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ICT and Productivity Growth in the 1990's: Panel Data Evidence on Europe

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ICT and Productivity Growth in the 1990's: Panel Data Evidence on Europe*

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Abstract

What has been the quantitative effect on productivity growth of information and communication technology (ICT) in Europe after 1995? Based on a multi-country sectoral panel data set, we provide econometric evidence of positive and significant productivity effects of ICT in Europe, mainly due to advances in total factor productivity. The impact of ICT in Europe has happened against a negative macro economic shock not related to ICT. This is in contrast to the established evidence for the US. Our main results challenge the consensus in the growth-accounting literature that

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there has been no acceleration of productivity growth in Europe, mainly due to a dismal performance of ICT-using sectors.

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JEL Classification codes: E32, C23, O47

1 Introduction

Since the mid-1990s, a puzzle has appeared in the development of productivity at the macroeconomic level across countries: The US economy experienced an increase in productivity growth that has not been reflected in the productivity developments of European countries. As a result, relative productivity levels between the two regions have diverged. This contrasts a prolonged period before the mid-1990s in which European countries experienced a catch-up with US productivity levels. In fact, the average rate of productivity growth in European countries even fell after 1995. Van Ark, O'Mahony, and Timmer (2008) found that whereas the US labor productivity growth rate *increased* from 1.5 per-cent before 1995 to 3 per cent after 1995, the productivity growth rate in Europe *declined* from 2.4 per cent to 1.5 percent.

Information and communication technology (ICT) is often argued to be the key determinant of the US productivity performance, see for example Jorgenson, Ho, and Stiroh (2005, 2008). Stiroh (2002) found that sectors using ICT intensively account for the majority of the increase in productivity growth of the US economy. In other words, US industries have been successful in transforming the new technology into higher productivity. The question is whether the disappointing European growth performance can be attributed to ineffective use of ICT.

Based on a growth-accounting framework, O'Mahony and Van Ark (2003) argued that this may indeed be the case. They found that although European ICT-*producing* sectors experienced a productivity acceleration similar to that of US ICT-producers, European ICT-*using* sectors failed to achieve a similar development. However, the fact that ICT-using industries in Europe showed stagnant productivity growth does not in itself preclude a positive differential impact of ICT. It may be the case that ICT-intensive sectors perform better relative to non-ICT-intensive sectors in Europe, even though their average productivity growth rate declined. In order to identify the impact of ICT use, this development will have to be compared to the aggregate scenario of declining productivity growth in Europe during the 1990s.

Our main hypothesis is based on these observations. We test if ICT had a positive *differential* impact on productivity growth in the sense that ICT–intensive industries had significantly higher productivity growth rates than non-ICT-intensive industries after 1995. To properly address this question it is crucial to distinguish aggregate macro effects from sectoral effects generated by differences in the use of ICT. Therefore, we apply econometric methods that control separately for macro effects, sector-specific fixed effects, and the effects from ICT-use.

We provide new econometric evidence on the relationship between ICT and productivity growth in Europe. We find that ICT-intensive industries went through a far less dramatic reduction in productivity growth after 1995 than industries which did not use ICT intensively in production. In effect, the overall slow-down in productivity growth that happened in Europe after 1995 would have been even more dramatic in the absence of the positive impact in ICT-intensive industries. This result is contrary to the general consensus reached in the growth-accounting literature as recently summarized by Draca, Sadun, and Van Reenen (2006): "There has been no acceleration of productivity growth in the EU, mainly due to the performance of the ICT-using sectors."[1] The econometric findings of this paper confirm the first part of this statement, however, significant positive effects of ICT on productivity growth are established, including a positive effect on productivity growth among ICT-using industries.

The study is based on industry data from the EUKLEMS database, which comprises a large set of internationally comparable data on productivity developments at a highly disaggregated sectoral level. The database also contains detailed data on capital investments, including ICT related capital expenditures. We exploit the panel structure of the country and industry data to control for unobserved industry-specific and country-specific fixed effects as well as time effects. This allows us to identify the productivity effects of ICT *within* industries and, therefore, separately from productivity effects generated by changes in the business structure.

[1]This consensus has also found its way to the Economist in the feature "Europe: Use IT or lose it" of May 17, 2007, a feature based on van Ark et al (2007).

The empirical findings of this paper document that the decline in labor productivity growth after 1995 is a general phenomenon across European industries, however, sectoral productivity growth rates decreased the most in non-ICT-intensive industries. More specifically, the average decline in sectoral growth rates was around 1 percentage point for labor productivity growth after 1995. This was partly countervailed by a positive effect of around 0.8 percentage points in industries that were ICT-intensive pre-1995. Our results weaken when ICT-producers are excluded although an economically significant differential effect of 0.5 percentage points remains for ICT-users versus remaining sectors.

The analysis is extended to total factor productivity (TFP) growth. The extension facilitates a distinction between genuine effects of technological progress due to ICT and capital-deepening effects of increasing the amounts of ICT capital used in sectoral production. The results show that the average TFP growth rate fell by around 0.6 percentage points after 1995 in European ICT non-intensive sectors. In ICT-intensive industries, there was a countervailing positive growth effect of 0.6 percentage points. Hence, we find evidence that a higher ICT-intensity has contributed positively to TFP growth in Europe, including an economically sizable and statistically significant TFP gain in ICT-using industries. In effect, the result does not depend critically on the inclusion of ICT-producing industries. Moreover, a comparison of TFP and labor productivity impacts of ICT shows that the impact of ICT in Europe is predominantly due to gains in TFP rather than capital-deepening.

The paper is laid out as follows. Section 2 is a brief review of the literature on ICT and productivity growth. Section 3 documents the basic descriptive facts about the aggregate growth scenario, the development of certain sectors, and the timing of a break in productivity in Europe during the 1990's. Section 4 describes the EUKLEMS data on which our analysis is based while section 5 summarizes our econometric approach. Our main empirical results are reported in Section 6, whereas a robustness analysis is presented in Section 7. Section 8 concludes.

2 Related Literature

The literature on the possible impact of ICT on productivity growth took off from the so-called Solow paradox, the observation by Solow (1987) that although enormous technological progress in ICT production had been realized and gone along with strong investments in ICT, hardly any effect on economic growth could be observed. Subsequent studies on ICT and productivity growth in the macro literature have mostly been performed for the United States using the growth-accounting framework. For an introduction to the growth-accounting methodology, see Jorgenson *et al.* (1987). The studies find that productivity growth has accelerated after 1995 and a consensus has been established that this acceleration is linked to ICT.[2] This was stated by Dale Jorgenson in his presidential address to the American Economic Association meeting, see Jorgenson (2001):

> "The resurgence of the American economy since 1995 has outrun all but the most optimistic expectations. Economic forecasting models have been seriously off track and growth projections have been revised to reflect a more sanguine outlook only recently......Productivity growth in IT-producing industries has gradually risen in importance and a productivity revival is now under way in the rest of the economy. Despite differences in methodology and data sources, a consensus is building that the remarkable behavior of IT prices provides the key to the surge in economic growth."

An implication of these findings is that the Solow Paradox no longer applies. The paradox was simply a consequence of ICT constituting a small part of the capital stock.

The growth-accounting method decomposes labor productivity growth into growth in labor input, growth contributions by capital-deepening, and growth in TFP. In order to assess the magnitude of the direct effects of ICT on growth, two additional steps are taken. First, to measure the contribution from the use of ICT capital, the growth in capital input is decomposed into two elements, one related to ICT capital and one related to other capital goods. Second, to single out the contribution from technological progress in the production of ICT capital, the private sector is decomposed into ICT-producing industries and ICT-using industries. The technological progress in the production of ICT is then measured by the TFP growth in the former industries. Using this method, Oliner and Sichel (2000) found that the growth rate in labor productivity increased by 1.04 percentage points from 1991-95 to 1996-99 for the US. Of this increase, 43 per cent can be attributed to the accumulation of ICT capital in all industries, whereas 36 per cent can be attributed to TFP growth in ICT-producing sectors. The method also provides a

[2] See for example, Oliner and Sichel (2000), Jorgenson, Ho, and Stiroh (2008), and Whelan (2002).

measure of TFP growth, however, this measure cannot be linked directly to ICT, though it may reflect that ICT-using sectors have higher productivity partly as a result of higher ICT use.

