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Knock-On Effect of Non-Manufacturing Regulation on Manufacturing Sectors Efficiency and Productivity

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Abstract: Since the mid of nineties European countries are registering an anemic growth of economic activity, in large part due to the dynamic of productivity. In 2010 the European Council adopted a new Agenda, Euro2020, which aim is to boost growth also improving European competitiveness. Regulation is one of the main factors influencing competitiveness. This paper focuses on the determinants of Total Factor Productivity (TFP) growth in 13 manufacturing sectors in a panel of 18 OECD countries from 1975 to 2007. Using the Stochastic Frontier Approach applied to the EU-KLEMS and OECD's Regulation Impact Indicator database I found that, given the strong negative relationship between regulation and Technical Efficiency, which is one of the drivers of TFP, countries with still tight regulation in services could/should reduced it in order to improve their economic performance without detriment for public finances.

Keywords: Total Factor Productivity, Technical Efficiency, Competition, Regulation, Stochastic Frontier.

JEL code: O47, L59, C23.

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1. Introduction[2]

After the almost complete failure of Lisbon Agenda in making Europe the most competitive and dynamic economy of the world before the end of 2010, in this same year the European Council renewed its commitment to improve the sluggish economic performance which have characterized the Union since 1995, adopting a new strategy for jobs and growth: Euro2020. The new agenda highlighted 5 main target which should be achieved before the end of current decade: *i*) increase the participation rate; *ii*) invest 3% of GDP in R&D; *iii*) contrast climate change by reducing gas emissions, increasing energy production from renewable, and increasing energy efficiency; *iv*) increase education; *v*) reduce poverty. These target should be pursued via seven flagship initiatives belonging to three priorities: smart growth (digital agenda for Europe, innovation union, youth on the move), sustainable growth (resource efficient Europe, industrial policy for the globalisation era), and inclusive growth (an agenda for new skills and jobs, European platform against poverty).

Among sustainable growth flagships, a special attention is posed by the Commission to industrial policy. In particular, markets regulation should promote pro-competitive behaviour in order to "*boost growth and jobs by maintaining and supporting a strong, diversified and competitive industrial base in Europe offering well-paid jobs*"[3].

The effects of regulation/competition policies on innovation, productivity and growth have long been investigated both at theoretical and empirical level, and in the latter case using firm or country/sector data.[4] In particular with respect to Total Factor Productivity (TFP), according to Havik et al. (2008) two different views distinguish the EU slowdown *vs* the US resurgence of TFP registered during the latest 15 years: an optimistic view and a pessimistic view. 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[5] 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. In their study Aghion, and Howitt 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 growth 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 countries which lag behind 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,[6] that while EU institutions were supportive in the post–WWII process of adoption/diffusion of

[2] The paper has been presented at the XII EWEPA conference in Verona 22-24 June 2011. I am grateful to Arne Henningsen for the support in explaining me how to implement the estimation with his R-package *frontier*. Any error is my sole responsibility.

[3] http://ec.europa.eu/enterprise/policies/industrial-competitiveness/industrial-policy/index_en.htm.

[4] For an overview of the studies see Aghion and Griffith (2005).

[5] Sapir *et al* (2003).

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

technologies at the frontier, from the mid–'90 onwards they were unable to revitalize EU growth through innovation promoting 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.

The empirical strategy in the Havik *et al.* paper is well established since Nicoletti e Scarpetta (2003) paper. Taking TFP growth as given,[7] they investigate the role of competition/regulation policy in promoting/curbing productivity, using OECD's Regulation Impact Indicators (RegImpact)[8], together with other variables, and in particular a measure o technology gap which should capture the extent to which TFP growth in a specific country can be explained by the adoption of more efficient technology (imitation), and an estimate of TFP growth at the frontier which should capture the spillover effects of innovation in the technologically most advanced country over catching-up countries. Using sector level data of OECD countries both Havick *et al.* and Nicoletti and Scarpetta find that the tighter the regulation the lower the productivity growth.

In this paper I adopt a different approach: the stochastic frontier production function approach (SFA), and in particular the Battese and Coelli (1993, 1995) specification. With this technique TFP growth is not taken as given, but is endogenously obtained from the estimation results, as explained in Kumbhakar and Lovell (2000),[9] that is it is the sum of four components obtained from the estimation of the production frontier: technical change, technical efficiency change, scale and allocative efficiency components. 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). The latest two components can be interpreted as the gain/loss in the production coming from scale economies and the gain/loss coming from the choice of the input mix with respect to the their relative elasticity respectively. In addition, as will be clearer later on, the specific model used in this paper can lead to a deeper analysis in so far some hypothesis regarding technology and factors driving technical efficiency can be tested.

A similar approach has been applied by Sharma *et al.* (2007) in investigating the influence of input factors and environmental variables on TFP growth in U.S. states. The main advantages of this approach with respect to other approaches[10] is that it permits both to identify the sources of TFP growth and it is developed in a stochastic environment, so that not everything unexplained by input factor growth is attributed to TFP growth, as the Solow approach does. The main drawback is that a specific functional form for the production function has to be assumed. Anyway, this drawback could be limited assuming a flexible production function. In this paper I use the translog specification, the flexibility of which is very well established.[11]

The paper is organized as follows: Section 2 describes the data, while Section 3 reviews the main concepts of SFA. Estimation results are showed in Section 4 and Section 5 concludes.

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[7] In their paper authors use OECD STAN database in which TFP growth iscalculated using the growth accounting technique.

[8] Conway and Nicoletti (2006)

[9] § 8.2.

[10] Growth Accounting and Data Envelopment Analysis.

[11] Berndt and Christensen (1973), Griffin *et al.* (1987).

2. Data

For the purpose of the analysis I have used two main database: the EU-KLEMS and the Regulatory Impact Indicators (RegImpact) database. As a first step in constructing the sample dataset I have selected all the countries which were present in the November 2009 EU-KLEMS database (30), for the complete period of observation (1970-2007), and for the subsample of manufacturing sectors (13). This is equivalent to 14820 observations. Once the RegImpact database has been added and variables transformed, the sample used in the estimation reduced to 6155 observation because of missing data.

2.1 EU-KLEMS

The EU-KLEMS database is the result of a research project performed by a consortium of 18 European institutions, funded by the European Commission.[12] 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*".[13] 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 25 EU member countries,[14] plus Australia, Canada, Japan, Korea and United States, for the period 1970-2007. Data are disaggregated at NACE Rev. 1 classification level. The main advantage in using EU-KLEMS database, with respect to national sources, relies on the fact that a single methodology is used to construct the variables, in particular capital services, so data are effectively comparable. The database is not complete, and in particular for most of the east European countries observations, if present, start in the nineties.
Table 1 reports the 13 manufacturing subsectors I have selected for the estimation purpose. Their level of aggregation depends on data availability.

Table 1: manufacturing sectors

Code	Sector
15t16	Food , Beverages and Tobacco
17t19	Textiles, Textile , Leather and Footwear
20	Wood and of Wood and Cork
21t22	Pulp, Paper, Printing and Publishing
23	Coke, Refined Petroleum and Nuclear Fuel
24	Chemicals and Chemical
25	Rubber and Plastics
26	Other Non-Metallic Mineral
27t28	Basic Metals and Fabricated Metal
29	Machinery, Nec
30t33	Electrical and Optical Equipment
34t35	Transport Equipment
36t37	Manufacturing Nec; Recycling

Source: EU-KLEMS database

[12] For a detailed description of the database and methodologies see Timmer *et al (2007).*

[13] www.euklems.net.

[14] Bulgaria and Romania are not included.

Regarding variables, since I use the stochastic production function approach, value added, labour and capital services have been selected. This variables are expressed both as index numbers (1995=100) and in nominal value.

2.2 OECD's Regulation Impact Indicators

Regulatory Impact Indicators is a set of OECD indicators which try to catch the "knock-on" effects of the regulations in one sector on the other sectors.[15] Specifically, the effect of product market regulations in a sector is not confined to this own sector, but influences the cost or organizational structure of all the sector using the products of supplying sector. In this way the costs of entry for new firms that rely on these inputs, the extent to which firms outsource these inputs, the organization of work within the firm, the allocation of resources between firms and ultimately the scope for the associated productivity improvements, are all effected by the burden of the regulation in sectors producing inputs for the using sector. Such a burden is weightier the tighter the regulation in the input sector and the greater the share of those inputs in the using sector. In formula:

$$\text{RegImpact}_{it} = \sum_{j} NMR_{jt} \cdot w_{ij} \quad (1)$$

where R_{jt} is an indicator of anti-competitive regulation in sector *j* at time *t* and the weight w_{ij} [16] is the total input requirement of sector *i* for intermediate inputs of sector *j*. Indicators are normalized so that they varies between 0 and 1. This indicator is available for 29 countries, 38 sectors from 1975 to 2007. As already noticed, once the database is completed with value added, capital, labour and RegImpact the database reduces from 14820 to 6155 observation, with 12 countries dropping out of the sample. This is because observations for RegImpact start in 1975, those for east European countries start in the nineties and in some cases no country observations are available in the RegImpact database, and various missing are presents in the EU-KLEMS database. Table 2 reports a summary of observations by country and sector, while Table 3 shows the over time average of RegImpact by country and sector.

Table 2: number of observations

	15t16	17t19	20	21t22	23	24	25	26	27t28	29	30t33	34t35	36t37	Total
AUS	26	26	26	26	26	26	26	26	26	26	26	26	26	**338**
AUT	28	28	28	28	28	28	28	28	28	28	28	28	28	**364**
BEL	22	22	22	22	22	22	22	22	22	22	22	22	22	**286**
CAN	30	30	30	30	30	30	30	30	30	30	30	30	30	**390**
CZE	13	13	13	13	13	13	13	13	13	13	13	13	13	**169**
DNK	28	28	28	28	28	28	28	28	28	28	28	28	28	**364**
ESP	28	28	28	28	28	28	28	28	28	28	28	28	28	**364**
FIN	33	33	33	33	33	33	33	33	33	33	33	33	33	**429**
FRA	28	28	28	28	28	28	28	28	28	28	28	28	28	**364**
GER	33	33	33	33	33	33	33	33	33	33	33	33	33	**429**
HUN	13	13	13	13	13	13	13	13	13	13	13	13	13	**169**
IRL	20	20	20	20	0	20	20	20	20	20	20	20	20	**240**
ITA	33	33	33	33	33	33	33	33	33	33	33	33	33	**429**
JPN	32	32	32	32	32	32	32	32	32	32	32	32	32	**416**
NLD	29	29	29	29	29	29	29	29	29	29	29	29	29	**377**
SWE	15	15	15	15	15	15	15	15	15	15	15	15	15	**195**
UK	33	33	33	33	33	33	33	33	33	33	33	33	33	**429**
USA	31	31	31	31	31	31	31	31	31	31	31	31	31	**403**
Total	**475**	**475**	**475**	**475**	**455**	**475**	**475**	**475**	**475**	**475**	**475**	**475**	**475**	**6155**

Source: author's calculation on EU-KLEMS database

[15] Conway and Nicoletti (2006).

[16] The weights, which have been calculated from the Input/Output, are not indexed with *t* because they are held constant at 2000 reference year.

Table 3: average value of RegImpact indicators

	15t16	17t19	20	21t22	23	24	25	26	27t28	29	30t33	34t35	36t37	Mean
AUS	0.0820	0.0765	0.0813	0.0808	0.0707	0.0948	0.0762	0.0918	0.0747	0.0822	0.0726	0.0730	0.0678	0.0788
AUT	0.1204	0.1214	0.1137	0.1179	0.1025	0.1403	0.1213	0.1261	0.1131	0.1150	0.1085	0.1210	0.0997	0.1170
BEL	0.1720	0.1761	0.1804	0.1770	0.1976	0.1662	0.1625	0.1764	0.1737	0.1469	0.1548	0.1835	0.1794	0.1728
CAN	0.0880	0.0563	0.0799	0.0849	0.0736	0.0856	0.0765	0.0791	0.0701	0.0618	0.0801	0.0892	0.0736	0.0768
CZE	0.0999	0.1040	0.0922	0.1082	0.1296	0.1067	0.1004	0.1137	0.1163	0.1048	0.1033	0.1170	0.0921	0.1068
DNK	0.0736	0.0761	0.0795	0.0751	0.0204	0.0631	0.0572	0.0696	0.0599	0.0607	0.0590	0.0624	0.0780	0.0642
ESP	0.1294	0.1337	0.1286	0.1224	0.1428	0.1389	0.1286	0.1621	0.1237	0.1123	0.1185	0.1308	0.1165	0.1299
FIN	0.1052	0.0793	0.1185	0.1063	0.1243	0.1100	0.0871	0.0909	0.0957	0.0891	0.0743	0.0847	0.0861	0.0963
FRA	0.1039	0.0921	0.0896	0.1231	0.0871	0.1033	0.0950	0.1150	0.0988	0.1010	0.0972	0.1154	0.1018	0.1018
GER	0.1212	0.1036	0.0935	0.0975	0.1145	0.1068	0.1066	0.1239	0.0941	0.1037	0.1030	0.1396	0.1110	0.1092
HUN	0.0951	0.0797	0.0913	0.1055	0.1118	0.1043	0.0951	0.1042	0.0989	0.0891	0.0981	0.0918	0.0894	0.0965
IRL	0.0743	0.0704	0.0921	0.0936		0.0850	0.0826	0.0602	0.0704	0.0722	0.0827	0.0805	0.0651	0.0774
ITA	0.1478	0.1510	0.1476	0.1644	0.1161	0.1682	0.1610	0.1635	0.1494	0.1509	0.1512	0.1812	0.1621	0.1550
JPN	0.1252	0.1252	0.1245	0.1218	0.1155	0.1310	0.1247	0.1279	0.1163	0.1140	0.1176	0.1492	0.1498	0.1263
NLD	0.0741	0.0649	0.0800	0.0679	0.0350	0.0667	0.0692	0.0750	0.0710	0.0702	0.0642	0.0848	0.0551	0.0676
SWE	0.0541	0.0481	0.0657	0.0632	0.0700	0.0506	0.0556	0.0655	0.0564	0.0514	0.0707	0.0624	0.0621	0.0597
UK	0.1097	0.1033	0.0848	0.0884	0.0480	0.1111	0.0963	0.1031	0.0951	0.0939	0.1010	0.1078	0.0912	0.0949
USA	0.0693	0.0596	0.0609	0.0530	0.0600	0.0610	0.0592	0.0577	0.0562	0.0582	0.0575	0.0712	0.0520	0.0597
Mean	0.1045	0.0970	0.1012	0.1031	0.0930	0.1069	0.0986	0.1070	0.0965	0.0943	0.0955	0.1101	0.0978	0.1004

Source: author's calculation on OECD Regulation Impact Indicator database

The overall average value of RegImpact for the European countries is 0.1035 compared to 0.0597 of United States. Taking the average for those countries belonging to the eurozone, the average is even larger and twice the value for US: 0.1141.

