant. However, compared to the LSDV results, the impact of combined growth in labor quality and ICT capital deepening increases twice the size. These findings, once again, corroborate the capability of Scandinavian goods-producing industries of reaping enormous productivity gains from ICT investments' bias toward a more educated workforce. For Scandinavian market services the first-difference GMM estimates now suggest some weakly significant effect from ICT capital deepening, which was not detected in the LSDV results, and insignificant effect from Non-ICT capital deepening (column IV-TL). Moreover, the first-difference GMM results suggest diminishing returns for ICT and Non-ICT capital deepening, but increasing returns to growth in quality.

5.3 System-GMM Estimates

Since reduced efficiency of the first-difference GMM estimates negatively affects the statistically inference of the estimators, system GMM is employed as an alternative estimation approach (Table 3). Thereby, system-GMM estimates of Cobb-Douglas elasticities for Continental countries provide mainly differing results. While the LSDV and the first-difference GMM approach estimates Non-ICT-capital deepening highly statistically significant for both sectoral types, the system-GMM approach renders Non-ICT capital deepening statistically insignificant (column I-CD and III-CD). Nevertheless, labor quality growth is still estimated statistically significant with a high elasticity in both sectors (column I-CD and III-CD). The system-GMM results for Anglo-Saxon and Scandinavian countries confirm the Cobb-

Douglas estimates of the first-difference GMM approach (column I-CD and III-CD, respectively).

The Translog specifications estimated via system GMM exhibit robust results for Continental goods-producing sectors compared to those of the first-difference GMM (column II-TL), while the substitution effect between ICT and Non-ICT capital as well as the complementarity between Non-ICT capital and labor quality growth in market services are not supported (column IV-TL). Once again, the negative marginal product of ICT capital deepening and its diminishing returns are estimated statistically significant for Continental goods-producing sectors, thereby supporting the previously mentioned conjecture of severe structural problems in exploiting the ICT potential on a board industry basis (column II-TL).

In case of Anglo-Saxon market services, the Translog system-GMM estimates show qualitatively the same results as for first-difference GMM (column IV-TL). In particular, all three production factors show positive and statistically significant elasticities with diminishing returns, where Non-ICT capital deepening constitutes the highest elasticity, followed by labor quality growth and ICT capital deepening. Most importantly, besides a positively estimated ICT effect on sectoral labor productivity growth, Anglo-Saxon market services also exhibit a clear complementarity effect between ICT and skills, where the substitution elasticities for first-difference and system-GMM are estimated of similar magnitude. Moreover, the system-GMM estimates show some weak evidence of complementarity effects between ICT and Non-ICT capital in Anglo-Saxon goods-producing sectors, meaning that the marginal contribution of Non-ICT capital deepening to labor productivity growth is increasing, the higher the growth in ICT capital deepening (column II-TL). On contrary, growth in labor quality substitutes growth in Non-ICT capital deepening as the substitution elasticity for both factors shows a negative sign (column II-TL). Seemingly, labor productivity growth of Anglo-Saxon goods-producing industries originated from SBTC and Non-ICT capital deepening, where latter's productivity effect was positively related to increased ICT investments. Isolated ICT, as commonly accepted, does not show positive productivity effects for Anglo-Saxon countries, at least not for the broad category of goods-producing sectors and the here covered period from 1980 to 2005.

The previously estimated Translog elasticities and substitution elasticities in Scandinavian goods-producing sectors via first-difference GMM are supported by the system-GMM estimates (column II-TL). Again, the labor productivity enhancing effect from complementarity between ICT and skills is estimated statistically significant, despite a slightly lower magnitude as in case of the first-difference GMM estimates. The importance of Non-ICT capital deepening and labor quality growth in Scandinavian goods-producing sectors is now reversed with the highest impact stemming from labor quality growth, similarly to Anglo-Saxon countries (column II-TL). Decisive changes occur in the Translog estimates for Scandinavian market services, in which only Non-ICT capital deepening and labor quality growth remain statistically significant driver of labor productivity growth (column IV-TL). Thereby, the system-GMM results contradict the first-different GMM results and resemble the LSDV estimates. However, the important productivity contribution in Scandinavian market services from shifting labor composition toward a more educated workforce, but also in Scandinavian sectors in general, becomes apparent.

6. Summary and Conclusion

Recent growth accounting exercises attribute strong productivity growth to increased investments in information and communication technologies (ICT). Particularly, differing ICT intensities across countries are often drawn upon explaining differing productivity growth developments, especially with regard to the post–1995 productivity increase in the US and the widening of the US-EU productivity gap. This observation of a productivity gap can be extended to high productivity growth in Anglo-Saxon countries, which are characterized by high ICT intensities, compared to other European countries. Nevertheless, also within the EU member countries exhibit strong differences in ICT intensities and productivity growth, providing a biased picture of single member countries' long-run productivity performances.

As the findings of this study show, aggregate average labor productivity (ALP) growth was indeed different within EU member countries. Moreover, productivity differences not only occurred on the aggregate economy level, but also on sectoral level within economies. Scandinavian countries, for example, exhibit significant growth in labor productivity over the period 1980–2005 and even exceeded ALP growth of Anglo-Saxon countries most of the time, especially in the goods-producing sectors. However, Anglo-Saxon investments in ICT were highest among Continental and Scandinavian countries, as well as growth in labor services of both goods-producing and market services sectors during 1990–1995. However, growth in labor services in Scandinavian countries jumpstarted post–1990 and was strongest during the period 1995–2005.

Scatter-plot analysis provided a first indication that complementarity between ICT and skills is positive in goods-producing sectors for all countries groups, but most pronounced in Scandinavian countries. Such a relationship is less pronounced for market services, which seems to originate from a less significant bias of ICT toward a more skilled workforce in these sectors. However, increasing shares of labor compensation for skilled workers suggest that skill-biased technological change still serves as main driving force behind the increased productivity of more educated workers, although this does not necessarily coincide with the technology adoption of ICT.

