ICT and Productivity Growth in the 1990's: The European Evidence*

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Abstract

Using a recent sectoral panel data set of European countries, we present econometric evidence to show that information and communications technologies (ICT) have indeed had a growth enhancing effect in Europe after 1995. In addition to ICT-producers who benefitted directly from the effects of rapid technological progress in ICT we also find positive effects for ICT-intensive service sectors and for manufacturing sectors outside of ICT production. We extend previous literature by showing these results to hold not only for labor productivity but also for total factor productivity. The main difference between

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the US and the European productivity experiences during the 1990's is that that the positive differential impact of ICT happened against an overall bleak productivity trend in Europe.

1 Motivation

The purpose of this paper is to investigate the relationship between information and communications technologies (ICT) and productivity growth for a number of European economies. Our analysis is based the so-called EU-KLEMS database which has recently become available. This is 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.

While aggregate labour productivity trends in Europe have been much less favourable than in the US over the 1990s, the US experience suggests that ICT intensive industries would still outperform non-intensive industries in relative terms. Our analysis is closely related to Stiroh (2002) who analyzes the relationship between ICT intensity across industries and productivity developments for the United States. Three results provide important points of departure for our analysis: First, Stiroh established that labor productivity growth for the private sector increased around 1995. Second, he showed that the increase was related to ICT in the sense that the increase in labor productivity growth was limited to ICT intensive industries. Third, labor productivity gains were not confined to ICT-*producing* industries. Also intensive ICT-*users* in the US have benefitted in terms of productivity increases over the course of the 1990's.

We extend Stiroh's analysis in a number of directions in this paper. First and foremost, the analysis of ICT-related productivity performance at the industry level is extended to Europe. There are few existing studies of Europe, mainly as a result of a lack of comparable data available so far. We take advantage of comparable data from EUKLEMS to perform analyses of data both for individual European countries and for a panel of European countries.

A second contribution of the paper is to provide new evidence on the issue if ICT matters to productivity mainly in the ICT-producing industries, or more broadly among ICT-users as well. The ICT *producing* sector is less important in Europe than in the US. Any direct producitivity-enhancing effects are therefore expected to be correspondingly smaller. However, the productivity impacts in ICT-*users* such as those established for the US by Stiroh (2002) should spread quickly in advanced economies through imports of hardware and software in proportion to the amount of ICT utilized in production.

The third contribution is our extension of the analysis to total factor productivity (TFP). This analysis makes it possible to distinguish genuine effects of technological progress due to ICT from the capital-deepening effects of increasing the amounts of ICT capital used in production in different sectors.

Finally, we exploit the panel structure of our country/sector data to control for unobserved industry and country specific effects that could be generated by differences in competition, regulation, etc., which could otherwise be hard to distinguish from the effects of ICT. This distinction is not possible in growth accounting exercises where all differences in the growth generating processes is attributed to contributions from inputs (of primary and secondary inputs) and TFP growth. The problem with the measure of TFP growth from the growth accounting framework is that it is very sensitive to measurement errors for input factors, differences in data generation methods across countries. We deal with these issues using a regression approach in decomposing the growth of output into contributions from inputs and from TFP.

Our main findings are as follows. Similar to Stiroh (2002), we find that sectors which are relatively ICT-intensive pre-1995 outperform remaining sectors post-1995 in terms of labour productivity. 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. Our TFP extension 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 intensive ICT-producers *as well as* for users.

The paper is laid out as follows. Section 2 addresses the timing of any break in productivity in Europe during the 1990's. Section 3 provides a detailed account of the EUKLEMS data on which our analysis is based while section 4 summarizes our econometric approach. Our empirical results are reported in three sections: Section 5 has the basic results on labour productivity as a European complement to Stiroh's findings for the US, section 6 provides the extension to TFP, and section 7 adds some robustness checks to these basic results in terms of different model specifications and different measures of ICT capital. Section 8 finally concludes.

2 The European productivity experience during the 1990s

It is a well-documented fact that Europe enjoyed a much less favourable productivity trend than the US after 1995, e.g. Timmer and Van Ark (2005). While the rate of productivity growth was generally very modest in Europe compared to the US, there was also some degree of dispersion in productivity growth rates across European countries. In order to be able to measure any differential productivity impact in relatively ICT-intensive sectors we will have to take into account that such differences happened against a much weaker general productivity trend than in the US.