3. Methodology: the stochastic frontier approach in calculating TFP growth

Stochastic frontiers were introduced by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) and are recently extensively reviewed in Kumbhakar and Lovell (2000), Coelli *et al* (2005) and Greene (2008). The main hypothesis underlying the stochastic frontier approach is that producers do not succeed in being fully efficient, so that there almost always be a waste of resources. From the economic point of view this means that producers do not position at the production possibility frontier, but stay below the frontier. For the estimation purpose the stochastic frontier can be represented as:

$$y_{it} = f\left(x_{it}, t, \beta\right)^{\varepsilon_{it}} \text{ with } \varepsilon_{it} = v_{it} - u_{it} \text{ and } u_{it} > 0 \tag{2}$$

or, taking natural logarithms,

$$\ln y_{it} = \ln f\left(x_{it}, t, \beta\right) + v_{it} - u_{it} \tag{3}$$

were y_{it} is the output of producer i at time t, x_{it} is the vector of inputs, t is a time trend which proxies technical change, β is the vector of parameters and ε_{it} is the stochastic error term. This latter is composed by two terms which are independent of one another. The first term, v_{it}, is a white noise normally distributed error, while u_{it} is one sided error term representing technical inefficiency. Various specification for the distribution of u_{it} have been used. In this paper, following Battese and Coelli (1993, 1995), I assume that u_{it} is obtained by the truncation at zero of the normal distribution with mean δz_{it} and variance σ_u^2. z_{it} denotes a vector of region/sector specific variables suspected to be factors contributing to the inefficiency of the region/sector while δ is a vector of unknown coefficients. Technical inefficiency is then specified by:

$$u_{it} = \delta z_{it} + \omega_{it} \tag{4}$$

where ω_{it} is a truncated normal random variable with zero mean and σ_u^2 variance. It follows that $u_{it} \sim N^+(\delta z_{it}, \sigma_u^2)$.

Given its flexibility I have chosen to use the translog specification of the functional form. That is:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_t t_{it} + \frac{1}{2}\left(\beta_{kk} k_{it}^2 + \beta_{ll} l_{it}^2 + \beta_{tt} t_{it}^2\right) + \beta_{kl} k_{it} l_{it} + \beta_{kt} k_{it} t + \beta_{lt} l_{it} t \tag{5}$$

where y, k and l are expressed in natural log. Technical efficiency can then be obtained:[17]

$$TE_{it} = \left\{ \frac{\Phi(r_{it} - \sigma_*)}{\Phi(r_{it})} \right\} \exp\left\{ -\mu_{*it} + \frac{1}{2}\sigma_*^2 \right\} \tag{6}$$

where

$$r_{it} = -\frac{\mu_{*it}}{\sigma_*}, \ \mu_{*it} = \frac{-\sigma_u^2 \varepsilon_{it} + \delta z_{it} \sigma_v^2}{\sigma_u^2 * \sigma_v^2}, \text{ and } \sigma_*^2 = \frac{\sigma_u^2 \sigma_v^2}{\sigma_u^2 + \sigma_v^2} \tag{7}$$

Once the model has been estimated and technical efficiency has been obtained, TFP growth can be obtained as a sum of four components: technical change, scale component, technical efficiency change and allocative efficiency component, that is:[18]

$$T\dot{F}P = \overbrace{\Delta T}^{\text{Technical change}} + \overbrace{(\xi - 1) \cdot \sum_h \left(\frac{\xi_h}{\xi} \right) \cdot \dot{x}_h}^{\text{Scale component}} + \overbrace{\Delta TE}^{\text{Technical efficiency change}} + \overbrace{\sum_h \left[\left(\frac{\xi_h}{\xi} \right) - s_h \right] \cdot \dot{x}_h}^{\text{Allocative inefficiency}} \tag{8}$$

where $\dot{x}_h$ is the change of input h, ξ_h is the elasticity of input h, $\xi = \sum_h \xi_h$ is the return to scale measure, and s_h is the share of compensation of input h over the total compensation. The first component of the (8) 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 ($\xi = 1$) this term disappears. Technical efficiency change, or technological catch-up, measures the changes in TFP as a consequence of a movement towards the frontier. The last term of (8) is the allocative inefficiency. It measures the deviation of each input share cost s_h from its elasticity ξ_h, or, to put it differently, the deviation of each input marginal productivity from output normalized cost. In an allocative efficient sector $\left(\frac{\xi_h}{\xi} \right) = s_h$, so that also this component disappears.

In the specific case of (5), technical progress is:

$$\Delta T_{it} = \frac{\partial y_{it}}{\partial t} = \beta_t + \beta_{tt} t_{it} + \beta_{kt} k_{it} + \beta_{lt} l_{it} \tag{9}$$

while capital and labour elasticities are:

[17] For the full derivation see for example Sharma *et al (2007)*.

[18] Kumbhakar and Lovell (2000), § 8.2.1

$$\xi_{itk} = \frac{\partial y_{it}}{\partial k_{it}} = \beta_k + \beta_{kk} k_{it} + \beta_{kl} l_{it} + \beta_{kt} t$$
$$\xi_{itl} = \frac{\partial y_{it}}{\partial l_{it}} = \beta_l + \beta_{ll} l_{it} + \beta_{kl} k_{it} + \beta_{lt} t \qquad (10)$$

It should be noticed from (8), (9) and (10) that TFP, technology and technical efficiency change, together with labour and capital elasticities and return to scale are observation specific.
In recent year the Battese and Coelli (1995) has received some criticisms because it is unable to distinguish factor affecting inefficiency in a specific sector from which should be considered true heterogeneity. To overcome this problem Greene (2005) proposed some extension to the stochastic frontier model which takes into account the possible presence of heterogeneity. Unfortunately, incidental parameter problem apart, which can be solved using different estimation technique,[19] estimation of "true fixed effect" which also account for exogenous determinant of inefficiency results being very difficult because of the shape of the log likelihood and the efficiency of the maximization algorithm, as stated in the Limdep 9.0 manual (2007)[20]. I had no success in different attempt to estimate a "true fixed effect" model.[21]

4. Results

In order to select the best model fitting the data and to test some hypotheses about the production function different models have been estimated. Results are reported in Table 4. TL is the complete translog model with RegImpact explaining the technical inefficiency together with the intercept and country and sector dummies. CD is the alternative restricted Cobb-Douglas specification of the production function. TLC is the translog with no sector dummies, while TLS is the opposite with no country dummies. TLCS is the translog specification which contains intercept, country and sector dummies in the model for technical inefficiency, without RegImpact indicator. TLNoTP is the translog estimated without the variables (trend and cross products of trend and both labour or capital) related to technical change, while TL_NTP is the specification which postulates Hicks-neutral technical change. Lastly, TLRI2 contains the quadratic term of RegImpact in the specification of the model for technical inefficiency.

In the table, ***gamma*** is $\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2}$ and indicates the share of the variance due to the presence of inefficiency. It vary between 0 and 1; the greater the value the stronger the support for the stochastic frontier technique. Values near 0 suggests no presence of inefficiency, hence ordinary regression techniques could be applied. ***SigmaSq*** is simply the denominator of ***gamma***.

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19 Wang and Ho (2010).

20 Ch. 33, pg 79.

21 I tried mainly two different estimators. The first one was the true fixed effect in the Normal-Truncated Normal model with heterogeneity in the production function and variables influencing inefficiency, according to Greene (2005), and implemented in Limdep 9.0. The second one, developed by Wang and Ho (2010) and implemented by the authors in Stata, also is a "true fixed effect", but uses a model transformation to overcome some of the Greene (2005) limits. None of the two models, for different reasons, succeeds in maximizing the LogLikelihood.

Table 4: estimation results

	TL	CD	TLC	TLS	TLCS	TLNoTP	TL_NTP	TLRI2
Intercept	2.491E+01 ***	-9.193E-01 ***	2.402E+01 ***	2.46E+01 ***	2.29E+01 ***	2.25E+01 ***	2.54E+01 ***	2.49E+01 ***
Capital	-4.820E+00 ***	2.085E-01 ***	-5.301E+00 ***	-4.90E+00 ***	-4.63E+00 ***	-3.54E+00 ***	-3.85E+00 ***	-4.82E+00 ***
Labour	-5.664E+00 ***	9.077E-01 ***	-4.849E+00 ***	-5.47E+00 ***	-4.94E+00 ***	-5.38E+00 ***	-6.43E+00 ***	-5.65E+00 ***
Time trend	1.000E-01 ***	1.794E-02 ***	1.000E-01 ***	1.06E-01 ***	9.48E-02 ***		2.93E-02 ***	1.01E-01 ***
Capital²	4.549E-01 ***		4.830E-01 ***	4.51E-01 ***	4.71E-01 ***	4.40E-01 ***	3.51E-01 ***	4.54E-01 ***
Labour²	7.812E-01 ***		5.591E-01 ***	7.28E-01 ***	6.72E-01 ***	8.35E-01 ***	1.02E+00 ***	7.79E-01 ***
Time trend²	-4.878E-04 **		-3.707E-04 **	-4.01E-04 **	-5.24E-04 ***		-5.81E-04 ***	-4.86E-04 **
Labour*Capital	6.800E-01 ***		7.458E-01 ***	7.02E-01 ***	6.24E-01 ***	4.59E-01 ***	5.47E-01 ***	6.81E-01 ***
Time trend*Capital	-4.796E-03 .		-3.595E-03	-5.20E-03 *	-3.80E-03			-4.81E-03 .
Time trend*Labour	-1.106E-02 ***		-1.225E-02 ***	-1.23E-02 ***	-1.08E-02 ***			-1.12E-02 ***
Z_(Intercept)	-2.270E+03 ***	-6.754E+02 ***	-1.325E+03 **	-4.34E+03 ***	-2.75E+03 ***	-4.05E+03 ***	-4.08E+03 ***	-2.18E+03 ***
Z_RegImpact	1.662E+03 ***	1.233E+03 ***	-1.594E+04 **	2.83E+03 ***		6.53E+03 ***	2.50E+03 ***	2.59E+03 ***
Z_RegImpact²								-4.53E+03 ***
Z_Country dummies	yes	yes	yes	no	yes	yes	yes	yes
Z_Sector dummies	yes	yes	no	yes	yes	yes	yes	yes
sigmaSq	1.473E+02 ***	3.264E+01 ***	4.099E+02 **	3.220E+02 ***	2.464E+02 ***	2.245E+02 ***	2.60E+02 ***	1.377E+02 ***
gamma	9.997E-01 ***	9.980E-01 ***	9.999E-01 ***	9.998E-01 ***	9.998E-01 ***	9.998E-01 ***	1.00E+00 ***	9.996E-01 ***
Mean Tech. Efficiency	0.8985	0.9206	0.8701	0.8858	0.8981	0.8932	0.8992	0.8988
N. Obs	6155	6155	6155	6155	6331	6155	6155	6155
LogLikelihood	-493.83	-874.00	-930.13	-657.59	-550.48	-780.75	-504.87	-490.77

Signif. codes: (***)=0.0001; (**)=0.001; (*)=0.01; (.)=0.05.

Table 5 reports LR tests of TL against all the other models in Table 4 whit three exception: *i*) the first test is automatically performed by the software[22] and test OLS vs TL; *ii*) estimation results for the model without country and sector dummies are not reported for problem related to Table 3 arrangement;[23] *iii*) the test of TLCS *vs* TL cannot be performed because the two estimates use a different subset of observations.

Table 5: hypotesis tests

Test	Restriction	Degrees of Feedom	χ^2	Prob
1	No Inefficiency (γ=0)[(*)]	44	760.34	0.0000
2	No country and sector dummies	41	1279.00	0.0000
3	No sector dummies	12	880.6	0.0000
4	No country dummies	29	327.52	0.0000
5	No technical progress	4	577.84	0.0000
6	Neutral technical progress	2	22.07	0.0000
7	Cobb-Douglas	6	760.34	0.0000
8	Quadratic RegImpact	1	2.13	0.1446

(*) LR test statistics follows a mixed-χ^2 distribution (see Coelli, 1995).

[22] The R package "frontier", Coelli and Henningsen (2011).

[23] They are available from the author upon request.

4.1 Description of estimation results

Estimations results and tests lead to choosing model TL. In this model all the coefficients are statistically significant at 5% level. The translog specification is preferred to the simple Cobb-Douglas (test 7). The hypothesis of no inefficiency is rejected (test 1) which support the adoption of the stochastic frontier approach. RegImpact together with country and sector variables are statistically significant and restricted models without such variables are rejected (test 2, 3, 4 – see also point *iii* of previous section). The restrictions of Hicks-neutral technical change (test 6) and no technical change at all (test 5) are both rejected. In particular technical change results being both labour and capital saving, given the negative sign of *Time*Labour* and *Time*Capital* coefficients. Testing the unrestricted model with a quadratic term for RegImpact against TL results in no significant difference between the two; the principle of parsimony leads to choose TL.[24]

From (6), (8) and (9) it follows that technical efficiency, factor elasticity, and return to scale are observation specific. For this reason it is not possible to describe every single observation specific result. It is notwithstanding worth to highlight some (simple) average result. Average labour and capital elasticities are 0.783 and 0.285 respectively, so that the model TL shows a slightly increasing return to scale (1.068). Technical change averaged 1.5% during the period, between country and sectors, with very small standard deviation (0.0058).

