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Determinants of innovation in a small open economy: the case of Belgium

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Abstract – Using dynamic panel data on 20 Belgian market sectors over 1987-2005, the paper analyses the link between Multifactor Productivity (MFP) growth and three frequently cited determinants: business R&D, labour skills and ICT use. The theoretical framework of the analysis is given by the Aghion-Howitt model which explains the rate of MFP growth by the distance to the world technology frontier.

The econometrical results show that the technology gap, measured by the difference between MFP levels, influences the growth of all Belgian sectors. The further the sector lies behind the global technology frontier, the faster its MFP will grow. Moreover, high skilled workers help to improve MFP growth and this positive impact increases over time. The effect of ICT intensity is more ambiguous and a positive effect is observed only for manufacturing. Finally, domestic R&D intensity has no statistically significant impact on MFP growth. By contrast, foreign R&D intensity has a positive impact on the productive efficiency of Belgian manufacturing.

Jel Classification – I20, O30, O41.

Keywords – Economic growth, human capital, innovation, ICT, technology frontier.

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1. Introduction

Formally demonstrated by Solow (1957), technical progress is one of the main determinants of long term economic growth. Over time, the definition of technical progress has progressively been extended to incorporate non-technological innovations such as new organisations of production processes. Today, various economic policies are designed to promote this progress even if they have not clearly identified its determinants.

Indeed, measuring technical progress is not an easy task. At the macroeconomic level, this measure is usually considered as a residual factor: the share of the value added growth that is not explained by capital and labour contributions. This improvement in the efficiency of factors combination is called multifactor productivity (MFP).

The main objective of this paper is to analyse, at the level of the Belgian sectors, three determinants of innovation frequently cited in the literature: business R&D intensity, high skilled labour intensity and ICT intensity. The theoretical framework of the analysis is given by the Aghion-Howitt model (2006) which explains MFP growth by the distance to the world technology frontier. According to this model, the further a sector is from the global technology frontier, the faster its MFP will grow. If a sector is already at the frontier, MFP growth depends on its own resources in terms of R&D efforts, a high skilled labour force, ICT use, competition intensity,etc.

This econometric analysis uses panel data covering 20 Belgian market services and manufacturing sectors over the period 1987-2005 to investigate links between MFP growth and the technological gap, R&D, high skilled workers and ICT intensity.

The paper is organised as follows. Section 2 briefly reviews the theoretical framework. Section 3 presents the econometric model. Data description is provided in the Section 4 and the results are commented on in Section 5. Finally, Section 6 concludes.

2. Theoretical framework

Aghion and Howitt (2006) propose a theory of economic growth mainly based on the Schumpeterian model of creative destruction in which long term growth is fuelled by quality-improving innovations. In their theory, the country's (or the sector's) growth performance will vary with its proximity to the world technology frontier. The further the country (the sector) is behind the technology frontier, the faster it will grow, under the condition that institutions and policies allow a catching-up process based on technological transfer by imitation. As the country (sector) catches up to the frontier, to maintain a high growth rate it has to develop other kinds of institutions and policies more focused on innovation from its own resources, notably in terms of skilled workers and R&D efforts. Based on this model, the authors suggest that the growth rate differential between the EU and the US is mainly due to the end of the catching up process set off by Europe at the end of the WWII and to the incapacity manifested by Europe to modify its institutions and policies to optimise the growth rate when close to the frontier. The Sapir report (2003), of which the conclusions are similar, used the same type of arguments.

In empirical literature, the main determinants of MFP growth are: R&D efforts, qualifications of the labour force, competition intensity and/or product market reform and ICT investment.

R&D efforts produce innovations of product, process or organisation, leading to an increase in output with unchanged inputs and therefore generating an increase in MFP. This relation between R&D and MFP growth has been proved in many empirical studies. Nadiri (1993), from a survey of the literature, suggests that output elasticity to R&D takes a value between 0.1 and 0.3 at enterprise level and between 0.08 and 0.30 at the level of sector.

The quasi-public-good nature of technological knowledge and the existence of R&D externalities are widely recognised in academic literature. As stated in Romer (1986): "The creation of new knowledge by one firm is assumed to have a positive external effect on the production possibilities of other firms because knowledge cannot be perfectly patented or kept secret." With the assumption of R&D spillovers, knowledge in sector i is not only derived from its own R&D intensity, but also from knowledge from other sectors or industries.

Griliches (1979) distinguishes two categories of spillovers: rent spillovers and knowledge spillovers. The first category reflects incomplete price adjustments for quality improvements in intermediate inputs, preventing the complete appropriation of the innovation rent by the innovator, due to imperfectly monopolistic pricing arising from competition. The second category of spillovers – knowledge spillovers - is defined by Griliches (1992) as ideas borrowed by the research teams of industry i from the research results of industry j and that accrue to the innovation process of the former. Poor patent protection, the inability to keep innovations secret, reverse engineering, technical meeting and mobility of (R&D) personnel (Levin, 1987) are possible channels of knowledge spillovers and reflect the non-rival and non-excludable nature of knowledge.