We will use the year 1995 in comparing productivity growth across subperiods. A break in productivity trends during 1995 is supported econometrically by Stiroh (2002) when analyzing quarterly data for the US business sector over the period from 1974 to 2001. This has become the accepted dividing line. It is also the standard point of reference used in analyzing the aggregate European experience, e.g. in Timmer and Van Ark (2005).

Empirically, the date of any break is less easily determined for individual European countries than for the US because the available data are annual.

Having a set of comparable panel data we can gain power by pooling across countries.[1]

[Figure 1 about here]

Figure 1 applies the Sup F test of Andrews (1993) to a pooled data set containing the nonfarm business sector industries across eight European countries: Austria, Denmark, Finland, France, Germany, Italy, the Netherlands, and the UK. Details on the model presented in section 4. The dotted curve shows the Sup F test of Andrews calculated for each potential break year using the data for all eight countries. We also calculate the test excluding data for Austria (the dashed line). This country turns out not to be poolable with the remaining countries, see section 5 below.

Figure 1 shows ample evidence of a trend break in productivity during the second half of the 1990's. In fact, a significant trend break is found for each year from 1995 onwards. 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 prior to 1995.

Overall, by pooling the evidence across countries, we find that the productivity trend in Europe breaks during the second half of the 1990s. 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). It confirms our presumption that the effects of a general-purpose technology such as ICT are spreading rather quickly across countries (Bassanini and Scarpetta, 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 5 and 6.

[1] Assuming that a break will happen simultaneously in those countries.

3 Data

The data source for the present study is the newly developed EUKLEMS database, see www.EUKLEMS.net. This database include among others 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 total factor productivity. For our purpose, we use data for Austria, Denmark, Finland, France, Germany, Italy, the Netherlands, and United Kingdom.

3.1 Output and Productivity Data

In the present study, we apply gross output as the measure of sectoral output. Gross output is superior to 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, see for example Arrow (1974).[2] Jorgenson, Fraumani, and Galop (1987) find that separability is heavily rejected.

We apply two measures of productivity growth. The first measure is based on labor productivity that is simply defined as output divided by labor input, whereas the second measure is based on total factor productivity that is output defined as a composite of primary factor inputs and intermediate inputs.

3.2 Labor Input

We apply three measures of labor input. These are the number of persons engaged, the total hours worked and labor service. The latter is a measure that takes into account that persons with different background characteristics have different marginal products and thereby observed wages if the outcome is located on the labor demand curve. As a consequence, persons with

[2] Another approach is to assume that the Hick's aggregation theorem applies, see Diewert (1978). In this application the theorem states that the price of gross output and the prices of intermediate inputs vary in strict proportions.

high relative wages weight more than persons with low relative wages in an aggregate measure of labor input.

3.3 Capital Input

Capital data are divided up in ICT capital and other capital. Capital stocks are constructed based on ICT investment tables with 11 asset types of which three assets are ICT assets. The applied method is the perpetual inventory method with geometric pattern and constant depreciation rates for each asset type. The depreciation rates used origin from BEA as described in Fraumeni (1997).

Capital input is measured as capital stocks and capital service. As for labor service, capital service is a measure where capital stocks of different asset types are weighted by relative compensations; in this case relative user costs.

3.4 Intermediate Input

Intermediate input origin from supply and use tables for the different economies.

3.5 Industry Coverage

Data are provided for 72 industries, the so-called Euk industries, in total. The industries are classified according to the European NACE rev 1 classification. This classification is very close the International Standard Industrial Classification (ISIC) revision 3. This industry division is more detailed than the 2-digit (A60) level which is often used in European statistics.

3.6 ICT intensity

Measures of ICT intensities are required to analyze the use of ICT at the industry level We follow Stiroh (2002) and investigate whether ICT intensive industries have higher growth compared to industries that do not use ICT intensively. The main analysis is based on dummy variables for ICT-intensity. The dummy variable is based on a measure of ICT-intensity defined as ICT-capital service out of total capital service. If the ICT-intensity for an industry exceeds the median value over industries, the dummy equals 1, whereas it equals 0 otherwise. The regression analysis is also performed using the continuous measure of ICT intensity.