Table 6 shows by country and sector, the over-time average of technical efficiency. Among countries Sweden shows the highest level of (mean) technical efficiency, while Czech Republic the lowest. Between sectors "Pulp, Paper, Paper , Printing and Publishing" (21t22) performed best and "Coke, Refined Petroleum and Nuclear Fuel" (23) worst. The overall average technical efficiency is 0.9.

Table 6: average technical efficiency

	15t16	17t19	20	21t22	23	24	25	26	27t28	29	30t33	34t35	36t37	Mean
AUS	0.94	0.89	0.93	0.94	0.74	0.89	0.91	0.95	0.92	0.93	0.86	0.94	0.82	**0.90**
AUT	0.93	0.90	0.94	0.94	0.61	0.86	0.90	0.95	0.91	0.92	0.87	0.95	0.92	**0.89**
BEL	0.94	0.92	0.95	0.95	0.78	0.91	0.92	0.94	0.93	0.94	0.92	0.95	0.93	**0.92**
CAN	0.95	0.92	0.95	0.96	0.86	0.91	0.91	0.95	0.94	0.94	0.89	0.94	0.94	**0.93**
CZE	0.93	0.86	0.94	0.95	0.23	0.86	0.92	0.94	0.88	0.92	0.86	0.95	0.87	**0.85**
DNK	0.94	0.89	0.94	0.95	0.84	0.91	0.92	0.95	0.91	0.92	0.85	0.93	0.92	**0.91**
ESP	0.94	0.91	0.93	0.94	0.85	0.87	0.90	0.94	0.92	0.92	0.85	0.94	0.92	**0.91**
FIN	0.93	0.79	0.92	0.94	0.77	0.84	0.84	0.93	0.87	0.91	0.71	0.93	0.90	**0.87**
FRA	0.93	0.88	0.92	0.94	0.47	0.83	0.75	0.93	0.91	0.89	0.85	0.93	0.90	**0.86**
GER	0.95	0.87	0.95	0.96	0.89	0.90	0.93	0.95	0.93	0.94	0.91	0.95	0.94	**0.93**
HUN	0.92	0.89	0.94	0.96	0.65	0.84	0.93	0.95	0.94	0.95	0.94	0.95	0.92	**0.91**
IRL	0.94	0.81	0.92	0.94		0.83	0.87	0.90	0.90	0.86	0.79	0.93	0.84	**0.88**
ITA	0.93	0.87	0.92	0.94	0.71	0.77	0.89	0.93	0.88	0.91	0.82	0.94	0.91	**0.88**
JPN	0.93	0.85	0.92	0.94	0.84	0.74	0.89	0.93	0.90	0.85	0.62	0.92	0.90	**0.86**
NLD	0.95	0.93	0.94	0.96	0.88	0.92	0.92	0.95	0.94	0.94	0.90	0.95	0.94	**0.93**
SWE	0.95	0.93	0.96	0.96	0.93	0.94	0.94	0.96	0.94	0.95	0.96	0.96	0.95	**0.95**
UK	0.94	0.87	0.93	0.95	0.84	0.79	0.88	0.93	0.87	0.92	0.82	0.94	0.93	**0.89**
USA	0.94	0.89	0.94	0.95	0.87	0.91	0.90	0.94	0.92	0.93	0.74	0.95	0.93	**0.91**
Mean	**0.94**	**0.88**	**0.94**	**0.95**	**0.77**	**0.86**	**0.89**	**0.94**	**0.91**	**0.92**	**0.83**	**0.94**	**0.91**	**0.90**

Source: author's calculation

[24] There is a further reason which pose doubt about the robustness of TLRI2. Given the signs of the two coefficient for RegImpact, the relation between this indicator and inefficiency would assume an inverted-U shape in the domain (0,1], with a maximum in 0.2863. On the other hand observations for RegImpact in the databases ranges in [0.011, 0.278], so that the estimation is performed without observation lying in the descending side of the inverted-U.

Following Olsen and Henningsen (2011), it is possible to calculate the marginal effect of RegImpact variable on technical inefficiency, that is:

$$\frac{\partial E\left[\exp\left(-u\right)\right]}{\partial z_{kit}} = \frac{\delta_k\left(1-\gamma\right)\exp\left(-\bar{\mu}_{it}+\frac{1}{2}\bar{\sigma}^2\right)}{\Phi\left(\frac{\bar{\mu}_{it}}{\bar{\sigma}}\right)} \cdot \left(\frac{\phi\left(-\bar{\sigma}+\frac{\bar{\mu}_{it}}{\bar{\sigma}}\right)}{\bar{\sigma}} - \frac{\Phi\left(-\bar{\sigma}+\frac{\bar{\mu}_{it}}{\bar{\sigma}}\right)\phi\left(\frac{\bar{\mu}_{it}}{\bar{\sigma}}\right)}{\bar{\sigma}\,\Phi\left(\frac{\bar{\mu}_{it}}{\bar{\sigma}}\right)} - \Phi\left(-\bar{\sigma}+\frac{\bar{\mu}_{it}}{\bar{\sigma}}\right)\right), \qquad (11)$$

where

$$\bar{\mu}_{it} = (1-\gamma)z_{it}'\delta - \gamma\varepsilon_{it},$$
$$\bar{\sigma} = \gamma(1-\gamma)\sigma^2.$$

Table 7 shows the over-time average marginal effect of RegImpact variable on technical efficiency.[25] All the marginal effects have the expected negative sign, that is an increase in the RegImpact, which correspond to an increase in regulation burden, negatively effects efficiency. The largest impact, among countries, is suffered by Finland and Ireland, while Sweden shows the smallest impact. Regarding sectors, knock-on effect are very high in Coke, Refined Petroleum and Nuclear Fuel sector and small in Transport Equipment. On average, marginal effect is -0.075.

Table 7: RegImpact average marginal effect

	15t16	17t19	20	21t22	23	24	25	26	27t28	29	30t33	34t35	36t37	Mean
AUS	-0.037	-0.094	-0.047	-0.033	-0.192	-0.104	-0.079	-0.029	-0.055	-0.051	-0.144	-0.036	-0.137	**-0.080**
AUT	-0.047	-0.085	-0.036	-0.032	-0.161	-0.134	-0.085	-0.031	-0.076	-0.063	-0.131	-0.030	-0.055	**-0.074**
BEL	-0.032	-0.058	-0.029	-0.025	-0.172	-0.078	-0.066	-0.036	-0.045	-0.033	-0.064	-0.026	-0.043	**-0.054**
CAN	-0.023	-0.054	-0.025	-0.018	-0.142	-0.077	-0.076	-0.023	-0.041	-0.040	-0.094	-0.034	-0.035	**-0.053**
CZE	-0.050	-0.133	-0.040	-0.028	-0.099	-0.138	-0.063	-0.032	-0.107	-0.062	-0.141	-0.027	-0.132	**-0.081**
DNK	-0.034	-0.103	-0.035	-0.025	-0.105	-0.077	-0.065	-0.029	-0.067	-0.060	-0.153	-0.049	-0.064	**-0.067**
ESP	-0.040	-0.077	-0.046	-0.031	-0.148	-0.127	-0.091	-0.042	-0.060	-0.066	-0.153	-0.038	-0.059	**-0.075**
FIN	-0.052	-0.194	-0.059	-0.042	-0.212	-0.156	-0.167	-0.048	-0.124	-0.076	-0.162	-0.042	-0.083	**-0.109**
FRA	-0.050	-0.116	-0.059	-0.034	-0.054	-0.175	-0.165	-0.049	-0.070	-0.101	-0.152	-0.047	-0.080	**-0.088**
GER	-0.024	-0.119	-0.028	-0.020	-0.067	-0.084	-0.053	-0.029	-0.043	-0.037	-0.068	-0.023	-0.037	**-0.049**
HUN	-0.064	-0.094	-0.035	-0.015	-0.211	-0.162	-0.048	-0.026	-0.040	-0.028	-0.040	-0.025	-0.064	**-0.065**
IRL	-0.042	-0.178	-0.057	-0.033		-0.167	-0.133	-0.088	-0.080	-0.110	-0.212	-0.050	-0.157	**-0.109**
ITA	-0.043	-0.133	-0.055	-0.040	-0.193	-0.175	-0.094	-0.043	-0.107	-0.078	-0.191	-0.038	-0.073	**-0.097**
JPN	-0.045	-0.129	-0.057	-0.036	-0.161	-0.164	-0.097	-0.051	-0.081	-0.120	-0.144	-0.061	-0.082	**-0.095**
NLD	-0.027	-0.044	-0.032	-0.020	-0.109	-0.064	-0.059	-0.024	-0.041	-0.039	-0.086	-0.022	-0.034	**-0.046**
SWE	-0.022	-0.044	-0.017	-0.016	-0.055	-0.036	-0.033	-0.020	-0.039	-0.028	-0.025	-0.018	-0.030	**-0.029**
UK	-0.040	-0.128	-0.042	-0.029	-0.160	-0.191	-0.113	-0.043	-0.116	-0.058	-0.180	-0.041	-0.053	**-0.092**
USA	-0.041	-0.095	-0.034	-0.022	-0.117	-0.076	-0.081	-0.036	-0.056	-0.050	-0.159	-0.029	-0.049	**-0.065**
Mean	**-0.039**	**-0.106**	**-0.042**	**-0.029**	**-0.140**	**-0.123**	**-0.091**	**-0.038**	**-0.071**	**-0.063**	**-0.133**	**-0.036**	**-0.068**	**-0.075**

Source: author calculation

[25] Technical efficiency can also be obtained as $TE_{it} = \exp(-u_{it})$.

4.2 TFP dynamic in manufacturing sectors

Once all the components of TFP growth have been estimated, the dynamic of the former can be calculated according to (8). Table 8 summarize, by country and sector, the over-time average of TFP growth and its components. Some general features could be noticed at a first look. Technical change has been the most important component of TFP growth during the period of observation (1975-2007), and in this period allocative inefficiency has been very often negative. Scale components has been the second most important component of TFP growth, while the contribution of technical efficiency change has been very small. Taking the overall average,[26] Table 8 shows that TFP grew by 2.1%, and technical progress contributed by 1.5 percentage point (pp); the contribution of the scale component is a full percentage point, technical change contributed by 3 decimal point, while the overall economy has allocated input factor in a relatively inefficient way (-0.6).

Looking at single countries, averaging also over sector in addition of over time, we see that France resulted the best performer in term of TFP growth, with an annual average of 3.5%, mainly due to technical efficiency change and technical progress, while Belgium is the worst performer, with a poor performance of all the TFP growth components. Averaging among time and countries, the Electrical and Optical Equipment sector registered a 3.5% growth of TFP, with a large positive contribution of scale component (4.2 pp), and also a large but negative contribution of allocative inefficiency (-3.4 pp). Both technical efficiency change and progress contributed by more than a percentage point.

Going deeply into the table, it is possible to see some anomalies, in particular for Germany in Textile sector, and Japan in Electrical and Optical Equipment. In the former case the anomalies is due to the sharp drop and rebound of nominal capital in 2002 and 2003 respectively, which influence the share of capital compensation (s_k) and its elasticity (ξ_k). In the latter case, both the deflation and the innovation are the possible causes of the extreme volatility of the nominal value of the capital in Electrical and Optical Equipment sector.

In order to have a complete view of TFP growth for each sector in each country and over time, a set of graphs are reported in the appendix (A.1-A.13). Each box in each graph shows TFP growth obtained according to (8) (TFPsf), the one directly calculated by the EU-KLEMS consortium using the growth accounting technique (TFPga), and the trend TFP growth extracted by applying the Hodrick-Prescott filter (TFPhp) to TFPga.[27] As can be seen from the graphs TFPga shows a higher variability with respect to the other measures of productivity growth. This is due to the fact that growth accounting is a deterministic non-parametric technique and it attributes all the change in value added not due to change in factor inputs to technical progress. On the other side, TFP growth estimated using the stochastic frontier approach does not suffer such limit, because it also consider measurement error and random shocks; from the figures emerges that TFPsf dynamic shows a path very close to the trend extracted from TFPga using the Hodrick-Prescott filter,[28] and these appears to show a more reasonable measure of the true TFP growth than TFPga which does not account for any possible stochastic element.

[26] The bottom-right of the table.

[27] As suggested by Ravn and Uhlig (2002) in the case of annual data, the parameter λ is set to 6.25. They also state that any value in $6.25 \leq \lambda \leq 8.25$ represents a reasonable choice. Anyway, no significant change is produced in the TFPhp going from one extreme to the other.

[28] It is important to remember that the HP filter suffers the problem of accuracy in the lower and upper extreme of observations.

