Estimation and Decomposition of Total Factor Productivity Growth in the EU Manufacturing Sector: a Stochastic Frontier Approach

by

Marco Fioramanti
ISAE, piazza dell'Indipendenza, 4, 00185 Roma, Italia
e-mail: m.fioramanti@isae.it

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ISAE - Piazza dell’Indipendenza, 4 - 00185 Roma.
Tel. +39-06444821; www.isae.it

ABSTRACT

In this paper the Stochastic Frontier approach was used for the estimation and decomposition of manufacturing TFP growth in 14 EU member countries, drawing upon the EU-KLEMS database. This study identifies some key issues: in the period 1970-2005, the TFP rate of change in the EU manufacturing sector constantly decreased, mainly due to the reduction in technical efficiency and, to a lesser extent, to the decline in the rate of growth of input factors and allocative efficiency. In the same period, the sector recorded considerable technical progress, which, nonetheless, did not offset the negative forces which pulled the EU TFP growth down, especially in the last decade of the sample period.

Keywords*:* Stochastic frontier; Total Factor Productivity; Technical efficiency; Technical change; Allocative efficiency.

JEL classification: D24; O47; C33.

NON-TECHNICAL SUMMARY

Lo scopo di qesto lavoro è quello di stimare e scomporre, nelle sue 4 componenti, la produttività totale dei fattori (PTF) nel settore manifatturiero in 14 paesi dell'Unione europea, utilizzando i dati del database EU-KLEMS. I risultati principali del lavoro sono: nel periodo 1970-2005 la PTF nella manifattura ha mostrato un decelerazione costante dovuta principalmente alla riduzione di efficienza tecnica e, in misura più limitata, al minore crescita nell'utilizzo dei fattori produttivi e alla efficienza allocativa. Nello stesso periodo la manifattura ha fatto registrare un consistente progresso tecnico, tuttavia non sufficiente a compensare le forze negative che hanno provocato il rallentamento della PTF, in particolar modo nell'ultima decade del periodo considerato.

CONTENTS

1 INTRODUCTION [1]

After a prolonged period of catching-up, which started after the Second World War (WWII) and lasted until the mid-'90s, EU member countries experienced an anaemic rate of economic expansion, particularly compared to the United States. In the latter country, GDP growth accelerated in both absolute and per-capita terms at a time when EU countries started to show a slowdown. Plenty of studies confirm that the different economic growth rates recorded in these areas stem from the gap in the production and adoption of ICT related technology, and in the amount of R&D and human capital investments, which directly affect labour and total factor productivity (TFP).

In recent years, the issue of low EU countries' productivity gained wide attention among both academic and national and international institutions. In 2000, the European Council adopted the Lisbon Strategy, recognizing the central role of knowledge, information technologies and R&D in enhancing productivity, but the ambitious goals highlighted therein are far from being achieved.

According to Havik *et al.* (2008) two different views distinguish the EU slowdown: the optimistic view and the pessimistic one. The "optimistic view" belongs to Blanchard (2004), according to whom differences in productivity growth between the EU and the US are not so wide if one considers the higher preference for leisure which characterizes the EU and the possible lag between the adoption in Europe of the latest market reforms and their effect on future economic growth. The "pessimistic view", supported by the Sapir report[2] and by Aghion and Howitt (2006), suggests that the EU might be unable to boost its growth rate because its institutions are not suitable for promoting a shift of resources towards sectors with high productivity growth prospects. Aghion and Howitt (2006) point out that economic growth depends on either innovation or imitation. In the former case, growth relies on the resources devoted to innovation (i.e. R&D and human capital) and on the stock of existing knowledge (knowledge spillovers), while in the latter one it depends on the adoption/diffusion of state-of-the-art technologies. Countries that are close to the technology frontier will grow mainly thanks to the introduction of new technologies which imply an upward shift of the frontier, whilst follower countries

[1] I am grateful to Luigi Benfratello, Luigi Giamboni, and Carlo Milana for the very useful comments and suggestions. The remaining errors are the author's sole responsibility.

[2] Sapir report (2003).

will derive the largest share of their TFP growth from the adoption of better, but already existing, technologies which are available at the frontier.

In this "Schumpeterian" world, institutions and policies play a key role in determining the relative position of countries in the global innovation race. The authors conclude, with the support of empirical evidence,[3] that while EU institutions were supportive in the post-WWII process of adoption/diffusion of technologies at the frontier, from the mid-'90 onwards they were unable to revitalize EU growth through innovation favouring policies. Havik *et al.* (2008) reach the same conclusion and suggest, for stimulating TFP and growth in the EU, the adoption of policies which favour competition, education, and R&D.[4]

In comparing the labour productivity trend in the EU and the US, van Ark *et al*. (2008) show that in the US the emergence of the knowledge economy and the acceleration of TFP played a key role in economic growth, especially in the market services sector. In Europe, instead, lower investment in ICT, smaller share of ICT producing industries, tighter regulations[5], and slower TFP growth contributed to the anaemic dynamics of the overall economy.

The aim of this paper is to analyze TFP growth and its components in the manufacturing sector of 14 out of the 15 European countries that founded and joined the EU in the earlier period, using the Stochastic Frontier Production Function approach (SFA). This method allows obtaining TFP growth as the sum of four components: technical change, technical efficiency change, scale and allocative efficiency. In particular, the first component is a measure of innovation (shift of the frontier) while the second a measure of imitation (movement towards the frontier).

Besides SFA, which is a parametric method, two other non-parametric methods are widely used in estimating TFP: the Growth Accounting (GA) techniques and the Data Envelopment Analysis (DEA). The advantage of SFA is that it allows for the presence of idiosyncratic shocks and can be used to investigate the determinants of technical (in)efficiency and, therefore, those of TFP. In particular, SFA is suitable for the analysis of TFP in the Aghion and Howitt (2006) framework. The drawback is that a specific functional form has to be specified and the efficient production frontier is the same for all the decision units.

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[3] Evidences came principally from Aghion *et al.* (2004).

[4] The same policy conclusions were reached by Nicoletti and Scarpetta (2003) and Aghion *et al.* (2005), but with only partial results. While the former stated that TFP is driven by the imitation process, the latter considered innovation as the main force.

[5] On the role of regulation in slowing down TFP, see Nicoletti and Scarpetta (2003).

In this paper, the classical SFA approach was firstly used to estimate technical (in)efficiency. Successively, estimation results were utilized to calculate the trend of TFP and of its components: technical change, technical efficiency change, scale and allocative efficiency. Moreover, relying upon the EU-KLEMS database guaranteed data homogeneity, particularly with respect to capital contribution, and hence comparability of the results.

The SFA method, which was developed by Aigner, Lovell, and Schmidt (1977) and Meeusen and van der Broeck (1977), was principally adopted for the analysis of micro-level data, but more recently it was used at a higher level of aggregation. For example, Sharma *et al.* (2007) utilized SFA for decomposing TFP growth in United States; Wu (2000) used it to examine Chinese regions; Gumbau-Albert (1998, 2000) used SFA to explain inefficiency and convergence in the Spanish regions; Osiewalski *et al.* (2000) analysed the TFP growth gap between Poland and Western countries using Bayesian SFA.

Some key findings emerged from our analysis: in the period 1970-2005, the TFP rate of change in the EU manufacturing sector constantly decreased, mainly due to the reduction in technical efficiency and, to a lesser extent, to the decline in the rate of growth of input factors and allocative efficiency. In the same period, the sector recorded considerable technical progress, which, nonetheless, did not offset the negative forces which pulled the EU TFP growth down, especially in the last decade of the sample period.