Throughout our analysis we distinguish between ICT-producing and -using industries. Stiroh (2002) found that although productivity growth in the US increased significantly in all ICT intensive industries, the effects were found to be stronger among ICT producers. We follow Stiroh and define ICT producers as the IT-producing manufacturing and service sectors, i.e., 30t33 and/or 64.[3]

A potential problem with the preferred measure of ICT-intensity is that it includes other capital service in the denominator. The problem is that the initial capital stock most likely is derived on late-1960's or 1970 investments. Due to lacking observations it is standard to use a steady state value of initial capital stock that equals $I_0/(g+\delta)$ - I_0 is earliest observed investments, g is the growth rate and δ is the depreciation rate. This is problematic for other capital with low depreciation rates because this initial capital stock will affect the value of capital stock for an extended period, because it is only phased out slowly. If for example the depreciation rate equals 3.1% as is the case for non-residential structures, then 73% of the initial capital stock is left in the capital stock 10 years after, more than half after 20 years, and around 40% after 30 years. This problem is not as severe for ICT where computing equipment has a depreciation rate of 31.5% implying that the initial capital stock basically is depreciated in full after 10 years only.

4 Econometric Approach

We specify a difference-in-difference regression in terms of the approximate growth rate of labour productivity, $\Delta \ln A_{ijt} = 100 * \Delta \ln (Y_{ijt}/E_{ijt})$. Here Y_{ijt} denotes real gross output of industry i in country j in year t and likewise

[3] OECD definition: ICT Producing Manufacturing: Office machinery (30), Insulated wire (313), Electronic valves and tubes (321), Telecommunication equipment (322), Radio and television receivers (323), Scientific instruments (331); ICT Producing Services: Communications (64), Computer & related activities (72).

for employment, E_{ijt}.

$$\Delta \ln A_{ijt} = a_{ij} + \alpha_{0j} \Delta \ln A_{ijt-1} + \alpha_{1j} d_t + \alpha_{2j} it_{ij} + \alpha_{3j} d_t * it_{ij} + \varepsilon_{ijt} \qquad (1)$$

where ε_{it} is an error term and

$$d_t = 1 \text{ for } t \geq 1995 \text{ and } d_t = 0 \text{ otherwise.}$$

ICT-intensity in the break year in industry j of country j is denoted it_{ij}. We will consider two different specifications of this term: A binary term that equals one if the ICT intensity of a particular industry is above the median (and zero otherwise) and a continuous specification that simply includes the intensity variable itself. Using a binary classification based on the median provides robustness to outlying measurements.

We exploit the fact that we have a panel of consistent data across a number of European countries to approach the estimation of (1) at several different levels of generality.

First, as a starting point to check the actual poolability of the data across countries, we will consider country-by-country analyses that allow full flexibility in terms of all parameters, including the α slopes.

Second, when pooling the data across countries we can allow for different fixed effects across countries and/or industries. Four cases are distinguished in terms the intercept a_{ij}: A fully pooled case of a common intercept ($a_{ij} = a$); a case of country-specific intercepts ($a_{ij} = a_j$) that do not vary across industries; a case of industry-specific intercepts ($a_{ij} = a_i$) that do not vary across countries; and finally, a general set of fixed effects that may vary both across countries and industries.

The regression (1) extends Stiroh's (2002) approach by including a term in lagged productivity growth, $\Delta \ln A_{ijt-1}$. We find ample evidence of the general significance of this extension. For consistent estimation of the dynamic panel data model we employ the generalized methods of moments approach of Arellano and Bond (1991).

A second main extension compared to Stiroh (2002) is the analysis of total factor productivity. For this we specify a diff-in-diff regression in terms of the growth rate of real output, $g_{ijt} = 100 * \Delta \ln Y_{ijt}$.

$$g_{ijt} = b_{ij} + \beta_{0j} g_{ijt-1} + \beta_{1j} d_t + \beta_{2j} it_{ij} + \beta_{3j} d_t * it_{ij} + \beta_{4j} \Delta \ln X_{ijt} + \beta_{5j} \Delta \ln L_{ijt} + \beta_{6j} \Delta \ln K_{ijt} + u_{ijt}. \quad (2)$$

The TFP regression furthermore includes controls for the growth rates of intermediate inputs, capital, and labor, and an error term, u_{ijt}.

5 Labour productivity

This section reports our results based on (1) for the basic case of labour productivity. For each country we divide industries into intensive and extensive industries depending on their ICT intensities in comparison to the median intensity according to our main measure based on ICT capital services. In section **??** we provide results based on two alternative measures and a continuous specification of ICT intensity.

[Table 1 about here]

Table 1 contains the individual country results for industries in the non-farm business sector. The results reported in Panels A through C differ in terms of their treatment of lagged effects and industry heterogeneity. Panel A reports the results for a simplified difference-in-difference specification similar to Stiroh (2002, Table 3). Panel B adds a term in lagged productivity growth. Panel C additionally extends the model to include industry fixed effects.