Table 8: average TFP growth by sector and country

		AUS	AUT	BEL	CAN	CZE	DNK	ESP	FIN	FRA	GER	HUN	IRL	ITA	JPN	NLD	SWE	UK	USA	Mean*
Food, Beverage & Tobacco	TE Change	-0.1	0.1	0.0	0.0	0.0	-0.1	-0.1	0.1	-0.1	-0.1	-0.4	0.2	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
	Technical Change	1.5	1.5	1.4	1.7	1.1	1.5	1.5	1.6	1.6	1.6	1.3	1.2	1.8	1.8	1.5	1.1	1.6	1.6	1.5
	Scale Component	0.4	0.0	0.0	0.1	0.1	0.0	0.4	0.1	0.0	0.1	0.7	0.2	0.0	-0.6	0.0	0.1	0.0	0.0	0.1
	Allocative Inefficiency	-0.6	0.0	-0.5	-0.5	-1.2	-0.2	-0.6	-0.3	-0.3	-0.1	-0.1	-0.6	-0.5	-1.3	-0.5	-0.6	-0.1	-0.3	-0.5
	TFP	**1.2**	**1.7**	**0.8**	**1.2**	**-0.1**	**1.2**	**1.1**	**1.4**	**1.1**	**1.5**	**1.5**	**0.9**	**1.2**	**-0.2**	**1.1**	**0.6**	**1.4**	**1.3**	**1.1**
Textil, Leather & Footwear	TE Change	-0.6	0.2	0.2	0.0	0.3	-0.8	-0.2	1.2	-0.2	0.8	-1.0	-1.7	-0.1	-1.4	0.0	-0.1	-0.3	-0.2	-0.2
	Technical Change	1.5	1.4	1.4	1.5	1.5	1.5	1.4	1.1	1.5	1.3	1.4	1.7	1.6	1.7	1.6	1.3	1.6	1.7	1.5
	Scale Component	1.1	0.7	0.7	-0.2	-3.4	1.7	0.0	-1.2	-1.0	61.7	2.7	6.9	0.2	-13.2	1.1	0.8	0.9	6.4	3.7
	Allocative Inefficiency	-0.3	0.1	0.0	0.0	5.6	-0.1	-0.3	0.6	2.0	-61.9	1.8	-2.0	0.3	15.3	-0.5	0.1	0.9	-5.1	-2.4
	TFP	**1.7**	**2.4**	**2.2**	**1.4**	**3.9**	**2.3**	**0.9**	**1.7**	**2.3**	**1.8**	**4.9**	**5.0**	**1.9**	**2.5**	**2.2**	**2.1**	**3.2**	**2.9**	**2.5**
Wood & Cork	TE Change	-0.2	0.0	0.1	0.1	0.1	0.0	-0.3	0.1	0.4	0.0	0.0	-0.1	0.1	-0.1	-0.1	0.1	0.0	-0.1	0.0
	Technical Change	1.4	1.6	1.3	1.8	0.9	1.6	1.4	1.5	1.5	1.8	1.0	1.0	1.5	1.6	1.5	1.1	1.6	1.7	1.4
	Scale Component	0.7	0.0	0.2	0.3	1.5	0.3	1.4	0.3	0.0	0.8	0.8	2.8	0.0	1.2	0.3	0.3	-0.4	0.2	0.6
	Allocative Inefficiency	-0.4	-0.2	0.0	-0.1	0.2	-0.3	-0.6	0.7	0.1	-0.1	0.0	0.3	0.5	-0.8	0.1	0.2	0.0	0.0	0.0
	TFP	**1.5**	**1.4**	**1.5**	**2.0**	**2.7**	**1.5**	**1.9**	**2.5**	**2.0**	**2.5**	**1.7**	**3.9**	**2.2**	**1.9**	**1.8**	**1.6**	**1.2**	**1.7**	**2.0**
Pulp, Paper, Print & Publishing	TE Change	-0.1	0.1	0.0	0.0	0.1	-0.1	-0.1	0.1	-0.1	0.0	0.2	0.2	0.1	-0.1	0.0	0.0	0.0	-0.1	0.0
	Technical Change	1.5	1.6	1.4	1.9	1.0	1.5	1.5	1.6	1.6	1.7	1.1	1.1	1.7	1.9	1.6	1.2	1.8	1.8	1.5
	Scale Component	0.3	0.2	0.0	-0.3	0.9	0.2	0.3	0.1	0.0	0.0	0.3	1.7	0.1	-3.3	0.1	0.0	0.2	0.0	0.0
	Allocative Inefficiency	-0.3	-0.8	-1.0	-0.2	-0.6	0.2	0.0	-0.4	-0.1	-0.4	0.0	-2.2	-0.3	2.2	-0.3	-0.6	-0.2	-0.4	-0.3
	TFP	**1.3**	**1.0**	**0.3**	**1.3**	**1.3**	**1.8**	**1.7**	**1.4**	**1.4**	**1.2**	**1.5**	**0.8**	**1.6**	**0.7**	**1.3**	**0.6**	**1.7**	**1.1**	**1.2**
Coke, Refined Petrol. & Nuclear Fuel	TE Change	4.1	6.5	-0.3	0.0	-7.5	2.0	-0.4	1.3	23.2	0.9	-1.3		-3.5	-1.0	-0.1	0.8	-0.3	1.0	1.5
	Technical Change	1.5	1.6	1.4	1.6	2.1	2.1	1.2	1.6	1.4	1.2	1.4		1.7	1.7	1.5	0.9	1.7	1.6	1.5
	Scale Component	3.6	0.9	0.3	1.1	16.1	0.0	-0.7	0.6	-0.7	-1.7	-7.2		0.1	0.3	0.0	3.2	0.3	0.2	1.0
	Allocative Inefficiency	-2.5	-2.3	-1.2	-0.4	-16.8	-0.4	-1.3	-1.1	-0.4	-0.9	7.3		-1.7	-2.3	0.7	-1.9	-0.3	-1.2	-1.6
	TFP	**6.6**	**6.7**	**0.1**	**2.3**	**-6.0**	**3.6**	**-1.2**	**2.4**	**23.5**	**-0.5**	**0.1**		**-3.5**	**-1.4**	**2.1**	**2.9**	**1.4**	**1.6**	**2.4**
Chemicals	TE Change	-0.2	0.9	-0.1	0.4	0.4	0.1	0.2	0.8	1.4	0.3	-0.4	1.0	3.1	5.3	0.2	0.0	1.6	0.1	0.8
	Technical Change	1.5	1.5	1.3	1.7	1.0	1.6	1.4	1.7	1.5	1.6	1.2	1.0	1.5	1.8	1.5	0.9	1.4	1.7	1.4
	Scale Component	0.2	0.0	0.4	0.1	0.3	0.0	0.4	-0.1	-0.1	0.1	0.3	4.3	0.0	0.1	0.1	1.1	-0.4	0.0	0.4
	Allocative Inefficiency	-0.7	-0.3	-1.6	-0.4	-1.0	-0.6	-0.3	-0.3	-0.5	-0.1	-2.5	-4.7	-0.2	-1.4	-0.5	-1.3	-0.1	-0.9	-1.0
	TFP	**0.7**	**2.0**	**0.0**	**1.7**	**0.6**	**1.1**	**1.6**	**2.0**	**2.4**	**1.8**	**-1.4**	**1.5**	**4.3**	**5.8**	**1.3**	**0.7**	**2.5**	**0.8**	**1.6**

Table 8 continue: average TFP growth by sector and country

		AUS	AUT	BEL	CAN	CZE	DNK	ESP	FIN	FRA	GER	HUN	IRL	ITA	JPN	NLD	SWE	UK	USA	Mean*
Rubber & Plastics	TE Change	0.0	0.2	0.4	0.5	0.1	-0.2	-0.1	0.8	2.6	0.1	0.2	0.0	0.1	0.1	0.2	0.1	0.2	0.2	0.3
	Technical Change	1.5	1.6	1.3	2.0	0.4	1.5	1.5	1.5	1.5	1.8	0.7	1.2	1.8	1.9	1.7	1.1	1.7	1.8	1.5
	Scale Component	0.5	0.2	0.1	-7.2	11.4	0.2	1.1	0.5	0.2	-0.4	4.0	0.9	0.0	0.1	-2.0	0.2	0.3	-0.1	0.6
	Allocative Inefficiency	-0.7	0.1	-0.6	6.1	-0.5	-0.1	-0.6	-0.3	-0.3	-0.2	0.1	-0.1	-0.4	-1.5	0.7	0.0	-0.1	-0.3	0.1
	TFP	**1.3**	**1.9**	**1.2**	**1.3**	**11.3**	**1.4**	**1.9**	**2.5**	**4.1**	**1.3**	**4.9**	**1.9**	**1.4**	**0.5**	**0.6**	**1.3**	**2.0**	**1.4**	**2.3**
Other Non-Metallic Mineral	TE Change	0.1	0.0	0.0	0.0	0.3	0.0	0.1	0.1	0.0	0.0	0.2	-0.7	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
	Technical Change	1.5	1.6	1.4	1.5	1.1	1.5	1.4	1.3	1.5	1.7	1.1	1.1	1.6	1.7	1.6	1.2	1.5	1.6	1.4
	Scale Component	0.3	0.1	0.0	0.1	0.1	0.0	0.6	0.3	-0.3	0.4	0.2	1.8	0.2	0.2	0.1	0.1	0.0	0.1	0.2
	Allocative Inefficiency	-0.8	-0.2	-0.4	0.0	-0.7	0.2	-0.5	0.0	0.0	0.0	-1.0	0.2	-0.3	-0.7	-0.1	0.0	0.4	-0.1	-0.2
	TFP	**1.1**	**1.5**	**0.9**	**1.6**	**0.7**	**1.6**	**1.6**	**1.6**	**1.2**	**2.1**	**0.5**	**2.2**	**1.4**	**1.1**	**1.4**	**1.3**	**1.9**	**1.5**	**1.4**
Basic Metals & Fabricated Metal	TE Change	0.1	0.4	0.0	0.0	-0.1	-0.2	-0.1	0.6	-0.3	0.0	0.2	0.0	0.3	0.0	0.0	-0.1	0.9	0.0	0.1
	Technical Change	1.5	1.4	1.3	1.6	1.1	1.5	1.4	1.5	1.5	1.5	1.0	1.1	1.5	1.7	1.5	1.0	1.4	1.6	1.4
	Scale Component	0.3	-0.2	0.1	0.3	0.1	0.2	0.7	0.8	-0.1	-0.1	0.7	1.0	0.3	0.1	0.1	1.1	-1.5	0.1	0.2
	Allocative Inefficiency	-0.5	0.0	0.0	0.1	-0.2	0.2	-0.4	0.0	0.0	0.3	0.0	0.0	0.1	-0.5	-0.1	-0.2	0.4	0.1	0.0
	TFP	**1.4**	**1.6**	**1.3**	**2.0**	**0.8**	**1.8**	**1.5**	**2.9**	**1.1**	**1.7**	**1.9**	**2.0**	**2.1**	**1.3**	**1.5**	**1.8**	**1.2**	**1.7**	**1.6**
Machinery, Nec	TE Change	0.1	0.2	0.0	0.0	0.4	-0.1	-0.2	0.1	0.7	0.0	0.4	-2.8	-0.1	2.1	0.0	0.1	0.0	-0.1	0.0
	Technical Change	1.6	1.5	1.3	1.8	1.1	1.6	1.4	1.6	1.5	1.6	1.3	1.2	1.6	1.8	1.5	1.1	1.6	1.6	1.5
	Scale Component	0.5	0.1	0.1	0.3	0.6	0.3	1.8	0.3	-0.2	0.0	0.9	5.0	0.0	0.1	0.5	0.3	0.1	0.1	0.6
	Allocative Inefficiency	0.4	0.1	0.0	-0.3	-0.1	-0.1	-0.4	0.0	0.1	0.4	-0.7	-0.6	-0.2	-1.3	0.1	0.0	0.4	0.0	-0.1
	TFP	**2.5**	**1.9**	**1.4**	**1.8**	**2.0**	**1.6**	**2.5**	**1.9**	**2.0**	**1.9**	**1.9**	**2.8**	**1.3**	**2.7**	**2.1**	**1.4**	**1.9**	**1.5**	**2.0**
Electrical & Optical Equipment	TE Change	0.1	0.6	0.0	0.0	0.2	0.6	0.4	3.4	0.2	0.2	0.6	2.1	0.6	7.7	0.0	0.8	0.7	4.2	1.2
	Technical Change	1.5	1.6	1.3	1.8	0.5	1.4	1.5	1.8	1.5	1.6	0.4	1.1	1.6	1.9	1.5	1.1	1.6	1.7	1.4
	Scale Component	0.4	0.0	0.1	0.8	8.0	1.3	4.9	-1.5	0.2	0.1	7.1	2.4	0.1	40.1	11.0	0.3	0.4	-0.9	4.2
	Allocative Inefficiency	-0.2	0.1	0.1	-1.1	0.1	-0.1	-5.1	-0.1	0.2	0.2	-0.4	-1.7	-0.3	-42.9	-9.4	0.5	0.0	-0.4	-3.4
	TFP	**1.8**	**2.3**	**1.5**	**1.5**	**8.6**	**3.2**	**1.8**	**3.6**	**2.0**	**2.0**	**7.7**	**3.8**	**2.0**	**6.7**	**3.1**	**2.6**	**2.7**	**4.8**	**3.4**
Transport Equipment	TE Change	0.0	0.0	-0.1	0.1	0.2	-0.1	0.0	-0.1	0.0	0.0	-0.1	0.2	0.0	0.6	0.1	0.1	0.0	0.0	0.1
	Technical Change	1.3	1.4	1.3	2.0	0.6	1.7	1.4	1.5	1.4	1.7	0.3	1.2	1.6	1.7	1.8	0.9	1.5	1.6	1.4
	Scale Component	0.7	0.6	0.0	-4.7	6.5	0.5	0.5	0.2	-0.1	0.0	10.6	-1.1	0.0	2.1	1.3	1.7	-3.3	-4.1	0.6
	Allocative Inefficiency	0.1	-0.3	0.2	3.0	-1.0	0.7	0.2	0.3	0.3	0.1	-1.2	2.2	0.4	-3.0	-0.6	-0.2	6.3	3.9	0.6
	TFP	**2.1**	**1.8**	**1.5**	**0.4**	**6.3**	**2.6**	**2.2**	**1.9**	**1.7**	**1.7**	**9.6**	**2.5**	**1.9**	**1.4**	**2.5**	**2.4**	**4.4**	**1.7**	**2.7**