Using industry data, Stiroh (2002) produced econometric evidence that there was significant productivity growth in the ICT-using sectors, even after controlling for macro economic shocks. The analysis was performed for US industries for the periods 1987-95 and 1995-2000.[3] The main findings were that the acceleration in productivity is a broad phenomenon across US industries — not only in ICT-producing sectors — but that growth rates increased the most in ICT-intensive industries. More specifically, ICT-intensive industries experienced a productivity acceleration about 2 percentage points greater than other industries after 1995. The results are developed for labor productivity growth, implying that it is unclear whether effects from ICT is generated through capital-deepening or TFP.[4]

Some growth-accounting studies have also appeared for European economies. Contrary to the United States, European productivity growth did not accelerate after 1995; instead aggregate labor productivity growth declined. In other words, the productivity gap between Europe and the United States widened, see van Ark et al (2008).

O'Mahony and van Ark (2003) performed a comparative study between the United States and a small number of European countries (EU-4). In the analysis the authors found that European ICT-producing sectors had similar productivity acceleration as in the United States. Moreover, the authors found that productivity growth in the EU is relatively stable across time in intensively ICT-using sectors, in contrast to a very large acceleration in the US. According to the authors, this is a clear indication that the US is ahead of Europe in terms of productive application of ICT outside the ICT-producing sector itself. Also based on the growth-accounting framework, Timmer and Van Ark (2005) found that the difference in ICT-capital-deepening and from the contribution from TFP growth in ICT-goods production explain the major gap in growth rates between Europe

[3] O'Mahony and Vecchi (2005) performed an econometric comparison of the United Kingdom and the US. Estimates suggest a strong impact in the United States, whereas the results are less conclusive for the United Kingdom.

[4] Jorgenson *et al.* (2008) argued that US productivity growth after 1995 and up to 2000 was driven by productivity growth in ICT producing sectors and ICT-capital-deepening effects. After 2000 productivity growth is driven by TFP growth in ICT-using industries.

and the United States after 1995. These conclusions are followed up in van Ark et al (2008) who conclude that "the European productivity slowdown is attributable to the slower emergence of the knowledge economy in Europe compared to the United States".[5]

3 European Productivity Development in the 1990s

Europe enjoyed a much less favorable productivity trend than the US after 1995. Table 1 details the labor productivity developments in eight European countries using the US for comparison. The table contains the unweighted average of labor productivity growth rates over industries for the pre- and post-1995 periods for the nonfarm business sector, and the nonfarm business sector excluding ICT producers or financial intermediation (FIRE) industries, respectively. The included European economies are Austria, Denmark, Finland, France, Germany, Italy, the Netherlands, and the United Kingdom.

[Table 1 about here]

It is evident that the average industry growth rates for the nonfarm business sector either decreased or increased only slightly in Europe post-1995 with the exception of Austria that experienced an increase in the growth rate of 0.7 percentage points. When excluding ICT production it is found that the average growth rates fell in all European economies except in Austria that experienced an increase of around half a percentage point. In contrast to the European economies, the average industry growth rate in the United States more than doubled post-1995.

When studying growth rates across subperiods, it is of course important to determine the break-year. In the growth-accounting literature the applied break-year is 1995, see for example Jorgenson *et al.* (2008). A break in productivity trends during 1995 is supported econometrically by Hansen (2001) and Stiroh (2002) who analyzed quarterly data for the US business sector over the period from 1974 to 2001. This tradition has been passed on as the standard point of reference used in analyzing the aggregate European experience, e.g.,

[5] Van Ark *et al.* (2008) evaluated the effect of structural changes on productivity growth. They find that reallocation of labor between industries has contributed negatively to labor productivity growth after 1995 in Europe. This can, however, not explain the low European growth rates, since the negative reallocation effect is numerically larger for the United States.

in van Ark *et al.* (2008). Although the dividing line of 1995 has been accepted for Europe as well, this tradition is not based on any statistical tests; to the best of our knowledge, no such statistical test of break-year for European productivity exists. Empirically, the date of any break is less easily determined for individual European countries than for the US because the available data are annual. By having a set of comparable panel data, we can pool the data across countries. The cost that we have to cover when pooling is an assumption that the break happens simultaneously across all countries. The test presented in Figure 1 is the Sup F test of Andrews (1993) applied to a pooled data set containing the nonfarm business sector industries across eight European countries.[6]

[Figure 1 about here]

Details on the applied model is presented in Section 5 below. The average for all eight countries of Sup F tests is calculated for each potential break-year (the dashed curve). We also calculate the test excluding data for Austria (the solid line). This country turns out to be non-poolable with the remaining countries, see Section 5 below.

Figure 1 shows that any trend break in productivity should be found during the second half of the 1990's. The test is not quite conclusive as to the exact timing of the break. When including all countries, the maximum test statistic is achieved in 1998. Also 1995 and 1999 are candidate break-years. When excluding Austria from the test, 1995 emerges as the main candidate for the break-year. In any case, there is little evidence of a break-year prior to 1995.

Overall, by pooling the evidence across countries, we find that the econometric evidence on the timing of the break is consistent with the ICT-induced break in the US during 1995 that was established by Stiroh (2002). In conclusion, we will follow existing literature in allowing for a break in productivity in 1995. We present further evidence on the robustness of our results as to the timing of the break in Section 6.

[6] We do not report any critical values since a panel data version of the Sup F test has not been worked out yet.

4 Data and Variables

The applied data source is the EUKLEMS Growth and Productivity Accounts.[7] This database include data on gross output, value added, ICT capital, other capital, hours worked, employment, and intermediate inputs at the industry level, implying that analyses of the relationship between productivity growth and ICT can be carried out for both labor productivity and TFP. The database comprises data for the period 1970 to 2004. In the following we discuss key aspects of the data set relevant for the empirical analysis.

4.1 Productivity Growth

We apply two measures of productivity growth. The first is labor productivity growth that is simply defined as the yearly log growth rate of output divided by labor input. The second measure is TFP growth, the yearly log growth rate of output corrected for a composite of primary factor inputs and intermediate inputs. We use two versions of this measure of productivity growth; our main TFP measure is derived from the estimation of production functions, whereas the alternative version is based on the growth-accounting framework in which the composite of inputs combines the growth rates of inputs weighted by shares of total costs.

The applied measure of output is sectoral gross output. This measure is superior to sectoral value added because an output measure based on a real value-added function is justified only when the production function of gross output is separable in real value-added and intermediate inputs. Jorgenson *et al.* (1987) found that separability is rejected.

We follow the standard in the literature and measure labor productivity as output in relation to the total hours worked. For TFP we measure inputs as labor service, capital service, and intermediate input that origins from supply and use tables. Labor service is a quality adjusted measure of labor input in the sense that labor types with high relative wages receive a higher weight than labor types with low relative wages. Similarly, capital service is a weighted measure with growth rates of capital input of different asset types being weighted by relative compensations, i.e., the relative user costs.

[7] See www.euklems.net or van Ark *et al.* (2008).