The estimates of the coefficients related to the trend-break term, d, and its interaction term with ICT-intensity, $d \times it$, are of 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 very significantly in the majority of countries and because we can control for any unobserved time-invariant level differences between industries by including industry fixed effects.

Comparing across countries, there is an apparent dispersion of estimates. Standard errors are also fairly large. This is partly due to the fact that we have fewer industries than in the US case of Stiroh (2002). The point estimates suggest that seven out of eight countries experienced a negative change in productivity growth rates in 1995 for ICT-extensive industries (the coefficient of d). Six countries have a positive interaction term with ICT intensity (the coefficient of $d \times it$). The pattern of effects is consistent with a positive impact of ICT after 1995 against an overall negative change in productivity growth. Still, we find that many individual country estimates remain insignificant.

Results for one country in particular, Austria, differ—even significantly—from the overall pattern of a negative break and a positive interaction term. Averaging the coefficients across countries including Austria, the mean interaction effect is 0.56 percentage points whereas it becomes 0.90 percentage points when Austria is excluded. We conclude from this that Austria cannot be included in an overall European panel data set. Crucially, we note that our basic conclusion about the timing of the productivity trend break from section 2 is left unaltered when Austria is excluded from the panel (compare the dotted and dashed curves in Figure 1).

[Table 2 about here]

Combining the data into a panel of seven European countries we find the results reported in Table 2. Results under the heading "All industries" apply to the full set of 26 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 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.

The results are consistent in terms of sign and magnitude both across methods and with significant results for individual countries in Table 1. There is evidence of an overall negative change of about one percentage point in the rate of productivity growth in ICT-extensive sectors after 1995 (a negative and significant coefficient of d). No significant difference can be recorded between ICT-intensive and ICT-extensive industries pre-1995 (the coefficient of it). 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 size of this differential productivity gain is lower than Stiroh's (2002) findings for the US over the same period. 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.[4]

The remaining results in Table 2 are obtained by excluding certain industries from the panel.[5] Excluding the ICT-producing industries (ICT hardware production and telecommunications) we find that the interaction term becomes less significant.[6] 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 into the importance of individual ICT-producing industries we find that the lower level of significance is primarily driven by the exclusion of telecommunications. The final set of results in Table 2 exclude FIRE industries. There is little change in the coefficient of the interaction term. In qualitative terms, our main results remain unaltered by excluding FIRE. Again, this is consistent with Stiroh's (2002) findings for the US.

[Figure 2 about here]

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 1999. It also depicts the approximate 95 per cent confidence bands.[7] 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.

In conclusion, and similar to Stiroh (2002), we find that sectors which are relatively ICT-intensive pre-1995 outperform remaining sectors post-1995 in terms of labour productivity. In contrast to the US, the change happened

[4]The mean country results (excluding Austria) from Table 1 are .061 for the coefficient of ΔlnA_{-1}, -1.094 for d, and .898 for $d \times it$.

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

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

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

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.

Table 1: Labor productivity: Individual country results

	AUT	DNK	FIN	FRA	GER	ITA	NLD	UK
Panel A: No lagged productivity growth rate, no industry fixed effects.								
d	1.689***	-1.122	-1.921***	-0.144	-0.206	-1.042**	-0.086	-2.415***
	(0.613)	(0.695)	(0.494)	(0.514)	(0.344)	(0.420)	(0.343)	(0.449)
it	0.154	-0.996**	-1.100	-0.122	0.579	0.195	0.480	-1.565**
	(0.423)	(0.390)	(0.680)	(0.744)	(0.522)	(0.679)	(0.513)	(0.708)
$d \times it$	-1.699**	-0.357	2.354***	0.683	1.467	1.292	0.593	0.737
	(0.797)	(0.770)	(0.737)	(0.693)	(1.001)	(1.039)	(0.779)	(0.672)
Panel B: Lagged productivity growth rate, no industry fixed effects.								
$\Delta \ln A_{-1}$	0.009	-0.040	0.185***	0.316***	0.039	0.149**	0.192**	0.221***
	(0.057)	(0.038)	(0.056)	(0.065)	(0.128)	(0.064)	(0.080)	(0.080)
d	1.537***	-1.287*	-1.940***	-0.380	-0.320	-1.070***	-0.185	-2.013***
	(0.585)	(0.724)	(0.406)	(0.327)	(0.325)	(0.376)	(0.295)	(0.466)
it	0.159	-1.071**	-0.792	-0.125	0.582	0.177	0.402	-1.281**
	(0.438)	(0.430)	(0.663)	(0.541)	(0.541)	(0.613)	(0.427)	(0.609)
$d \times it$	-1.689**	-0.348	1.843***	0.551	1.385	1.071	0.455	0.669
	(0.781)	(0.791)	(0.531)	(0.472)	(1.047)	(0.879)	(0.630)	(0.559)
Panel C: Lagged productivity growth rate, industry fixed effects.								
$\Delta \ln A_{-1}$	-0.077	-0.076***	0.065***	0.160**	-0.044	0.050	0.145**	0.124**
	(0.054)	(0.027)	(0.025)	(0.073)	(0.108)	(0.051)	(0.072)	(0.060)
d	1.699***	-1.299*	-2.122***	-0.337	-0.325	-1.118***	-0.185	-2.271***
	(0.623)	(0.745)	(0.476)	(0.418)	(0.356)	(0.411)	(0.309)	(0.463)
it	—	—	—	—	—	—	—	—
$d \times it$	-1.843**	-0.379	2.116***	0.619	1.509	1.212	0.484	0.728
	(0.832)	(0.821)	(0.648)	(0.591)	(1.123)	(0.979)	(0.666)	(0.614)