The rest of the papaer is organized as follows: Section 2 briefly reviews the specific econometric theory behind the SFA model used in our analysis; Section 3 describes the EU-KLEMS database; Section 4 contains estimation and test results; Section 5 shows the decomposition of the trend in TFP; lastly, Section 6 presents the conclusions.

2 STOCHASTIC FRONTIER APPROACH

Following Battese and Coelli (1992), we considered a stochastic frontier production function with an exponential specification of time-varying country effect for an unbalanced panel of EU members. The general specification is:

$$Y_{it} = f(x_{it};\beta)\exp(V_{it} - U_{it}) \qquad (1)$$

where Y_{it} is the output of country *i* at time *t*, x_{it} are factor inputs, β is the vector of parameters to be estimated, and V_{it} is an *i.i.d.* random error such that $V_{it} \sim N(0,\sigma_V^2)$. The idea behind SFA is that firms/industries/sectors are not fully efficient and, given the level of technology, there is always a waste of resources in the production process. This inefficiency is captured by U_{it} which is modelled according to the following:

$$U_{it} = \eta_{it} \cdot U_i = \left\{\exp\left[-\eta \cdot \left(t - T\right)\right]\right\} \cdot U_i \qquad (2)$$

where U_i is assumed to be an independent and identically distributed non-negative truncation of $N(\mu,\sigma^2)$. Given (1) and (2), technical efficiency, $TE_{it} = \exp(-U_{it})$, increases at a decreasing rate if $\eta>0$, decreases at an increasing rate if $\eta<0$, or remains constant if $\eta=0$; in the latter case the model comes down to a time-invariant specification.

For estimation purposes we chose a Cobb-Douglas specification of the production function:

$$\ln Y_{it} = \beta_0 + \beta_t \cdot t + \beta_K \cdot \ln K_{it} + \beta_L \cdot \ln L_{it} + V_{it} - U_{it} \qquad (3)$$

where *t* is a time trend which captures the Hicks-neutral technical change.

We decided not to use a translog specification because of the multicollinearity problem that arises in the Battese and Coelli (1992) specification. In the Battese and Coelli (1995) specification, this problem was less severe but, given the lack of long time series needed to incorporate a model for the TE effect, we preferred to use a less flexible time-varying specification in order to analyse the full sample period covered in the EU-KLEMS database. As will be shown later on, the cost of this choice is that the changes in TE for a single country are restricted to be monotonic and are smoothed through the sample period. A further drawback of the Battese and Coelli (1992) model is that it does not allow for changes in rank efficiency ordering over time: the n-th ranked country at time t_0 will remain n-th ranked until *T*.

3 THE EU-KLEMS DATABASE

In the estimation and decomposition of TFP the EU-KLEMS database was used.[6] The database is the result of a research project performed by a consortium of 14 European institutions, funded by the European Commission. Its aim was to "create a database on measures of economic growth, productivity, employment creation, capital formation and technological change at the industry level for all European Union member states from 1970 onwards. This work will provide an important input to policy evaluation, in particular for the assessment of the goals concerning competitiveness and economic growth potential as established by the Lisbon and Barcelona summit goals. The database should facilitate the sustainable production of high quality statistics using the methodologies of national accounts and input-output analysis".[7] The database contains observations on output (Gross Output and Value Added) and input (capital – decomposed into ICT and non-ICT related capital – , labour – decomposed into high-, medium- and low-skilled labour –, energy, materials, and services) for 27 EU member countries, plus the US and Japan, for the period 1970-2005. Data are disaggregated at NACE Rev. 1 classification level. A further advantage of the EU-KLEMS database, with respect to using data from different sources, relies on the fact that a single method of estimation of capital services is used.

Since the database is far from being complete[8], we concentrated our attention on 14 out of the 15 older EU member countries[9]. In addition EU countries operate in the same environmental set-up because of the common regulatory regime. We focused on the manufacturing sector because: *i)* it is more complete with regard to data availability; *ii)* it is a market goods producing sector, thus sharing the same technology in all countries. All these elements should prevent the common production frontier hypothesis from being too binding.

We used value added, capital and labour quantity indices, along with a time trend variable, which is a proxy for technological change, to estimate a standard Cobb-Douglas stochastic frontier production function with time-varying technical efficiency (equation (2) and (3)), according to Battese and Coelli (1992).

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6 March 2008 release.

7 www.euklems.net.

8 The panel is strongly unbalanced.

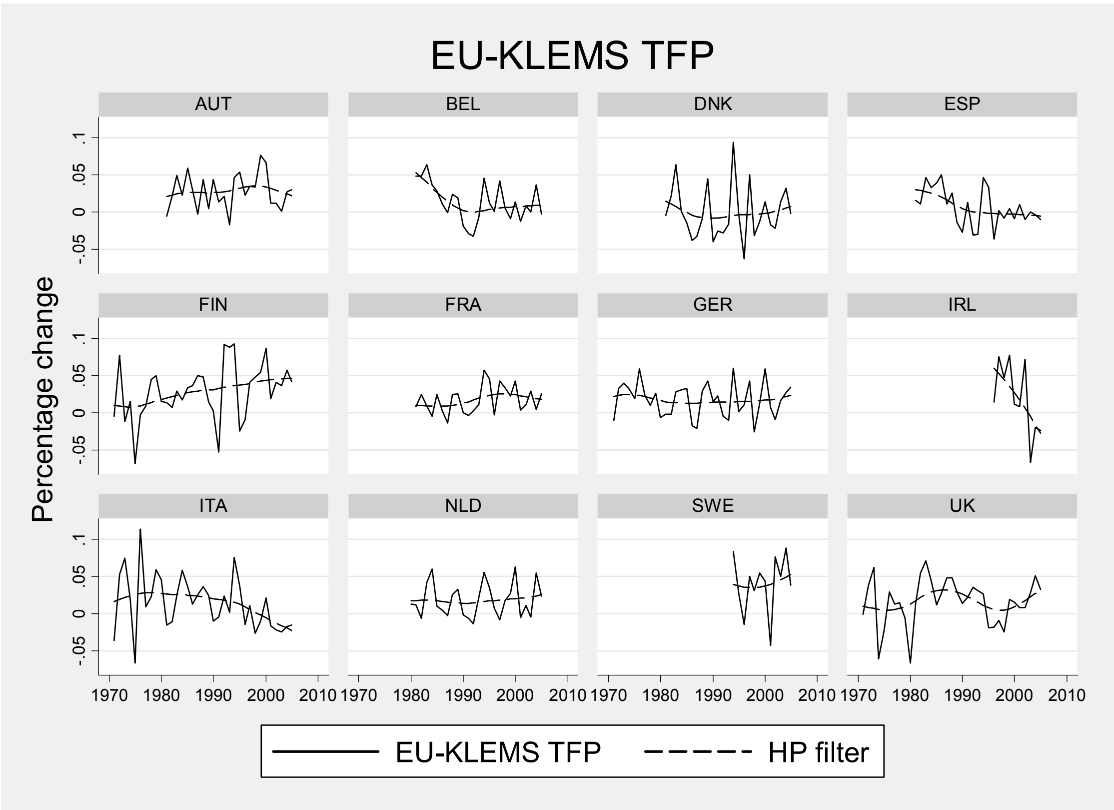
9 Greece was not included because of lack of data.