4.2 ICT-intensity

The base measure of ICT-intensity is a dummy variable. First, we construct a measure of ICT-intensity that is defined as ICT-capital service out of total capital service. If this measure of ICT-intensity for a particular industry exceeds the median value over industries in a country, the dummy equals 1, whereas it equals 0 otherwise. Using a binary classification based on the median provides robustness to outlying measurements. In a robustness analysis, the empirical results are checked by using the continuous version of the base measure. The regression analyses are also performed using two alternative measures of ICT-intensity, ICT-capital service per worked hour and ICT-capital service in relation to gross output. All of the applied measures follow Stiroh (2002).

4.3 Countries and Industry Coverage

The relevant variables are provided for 31 industries in the EUKLEMS database. We exclude three primary industries: agriculture; hunting, forestry and fishing; and mining and quarrying. Moreover, we exclude four industries within non-market services. This leaves 24 industries within the nonfarm business sector on which the analysis is based. The industries are listed in Table 2.

[Table 2 about here]

Throughout the analysis we distinguish between ICT-*producing* and ICT-*using* industries. Stiroh (2002) found that although productivity growth in the US increased significantly in all ICT intensive industries, the effects were stronger among ICT producers. In order to investigate whether ICT-producing industries are driving the results, we also present results that exclude those industries. We follow van Ark et al. (2007) and define ICT producers as the ICT-producing manufacturing sectors in electrical and optical equipment (30t33) and the ICT-producing service sector in post and telecommunication (64). The aggregate 30t33 consists of 31 (electrical machinery and apparatus), 32 (radio, television and communication equipment), and 33 (medical, precision and optical instruments).

Following Stiroh (2002) we also want to investigate if the so-called FIRE industries are the main drivers of the results. The FIRE industries (denoted J in Table 2) consist of three industries: financial intermediation, except insurance and pension funding; insurance and pension funding, except compulsory social security; and activities related to financial intermediation. We provide additional results that exclude these industries.

We use data for the following 8 European countries: Austria (AUT), Denmark (DNK), Finland (FIN), France (FRA), Germany (GER), Italy (ITA), the Netherlands (NLD), and United Kingdom (UK). [8]

5 Econometric Approach

In this section, the econometric models that we apply are presented. We start with a discussion of the model for labor productivity growth that builds on Stiroh (2002). Next, we turn to the econometric models used for estimating the effects on TFP growth from ICT. This extension facilitates a distinction between genuine effects of technological progress due to ICT and capital-deepening effects of increasing the amounts of ICT capital used in sectoral production.

5.1 Labor Productivity Growth

The applied econometric model is a modified version of the difference-in-difference model used in Stiroh (2002). The regression model is specified in terms of the growth rate of labor productivity, $\Delta \ln A_{ijt} = \Delta \ln (Y_{ijt}/E_{ijt})$ measured in percentage terms, where Y_{ijt} denotes real gross output of industry i in country j in year t and likewise for the number of hours worked, E_{ijt}.

$$\Delta \ln A_{ijt} = a_{ij} + \alpha_0 \Delta \ln A_{ijt-1} + \alpha_1 d_t + \alpha_2 it_{ij95} + \alpha_3 d_t \times it_{ij95} + \varepsilon_{ijt} \qquad (1)$$

where ε_{ijt} is an error term. The specification in (1) extends Stiroh's (2002) approach by including lagged productivity growth, $\Delta \ln A_{ijt-1}$, on the right hand side of the equation. In the results section, we present ample evidence of the general significance of coefficient α_0. For consistent estimation of the dynamic panel data model, we employ the generalized methods of moments approach (GMM) of Arellano and Bond (1991).

[8] Belgium and Spain have been excluded from the analysis because the break-down of ICT-data is not detailed enough.

The dummy variable d_t equals 1 for 1995 and later years, whereas it attains the value 0 for years prior to 1995. Consequently, the dummy variable captures a potential trend-break in average productivity in 1995. The variable it_{ij95} denotes the ICT-intensity in the break-year 1995 in industry j of country i.

The parameters of main interest in this study are α_1 and α_3. The values of these parameters contain information on common macro effects and the sectoral effects generated by differences in ICT-intensities, respectively. A positive (negative) value of α_1 implies that the aggregate productivity trend increases (falls) from 1995 and onwards, whereas a positive (negative) value of α_3 indicates a partial increase (decrease) in productivity growth in ICT-intensive industries from 1995 and onwards. In other words, α_3 is the difference-in-difference coefficient that measures the additional growth difference between ICT-intensive and non-ICT-intensive industries after 1995.

The parameter α_2 measures the growth difference between ICT-intensive and non-ICT-intensive industries before 1995. If the parameter attains a positive (negative) value this means that ICT-intensive industries on average experience higher (lower) growth rates than other industries.

We approach the estimation of (1) at several different levels of generality, exploiting the availability of a consistent panel data set across a number of European countries. First, as a starting point to check the poolability of the data across countries, we consider country-by-country analyses that allow the $\alpha-$coefficients to vary by country. Second, when pooling the data across countries and obtaining a common set of estimated $\alpha-$parameters, we allow for different specifications of the fixed effects. Four cases are distinguished in terms of the intercept a_{ij}: A fully pooled case of a common intercept ($a_{ij} = \delta$); a case of country-specific intercepts ($a_{ij} = \delta_j$) that do not vary across industries; a case of industry-specific intercepts ($a_{ij} = \delta_i$) that do not vary across countries; and finally, a general set of fixed effects that may vary both across countries and industries ($a_{ij} = \delta_{ij}$).

5.2 TFP Growth

In a second set of regressions, we extend the approach applied by Stiroh (2002) to estimate the impact of ICT on TFP. To do this, we specify a difference-in-difference regression in terms of the growth rate of real output:

$$\begin{aligned}\Delta \ln Y_{ijt} &= b_{ij} + \beta_0 \Delta \ln Y_{ijt-1} + \beta_1 d_t + \beta_2 it_{ij95} + \beta_3 d_t \times it_{ij95} \\ &\quad + \beta_4 \Delta \ln X_{ijt} + \beta_5 \Delta \ln L_{ijt} + \beta_6 \Delta \ln K_{ijt} + u_{ijt},\end{aligned} \tag{2}$$

where u_{ijt} is an error term. We have added additional variables to control for the growth rates of intermediate inputs ($\Delta \ln X_{ijt}$), labor service ($\Delta \ln L_{ijt}$), and capital service ($\Delta \ln K_{ijt}$).

For a first-differenced specification such as (2), it is commonly found that the estimates of the input coefficients, β_4, β_5, and β_6, are fairly small. This, in turn, implies a low estimate of the returns to scale parameter, $\beta_4 + \beta_5 + \beta_6$. However, there are well-known econometric issues concerning the estimation of the parameters of sectoral production functions. They include the identification of long-run versus short-run adjustments and potential biases due to the simultaneous determination of inputs and output as well as general forms of measurement error (Griliches and Mairesse, 1998).

In treating the long-run versus short-run issue and examining US and UK sectoral data, O'Mahony and Vecchi (2005) considered a value added-based model. They estimated significantly higher input coefficients for a long-run levels specification than for their first-differenced specification. Moreover, they found that the sum of the long-run input coefficients did not differ significantly from a case of long-run constant returns to scale. While identifying the long-run returns to scale parameter is an important issue in itself, it is not a central focus of our study. In order to keep the direct comparison with the US experience as analyzed by Stiroh (2002), we limit our investigation to the short-run coefficients identified by (2).

The potential biases that arise due to simultaneity or measurement error can be treated by instrumenting the inputs. Obtaining valid external instruments for the estimation of production functions is generally a non-trivial exercise (Diewert and Fox, 2008). Inklaar (2007) recently proposed the use of a variable that captures downstream demand in each industry to instrument a composite of inputs, finding evidence of constant or increasing returns to scale. He considered a regression of the form: $\Delta \ln Y = \alpha + \gamma \Delta \ln W + \varepsilon$ where W is the inputs composite and γ is the returns to scale parameter. The use of a single composite of inputs reduces the dimensionality of the problem of finding suitable instrumental variables to eliminate potential biases. In our case, we would need to identify at least three different instrumental variables for the input variables in (2). While noting that our short-run input coefficient estimates could potentially be downward biased, we argue that there is little reason to expect the bias to be different across the potential break-year 1995 or to be related to the ICT intensity of any particular industry. We will therefore not pursue the identification of external instruments further in this paper.