'*','**', '***': Significant at the 10, 5, or 1 percent level, respectively.

Table 2: Labor productivity: Panel results

	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)

'*','**', '***': Significant at the 10, 5, or 1 percent level, respectively.

6 Total Factor Productivity

We next extend the basic analysis of labour productivity and analyze total factor productivity. We employ the extended difference-in-difference regression (2) in decomposing the growth rate of real output. Industries are again divided into ICT-intensive and ICT-extensive sectors as above. The basic diff-in-diff regression is augmented by terms to capture the growth rates of input in terms of labor, capital, and intermediate products.

[Table 3 about here]

The magnitude of the post-1995 productivity slowdown in ICT-extensive sectors reduces to approximately .6 percentage points (the coefficient of d) as compared to the fall of about one percentage point in the rate of growth of labor productivity. As for the case of labor productivity, we find no significant pre-1995 differences in TFP growth between ICT-intensive and ICT-extensive industries (the coefficient of it). The ICT-intensive sectors significantly outperform the remaining 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. The negative overall TFP trend break is now completely counterweighted by the positive interaction term.

We address the robustness of our main TFP results 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 reduced compared to the results on labor productivity. Second, Table 3 shows that the total factor productivity differential does not depend on the presence of ICT-producing industries nor on developments in the FIRE industries. Significant effects remain when excluding each of these sectors.

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 intensive ICT-producers *as well as* for users.

7 Alternative ICT intensity measures

In this section we address the robustness of our main results in further dimensions related to the measurement of ICT intensity. First, instead of the binary classification of ICT intensity in relation to the median industry intensity we will now include the underlying measurements directly in order to more fully utilize the information in this variable. Second, we apply several different possible measurements of ICT intensity.

[Table 4 about here]

Table 4 shows the results of including each of three different measurements of ICT intensity in a continuous fashion in the diff-in-diff regressions for labor productivity and TFP, respectively.

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.[8]

8 Conclusion

Similar to Stiroh (2002), we find that sectors which are relatively ICT-intensive pre-1995 outperform remaining sectors post-1995 in terms of labour productivity. 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.

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

[8] Note that the estimates of the coefficient of the interaction term, $d \times it_{cont}$ are not directly comparable across measurements or with the main results based on the binary measure due to differences in the normalizations of these variables.

than capital deepening. Third, we find economically sizable and statistically significant TFP gains for intensive ICT-producers *as well as* for users.

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Table 3: Total factor productivity: Panel results