The database also contains TFP estimates obtained using growth accounting techniques. Figure 1 shows the TFP dynamics in the manufacturing sector according to this technique, along with the trend obtained using the Hodrick-Prescott filter.[10] The original series is very erratic, but some evidence comes from the trend. A clear negative path emerged from Spain, Italy and Ireland during the entire period. In Belgium and Denmark, after a sharp deceleration during the '80s, TFP growth stabilised around 0. Finland was the only country which showed an increasing growth path during the entire sample period, while the trend in the

Table 1 Sample period

	T_0	T
Austria	1980	2005
Belgium	1980	2005
Denmark	1980	2005
Spain	1980	2005
Finland	1970	2005
France	1980	2005
Germany	1970	2005
Ireland	1988	2005
Italy	1970	2005
Luxembourg	1992	2005
Netherlands	1979	2005
Portugal	1992	2005
Sweden	1993	2005
United Kingdom	1970	2005

Figure 1



[10] We did not report the figures for Luxembourg and Portugal in order to display the other countries' dynamics more clearly. The additional graphs are available from the author upon request.

UK recorded oscillating movements. The other countries did not show any significant change in the underlying long-run dynamics of TFP. Results of filtering have to be interpreted with caution because the symmetric nature of this filter does not produce a very reliable description of the trend towards the extremes of the sample period.

4 ESTIMATION AND TEST RESULTS

Estimations are carried out using the maximum likelihood method. One of the main problems with stochastic frontiers is that, given the high non-linearity of the log likelihood function, the optimization process can converge to a local maximum. In order to make sure that parameters represent the *argmax* of the likelihood function, we used different starting values.[11] A further check was the adoption of a different software, which uses a different searching method and optimization algorithm.[12] Almost every time, the best results, in terms of likelihood, were obtained using OLS parameters as starting values, and the alternative software confirmed the results obtained with the main one. Just in few and particular cases the model did not converge at all.

Table 2 shows estimation results for different stochastic frontier production function models, while Table 3 reports tests of hypotheses of different models compared to the base model.[13] The specifications of the various models are the following:

Model 0: Eq (3) and $U_i \overset{iid}{\sim} N^+(\mu, \sigma_\mu^2)$, Truncated Normal (Base model)

Model 1: $\beta_t = 0$, No Technical Progress

Model 2: $\beta_K + \beta_L = 1$, Constant Return to Scale

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[11] OLS, pooled frontiers and the parameters obtained in models M0 to M6 as a starting value in a different model.

[12] In particular, we used Frontier 4.1 to check the results.

[13] Estimations and tests were performed using Stata10. The maximum likelihood estimator of stochastic frontier in Stata was implemented in terms of the inverse logistic of gamma. We reported in the table both the latter value and the value for gamma, where $\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$. γ is bounded between 0 and 1. If *γ=0* there is no inefficiency and we can estimate the production function. If *γ=1* all the variation is due to inefficiency and we must use the stochastic frontier.

Model 3: $\mu = 0$, Half Normal

Model 4: $\beta_K + \beta_L = 1 \text{ and } \mu = 0$, Constant Return to Scale and Half Normal

Model 5: $\eta = 0$, Time Invariant Efficiency

Model 6: $\gamma = \eta = \mu = 0$, No inefficiency

Table 2 **Parameter estimates**

	M0	M1	M2	M3	M4	M5	M6
β_K	0.2720***	0.3323***	0.2297***	0.3238***	0.2863***	0.3533***	0.4145***
β_L	0.9093***	0.8741***	0.7703***	0.8596***	0.7137***	0.8164***	0.7137***
β_t	0.0256***		0.0260***	0.0138***	0.0144***	0.0165***	0.0147***
Constant	-1.1436***	-0.0811	-0.6180***	-1.1614***	-0.3327***	-1.1675***	-0.9800***
μ	-0.3288	0.7267	-0.0892			-0.1222	
η	-0.1650***	0.0178**	-0.1572***	0.0479***	0.0519***		
inv.lgt(γ)	2.5878	-2.0813***	2.082	-2.0362**	-2.4604***	0.0334	
γ	0.9301	0.1109	0.8891	0.1155	0.0787	0.5083	
N.obs.	360	360	360	360	360	360	360
log-likelihood	334.72	311.94	329.27	321.74	317.88	309.46	289.48
χ^2	1862.53 (0.0000)	369.03 (0.0000)	2339.41 (0.0000)	725.42 (0.0000)	738.38 (0.0000)	1675.72 (0.0000)	1659.53 (0.0000)

* p<0.05, ** p<0.01, *** p<0.001

In the base model (**M0)** the production function exhibits increasing returns to scale (1.1813), with a robust LR test (Table 3 - Test 3). The yearly growth rate for technical progress is 2.56% and is highly significant (Test 2). Model **M3** and the corresponding LR test (Test 4) show that the greater flexibility of the Truncated-Normal *versus* the half normal specification of inefficiency is worthwhile, and this is also true for the model which incorporates both the CRS and the half normal hypothesis (Test 5). The further hypothesis of time-invariant technical inefficiency (**M5**) against a time-varying one is rejected, favouring the latter specification for efficiency (Test 6). The negative value of *η* in the base model (-0.1650), which is also known as *technological catch-up rate*,[14] implies that technical efficiency decreases over time at an increasing rate; i.e. it shows a negative technological catch-up. With respect to this parameter, the last and most important test (Test 7) checks if the EU manufacturing sector is fully efficient, so that all countries are at the production frontier and the OLS techniques can be used to estimate the (unique) production function. The null hypothesis is strongly rejected in favour of the stochastic frontier production

[14] Kumbhakar and Wang (2005).

function paradigm.[15] This conclusion is also supported by the high value of γ in **M0**. Since all tests favour model **M0**, this model was chosen for all further analyses.

Table 3 **LR tests**

	H0	D.F.	LR-TEST
Test 1	$\beta_K = \beta_L = \beta_t = 0$	3	309.48 (0.0000)
Test 2	$\beta_t = 0$	1	45.56 (0.0000)
Test 3	CRS $(\beta_K + \beta_L = 1)$	1	10.89 (0.0010)
Test 4	$\mu = 0$	1	25.97 (0.0000)
Test 5	CRS & $\mu = 0$	2	33.68 (0.0000)
Test 6	ti vs tvd	1	50.52 (0.0000)
Test 7	No inefficiency $\mu = \gamma = \eta = 0$	3	90.48 (*) (0.0000)

(*) Mixed χ^2 distribution.

To check for parameters' stability a by country jack-knife estimate over the full sample was performed. Figures A1 and A2 in the appendix show the differences between the coefficients of the base model (**M0**) and those obtained leaving, at each step, one country out of the estimation (the one showed near the marker). The average difference, in percentage, is: 0.67% for capital; 0.10% for labour; -0.14% for the trend; 0.31% for η. In conclusion, parameters can be considered quite stable with respect to country exclusion.

Figure 2 shows the dynamics of Technical Efficiency (TE) for 12 out of 14 EU countries.[16] It is possible to divide the countries in four groups according to the size of the TE reduction: from 1970 to 2005, Italy, Spain, and Denmark recorded a reduction in the TE greater than 3 tenths of a point; UK registered a reduction between 2 and 3 tenths; for Belgium, Germany, and the Netherlands the TE declined by 1 to 2 tenths; Austria, Finland, France, Ireland, and Sweden showed a decrease in the TE of less than one tenth of a point.

[15] In this special case, the LR test was performed according to Kodde and Palm (1986), because of the mixed χ^2 distribution of the test.