Analyzing the effect of ICT-skill-biased technological change on labor productivity growth, in particular during the New Economy, provides robust and weakly robust econometric results. Although Michaels, Natraj, and Van Reenen (2010) show that ICT induced increasing demand for high-skilled workers in OECD countries over the last decades, and O'Mahony, Robinson, and Vecchi (2008) find similar supporting evidence on the demand for IT workers in the US, UK and France, these studies do not explicitly account for parameter heterogeneity in ICT-skill effects across sectors, neither do they examine the impact of these complementarity effects on sectoral productivity growth. Closing this gap, this study provides robust econometric results on ICT-skill complementarities for Scandinavian goods-producing sectors, which spurred those sectors labor productivity growth during the period 1980–2005. These labor productivity enhancing effects are robustly confirmed by LSDV and GMM estimation approaches. Weakly robust results on ICT-skill complementarities are provided for Anglo-Saxon countries, where complementarities between ICT and an educated workforce significantly affected labor productivity growth of market services for the GMM estimators. However, this effect is not supported by the LSDV estimates. Moreover, ICT capital deepening appears to be a robust driver of labor productivity growth in Anglo-Saxon market services as it is estimated statistically significant throughout all econometric specifications. ICT-skill complementarities are not detected either for Continental goods-producing sectors or market services throughout the econometric specifications. And as I am arguing here, the lack of such complementarity effects play an important role in the productivity growth demise of Continental countries.

Concluding results, the previous analysis shows that technological progress, which fueled Anglo-Saxon and Scandinavian aggregate productivity growth over the last decades, originated in different sectors and was of a directed nature. This means that growth in labor composition, which endogenously shifted toward a more educated workforce, was induced by technological progress as embedded in ICT capital. This interaction between new technologies and a more educated workforce enabled countries to foster economic growth over the last 25 years. What supported the emergence of these complementarities within sectors of one country compared to sectors of another, and why especially Continental countries are characterized by non-directed technological progress induced by ICT toward high-skilled labor is on the agenda of future research.

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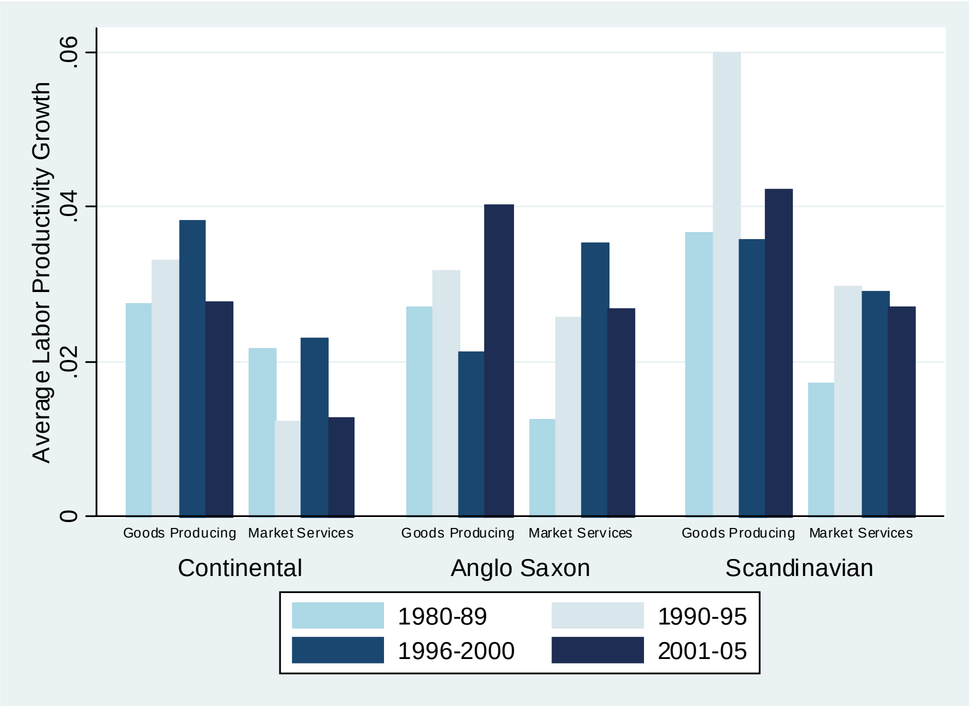
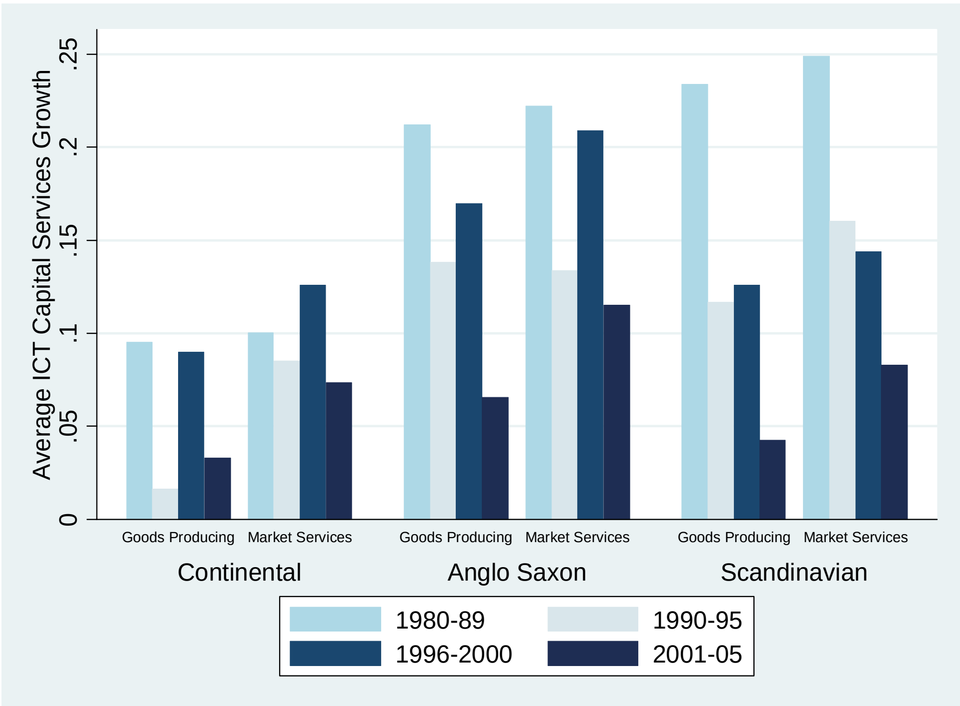
Figure 1: Average Labor Productivity Growth, by Sectoral Type, Country Comparison