As a check on the viability of our approach, we also apply an alternative approach to the analysis of ICT-effects on TFP growth that does not rely on the econometric estimation of input coefficients.[9] It combines the TFP growth rates constructed using the growth-accounting framework with a difference-in-difference specification similar to (1).[10] The combined method is of interest here mainly for two reasons. First, it will enable us to distinguish aggregate macro effects from sectoral effects of ICT using the growth-accounting measure of TFP that has been the workhorse of much of the existing literature. Second, the purely econometrics-based approach and the combined approach each rely on different assumptions so it is of interest to see if they lead to similar results.

The combined method is based on a measure of TFP growth obtained under the assumption that a composite of inputs can be constructed using cost shares as weights. More precisely, the cost share is measured by the two-period average share of the relevant input in total costs, s_{Iijt}, $I \in (X, L, K)$. Consequently, TFP growth rates are measured by $\Delta \ln TFP_{ijt} = \Delta \ln Y_{ijt} - \Delta \ln W_{ijt}$ where the growth of the inputs composite is defined as $\Delta \ln W_{ijt} = s_{Xijt} \Delta \ln X_{ijt} + s_{Lijt} \Delta \ln L_{ijt} + s_{Kijt} \Delta \ln K_{ijt}$. Thereby, the alternative difference-in-difference specification is given by

$$\Delta \ln TFP_{ijt} = g_{ij} + \gamma_0 \Delta \ln TFP_{ijt-1} + \gamma_1 d_t + \gamma_2 it_{ij95} + \gamma_3 d_t \times it_{ij95} + w_{ijt} \qquad (3)$$

which is similar to (1) except for using TFP growth as the dependent variable rather than labor productivity growth. w_{ijt} is an error term.

The two approaches for studying the relationship between TFP-growth and ICT-intensities impose different restrictions on the inputs composite. Under the pure econometric method in (2), it is assumed that production functions are equal across countries

[9] We thank a referee for suggesting this as a robustness check.

[10] Using a combination of econometric methods and growth-accounting measures of factor inputs is in line with existing literature that studies the returns to scale of production functions and the cyclicality of productivity, see Basu (1996), Basu and Fernald (1997), and Inklaar (2007).

and industries (apart from country/industry fixed effects) and across time. Under the combined approach in (3), the input coefficients measured directly by the cost shares are industry×country×time specific. In this sense, this approach does not use the constancy restrictions imposed in (2). The restrictions under this approach, however, are that output elasticities are correctly measured by cost shares. This is a result of profit maximizing and cost minimizing behavior in perfect markets under constant returns to scale production.

6 Empirical Results

In this section, we present the results found when the base measure of ICT-intensity is applied. First, we present findings for labor productivity growth after which we look into the results for TFP-growth. In the next section, we pursue additional robustness tests.

6.1 Labor Productivity Growth

Table 3 contains the individual country results for industries in the nonfarm business sector. It is based on (1) while allowing for country-specific coefficients. The results reported in Panels A through C differ in terms of the treatment of lagged effects and industry heterogeneity. Panel A reports the results for a simplified difference-in-difference specification without lagged productivity growth and industry effects. Panel B adds lagged productivity growth whereas Panel C additionally extends the model to include industry fixed effects. In the latter case, the coefficient of 1995-ICT intensity (it) is not identified due to its time-invariance.

[Table 3 about here]

The estimates of the coefficients related to the trend-break term, d, and its interaction term with ICT-intensity, $d \times it$, are of main interest. They remain fairly stable across specifications. The most general specification (panel C) is preferred because it encompasses the fact that lagged productivity growth enters significantly in some countries and because we control for unobserved time-invariant level differences between industries by including industry fixed effects.

The point estimates suggest that seven out of eight countries experienced negative changes in productivity growth rates in 1995 for non-ICT-intensive industries (the coefficient of d). This is consistent with the overall decrease in the aggregate productivity growth rate in Europe after 1995. Moreover, since the present analysis is carried out on industry data, it shows that productivity growth falls on average within industries meaning that the trend break cannot be (fully) attributed to changing business structure.

With respect to the interaction term $d \times it$, six countries have positive point estimates. This pattern of the effects is consistent with a positive impact of ICT after 1995 against an overall negative change in productivity growth. In this sense, the results suggest that ICT has affected productivity growth positively after all, even though overall productivity growth has fallen.

Comparing across countries, there is an apparent dispersion of point estimates. Moreover, the standard errors of single country estimates are fairly large and we find that many estimates remain insignificant. To reduce the uncertainty of point estimates, we will exploit the availability of a cross-country panel and pool the data over European countries. The potential cost of pooling is that we have to assume that growth effects of ICT and trend breaks are equal across countries and industries.

Results for Austria differ substantially from the overall pattern of negative breaks and positive interaction terms. We conclude that this country is too different to be included in an overall European panel data set.[11] Crucially, we note that our basic conclusion about the timing of the productivity trend break from Section 3 is left unaltered when Austria is excluded from the panel. This can be seen by comparison of the dotted and dashed curves in Figure 1. Therefore, we can still use 1995 as the break-year when combining the data into a panel of seven European countries (EU-7).

The results of the EU-7 panel data regressions are reported in Table 4. Results under the heading "All industries" apply to the full set of 24 industries. They differ according to the type of fixed effects allowed: "Pooled" excludes fixed effects altogether and imposes a common constant term across countries and industries; "FE Country" allows intercepts to vary across country (but not across industry); "FE Industry" allows intercepts to vary

[11] Averaging the interaction term across countries including Austria, the mean effect is 0.56 percentage points, whereas it becomes 0.80 percentage points when Austria is excluded.

across industry (but not across country); and "FE General" allows a full set of industry/country specific intercepts. In the latter case, the coefficient of 1995-ICT intensity (it) is not identified due to its time-invariance.

[Table 4 about here]

There is evidence of an overall negative change of about one percentage point in the rate of labor productivity growth in non-ICT-intensive industries after 1995; a negative and significant coefficient of d around -1%. No significant difference can be recorded between ICT-intensive and non-ICT-intensive industries pre-1995; the coefficient of it attain values between -0.3% to -0.1% that are not significantly different from zero. The overall negative trend break is to a large extent counterweighted by the positive and significant interaction term for the ICT-intensive industries; the coefficient of $d \times it$. The value of this coefficient is between 0.8 to 0.9%.

The results are consistent in terms of sign and magnitude both across methods and with the average results for individual countries in Table 3. As mentioned, we find that the coefficients to the break dummy and the interaction term equal -1.10 and .90 in the 'FE general' model, whereas the single country regressions lead to average coefficients of -1.14 and .80, respectively.[12] The fact that our panel estimates remain very close to the average of country-specific results supports the poolability of the seven countries in the panel.

The remaining results in Table 4 are obtained by excluding certain industries from the panel.[13] Excluding the ICT-producing industries we find that the interaction term becomes less significant.[14] The finding of a smaller effect when excluding ICT-producers is consistent with Stiroh's results for the US. The marginal loss of significance is in keeping with the fact that overall effects for the European case are less significant. Looking closer into the importance of individual ICT-producing industries, we find that a lower level of significance is primarily driven by the exclusion of telecommunications. We get back

[12] The mean country results (excluding Austria) from Table 3 are .057 for the coefficient of ΔlnA_{-1}, -1.136 for d, and .801 for $d \times it$.