[16] See note 11.

Figure 2

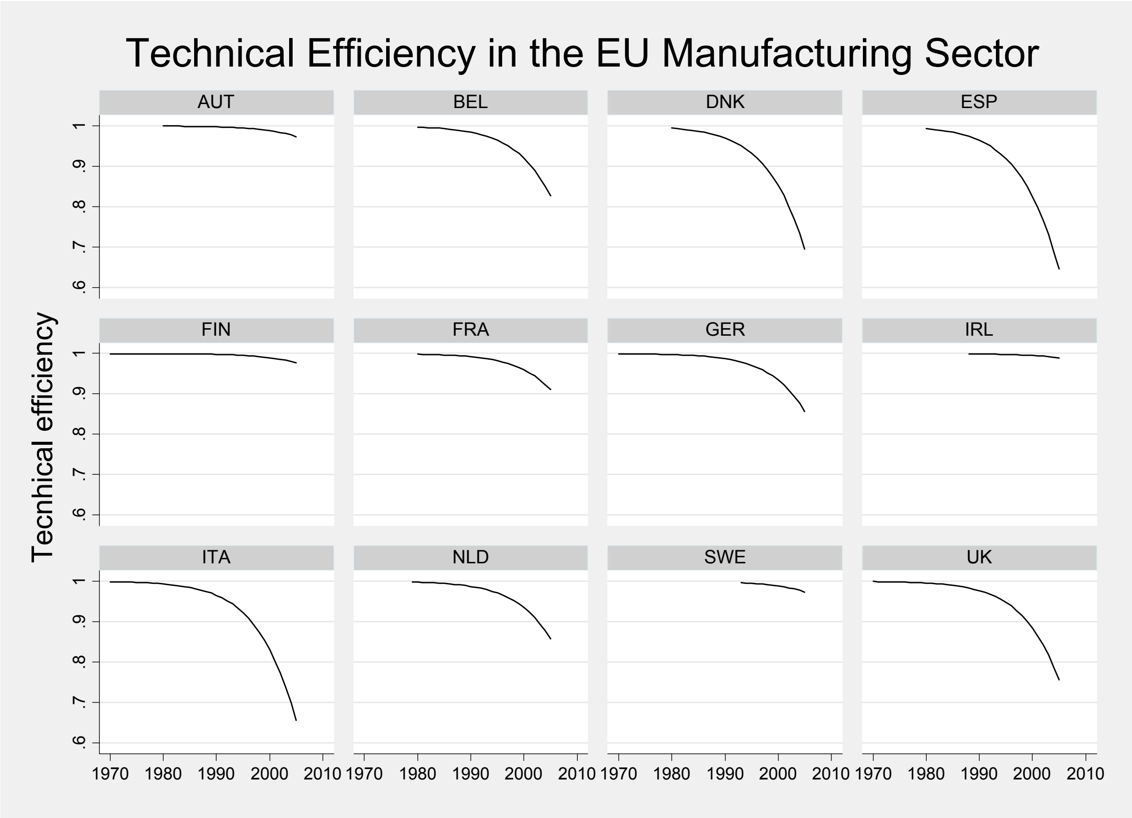


Table 4 reports estimation results for two sub-periods: the period of relatively fast growth and the period of a slowdown in EU productivity. Estimations do not seem to lead to very satisfactory results, in particular because of strong decreasing returns to scale and parameter instability.[17] This can be the consequence of the small size of the sub-samples. Anyway, two facts are worth noting wich are consistent with the Aghion-Howitt view: *i)* the rate of technical change

Table 4 Parameter estimates in sub-samples

	1970-'95	1995-'05
β_K	0.0747	0.3319**
β_L	0.6483***	0.3537*
β_t	0.0145***	0.0489***
Constant	0.9741**	0.2600
μ	0.1030***	0.4315***
η	0.0505***	-0.1402***
inv.lgt(γ)	-0.4125*	3.2470***
γ	0.6017	0.9626
N.obs.	206	154
log-likelihood	298.42	242.86
χ^2	120.62 (0.0000)	1317.21 (0.0000)

* p<0.05, ** p<0.01, *** p<0.001.

[17] Also in these cases we used a by country jack-knife estimates. Figures A3 to A6 show the results. The percentage difference between the base model and the jack-knife averages for the 1970-1995 sub-sample is: 96.33% for capital; -0.08% for labour; -19.72% for the trend; -13.46% for η. For the 1995-2005 sub-sample: 3.17% for capital; -0.96% for labour; 2.08% for the trend; -1.56% for η.

in the 1970-'95 period (1.45%) was more than three time lower than the rate in the 1995-'05 one (4.89%); *ii)* technical efficiency showed a decreasing pattern in the latter period ($\eta = -0.14$), but an increasing pattern in the former one ($\eta = 0.05$). These results seem to be consistent with the interpretation that in the former period the EU countries' manufacturing sector grew principally through technological catching-up, i.e. moving production towards the frontier, and, to a lesser extent, via innovation. In the latter period, the manufacturing sector's growth was determined by technical change, i.e. by the upward shift in the frontier production function, in parallel with a reduction in efficiency. This is probably due to the fact that, in periods of deep changes, it is more difficult to manage all inputs in an efficient way.

5 TFP GROWTH DECOMPOSITION

According to Kumbhakar and Lovell (2000), in the primal approach, when price information is available, total factor productivity changes can be split in 4 components:

$$\dot{TFP} = \overbrace{\Delta T}^{\text{Technical change}} + \overbrace{(\varepsilon - 1) \cdot \sum_h \left(\frac{\varepsilon_h}{\varepsilon} \right) \cdot \dot{x}_h}^{\text{Scale component}} + \overbrace{\Delta TE}^{\text{Technical efficiency change}} + \overbrace{\sum_h \left[\left(\frac{\varepsilon_h}{\varepsilon} \right) - s_h \right] \cdot \dot{x}_h}^{\text{Allocative inefficiency}} \quad (4)$$

The first component of the above equation is technical change, which captures the upward shift in the production function. The second term is the scale component, which accounts for TFP changes due to variations in the scale of operations. If the production function exhibits constant returns to scale ($\varepsilon = 1$) and this term disappears. The technical efficiency change, or technological catch-up, measures the changes in TFP as a consequence of a movement towards the production function. The last term of (4) is allocative inefficiency. It measures the deviation of each input share cost s_h from its elasticity ε_h, or, to put it differently, the deviation of each input marginal productivity from output normalized cost. In an allocative efficient sector $\left(\frac{\varepsilon_h}{\varepsilon} \right) = s_h$, so that this component disappears.