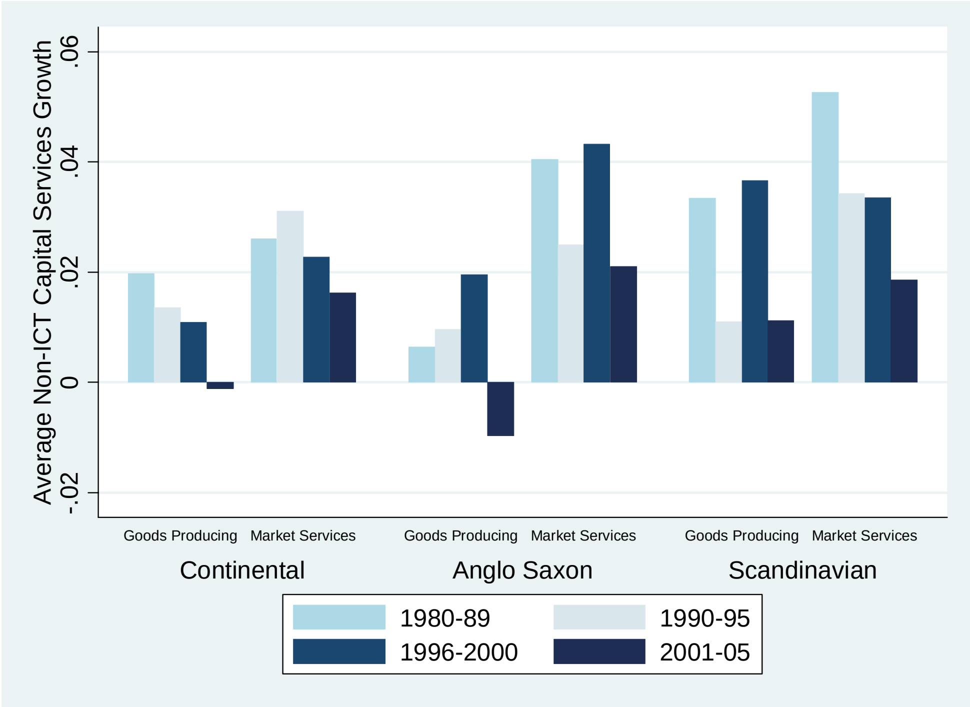
Notes: Average labor productivity growth is industry averages over the four sub-periods 1980–89, 1990–1995, 1996–2000, and 2001–2005. Outliers and Non-Market Services excluded. *Source:* EU KLEMS (2009).

Figure 2: Average ICT Capital Services, by Sectoral Type, Country Comparison



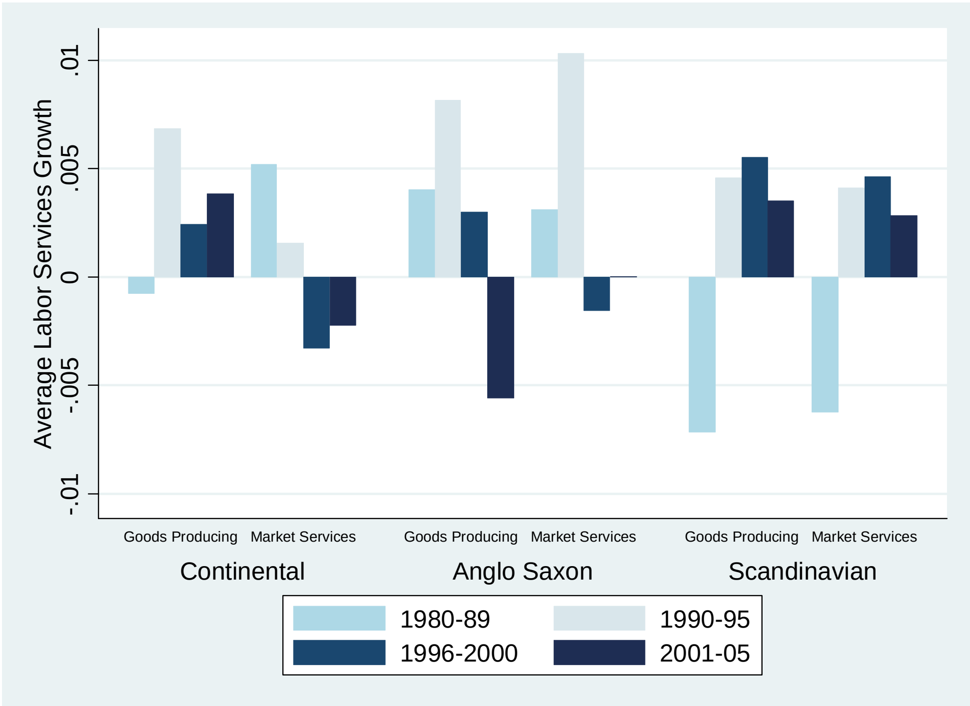
Notes: Average ICT capital services growth is industry averages over the four sub-periods 1980–89, 1990–1995, 1996–2000, and 2001–2005. Outliers and Non-Market Services excluded. *Source:* EU KLEMS (2009).