[13] As results have been found to remain very stable across methods, we report only the most general fixed effects specification.

[14] The coefficient estimate is borderline insignificant at the ten per cent level.

to this issue below where we focus on TFP growth. The final set of results in Table 4 excludes the FIRE industries. There is little change in the coefficient of the interaction term. In qualitative terms, our main results remain unaltered by excluding FIRE. This is also consistent with Stiroh's (2002) findings for the US.

In Figure 2 we address our initial choice of 1995 as the break-year. The figure shows the estimated coefficient of the interaction term between break-year ICT-intensity, it, and the corresponding break dummy, d, when the break-year is varied between 1990 and 2000. It also depicts the approximate 95 per cent confidence bands.[15] The magnitude of the break in the trend of labor productivity seems fairly robust to the choice of a different break-year around the middle of the 1990s.

[Figure 2 about here]

In conclusion, we find that European industries which are relatively ICT-intensive pre-1995, outperform remaining industries post-1995 in terms of labor productivity growth. In contrast to the US, the change happened against a bleak overall European productivity growth scenario. Our results become weaker when ICT-producers are excluded although an economically significant differential effect of 0.5 percentage points remains for ICT-users versus remaining sectors. The result does not depend critically on the developments in FIRE industries nor on the exact timing of the break.

6.2 TFP growth

We next turn to TFP growth. We employ the extended difference-in-difference model in (2) that augments the basic difference-in-difference regression by the growth rates of inputs.

[Table 5 about here]

[15] Note that this band has a pointwise interpretation only.

The importance of the post-1995 productivity slowdown in ICT-extensive sectors (the coefficient to d) reduces to approximately .6 percentage points as compared to the fall of about one percentage point in the rate of growth of labor productivity. This suggests that part of the fall in labor productivity around 1995 is due to reduced capital-deepening and reduced accumulation of intermediate inputs.

As for the case of labor productivity growth, the ICT-intensive sectors significantly outperform other sectors post-1995. The size of the differential TFP gain in ICT-intensive industries (the coefficient of $d \times it$) is marginally reduced to .6 percentage points from the .8 percentage gain in labor productivity. Again, this reduction is due to the fact that we take factor accumulation into account. The negative overall TFP trend break is now completely counterweighted for the ICT-intensive industries by the positive interaction term. Finally, it is observed that the growth difference between ICT-intensive and non-ICT-intensive industries pre-1995 attains a small negative and insignificant size (the coefficient of it).

We address the sensitivity of our main TFP results with respect to break-year in the same directions as above. First, in Figure 3 we repeat the exercise of changing the break-year. A very similar picture emerges although the overall level of significance is somewhat reduced compared to the results on labor productivity. Second, Table 5 shows that the TFP differential does not depend on the presence of ICT-producing industries nor on developments in the FIRE industries. Significant effects remain when excluding either of these sectors.

[Figure 3 about here]

Overall, our TFP extension of the analysis yields three main conclusions. First, there are significant TFP gains from ICT in Europe post-1995. Secondly, a comparison of TFP and labor productivity impacts of ICT shows that most of the impact of ICT in Europe is indeed due to gains in TFP rather than capital-deepening. Third, we find economically sizable and statistically significant TFP gains for intensively ICT-using industries.

An important observation when comparing the results of Tables 4 and 5 is the growth effect for intensively ICT-using industries, i.e., the results obtained when excluding ICT-producing industries. Under the study of labor productivity growth, a positive but statistically insignificant difference is found between ICT-intensive and non-ICT-intensive industries post-1995, whereas the effect is positive and statistically significant for the regressions for TFP growth. In other words, there is a strong positive *differential* impact on TFP growth in ICT-using sectors, whereas it is less pronounced for labor productivity growth. This suggests the European economies experienced a reduction in capital-deepening which is especially pronounced for industries that use ICT intensively.

Another important observation on the results of Table 5 is that the estimated production function exhibits an estimated returns to scale parameter $\beta_4 + \beta_5 + \beta_6$ that appear significantly less than one in all specifications. This is in line with previous results found by O'Mahony and Vecchi (2005) when estimating short-run production functions on similar data. As we discussed above in section 5, it is most likely an artifact due to different sources of downward bias in the estimated input coefficients. The implied measure of TFP growth is likely to be biased, although we argue that there is little reason to expect the degree of bias to be different across 1995 or to be related to the ICT intensity of a particular industry.

7 Robustness

Next, we investigate the robustness of the results presented in the previous section. First, we present results on the relationship between productivity growth and ICT for different specifications of ICT-intensity. Second, we provide results for an alternative measure of TFP-growth rates obtained from the growth-accounting framework. This is of interest because this TFP-index is used extensively in the literature.

7.1 Continuous and Alternative ICT-intensity Measures

To investigate the importance of using a binary measure of ICT-intensity, we include the underlying continuous measure directly in order to more fully utilize the information in this variable.[16] Moreover, we apply two alternative measurements of ICT-intensity, ICT capital service per worked hour and ICT capital service relative to gross output. Note that the estimates of the coefficient of the interaction term, $d \times it_{cont}$, are not directly comparable across definitions due to differences in the normalizations of these variables. We check robustness regarding the statistical significance of each measure in explaining productivity growth.

[16] The continuous measures are normalized using country-specific means and standard deviations.

[Table 6 about here]

Table 6 presents the results both for labor productivity and for TFP growth. Results are based the most general specification, i.e., the FE general model with fixed effects for every industry, country combination. The first column under each of the growth measures shows that the significance of pre-1995 ICT intensity in explaining post-1995 productivity growth differentials is robust to using the corresponding continuous measure. In the following two columns under each growth measure, we present results for the alternative definitions of ICT-intensity. Again, the interaction term, $d \times it_{cont}$, remains strongly significant in all cases.

The results show that our basic conclusion holds: Both labor productivity and TFP experienced a significant differential post-1995 gain in ICT intensive industries irrespective of the measure applied.

7.2 Growth-Accounting Based TFP

The alternative approach to the analysis of ICT-effects on TFP growth rates was described in (3). It combines the growth accounting framework with econometric methods. The results for this method are presented in Table 7.

[Table 7 about here]

Again, there is evidence of an overall negative change in the rate of TFP-growth in non-ICT-intensive industries after 1995; a negative and significant coefficient of d around -1.1%. The overall negative trend break is to some extent counterweighted by the positive but insignificant interaction term for the ICT-intensive industries; the coefficient of $d \times it$. The value of this coefficient is around 0.6 percent. Comparing the results of Table 7 with the results for estimated TFP-growth in Table 5, it is seen that the point estimates on the interaction term are of similar size. The important difference is that the coefficient the interaction term is no longer significant.

Our results show that in terms of quantifying the effects of ICT intensity on productivity growth rates, the methods yield similar results. Moreover, the TFP results are comparable to our results for labor productivity in Table 3 which are not subject to the potential sources of bias discussed in section 5.2.

8 Discussion and Conclusions

We challenge the general consensus that the performance of productivity growth in European economies is mainly explained by a disappointing performance of the ICT-using sectors. We find significant productivity gains from ICT in Europe post-1995. We also document the importance of treating macro economic shocks and productivity effects from ICT separately in an econometric analysis.

One explanation for TFP gains is that they work through new technology. This view is supported in studies based on firm-level data; if there are prominent ICT-effects in many firms, they will show up in industry and even macro data. Bresnahan, Brynjolfsson and Hitt (2002) study the joint effects on productivity of ICT, labor demand and workplace organization for the United States. Besides documenting complementarity between ICT investments and workplace reorganization, the authors demonstrate that firms that adopt these innovations tend to use more skilled labor. Consequently, the implementation of ICT in the production process of the firm not only requires ICT. In addition, firms need to reorganize and upgrade their employees. Bloom *et al.* (2009) also find that ICT has a significant impact on productivity.