Table 8 continue: average TFP growth by sector and country

		AUS	AUT	BEL	CAN	CZE	DNK	ESP	FIN	FRA	GER	HUN	IRL	ITA	JPN	NLD	SWE	UK	USA	Mean*
Manufacturing Nec; Recycling	TE Change	4.6	0.1	-0.1	0.0	-0.2	-0.1	-0.1	0.0	0.0	-0.1	-0.1	-1.1	-0.1	0.0	-0.1	0.2	-0.2	-0.1	0.1
	Technical Change	1.6	1.6	1.4	1.7	0.8	1.6	1.4	1.4	1.5	1.6	0.9	1.2	1.7	1.8	1.6	1.1	1.8	1.7	1.5
	Scale Component	-8.3	0.1	0.2	0.5	1.5	-0.1	1.0	0.2	0.0	0.1	2.0	7.8	-0.1	-0.1	0.2	0.5	0.4	0.1	0.3
	Allocative Inefficiency	5.2	0.3	0.0	0.1	0.2	0.0	-0.3	0.1	-0.1	0.6	0.7	-3.5	-0.1	0.0	0.3	5.9	-0.6	0.0	0.5
	TFP	**3.0**	**2.1**	**1.5**	**2.3**	**2.2**	**1.3**	**2.0**	**1.7**	**1.3**	**2.2**	**3.6**	**4.3**	**1.4**	**1.7**	**2.0**	**7.6**	**1.4**	**1.6**	**2.4**
Overall mean*	TE Change	0.6	0.7	0.0	0.1	-0.4	0.1	-0.1	0.7	2.1	0.2	-0.1	-0.2	0.0	1.0	0.0	0.2	0.2	0.4	0.3
	Technical Change	1.5	1.5	1.3	1.7	1.0	1.6	1.4	1.5	1.5	1.6	1.0	1.2	1.6	1.8	1.6	1.1	1.6	1.7	1.5
	Scale Component	0.1	0.2	0.2	-0.7	3.4	0.4	1.0	0.0	-0.2	4.7	1.8	2.8	0.1	2.1	1.0	0.7	-0.2	0.2	1.0
	Allocative Inefficiency	-0.1	-0.3	-0.4	0.5	-1.2	0.0	-0.8	-0.1	0.1	-4.8	0.3	-1.1	-0.2	-2.9	-0.8	0.1	0.5	-0.4	-0.6
	TFP	**2.0**	**2.2**	**1.1**	**1.6**	**2.6**	**1.9**	**1.5**	**2.1**	**3.5**	**1.6**	**3.0**	**2.6**	**1.5**	**1.9**	**1.8**	**2.1**	**2.1**	**1.8**	**2.1**

(*) Simple average

Source: author's calculation.

5. Conclusions

The negative effect of anti-competitive regulation on economic growth has long being stressed. This paper has its focus on "knock-on" effect of non-manufacturing regulation on manufacturing sector efficiency and productivity in a panel of 18 countries aver the period 1975-2007, using the Stochastic Frontier Approach. I find that regulation has high and significant negative impact on technical efficiency, which contribution to TFP growth has been, on average, positive although not very large. The main driver of TFP growth over time, across sectors and countries has been technical change, which also resulted being both labour and capital saving. Scale component has given the second largest contribution to TFP growth, while the contribution of allocative efficiency resulted, on average, negative.

Given the strong negative relation between regulation and technical efficiency first, and then on TFP growth, it is immediate to suggest, for those countries with still very tight regulation in services (i.e Belgium, Italy, Japan) to reduce it in order to accelerate the productivity dynamic and the growth of the overall economy.

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Appendix

Figure A.1

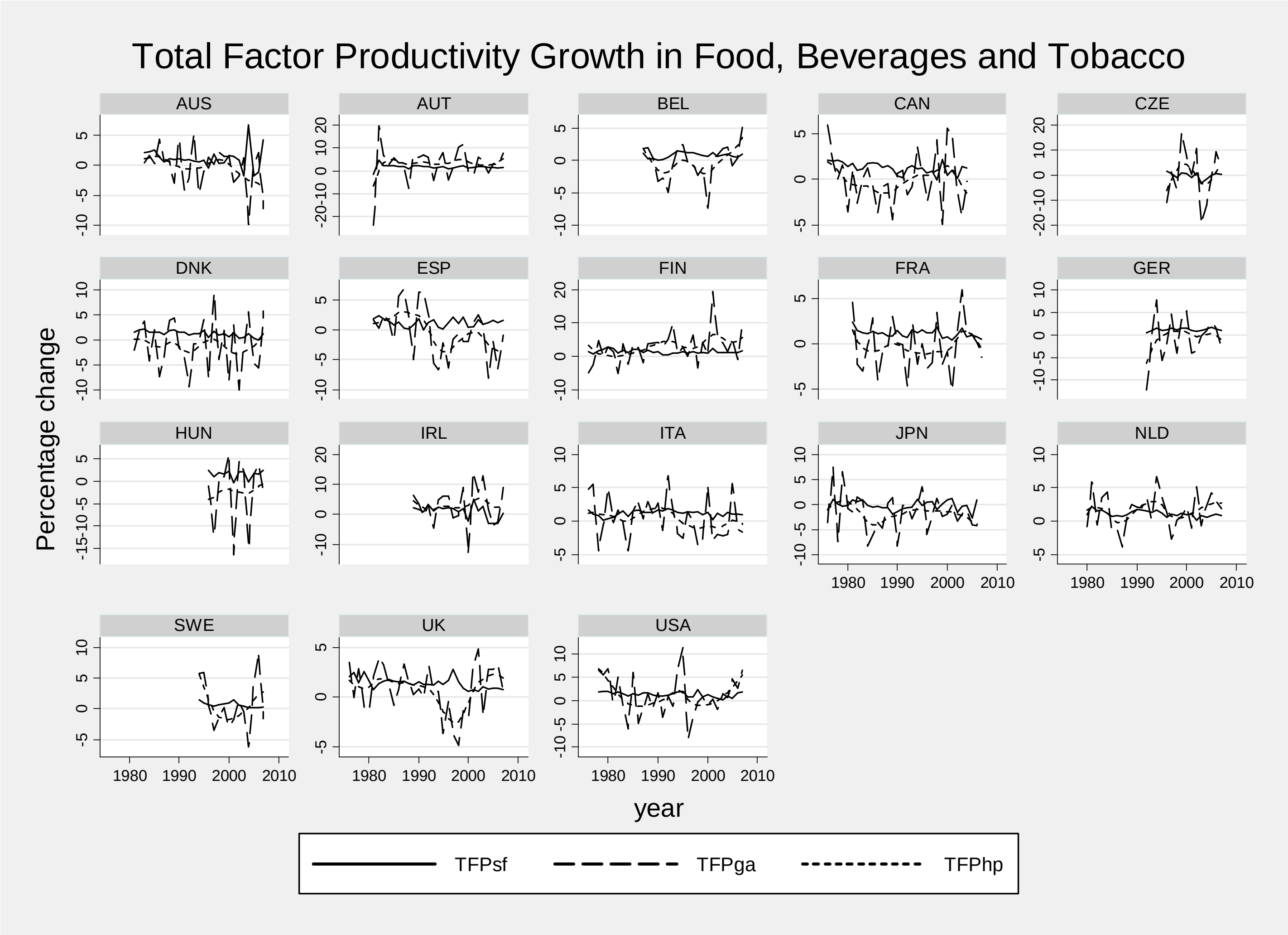


Figure A.2

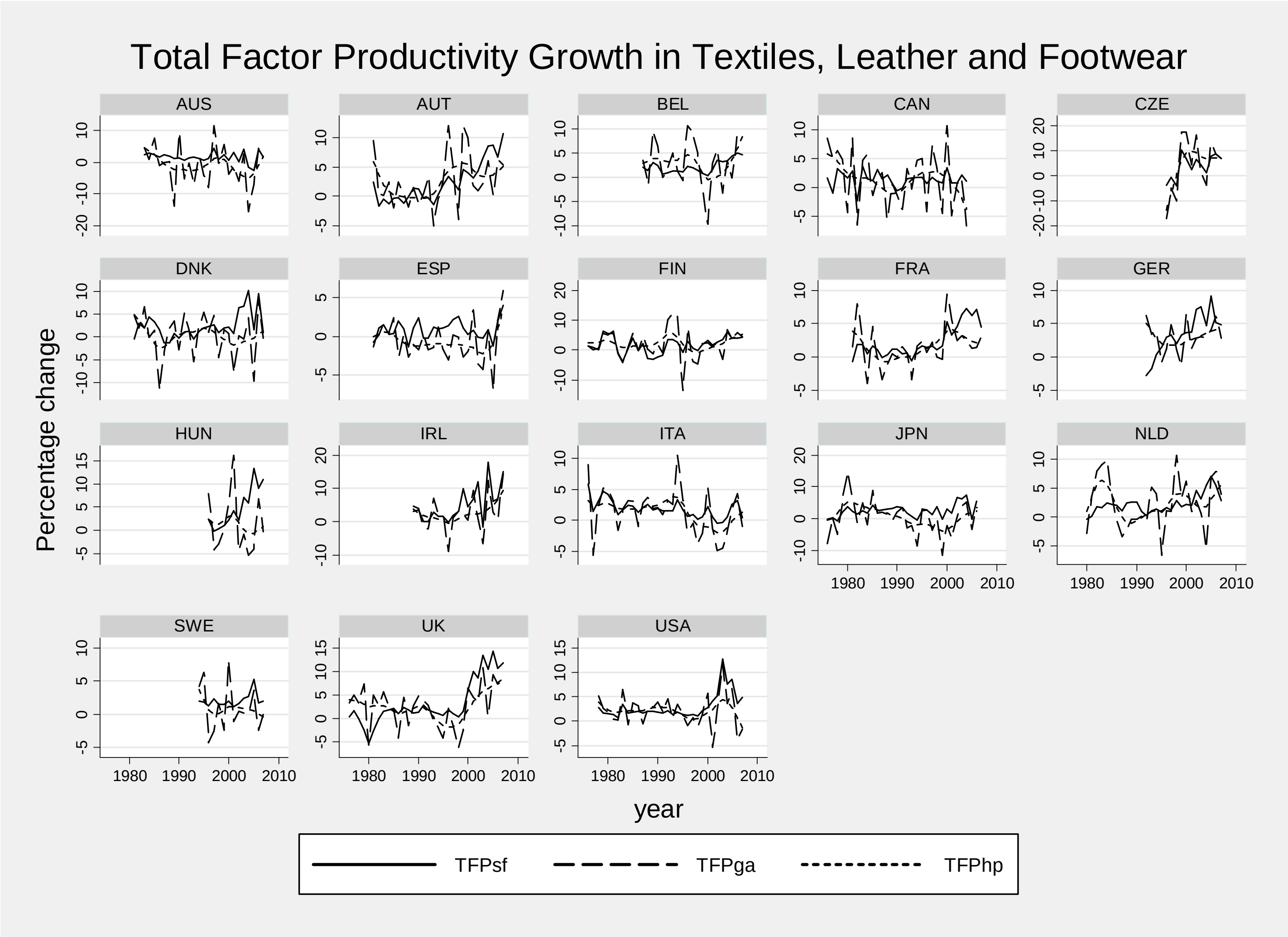
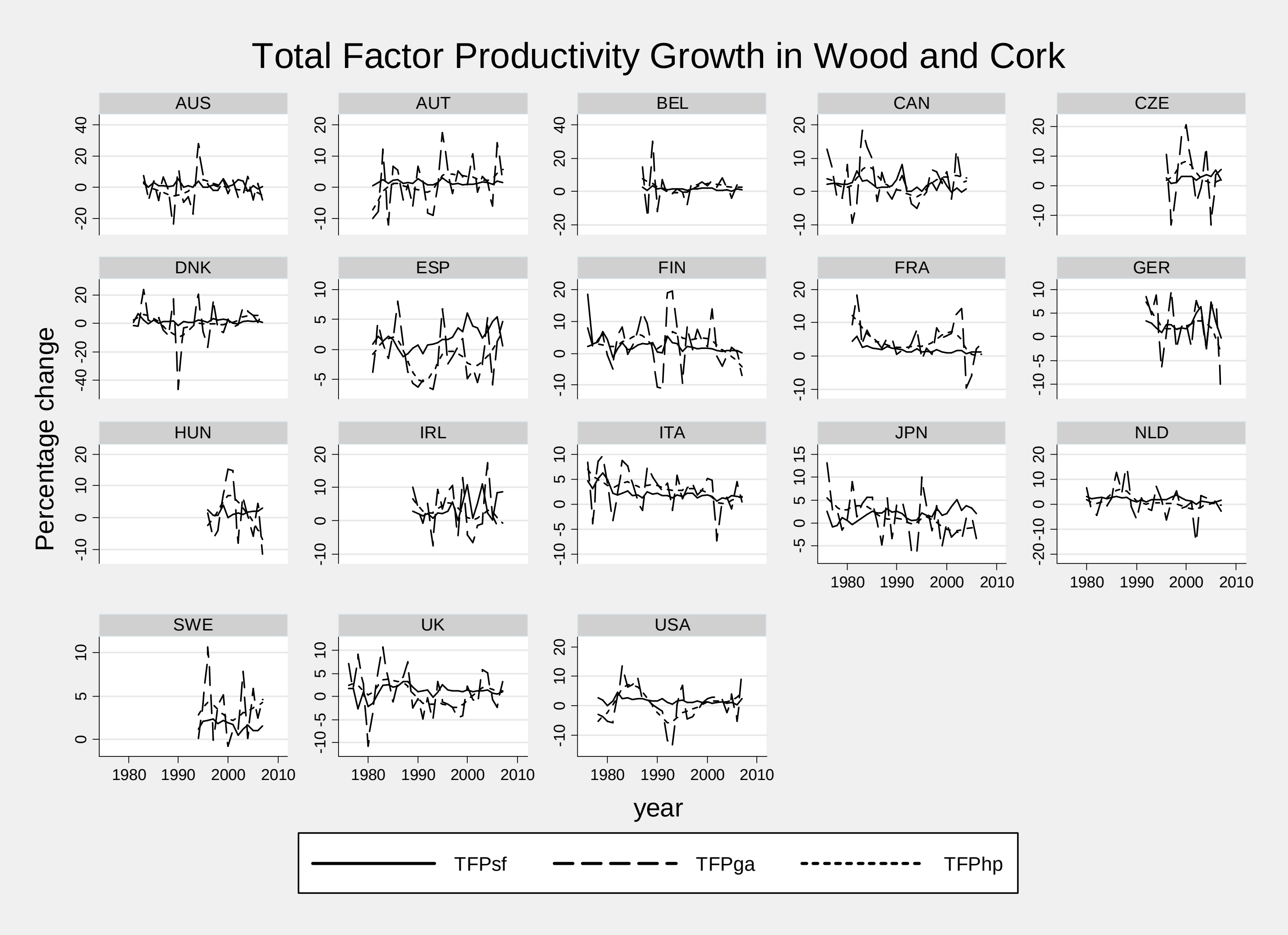
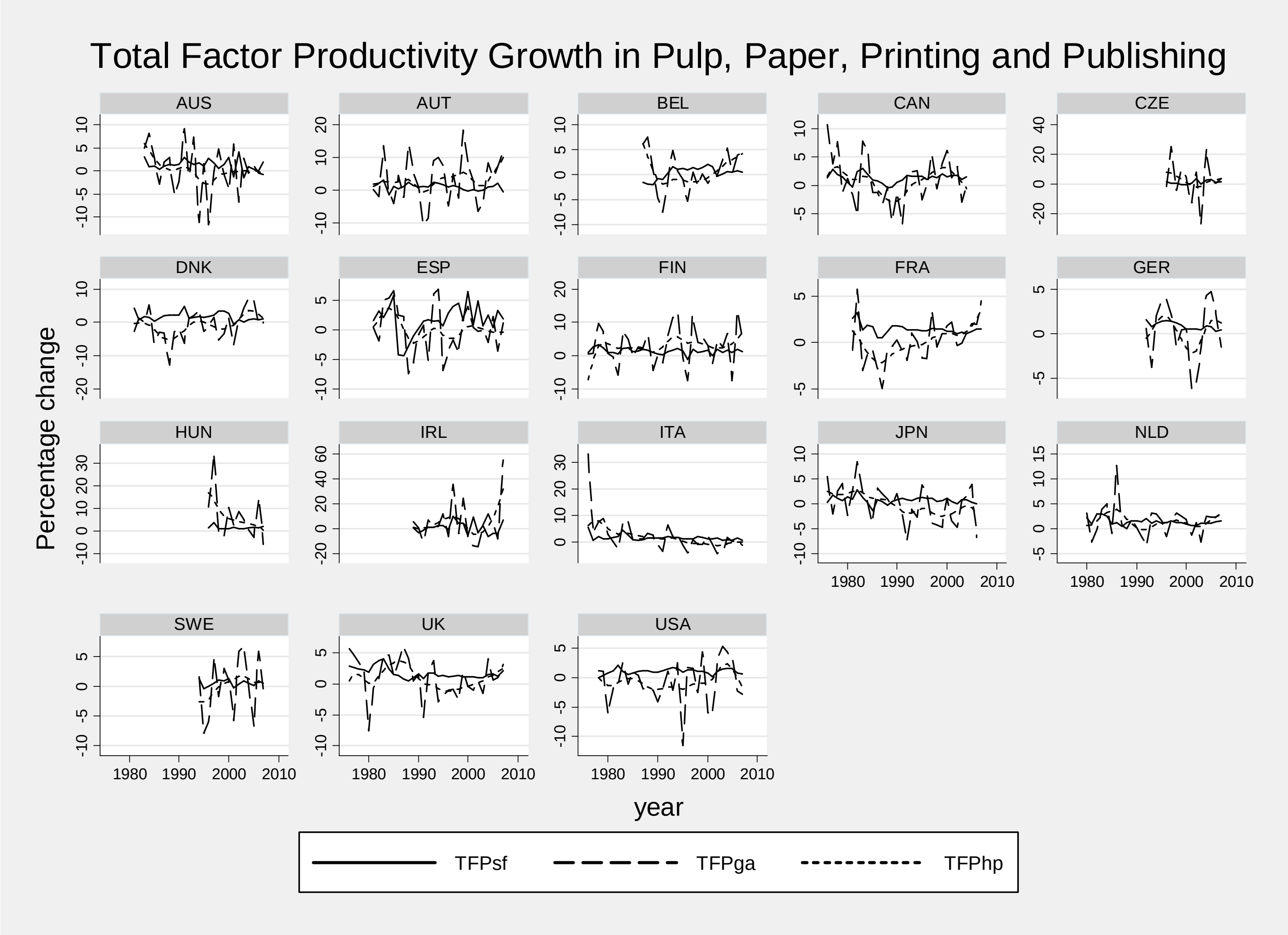