Figure 3: Average Non-ICT Capital Services, by Sectoral Type, Country Comparison



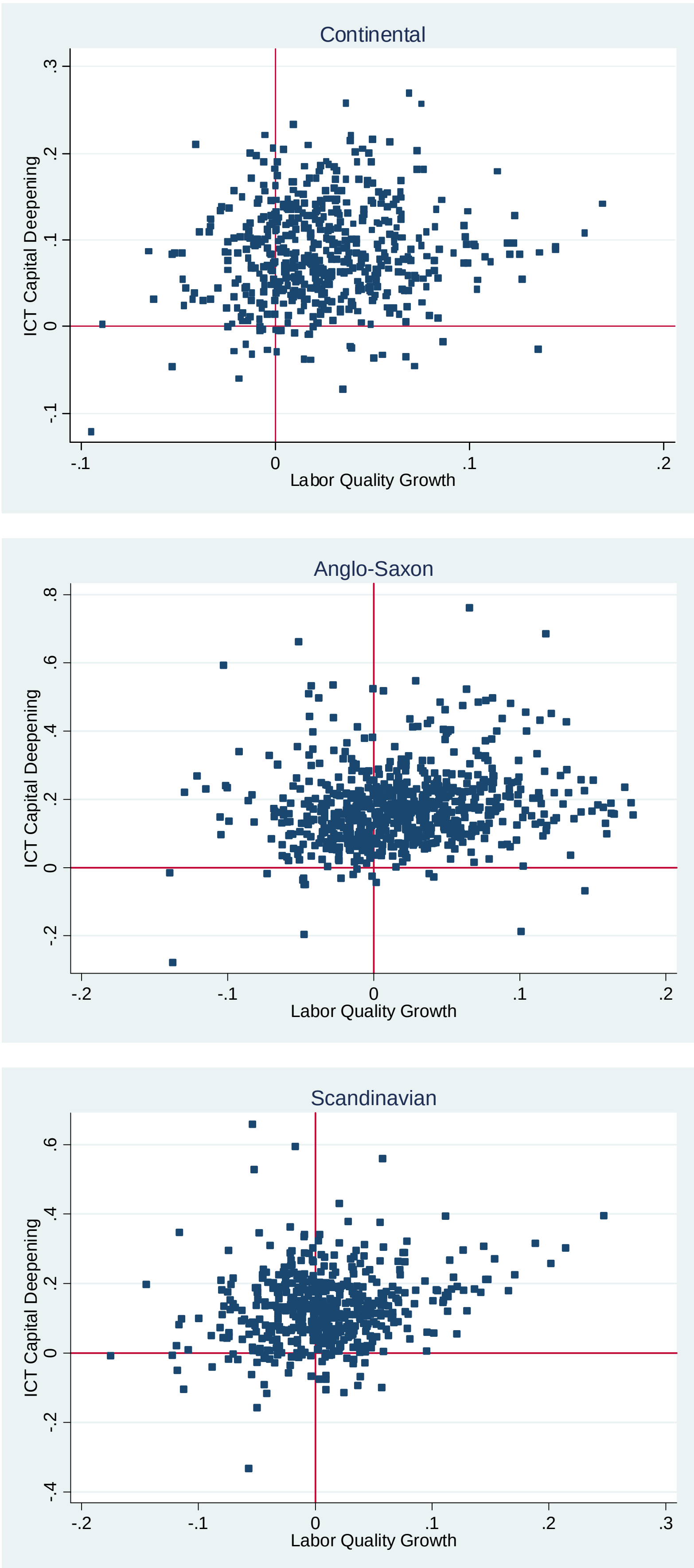
Notes: Average Non-ICT capital services growth is industry averages over the four sub-periods 1980–89, 1990–1995, 1996–2000, and 2001–2005. Outliers and Non-Market Services excluded. *Source:* EU KLEMS (2009).

Figure 4: Average Labor Services Growth, by Sectoral Type, Country Comparison



Notes: Average labor services growth is industry averages over the four sub-periods 1980–89, 1990–1995, 1996–2000, and 2001–2005. Outliers and Non-Market Services excluded. *Source:* EU KLEMS (2008).

Figure 5a: ICT Capital Deepening and Labor Quality Growth, Country Comparison in Goods-Producing Sectors