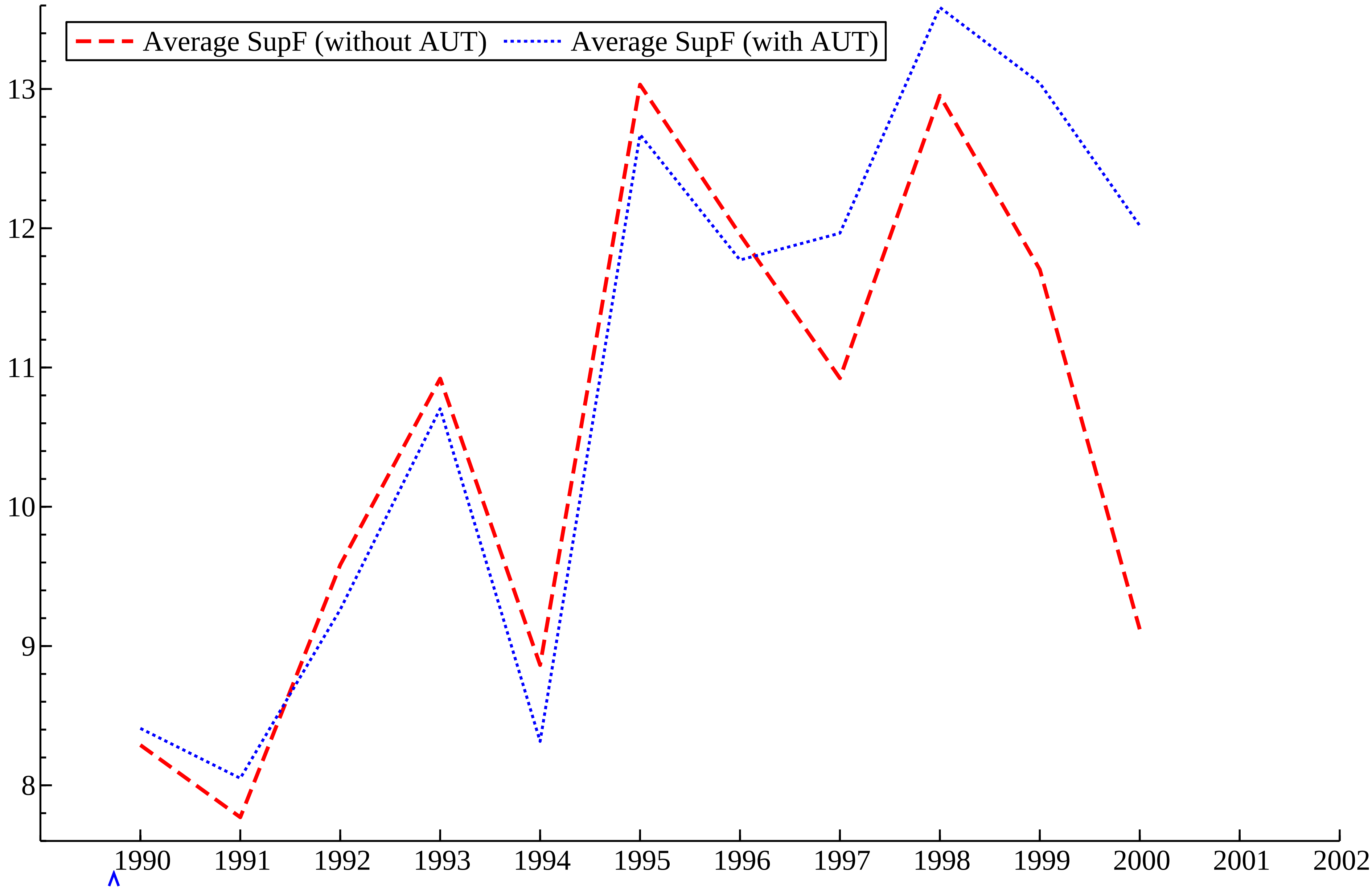
	All industries				W/o ICT prod.	W/o FIRE
	Pooled	FE Country	FE Industry	FE General	FE General	FE General
DlnY(-1)	0.118***	0.114***	0.098***	0.061**	0.035	0.054*
	(0.035)	(0.034)	(0.032)	(0.028)	(0.027)	(0.028)
d	-0.653***	-0.644***	-0.677***	-0.623***	-0.643***	-0.622***
	(0.139)	(0.135)	(0.142)	(0.145)	(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)
DlnX	0.360***	0.359***	0.353***	0.351***	0.370***	0.360***
	(0.080)	(0.080)	(0.080)	(0.081)	(0.099)	(0.086)
DlnL	0.180***	0.181***	0.203***	0.210***	0.208***	0.210***
	(0.048)	(0.049)	(0.052)	(0.054)	(0.064)	(0.056)
DlnK	0.026	0.031	0.028	0.051**	0.053**	0.056**
	(0.022)	(0.022)	(0.022)	(0.025)	(0.026)	(0.025)

'*','**', '***': Significant at the 10, 5, or 1 percent level, respectively.