In our simple Cobb-Douglas production function specification, once the model **M0** has been estimated, the calculation of the four components is straightforward:

$$\Delta T = \beta_t$$

$$(\varepsilon - 1)\cdot \sum_h \left(\frac{\varepsilon_h}{\varepsilon}\right)\cdot \dot{x}_h = \left[(\beta_K + \beta_L) - 1\right]\cdot \left[\left(\frac{\beta_K}{\beta_K + \beta_L}\right)\cdot \Delta \ln K + \left(\frac{\beta_L}{\beta_K + \beta_L}\right)\cdot \Delta \ln L\right]$$

$$\Delta TE = u_i \cdot \eta \cdot \exp\left\{-\eta\left(t - T\right)\right\} = \eta \cdot u_{it}$$

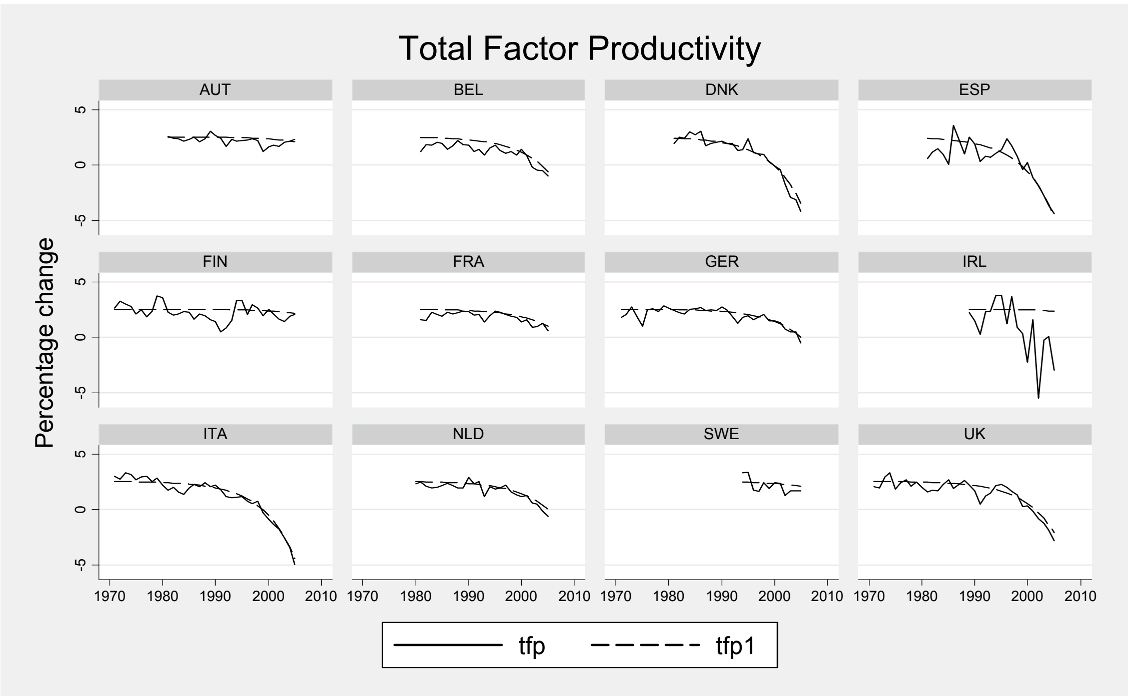
$$\sum_h \left[\left(\frac{\varepsilon_h}{\varepsilon}\right) - s_h\right]\cdot \dot{x}_h = \left[\left(\frac{\varepsilon_K}{\varepsilon}\right) - \left(\frac{\dfrac{\omega_{Kt}\cdot K_t}{\omega_{Kt}\cdot K_t + \omega_{Lt}\cdot L_t} + \dfrac{\omega_{Kt-1}\cdot K_{t-1}}{\omega_{Kt-1}\cdot K_{t-1} + \omega_{Lt-1}\cdot L_{t-1}}}{2}\right)\right]\cdot \Delta \ln K +$$

$$+\left[\left(\frac{\varepsilon_L}{\varepsilon}\right) - \left(\frac{\dfrac{\omega_{Lt}\cdot L_t}{\omega_{Kt}\cdot K_t + \omega_{Lt}\cdot L_t} + \dfrac{\omega_{Lt-1}\cdot L_{t-1}}{\omega_{Kt-1}\cdot K_{t-1} + \omega_{Lt-1}\cdot L_{t-1}}}{2}\right)\right]\cdot \Delta \ln L$$

were ω_{it} is the price of factor *i* at time *t*.

Figure 3 shows the dynamics of total factor productivity according to (4) with (tfp) and without both allocative efficiency and scale components (tfp1).

Figure 3



Since $\eta < 0$ we observe a negative and increasing catch-up rate, and hence a reduction in TFP growth. Without the two above mentioned components the decreasing path of the TFP rate of change appears quite smooth. Looking deeper inside the scale component (Figure 4) we can see that during the period of observation the capital growth rate is positive almost always and for each country, while we observe, on average, a negative growth rate for labour utilization, indicating a capital/labour substitution in the manufacturing sector during the four decades. The allocative efficiency component is negative almost always and for each country.

Figure 4

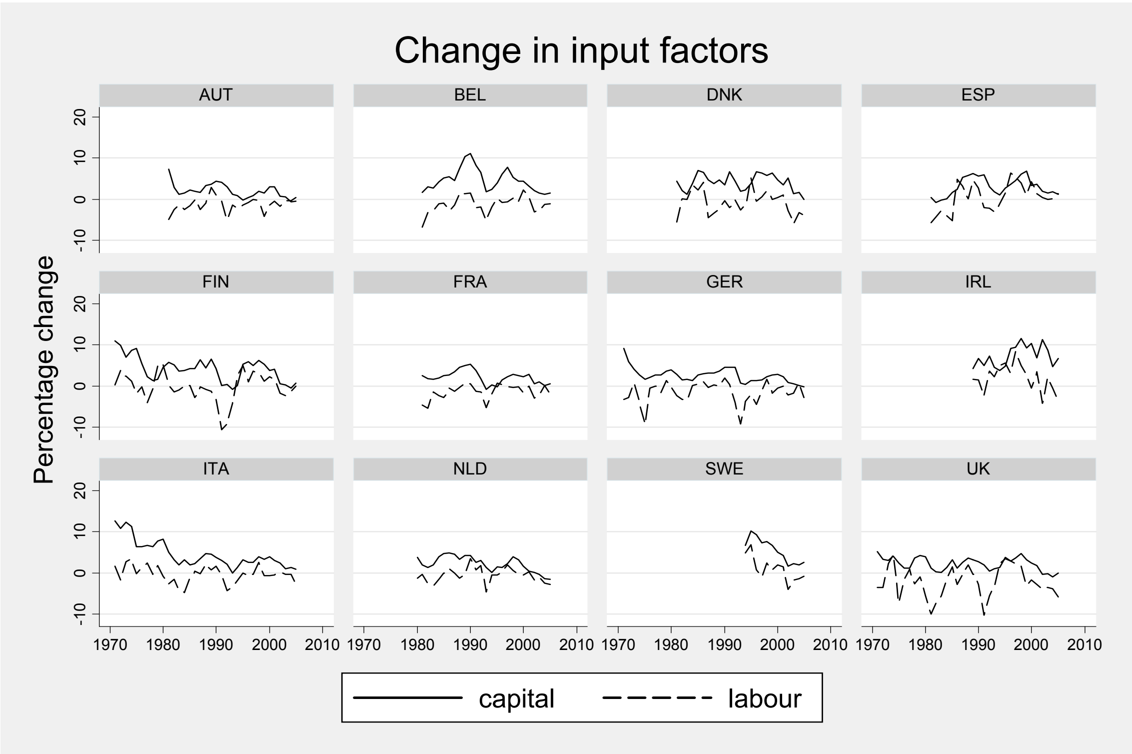


Table 5 reports average TFP growth and its components for the 14 countries ranked in decreasing order. For Finland, Austria, Sweden, and Ireland, allocative efficiency is the main negative component of TFP growth, while technical (in)efficiency change is the most important for the remaining countries. The scale component is negative just for 4 countries, i.e. Austria, Germany, France, and the UK. In no country, on average, TFP growth is greater than technical change.