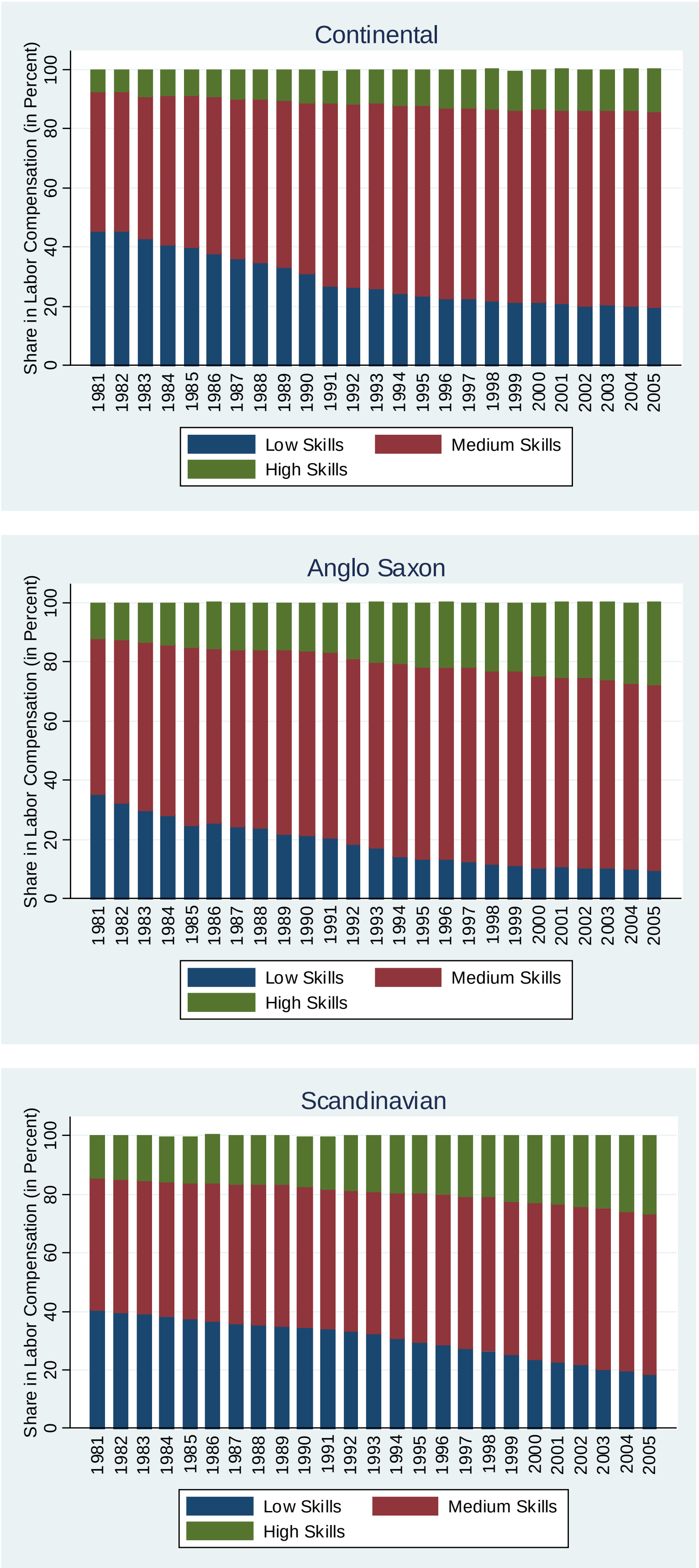


Note: Outliers excluded. *Source:* EU KLEMS (2008, 2009).

Figure 5b: ICT Capital Deepening and Labor Quality Growth, Country Comparison in Market Services

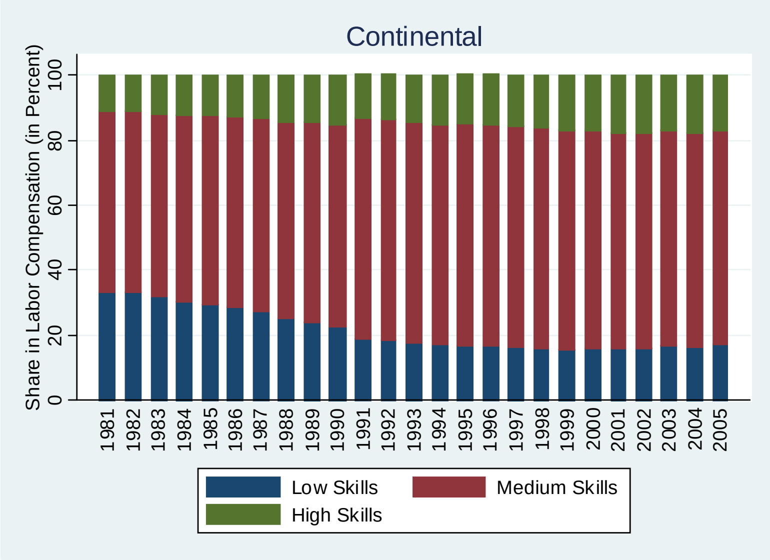
Note: Outliers excluded. *Source:* EU KLEMS (2008, 2009).

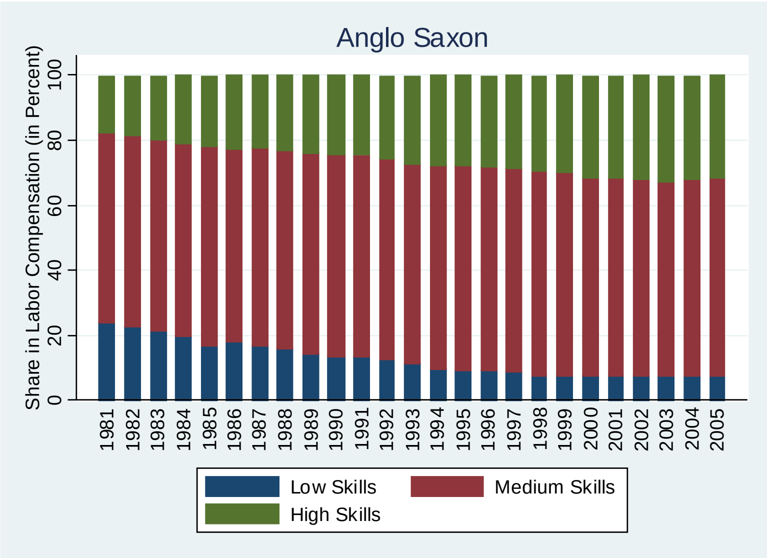
Figure 6a: Labor Compensation by Skill Type,
Country Comparison in Goods-Producing Sectors