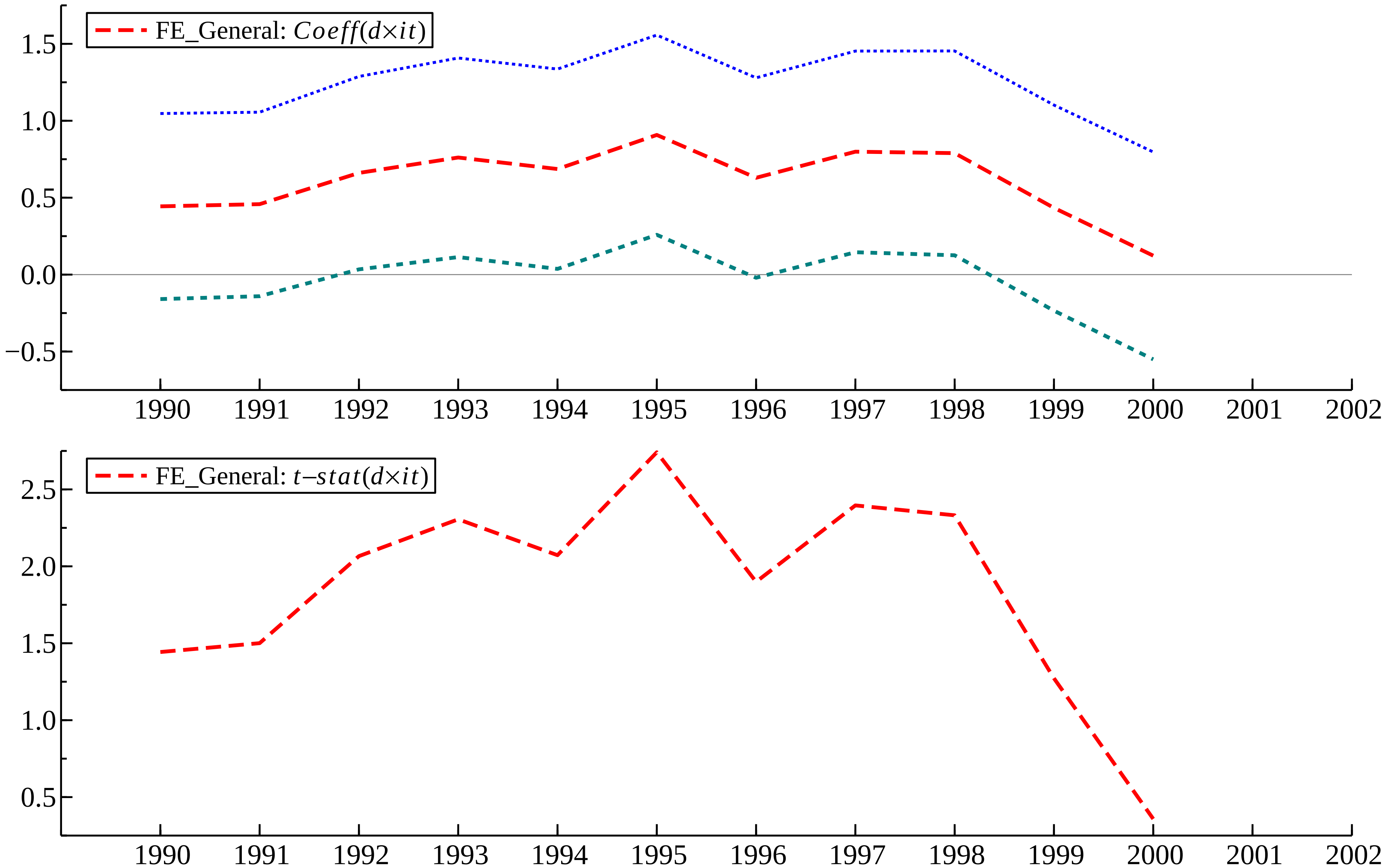
Table 4: Continuous measures of ICT intensity: Labor productivity and TFP, panel results