It is of interest to compare the European evidence to results for the United States. Stiroh (2002) found an increase of two per cent for US labor productivity growth in ICT-intensive industries post-1995. We find an interaction term for European economies of around 40 percent of this. Thus, ICT has a positive effect on productivity growth in Europe, however, it is less than half of the size of the effect found for the United States. In this sense, the difference in the utilization of ICT between the two regions has partially lead the divergence in productivity levels, but it does not explain the fall in European productivity growth after 1995.

The flip side of the positive ICT-effects on productivity growth is that the overall European productivity growth is still bleak. Thus, aggregate as well as industry averages of productivity growth decreased in Europe after 1995. Our findings thus clear ICT-using industries from being the main cause of weak performance because of unexploited productivity gains from ICT. Rather, the aggregate economy experienced a negative macro economic shock that lead to deceleration of productivity growth.

A note should be made on the use of econometric methods since the conventional choice in the literature is the growth-accounting framework. For the purpose of studying growth effects of ICT, econometrics methods have pros and cons. The main advantages are that the impact of ICT is quantified by exploiting the variation in industry-level data and that it allows for statistical tests of significance of the economic impact of ICT. Moreover, we are able to treat macro economic shocks and productivity effects from ICT separately in the econometric analysis. However, the econometric methods also face some challenges, e.g., potential simultaneity problems when inputs and output are determined and potential omission of explanatory variables such as measures of effects of labor market reforms, changes in competition, regulation, etc. that could also be a source of bias.

There are some broader issues—empirical and methodological—related to our analysis. First, why are effects on productivity growth in Europe not as large as in the United States? This question can be divided into the study of why the ICT-capital-deepening effect has been more extensive in the United States and the study of why US industries have been better to realize technology advances to productivity growth. The two effects may of course be related. One explanation for the difference in growth performance is put forward by Bloom *et al.* (2009) using firm-level data. The authors find that the productive effect of ICT is greater for US firms than for non-US firms and present evidence for US-style management practices to be related to a more productive use of ICT.

Second, an important but unresolved issue suggested by the results of this paper is the different results generated from the two approaches applied to studying ICT effects on TFP growth. When production functions are estimated, we find a positive and significant effect on TFP growth in ICT-intensive sectors post-1995. When we apply an accounting approach, the effect turns insignificant. This difference is most likely a consequence of the different restrictions applied under the two approaches. When estimating TFP-growth we assume that production functions are equal across industries and countries (apart from country/industry fixed effects). Under the growth-accounting method, sectoral production functions vary as a consequence of assuming that factor shares equal output elasticities.

Third, the underlying reason for the overall deceleration in European productivity growth is not explained by our analysis. For labor productivity growth, this may partly be explained by a smaller capital-deepening effect and reduced growth in intermediate inputs, which our analysis suggests is part of the explanation. The main part of the shift is, however, due to a lower TFP growth rate. Is a potential explanation behind the European slowdown that it can be generated by labor market reforms getting less skilled/productive workers back into jobs? According to Bloom *et al.* (2009) this may be part of the reason, but not all.[17] In principle, this effect should only affect labor productivity growth and not TFP growth because we control for labor service when estimating the measure. In this sense, effects from increased use of low-productive labor input should have been taken into account. However, the measure of labor service is constructed (*i*) under the assumption that wages reflect marginal value products and (*ii*) as a weighted average of growth in hours worked for different labor groups using weights based on average relative wages, see van Ark *et al.* (2007). Less productive workers, however, are likely to earn wages in the lower end of the wage distribution within each group. This variation is not captured when weights are based on averages. Moreover, it is unclear whether the marginal value products for these workers are well-measured by wages. Taken together, it is unlikely that the measure of growth in labor inputs fully controls for the effect of labor market reforms.

[17] Bloom *et al.* (2009): "Although some part of the observed European slowdown is due to labor market reforms getting less skilled workers back into jobs, most analysts agree there was still a gap in productivity growth between the US and EU of at least 0.8% over the course of a decade."

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Table 1: Labor productivity growth (per cent per year): EU-8 and US

	Austria	Denmark	Finland	France	Germany	Italy	Netherlands	United Kingdom	United States
Panel A: Nonfarm business sector.									
1980-1994	3.4	3.1	3.7	3.6	3.1	2.6	2.6	3.5	1.5
1995-2004	4.1	2.1	3.2	3.7	3.5	1.6	2.8	1.7	3.3
Panel B: Nonfarm business sector excluding ICT production.									
1980-1994	3.3	2.9	3.4	3.4	3.0	2.7	2.5	3.6	1.2
1995-2004	3.7	1.3	2.4	3.1	2.9	1.2	2.4	1.6	2.8
Panel C: Nonfarm business sector excluding FIRE.									
1980-1994	3.4	3.0	3.6	3.7	3.2	2.8	2.6	3.6	1.4
1995-2004	4.0	1.8	3.1	3.7	3.4	1.6	2.8	1.7	3.3

Source: EUKLEMS database, March 2007.

Table 2: Industries with sufficient ICT information in the EUKLEMS database

Food, beverages and tobacco	15t16
Textiles, textile products, leather and footwear	17t19
Wood and products of wood and cork	20
Pulp, paper, paper products, printing and publishing	21t22
Coke, refined petroleum products and nuclear fuel	23
Chemicals and chemical products	24
Rubber and plastics products	25
Other non-metalling mineral	26
Basic metals and fabricated metal products	27t28
Machinery, nec	29
Electrical and optical equipment	30t33
Transport equipment	34t35
Manufacturing nec; recycling	36t37
Electricity, gas and water supply	E
Construction	F
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	50
Wholesale trade and commission trade, except of motor vehicles and motorcycles	51
Retail trade, except of motor vehicles and motorcycles; repair of household goods	52
Hotels and restaurants	H
Transport and storage	60t63
Post and telecommunications	64
Financial intermediation	J
Renting of machinery and equipment and other business activities	71t74
Other community, social and personal services	O

Source: Van Ark *et al.* (2007).

Table 3: Labor productivity: Individual country results

	Austria	Denmark	Finland	France	Germany	Italy	Netherlands	United Kingdom
Panel A: No lagged productivity growth rate, no industry fixed effects.								
d	1.689***	-1.122	-1.921***	-0.141	-0.206	-1.042**	-0.086	-2.415***
	(0.639)	(0.676)	(0.610)	(0.539)	(0.553)	(0.454)	(0.582)	(0.719)
it	0.154	-0.999**	-1.100**	-0.119	0.573	0.184	0.462	-1.562***
	(0.347)	(0.393)	(0.550)	(0.537)	(0.522)	(0.428)	(0.513)	(0.488)
$d \times it$	-1.699**	-0.354	2.354***	0.681	1.474	1.303	0.612	0.734
	(0.933)	(0.877)	(1.045)	(1.026)	(1.029)	(0.930)	(1.031)	(0.956)
Panel B: Lagged productivity growth rate, no industry fixed effects.								
$\Delta \ln A_{-1}$	-0.025	-0.114	0.189***	0.298***	-0.002	0.149**	0.227**	0.270***
	(0.069)	(0.056)	(0.050)	(0.061)	(0.120)	(0.060)	(0.073)	(0.064)
d	1.127	-1.293	-2.079***	-0.580	-0.642	-1.459***	-0.172	-1.329**
	(0.686)	(0.829)	(0.514)	(0.383)	(0.593)	(0.391)	(0.538)	(0.597)
it	-0.160	-0.693	-0.869	-0.247	0.491	0.038	0.505	-0.886*
	(0.449)	(0.526)	(0.558)	(0.412)	(0.490)	(0.460)	(0.670)	(0.457)
$d \times it$	-1.015	-0.712	1.821**	0.610	1.604	1.101	0.326	0.219
	(1.039)	(1.064)	(0.902)	(0.699)	(1.127)	(0.793)	(0.894)	(0.744)
Panel C: Lagged productivity growth rate, industry fixed effects.								
$\Delta \ln A_{-1}$	-0.107	-0.151***	0.063	0.148**	-0.086	0.056	0.182**	0.184**
	(0.065)	(0.055)	(0.040)	(0.070)	(0.109)	(0.047)	(0.075)	(0.048)
d	1.270**	-1.327*	-2.308***	-0.463	-0.629*	-1.492***	-0.130	-1.603***
	(0.594)	(0.683)	(0.484)	(0.340)	(0.372)	(0.3481)	(0.481)	(0.483)
it	—	—	—	—	—	—	—	—
$d \times it$	-1.134	-0.691	2.198***	0.613	1.718*	1.165	0.307	0.294
	(0.783)	(0.870)	(0.676)	(0.587)	(0.902)	(0.745)	(0.827)	(0.631)