Total Factor Productivity Growth in Textiles, Leather and Footwear
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
IRL
ITA
JPN
NLD
SWE
UK
USA
Percentage change
year
1980 1990 2000 2010
TFPsf
TFPga
TFPhp

Figure A.3



Total Factor Productivity Growth in Wood and Cork
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
IRL
ITA
JPN
NLD
SWE
UK
USA
Percentage change
year
1980 1990 2000 2010
TFPsf
TFPga
TFPhp

Figure A.4



Total Factor Productivity Growth in Pulp, Paper, Printing and Publishing
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
IRL
ITA
JPN
NLD
SWE
UK
USA
Percentage change
year
1980 1990 2000 2010
TFPsf
TFPga
TFPhp

Figure A.5

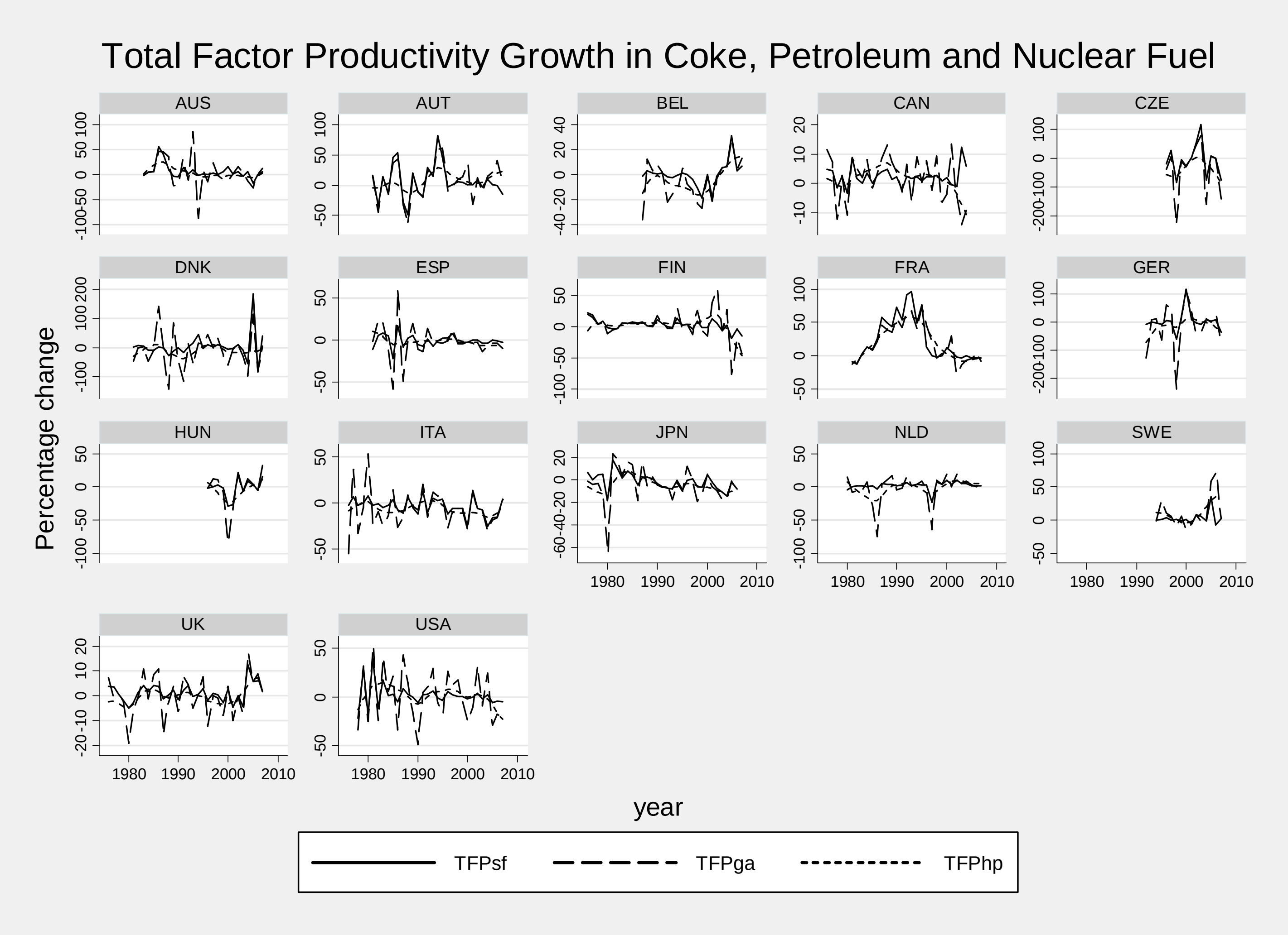
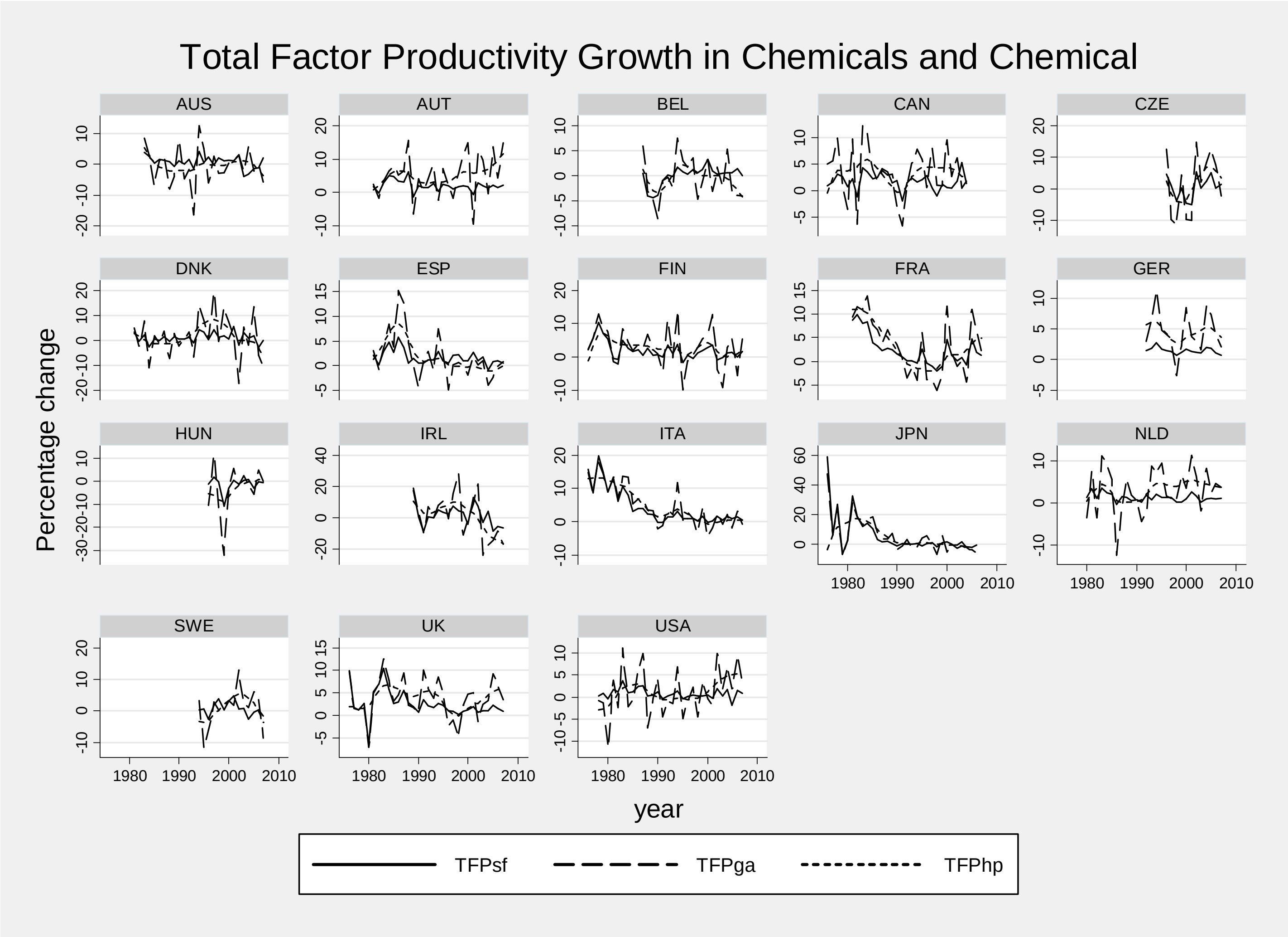

Total Factor Productivity Growth in Coke, Petroleum and Nuclear Fuel
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
ITA
JPN
NLD
SWE
UK
USA
Percentage change
year
1980
1990
2000
2010
TFPsf
TFPga
TFPhp

Figure A.6



Total Factor Productivity Growth in Chemicals and Chemical
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
IRL
ITA
JPN
NLD
SWE
UK
USA
Percentage change
year
TFPsf
TFPga
TFPhp