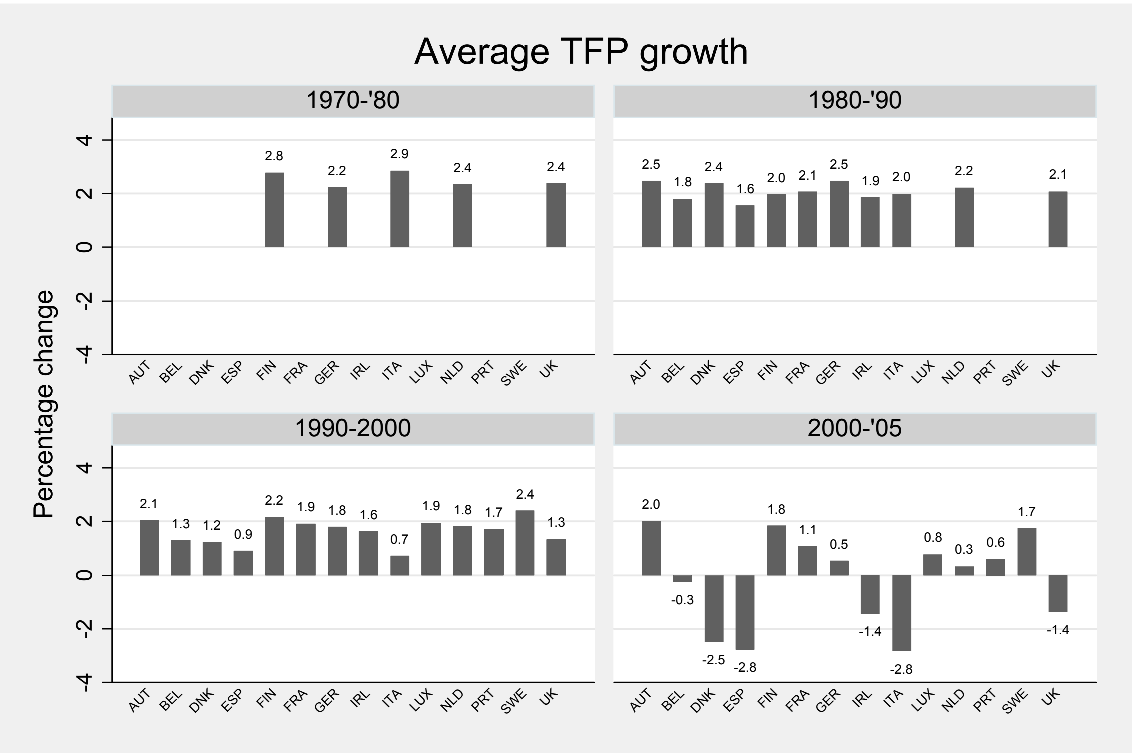
Table 5 **TFP growth ranking and components**

	Rank	TFP growth	Tech. change	Scale component	Tech. efficiency change	Allocative efficiency
FIN	1	2.24%	2.56	0.15	-0.07	-0.40
AUT	2	2.22%	2.56	-0.09	-0.11	-0.14
SWE	3	2.13%	2.56	0.35	-0.20	-0.57
GER	4	1.93%	2.56	-0.11	-0.47	-0.04
FRA	5	1.81%	2.56	-0.10	-0.39	-0.24
NLD	6	1.71%	2.56	0.01	-0.61	-0.23
LUX	7	1.50%	2.56	0.07	-0.89	-0.19
UK	8	1.46%	2.56	-0.21	-0.85	-0.02
PRT	9	1.29%	2.56	0.01	-0.86	-0.38
ITA	10	1.19%	2.56	0.14	-1.27	-0.20
BEL	11	1.19%	2.56	0.01	-0.79	-0.57
DNK	12	0.94%	2.56	0.06	-1.50	-0.12
IRL	13	0.78%	2.56	0.58	-0.06	-2.30
ESP	14	0.44%	2.56	0.19	-1.80	-0.45

Note: Components of TFP growth are expressed in percentage points.

Figure 5 displays the average rate of TFP growth during four sub-periods. The decreasing trend is rather clear for all the countries in the sample, but for

Figure 5



some of them it appears more marked: Denmark, Spain, Ireland, Italy, and the UK lost 3 to 6 percentage point (pp) of productivity growth from 1970-'80 to 2001-'05. A second group, composed by Belgium, Germany, Luxembourg, and the Netherlands, posted a TFP growth reduction of between 1 and 2 pp. For Austria, Finland, France, Portugal, and Sweden the decline was limited to less than one single pp. Italy is the country, among those observed in the early '70s, that showed the most dramatic deterioration in TFP growth: a reduction of 5.7 pp. Furthermore, it is worth considering the case of Ireland. In the first year of observation (1988) Ireland had a labour-capital cost share $\left(s_L/s_K\right)$ equal to 1, while at the end of the period (2005) this ratio amounted to 0.41. Since the elasticity ratio $\left(\beta_L/\beta_K = \varepsilon_L/\varepsilon_K\right)$ is equal to 3.34, the largest part of the reduction of TFP growth in this country was due to allocative inefficiency, which accounted for 4.1 pp in the period 2000-'05. Without this component, Ireland's TFP change in the manufacturing sector would have been 2.7%. In the others countries, allocative efficiency accounted for just a few tenths of a point.

6 CONCLUSIONS

In this paper the Stochastic frontier approach was used to estimate and decompose manufacturing total factor productivity growth for 14 countries out of the 15 founding members of the EU. The results show that in the period 1970-2005 these countries recorded a dramatic fall in the TFP rate of change, due principally to the decline in technical efficiency and, to a lesser extent, to the reduction in allocative efficiency and input factor rates of growth. In the same period technical progress gave a positive contribution, although it did not reverse the TFP negative trend.

Even thought these results are consistent with the general view, the rigidity of the model seems to exacerbate the dynamics of TFP at the end of the sample period. Better results, in terms of understanding the innovation-imitation debate, could be obtained splitting the sample period in two parts (1970-'95 and 1995-2005) and allowing for a more flexible functional form for inefficiency. The first of these two new steps could be achieved once the EU-KLEMS database is completed, while the second is more difficult to reach. Actually, to our knowledge, there is no useful data[18] available to estimate a model which also incorporates a model for technical efficiency, along the lines of Battese and Coelli (1995), covering the whole sample period used in this paper.