Note: Heteroskedasticity and autocorrelation consistent standard errors in parentheses.
'*','**', '***': Significant at the 10, 5, or 1 percent level, respectively.
$N = 24$ industries. Estimation period 1970—2004. Source: EUKLEMS database, March 2007.

Table 4: Labor productivity: Panel results (EU-7)

	All industries				W/o ICT prod.	W/o FIRE
	Pooled	FE Country	FE Industry	FE General	FE General	FE General
ΔlnA_{-1}	0.150***	0.144***	0.094***	0.054	0.022	0.050**
	(0.040)	(0.040)	(0.034)	(0.033)	(0.032)	(0.034)
d	-1.031***	-1.035***	-1.048***	-1.098***	-1.194***	-1.101***
	(0.178)	(0.181)	(0.189)	(0.199)	(0.194)	(0.200)
it	-0.286	-0.288	-0.117	—	—	—
	(0.228)	(0.223)	(0.229)			
$d \times it$	0.814***	0.819***	0.861***	0.901***	0.490	0.824**
	(0.298)	(0.301)	(0.318)	(0.332)	(0.306)	(0.349)

Note: Heteroskedasticity and autocorrelation consistent standard errors in parentheses.
'*','**', '***': Significant at the 10, 5, or 1 percent level, respectively.
$N = 24$ industries. Estimation period 1970—2004. Source: EUKLEMS database, March 2007.

Table 5: Total factor productivity: Panel results (EU-7)

	All industries				W/o ICT prod.	W/o FIRE
	Pooled	FE Country	FE Industry	FE General	FE General	FE General
$\Delta \ln Y_{-1}$	0.118***	0.114***	0.098***	0.061**	0.035	0.054*
	(0.035)	(0.034)	(0.032)	(0.028)	(0.027)	(0.028)
d	-0.653***	-0.644***	-0.677***	-0.623***	-0.643***	-0.622***
	(0.139)	(0.135)	(0.142)	(0.145)	(0.151)	(0.145)
it	-0.104	-0.112	-0.172	—	—	—
	(0.160)	(0.161)	(0.203)			
d × it	0.572**	0.582**	0.633**	0.619**	0.481*	0.660**
	(0.256)	(0.258)	(0.262)	(0.274)	(0.282)	(0.287)
$\Delta \ln X$	0.360***	0.359***	0.353***	0.351***	0.370***	0.360***
	(0.080)	(0.080)	(0.080)	(0.081)	(0.099)	(0.086)
$\Delta \ln L$	0.180***	0.181***	0.203***	0.210***	0.208***	0.210***
	(0.048)	(0.049)	(0.052)	(0.054)	(0.064)	(0.056)
$\Delta \ln K$	0.026	0.031	0.028	0.051**	0.053**	0.056**
	(0.022)	(0.022)	(0.022)	(0.025)	(0.026)	(0.025)

Note: Heteroskedasticity and autocorrelation consistent standard errors in parentheses.
'*','**', '***': Significant at the 10, 5, or 1 percent level, respectively.
$N = 24$ industries. Estimation period 1970—2004. Source: EUKLEMS database, March 2007.

Table 6: Continuous and alternative measures of ICT intensity: Labor productivity and TFP, panel results (EU-7)

	Labor productivity			Total factor productivity		
	Standard	Altern. 1	Altern. 2	Standard	Altern. 1	Altern. 2
$\Delta \ln A_{-1}$	0.053	0.047	0.049	—	—	—
	(0.033)	(0.032)	(0.032)			
$\Delta \ln Y_{-1}$	—	—	—	0.061**	0.060**	0.061**
				(0.028)	(0.028)	(0.028)
d	-0.648***	-0.649***	-0.649***	-0.314***	-0.316***	-0.317***
	(0.160)	(0.148)	(0.155)	(0.113)	(0.110)	(0.112)
it_{cont}	—	—	—	—	—	—
$d \times it_{cont}$	0.647**	1.018***	0.829***	0.288***	0.402***	0.338***
	(0.224)	(0.240)	(0.265)	(0.171)	(0.193)	(0.171)
$\Delta \ln X$				0.351***	0.350***	0.351***
				(0.081)	(0.081)	(0.081)
$\Delta \ln L$				0.211***	0.214***	0.213***
				(0.054)	(0.055)	(0.054)
$\Delta \ln K$				0.050**	0.048**	0.049**
				(0.025)	(0.024)	(0.024)

Note: Heteroskedasticity and autocorrelation consistent standard errors in parentheses.
'*','**', '***': Significant at the 10, 5, or 1 percent level, respectively.
$N = 24$ industries. Estimation period 1970—2004. Source: EUKLEMS database, March 2007.

Table 7: Total factor productivity with growth-accounting inputs composite: Panel results (EU-7)

	All industries				W/o ICT prod.	W/o FIRE
	Pooled	FE Country	FE Industry	FE General	FE General	FE General
$\Delta lnTFP_{-1}$	0.009	0.008	0.002	-0.036	-0.042	-0.039
	(0.028)	(0.028)	(0.026)	(0.026)	(0.028)	(0.027)
d	-1.049***	-1.059***	-1.104***	-1.099***	-1.160***	-1.101***
	(0.244)	(0.255)	(0.248)	(0.268)	(0.285)	(0.268)
it	-0.481	-0.482	-0.454	—	—	—
	(0.424)	(0.421)	(0.637)			
$d \times it$	0.578	0.579	0.678	0.598	0.553	0.601
	(0.449)	(0.449)	(0.483)	(0.535)	(0.604)	(0.570)

Note: Heteroskedasticity and autocorrelation consistent standard errors in parentheses.
'*','**', '***': Significant at the 10, 5, or 1 percent level, respectively.
$N = 24$ industries. Estimation period 1970—2004. Source: EUKLEMS database, March 2007.