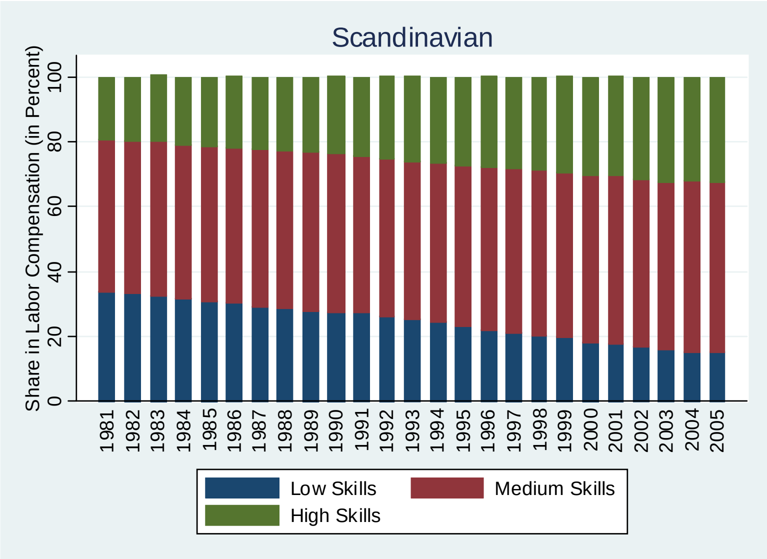


Note: Outliers excluded. *Source:* EU KLEMS (2008).

Figure 6b: Labor Compensation by Skill Type,
Country Comparison in Market Services







Note: Outliers excluded. *Source:* EU KLEMS (2008).

Table 1:
Labor Productivity Growth Regressions, LSDV, 1980–2005

	Continental				Anglo-Saxon				Scandinavian			
	Goods Producing		Market Services		Goods Producing		Market Services		Goods Producing		Market Services	
	I-CD	II-TL	III-CD	IV-TL	I-CD	II-TL	III-CD	IV-TL	I-CD	II-TL	III-CD	IV-TL
α_1	0.059	0.039	0.027	0.077	**0.052****	0.082	**0.071****	**0.144***	-0.006	-0.023	-0.005	0.020
	[0.069]	[0.105]	[0.048]	[0.090]	[0.025]	[0.068]	[0.033]	[0.077]	[0.008]	[0.037]	[0.010]	[0.035]
α_2	**0.595*****	**0.674*****	**0.367****	**0.648*****	**0.537*****	**0.617*****	**0.369*****	**0.488*****	**0.231****	**0.419*****	0.028	**0.085****
	[0.147]	[0.175]	[0.173]	[0.187]	[0.083]	[0.137]	[0.068]	[0.083]	[0.096]	[0.149]	[0.019]	[0.035]
β	**0.346****	**0.287****	**0.606*****	0.275	**0.411*****	**0.301*****	**0.560*****	**0.368*****	**0.775*****	**0.604*****	**0.977*****	**0.895*****
	[0.126]	[0.127]	[0.175]	[0.197]	[0.073]	[0.103]	[0.067]	[0.101]	[0.100]	[0.163]	[0.018]	[0.056]
δ_1	**-0.000****	**-0.002*****	0.000	0.001	0.000	**-0.004*****	0.000	**-0.003*****	0.000	**0.002****	0.000	0.001
	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.001]	[0.000]	[0.000]
γ_{11}		-4.064		-2.411		-2.658		**-2.323***		-6.430		-0.070
		[6.159]		[3.981]		[2.596]		[1.807]		[2.448]		[0.035]
γ_{12}		-0.674		-2.280		-0.344		-0.159		0.277		-0.112
		[2.521]		[1.766]		[0.593]		[0.482]		[0.343]		[0.377]
γ_{13}		4.738		4.691		3.002		2.483		**6.152****		0.183
		[4.306]		[2.824]		[2.196]		[1.470]		[2.300]		[0.374]
γ_{21}		0.464		0.001		-0.129		**-0.244***		0.005		-0.022
		[1.527]		[0.762]		[0.239]		[0.229]		[0.022]		[0.026]
γ_{22}		0.210		2.279		0.474		0.403		-0.282		0.134
		[1.647]		[1.610]		[0.505]		[0.455]		[0.349]		[0.392]
γ_3		-4.948		-6.970		-3.476		**-2.886***		-5.870		-0.317
		[3.145]		[2.492]		[1.905]		[1.235]		[2.204]		[0.766]
δ_{11}		**0.000*****		0.000		**0.000*****		**0.000*****		**-0.000****		0.000
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
Obs.	546	546	351	351	728	728	468	468	530	530	341	341
Adj-R^2	0.71	0.71	0.88	0.88	0.93	0.93	0.95	0.95	0.92	0.92	0.97	0.97

Notes: All variables are in exponential growth rates. Regressions control for industry, time, and country effects. Robust standard errors in brackets allow for intra-industry correlation. Continental = Germany and France, Anglo-Saxon = United Kingdom and United States, Scandinavian = Sweden and Finland. Outliers excluded. Significance levels: * significant at 10, ** significant at 5, *** significant at 1 percent. *Source:* EU KLEMS (2008, 2009).