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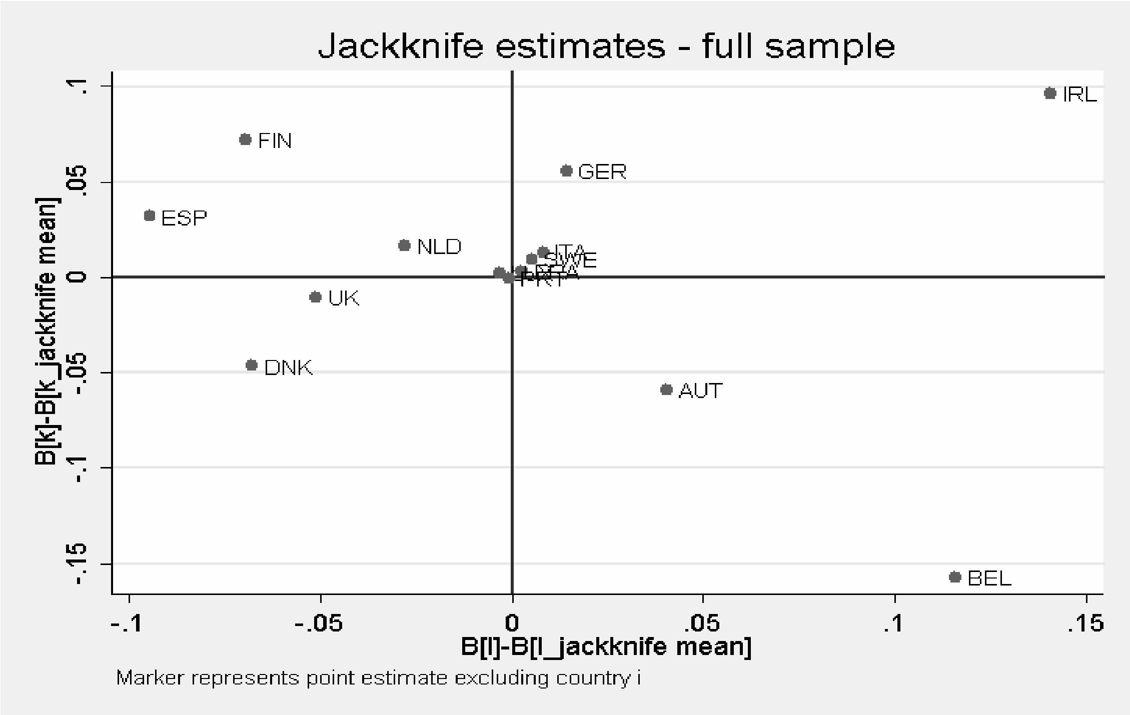
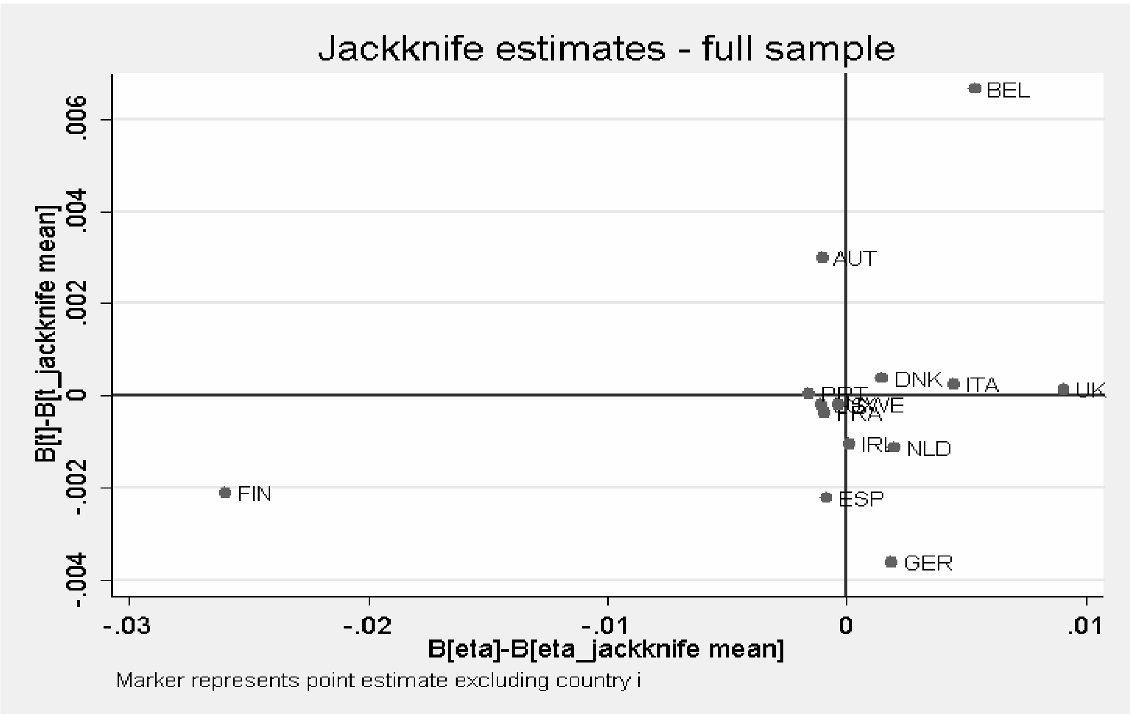
[18] For example, data on Product Market Regulation. Nicoletti and Scarpetta (2003).