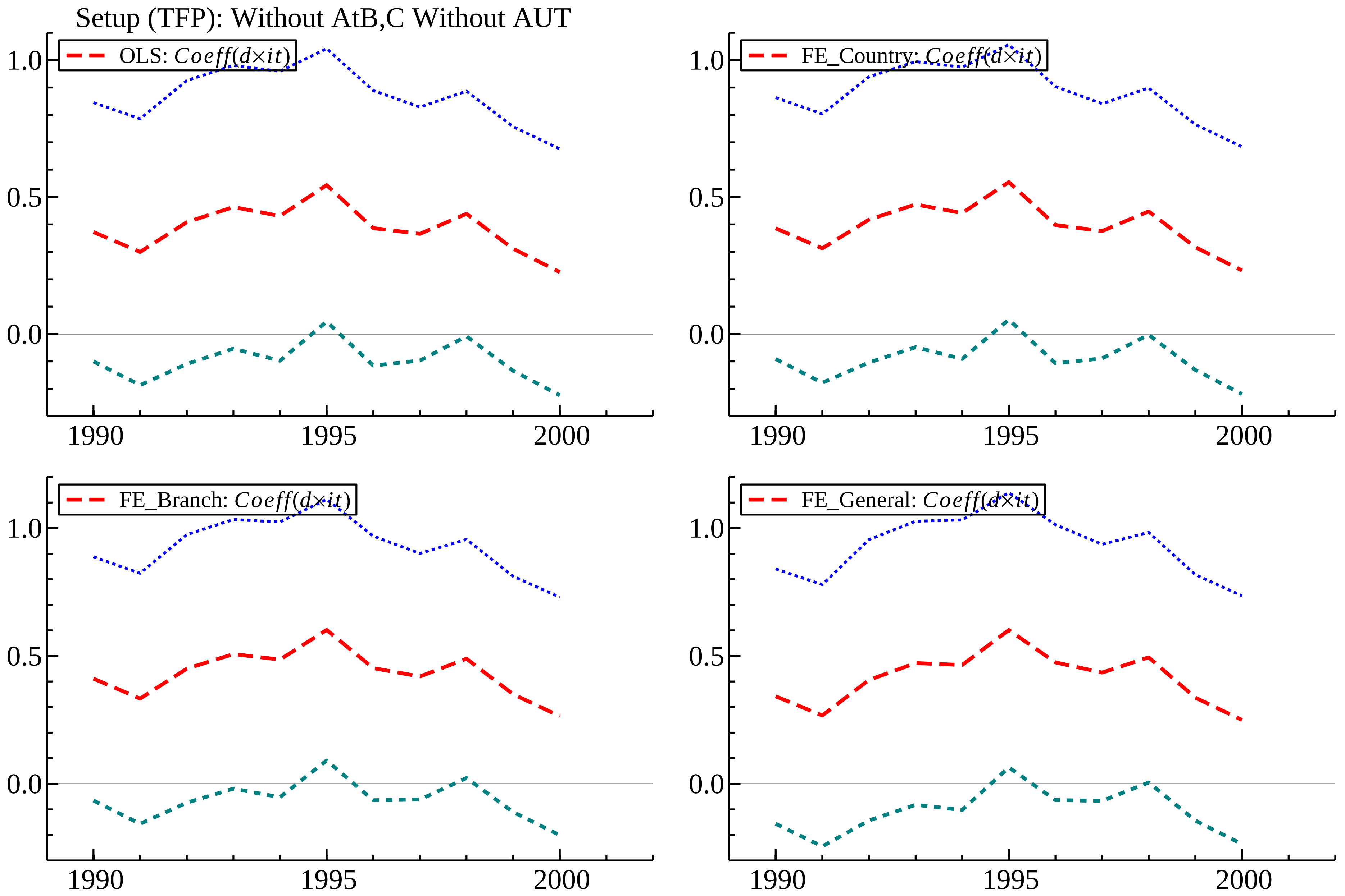
	Labor productivity			Total factor productivity		
	Standard	Altern. 1	Altern. 2	Standard	Altern. 1	Altern. 2
ΔA_{-1}	0.054	0.049	0.051	—	—	—
	(0.035)	(0.034)	(0.035)			
y_{-1}	—	—	—	0.061**	0.060**	0.061**
				(0.028)	(0.028)	(0.028)
d	-0.596***	-0.598***	-0.597***	-0.314***	-0.316***	-0.317***
	(0.159)	(0.147)	(0.154)	(0.113)	(0.110)	(0.112)
it_{cont}	—	—	—	—	—	—
$d \times it_{cont}$	0.622**	0.983***	0.794***	0.288***	0.402***	0.338***
	(0.225)	(0.242)	(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)

'*','**', '***': Significant at the 10, 5, or 1 percent level, respectively.


Average SupF (without AUT)
Average SupF (with AUT)
13
12
11
10
9
8
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

Case 4: Baseline model without AtB, and C and without AUT.




Setup (TFP): Without AtB,C Without AUT
OLS: Coeff(d×it)
FE_Country: Coeff(d×it)
FE_Branch: Coeff(d×it)
FE_General: Coeff(d×it)
1.0
0.5
0.0
1990
1995
2000