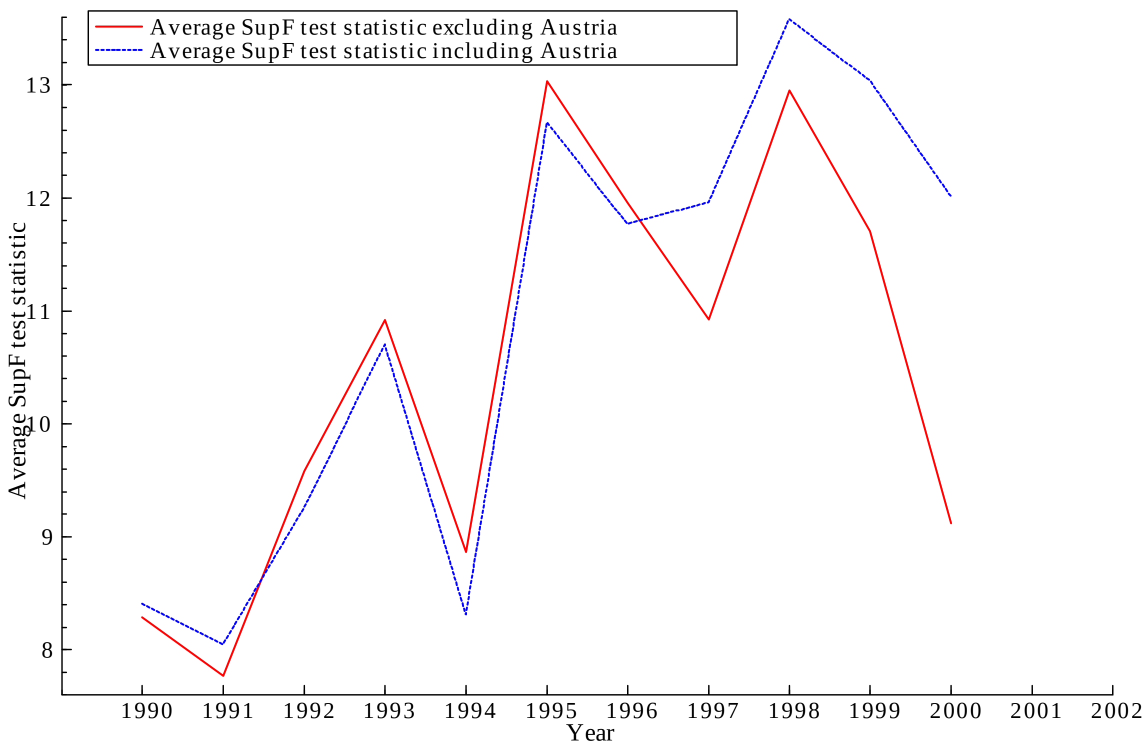

Figure 1: The average of the Sup F tests of Andrews (1993) when applied to a pooled data set containing the nonfarm business sector industries: Across eight European countries (dashed curve); excluding Austria (solid curve)

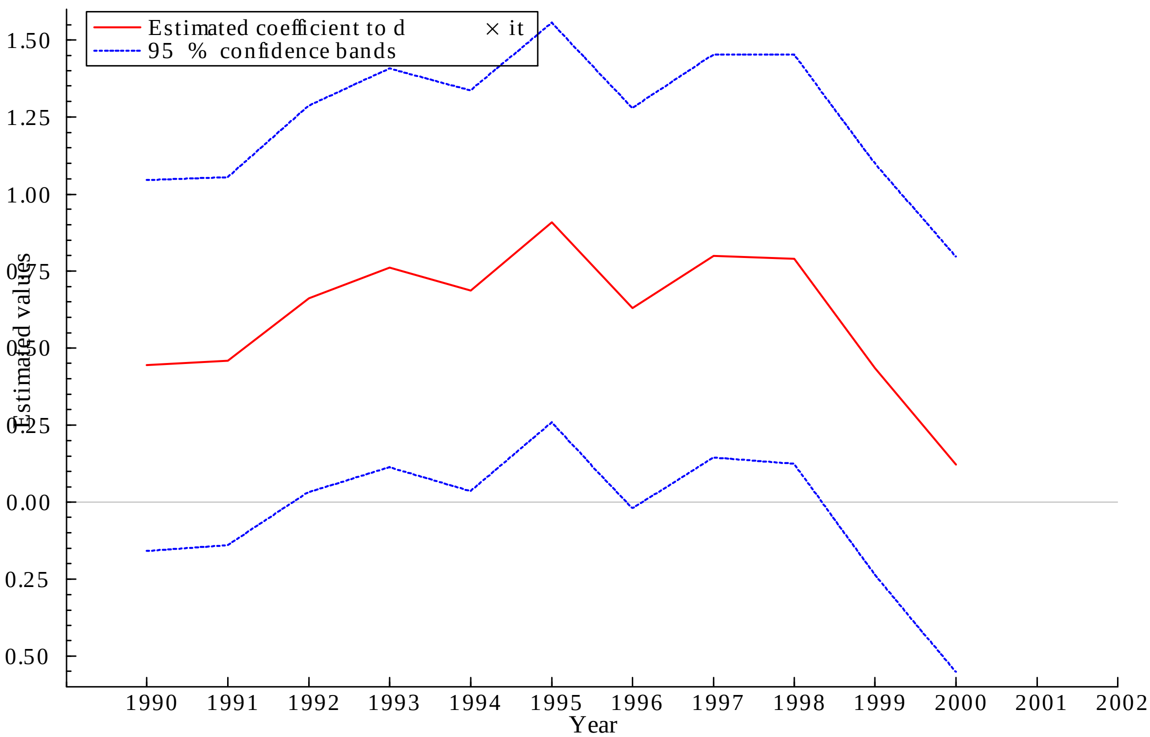

Figure 2: The estimated difference-in-difference coefficient for labor productivity, α_3, with bands of plus and minus two standard error (pointwise) for different break year

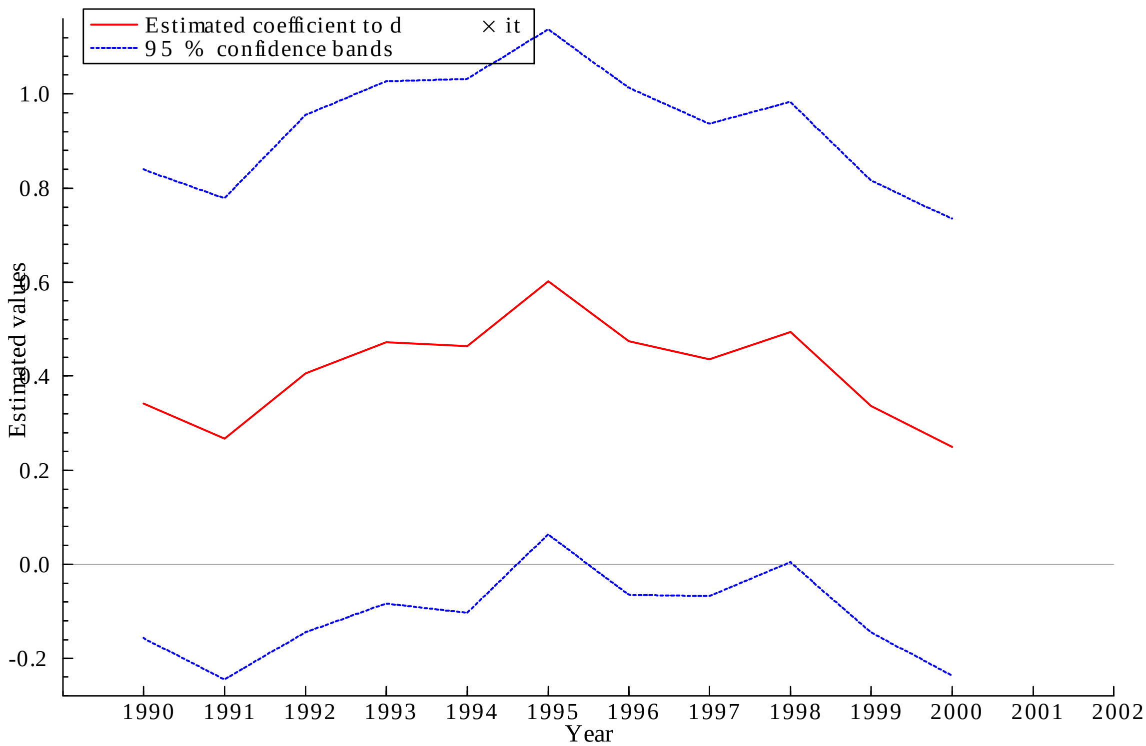

Figure 3: The estimated difference-in-difference coefficient for total factor productivity, β_3, with bands of plus and minus two standard error (pointwise) for different break year

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