APPENDIX

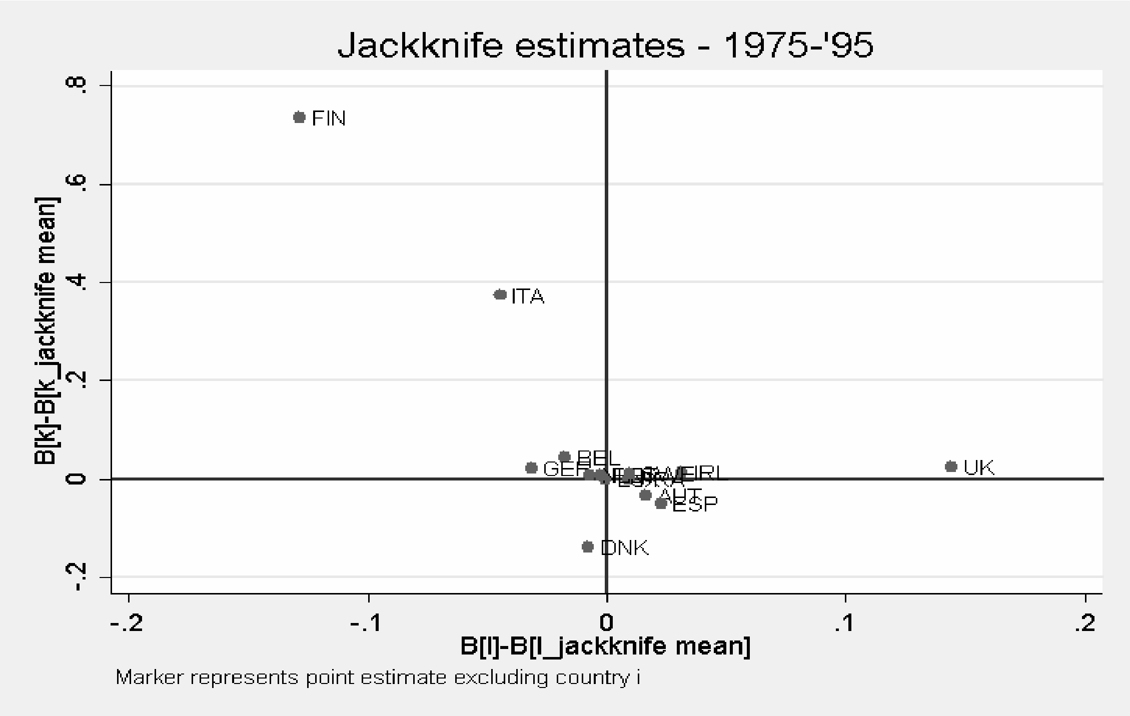
Graf. A1



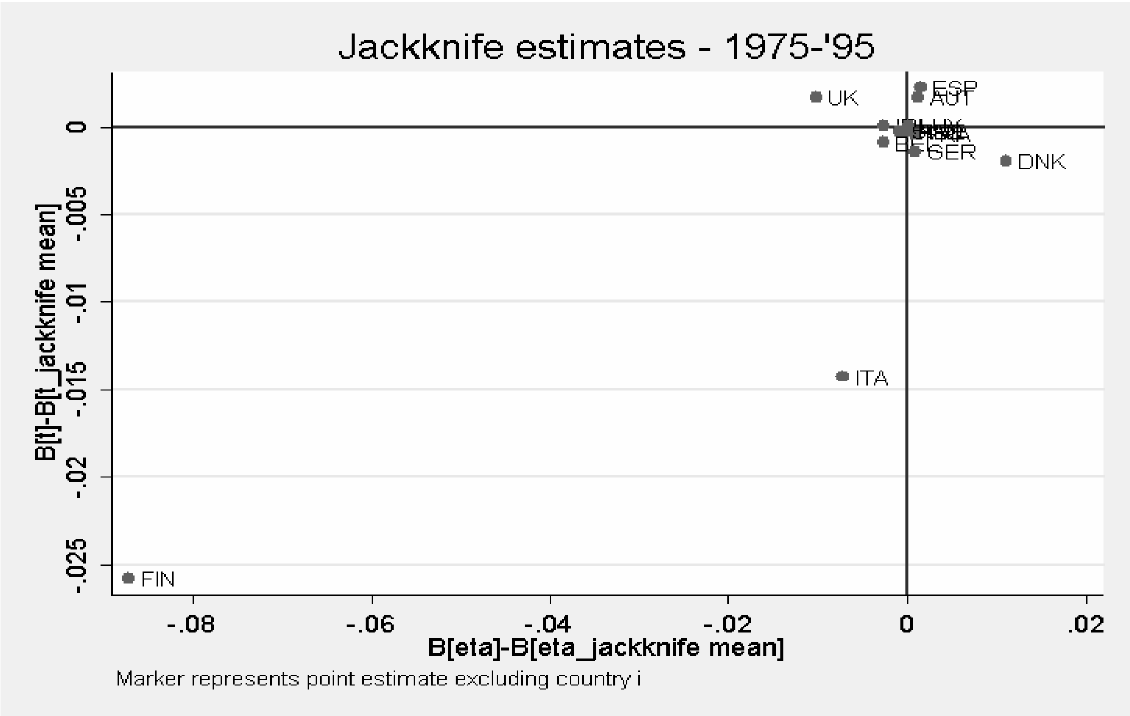
Graf. A2



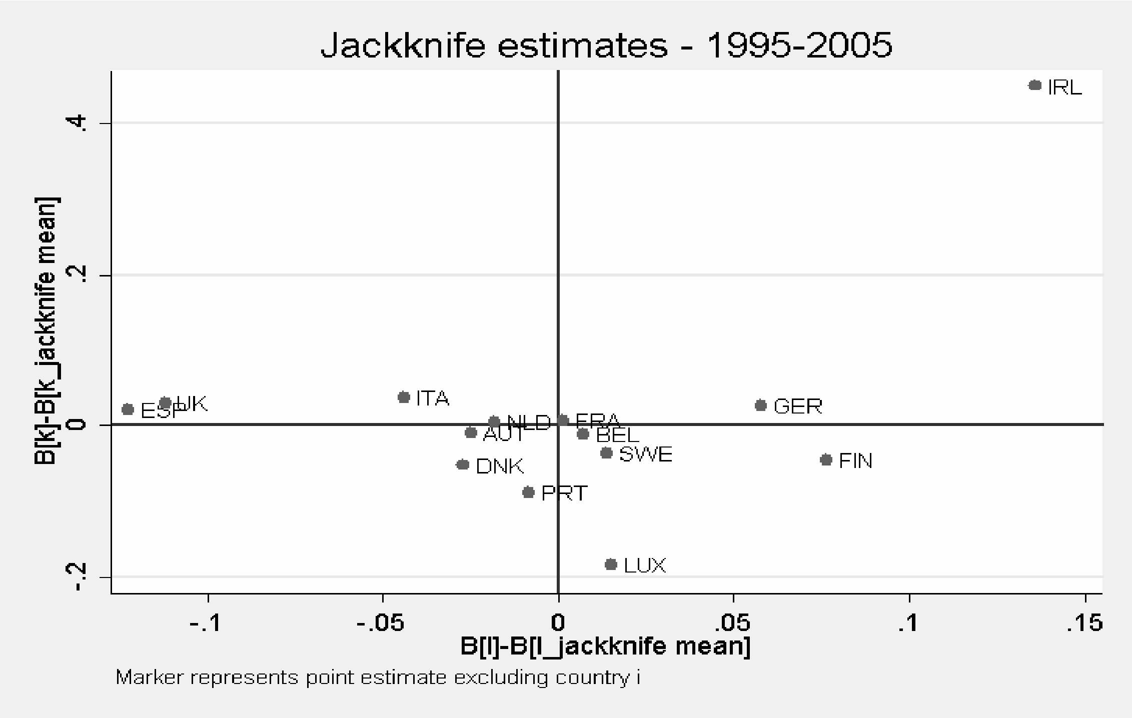
Graf. A3



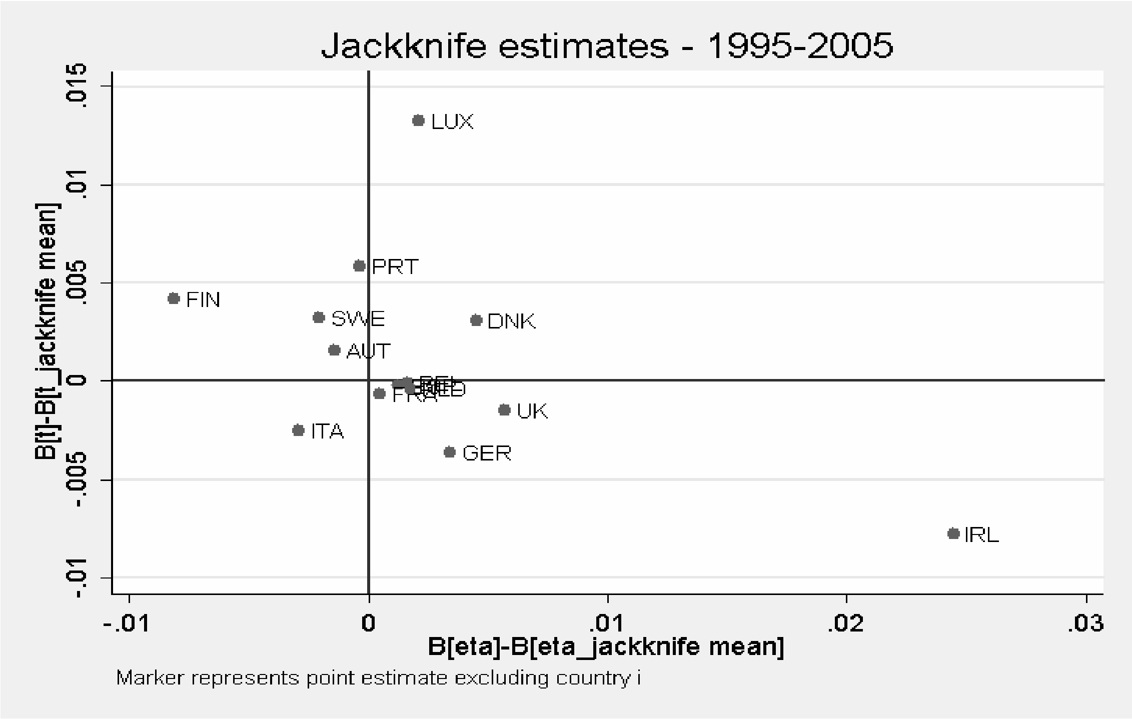
Graf. A4



Graf. A5



Graf. A6



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