Table 2:
Labor Productivity Growth Regressions, First-Difference GMM, 1980–2005

	Continental				Anglo-Saxon				Scandinavian			
	Goods Producing		Market Services		Goods Producing		Market Services		Goods Producing		Market Services	
	I-CD	II-TL	III-CD	IV-TL	I-CD	II-TL	III-CD	IV-TL	I-CD	II-TL	III-CD	IV-TL
α_1	-0.109	**-0.324***	0.067	-0.003	0.036	0.006	0.085	**0.130***	-0.018	0.006	0.056	**0.133***
	[0.184]	[0.160]	[0.093]	[0.095]	[0.074]	[0.068]	[0.075]	[0.073]	[0.053]	[0.036]	[0.056]	[0.076]
α_2	**0.564***	**0.958*****	**0.403***	**0.830*****	**0.507****	**0.374****	0.142	**0.603*****	0.251	**0.571****	-0.012	0.043
	[0.305]	[0.301]	[0.203]	[0.244]	[0.232]	[0.173]	[0.139]	[0.111]	[0.267]	[0.230]	[0.038]	[0.070]
β	**0.545****	**0.366***	**0.530*****	0.173	**0.457****	**0.620*****	**0.773*****	**0.268***	**0.767*****	**0.423***	**0.955*****	**0.824*****
	[0.251]	[0.185]	[0.173]	[0.253]	[0.203]	[0.141]	[0.140]	[0.143]	[0.246]	[0.233]	[0.059]	[0.119]
δ_1	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**
	---	---	---	---	---	---	---	---	---	---	---	---
γ_{11}		**-8.551***		3.273		-6.304		**-7.879***		-12.619		**-0.074***
		[12.065]		[7.190]		[3.614]		[3.882]		[5.830]		[0.065]
γ_{12}		-0.337		**-5.781****		1.527		-0.049		0.407		0.387
		[4.981]		[2.706]		[1.143]		[0.767]		[0.691]		[0.610]
γ_{13}		8.888		2.508		4.777		**7.928****		**12.212****		-0.313
		[7.860]		[5.321]		[3.096]		[3.448]		[5.499]		[0.616]
γ_{21}		**2.252***		1.570		0.225		**-0.135***		-0.080		**-0.242***
		[2.961]		[0.857]		[0.372]		[0.237]		[0.079]		[0.123]
γ_{22}		-1.915		**4.211***		-1.752		0.184		-0.327		-0.144
		[2.565]		[2.318]		[1.101]		[0.704]		[0.630]		[0.579]
γ_3		**-6.973***		-6.719		-3.025		**-8.111***		-11.885		**0.457***
		[5.858]		[4.550]		[2.761]		[3.192]		[5.251]		[1.192]
δ_{11}	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**	**---**
	---	---	---	---	---	---	---	---	---	---	---	---
Obs.	518	518	333	333	728	728	468	468	485	485	291	291
AR1	0.001	0.000	0.002	0.001	0.000	0.000	0.001	0.002	0.003	0.002	0.003	0.003
AR2	0.300	0.271	0.263	0.221	0.298	0.552	0.456	0.262	0.390	0.418	0.278	0.122
Hansen Test	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Notes: All variables are in exponential growth rates. Regressions control for industry, time, and country effects. Robust standard errors in brackets allow for intra-industry correlation. Predetermined variables are employed as instruments for lags t-3 and deeper, and are collapsed to reduce the number of potential instruments (Roodman, 2008). Time dummies are specified as exogenous instruments. All specifications employ lagged dependent variables according to the statistical inference of autocorrelation tests. Continental = Germany and France, Anglo-Saxon = United Kingdom and United States, Scandinavian = Sweden and Finland. Outliers excluded. Significance levels: * significant at 10, ** significant at 5, *** significant at 1 percent. *Source:* EU KLEMS (2008, 2009).

Table 3:
Labor Productivity Growth Regressions, System GMM, 1980–2005

	Continental				**Anglo-Saxon**				**Scandinavian**			
	Goods Producing		Market Services		Goods Producing		Market Services		Goods Producing		Market Services	
	I-CD	II-TL	III-CD	IV-TL	I-CD	II-TL	III-CD	IV-TL	I-CD	II-TL	III-CD	IV-TL
α_1	-0.074	**-0.345****	0.090	0.045	0.070	0.032	0.060	**0.125***	0.009	0.017	0.005	0.114
	[0.178]	[0.168]	[0.090]	[0.074]	[0.068]	[0.077]	[0.066]	[0.072]	[0.060]	[0.045]	[0.038]	[0.088]
α_2	0.380	**0.817****	0.223	**0.709*****	**0.459****	**0.342****	0.137	**0.564*****	0.357	**0.444***	0.005	**0.118****
	[0.274]	[0.306]	[0.166]	[0.223]	[0.209]	[0.157]	[0.144]	[0.121]	[0.318]	[0.221]	[0.035]	[0.042]
β	**0.693*****	**0.528*****	**0.687*****	0.246	**0.471****	**0.626*****	**0.802*****	**0.311***	**0.634***	**0.539****	**0.990*****	**0.768*****
	[0.230]	[0.189]	[0.131]	[0.232]	[0.176]	[0.121]	[0.148]	[0.152]	[0.311]	[0.207]	[0.047]	[0.087]
δ_1	---	---	---	---	---	---	---	---	---	---	---	---
	---	---	---	---	---	---	---	---	---	---	---	---
γ_{11}		**-9.570****		-2.547		-6.437		**-8.225***		-11.328		-0.162
		[11.372]		[7.829]		[3.152]		[3.574]		[5.170]		[0.041]
γ_{12}		-1.313		-2.912		**1.681***		0.266		0.541		0.428
		[4.936]		[1.878]		[0.968]		[0.724]		[0.722]		[0.545]
γ_{13}		10.883		5.459		4.756		**7.959****		**10.787****		-0.266
		[7.092]		[6.644]		[2.831]		[3.241]		[4.990]		[0.533]
γ_{21}		**3.431****		0.563		-0.002		**-0.203***		-0.084		-0.233
		[2.917]		[0.531]		[0.416]		[0.203]		[0.074]		[0.144]
γ_{22}		-2.117		2.349		**-1.679***		-0.063		-0.457		-0.195
		[2.673]		[1.844]		[0.923]		[0.712]		[0.664]		[0.530]
γ_3		**-8.766****		-7.808		-3.077		**-7.897***		-10.330		0.461
		[4.980]		[6.081]		[2.691]		[3.072]		[4.907]		[1.052]
δ_{11}	---	---	---	---	---	---	---	---	---	---	---	---
	---	---	---	---	---	---	---	---	---	---	---	---
Obs.	546	546	351	351	728	728	468	468	515	515	301	301
AR1	0.001	0.000	0.001	0.001	0.000	0.000	0.001	0.002	0.006	0.001	0.003	0.003
AR2	0.682	0.629	0.123	0.256	0.531	0.547	0.449	0.261	0.240	0.429	0.374	0.190
Hansen Test	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Notes: All variables are in exponential growth rates. Regressions control for industry, time, and country effects. Robust standard errors in brackets allow for intra-industry correlation. Predetermined variables are employed as instruments for lags t-3 and deeper, and are collapsed to reduce the number of potential instruments (Roodman, 2008). Time dummies are specified as exogenous instruments. All specifications employ lagged dependent variables according to the statistical inference of autocorrelation tests. Continental = Germany and France, Anglo-Saxon = United Kingdom and United States, Scandinavian = Sweden and Finland. Outliers excluded. Significance levels: * significant at 10, ** significant at 5, *** significant at 1 percent. *Source:* EU KLEMS (2008, 2009).