Figure A.7

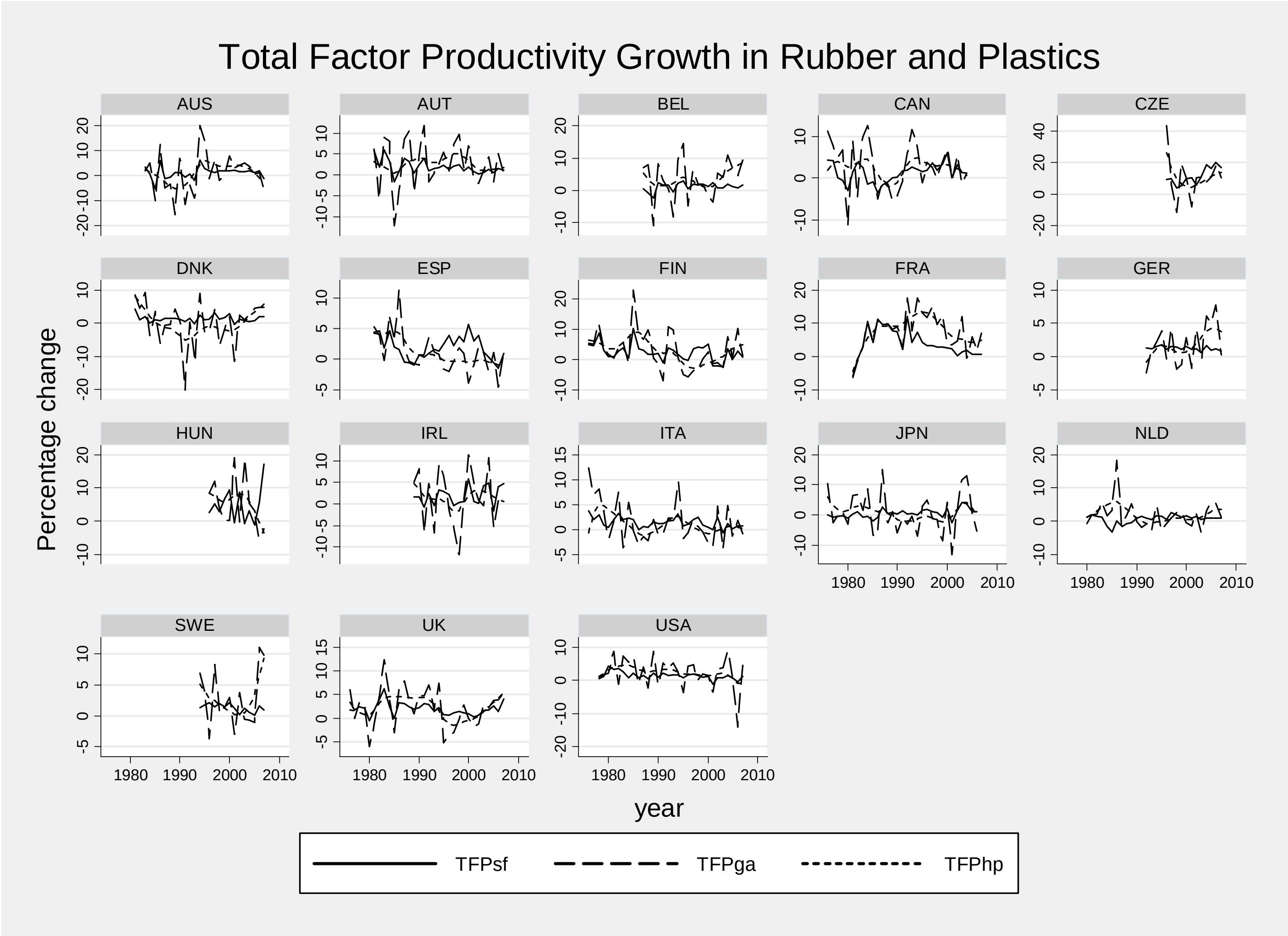
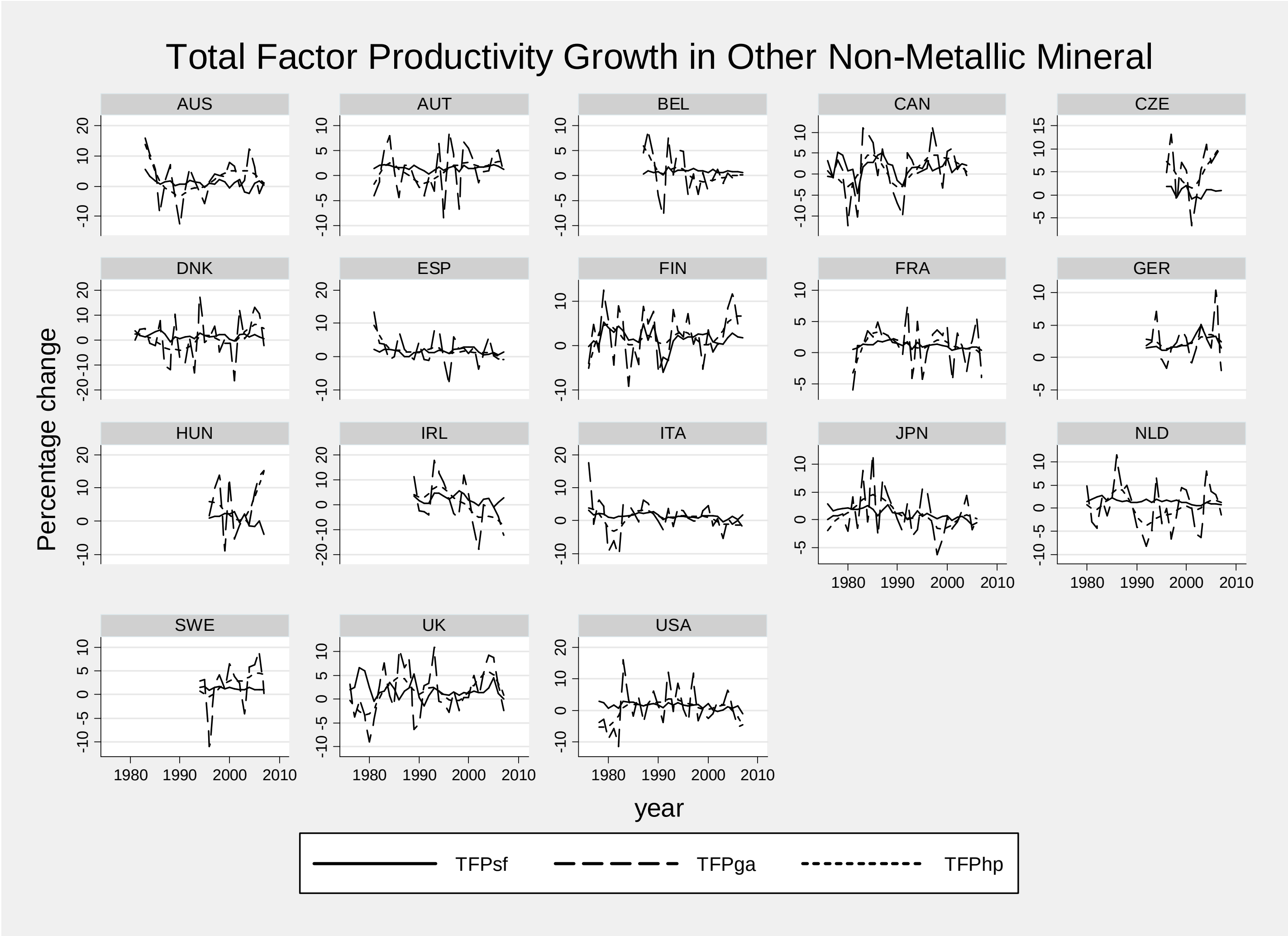
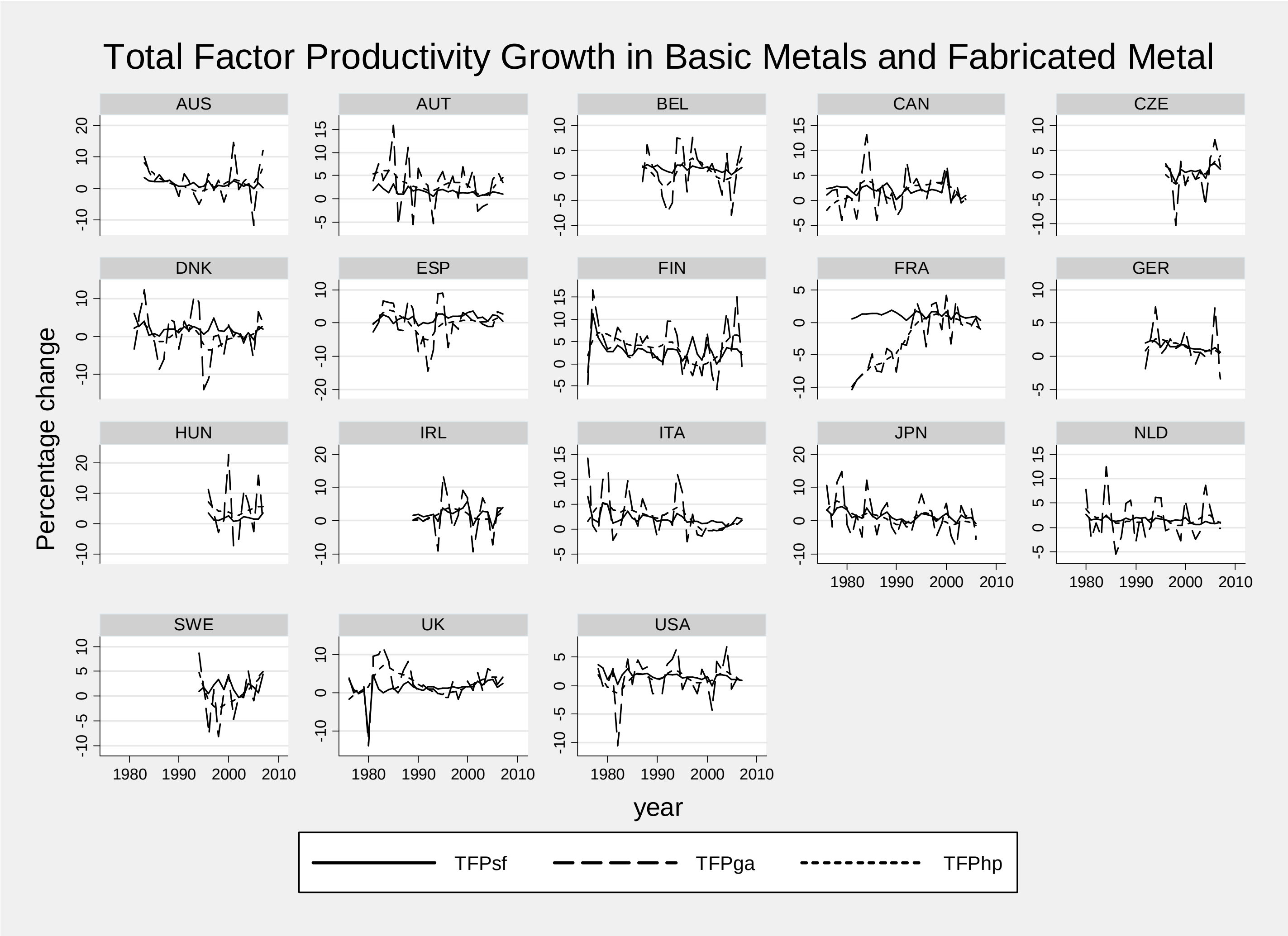

Total Factor Productivity Growth in Rubber and Plastics
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
IRL
ITA
JPN
NLD
SWE
UK
USA
Percentage change
year
1980 1990 2000 2010
TFPsf
TFPga
TFPhp

Figure A.8



Total Factor Productivity Growth in Other Non-Metallic Mineral
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
IRL
ITA
JPN
NLD
SWE
UK
USA
Percentage change
year
1980 1990 2000 2010
TFPsf
TFPga
TFPhp

Figure A.9


Total Factor Productivity Growth in Basic Metals and Fabricated Metal
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
IRL
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SWE
UK
USA
Percentage change
year
TFPsf
TFPga
TFPhp

Figure A.10

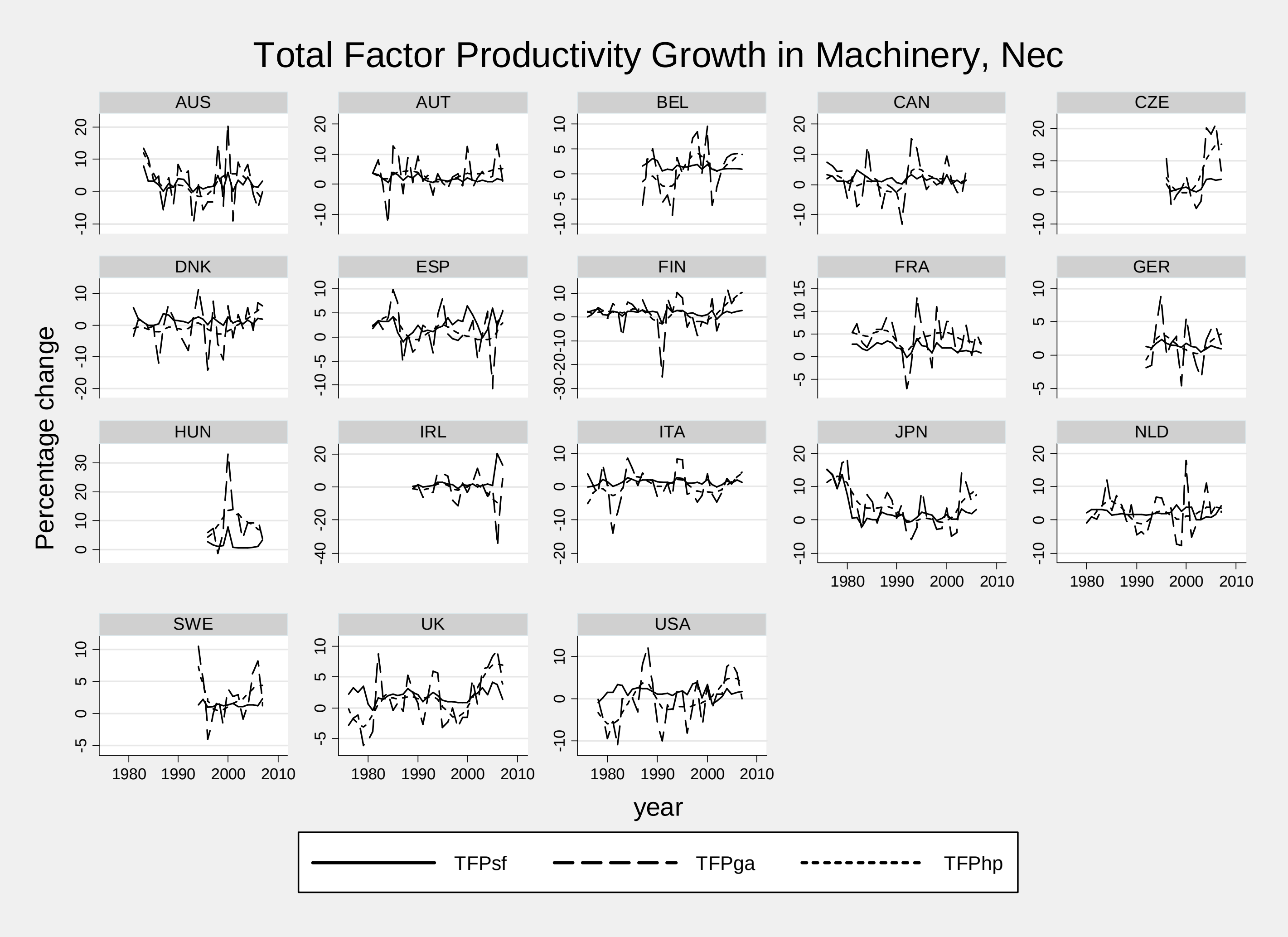

Total Factor Productivity Growth in Machinery, Nec
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
IRL
ITA
JPN
NLD
SWE
UK
USA
Percentage change
year
TFPsf
TFPga
TFPhp