Appendix

Table A1:
ISIC Classification

			Industry Abbreviations	ISIC Classification Revision 3.0
Goods-Producing Sectors	1	Agriculture, Hunting and Forestry	Goods-Producing	A: 01 to 02, B: 05
	2	Mining and Quarrying	Goods-Producing	C: 10 to 14
	3	Food and Tobacco	Goods-Producing	D: 15 to 16
	4	Textiles, Apparel, and Leather	Goods-Producing	D: 17 to 19
	5	Wood Products	Goods-Producing	D: 20
	6	Paper, Pulp, Publishing, Printing	Goods-Producing	D: 21 to 22
	7	Coke, Petroleum, Nuclear Fuels	Goods-Producing	D: 23
	8	Chemicals	Goods-Producing	D: 24
	9	Rubber and Plastics	Goods-Producing	D: 25
	10	Other Non-metallic Mineral Products	Goods-Producing	D: 26
	11	Basic and Fabricated Metals	Goods-Producing	D: 27 to 28
	12	Machinery	Goods-Producing	D: 29
	13	Office Machinery and Electronic Equipment	Goods-Producing	D: 30 to 33
	14	Motor Vehicles and Other Transport	Goods-Producing	D: 34 to 35
	15	Manufacturing n.e.c.[a)]	Goods-Producing	D: 36 to 37
	16	Electricity, Gas, and Water Supply	Goods-Producing	E: 40 to 41
	17	Construction	Goods-Producing	F: 45
Market Services	18	Sale and Repair of Motor Vehicles	Market Services	G: 50
	19	Wholesale Trade	Market Services	G: 51
	20	Retail Trade	Market Services	G: 52
	21	Hotels & Restaurants	Market Services	H: 55
	22	Transportation	Market Services	I: 60 to 63
	23	Communications	Market Services	I: 64
	24	Financial Intermediation and Insurance	Market Services	J: 65 to 67
	25	Real Estates	Market Services	K: 70
Non-Market Services	26	Business Services [b)]	Market Services	K: 71 to 74
	27	Public Administration and Social Security	Non-Market Services	L: 75
	28	Education	Non-Market Services	M: 80
	29	Health and Social Work	Non-Market Services	N: 85
	30	Other Community and Social Services [c)]	Non-Market Services	O: 90 to 93

Notes: a) consists of furniture; recycling; manufacturing, n.e.c.; b) consists of rental and leasing services; computer and related activities; research and development; other business services; c) consists of sewage and refuse disposal; organizations, n.e.c.; recreational, cultural, sports activities; other services. Because of measurement issues in output of non-market services, those sectors are excluded from the sample.

Table A2:
Skill Definition by Country

	High Skills	Medium Skills	Low Skills
Continental			
Germany	University graduates	Intermediate	No formal qualifications
France	University graduates	Higher education below degree, low intermediate, and vocational education	No formal qualifications
Anglo Saxon			
United Kingdom	University degree	HND, HNC, BTEC, teaching qualification, nursing qualification, A level or equivalent, trade apprenticeship, O level or equivalent, BTEC, BEC, TEC GENERAL, city and guilds	No qualifications
United States	College graduate and above	High school and some years of college (but not completed)	Less then high school and some years of high school (but not completed)
Scandinavian			
Sweden	Post- and undergraduates	Higher and intermediate vocational	Intermediate education and no formal qualifications
Finland	Tertiary schooling (or parts there of)	Upper secondary level with or without matriculation	Lower secondary or unknown

Sources: EUKLEMS (2008) and Timmer et al. (2007a, b).

Table A3:
Coverage of Variables by Time and Country

Variables	**Time Period**
Continental	
Germany	
Value-added	1980–2005
ICT capital services	1980–2005
Non-ICT capital services	1980–2005
Labor services	1991–2005
Hours	1980–2005
France	
Value-added	1980–2005
ICT capital services	1980–2005
Non-ICT capital services	1980–2005
Labor services	1980–2005
Hours	1980–2005
Anglo Saxon	
United Kingdom	
Value-added	1980–2005
ICT capital services	1980–2005
Non-ICT capital services	1980–2005
Labor services	1980–2005
Hours	1980–2005
United States	
Value-added	1980–2005
ICT capital services	1980–2005
Non-ICT capital services	1980–2005
Labor services	1980–2005
Hours	1980–2005
Scandinavian	
Sweden	
Value-added	1980–2005
ICT capital services	1993–2005
Non-ICT capital services	1993–2005
Labor services	1980–2005
Hours	1981–2005
Finland	
Value-added	1980–2005
ICT capital services	1980–2005
Non-ICT capital services	1980–2005
Labor services	1980–2005
Hours	1980–2005

Source: EUKLEMS (2008, 2009).