Figure A.11

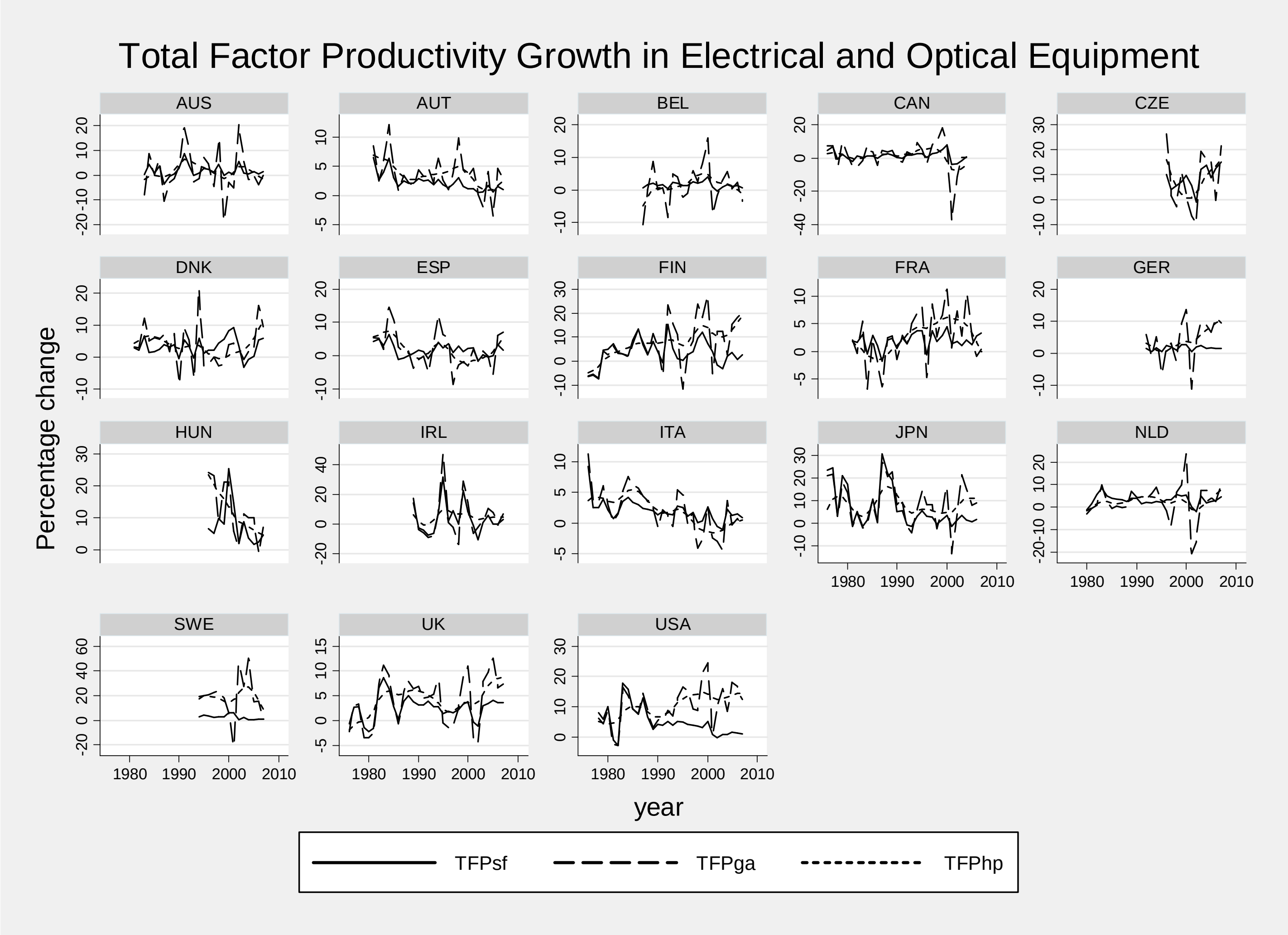
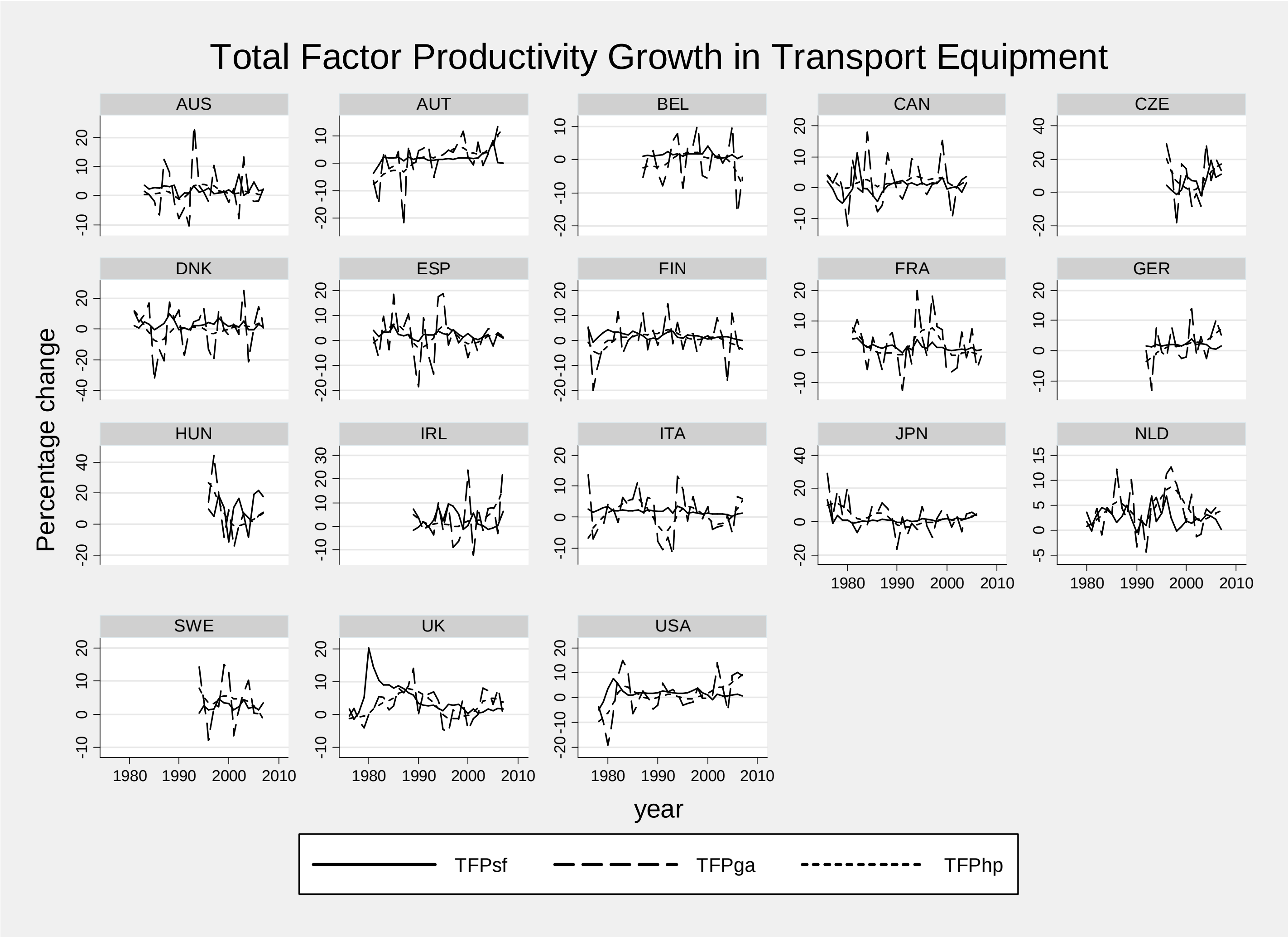
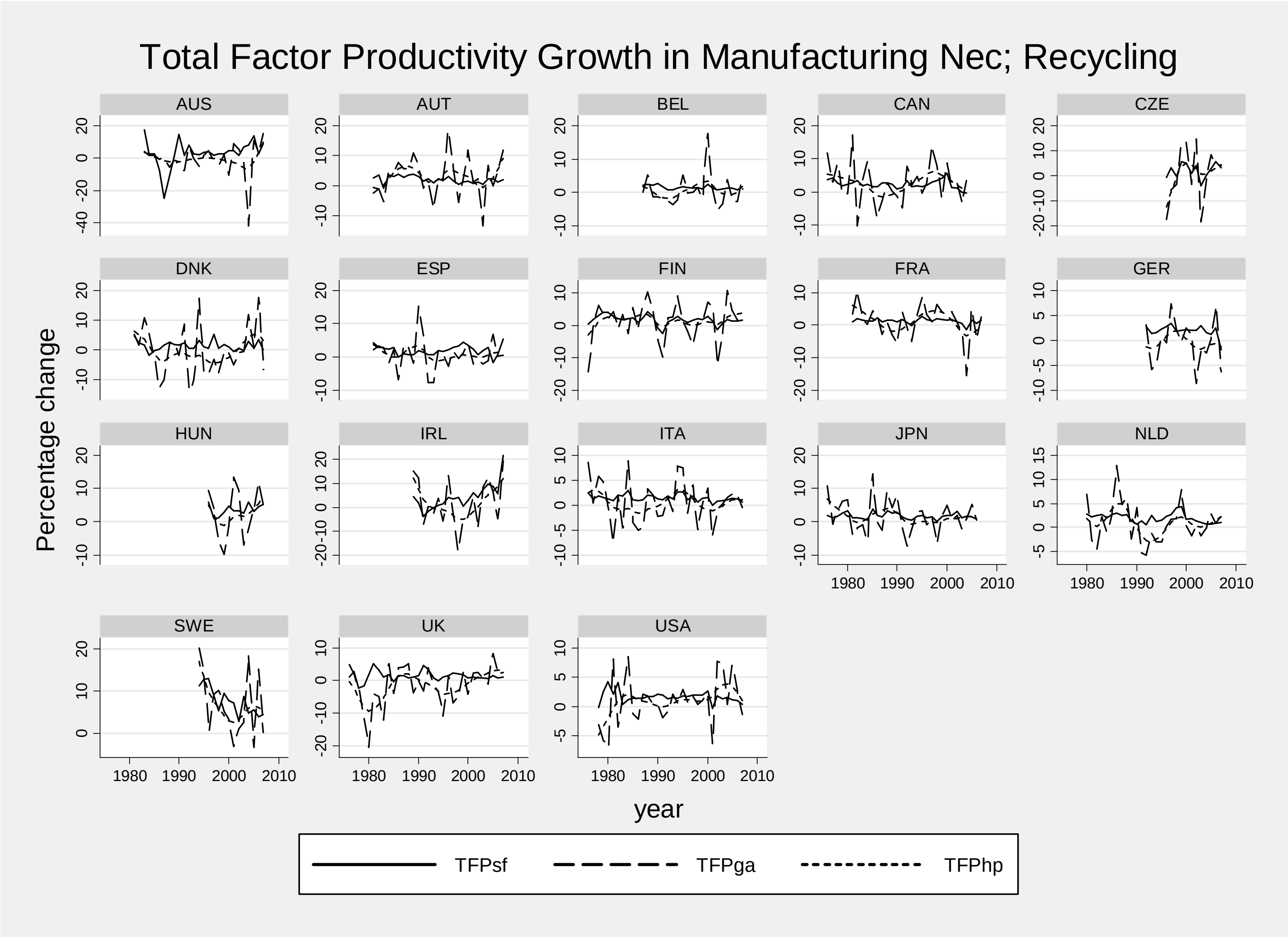

Total Factor Productivity Growth in Electrical and Optical Equipment
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
IRL
ITA
JPN
NLD
SWE
UK
USA
Percentage change
year
1980 1990 2000 2010
TFPsf
TFPga
TFPhp

Figure A.12



Total Factor Productivity Growth in Transport Equipment
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
IRL
ITA
JPN
NLD
SWE
UK
USA
Percentage change
year
TFPsf
TFPga
TFPhp

Figure A.13


Total Factor Productivity Growth in Manufacturing Nec; Recycling
AUS
AUT
BEL
CAN
CZE
DNK
ESP
FIN
FRA
GER
HUN
IRL
ITA
JPN
NLD
SWE
UK
USA
Percentage change
year
1980 1990 2000 2010
TFPsf
TFPga
TFPhp