Although there are a lot of potential innovations and new kinds of knowledge available via these spillovers, not all firms are equally able to capture them and transform them into useful information for their business. According to Cohen and Levinthal (1989), the absorptive capacity of a firm (or a sector) is determined by its own R&D intensity. There are in fact two roles or faces of R&D activity. The first face is that of stimulating innovation and the second face is that of facilitating the imitation of others' discoveries. Griffith, Redding and Van Reenen (2001) have empirically tested the existence of these two faces of R&D in the Aghion-Howitt framework. Using panel data on 12 OECD countries at industry level, they show that R&D might both accelerate the growth of a country that is behind the technology frontier by improving the absorption of innovations implemented elsewhere in the world, and accelerate the growth of a country already at the frontier by increasing its innovative capacity.

As has been proved for R&D, human capital might also have two impacts on the MFP growth. Using their abilities and qualifications, skilled workers might directly contribute to MFP growth by stimulating innovation. They might also indirectly sustain MFP growth by facilitating the imitation of innovations implemented by countries at the frontier. Aghion and Howitt (2006), taking into account the heterogeneity of the labour force, predict that higher education investment should have a bigger impact on a country's ability to make leading-edge innovations, whereas primary and secondary education are more likely to make a difference in terms of the country's ability to implement existing technologies. Vandenbussche, Aghion and Méghir (2006), using panel data on 19 OECD countries over 1960-2000, show that qualified labour force has a higher growth-enhancing effect closer to the technological frontier.

ICT, like other forms of capital, contribute to labour productivity growth via capital deepening. In addition, ICT might also generate productivity gains through their impact on MFP. Two channels of transmission of a direct impact of ICT on MFP have been identified in the literature (OECD (2004)). Firstly, as general purpose technology, ICT might allow new production and sales organisation at the firm level as well as at that of the economy as a whole (Van Leeuwen and van der Wiel (2003)) and then might generate a temporary acceleration of MFP. ICT might also be helpful in the creation of new knowledge leading to new products or services and improving long run productivity growth (OECD (2002)). Secondly, ICT use might generate positive externalities such as network externalities. However, productivity gains due to ICT generally appear progressively and under the condition that they are accompanied by complementary immaterial investment such as new organisation of work and upgrading of labour force qualifications. As observed with R&D and human capital, ICT might also make the technology frontier transfer by imitation easier. Empirically, Ict impact on MFP growth is still difficult to prove. Using international panel data on 9 market services sectors between 1980 and 2004, Inklaar and Timmer (2006) do not identify an econometrically significant link between use of ICT and MFP growth.

Concerning product market competition, Aghion and Howitt show that it should have a more positive effect on innovation and productivity growth in industries where firms are more neck-and-neck. Moreover, entry, exit and turnover have all a positive effect on innovation and productivity growth, not only in the economy as a whole but also within incumbent firms. Using a panel data on OECD countries, Nicoletti and Scarpetta (2003) find econometrically significant links between market product reform and productivity growth. Entry liberalisation generates productivity gains for all countries covered by the analysis.

In the empirical literature, the technological gap -the distance to the technology frontier- is usually measured by the differential in MFP levels. Indeed, under strict neo-classical assumptions, MFP measures the technological efficiency of a country or a sector. However, in practice, with MFP growth being calculated as a residual in the growth accounting model, it covers more than "pure" technical progress. It includes, among others, mistakes in the quality adjustment of inputs and output, effects of unmeasured inputs such as intangibles or R&D, impacts of changes in returns to scale, impacts of organisational and institutional changes as well as the consequences of all elements that prevent marginal costs equalling marginal revenues (Inklaar, Timmer and van Ark (2008)). Nevertheless, MFP remains the only available instrument for capturing the efficiency in the combination of inputs reached by a country or a sector even if it has to be used with caution.

The theoretical framework of the analysis is close to that developed in Griffith, Redding and Van Reenen (2004). The value added (Y) of each sector (i) at time t is obtained by combining labour (L) and capital (K) in a neo-classical production function where A is an index of technical efficiency or MFP:

$$Y_{it} = A_{it} F_i (L_{it}, K_{it}) \tag{1}$$

F_i is assumed to be homogenous of degree one and to exhibit decreasing marginal returns to the accumulation of each factor alone. For each sector and each year, the technology frontier is reached by the country with the highest MFP level among those studied and is denoted A_{Ft}.

For sector i, the MFP is a function of two terms: the technological gap (ET) and the stock of knowledge (D)

$$A_{it} = \Phi(ET_{it}, D_{it}) \tag{2}$$

With a Cobb-Douglas function and taking logarithms and differencing with respect to time, one obtains the following equation:

$$\Delta \ln A_{it} = \nu_{it} \Delta \ln ET_{it} + \eta_{it} \Delta \ln D_{it} \tag{3}$$

The first term of this equation is the basic idea of the Aghion-Howitt model. Firstly, MFP growth depends on the distance to the technology frontier ($\ln(\frac{A_i}{A_F})$). Indeed, a sector behind this frontier could benefit from technological transfer (catching-up) by imitating the technology used by the leader. The more negative this variable, the further sector i lies behind the frontier and the greater the potential technological transfer. Secondly, the MFP growth of a sector could be reinforced by the MFP growth of the leader by technological spillovers of innovation at the frontier ($\Delta \ln A_F$). The effect of the technological gap on the MFP growth takes the following form:

$$\Delta \ln A_{it} = \alpha_{it} \Delta \ln A_{Ft} - \delta_{it} \ln \left(\frac{A_i}{A_F} \right)_{t-1} + \mu_{it} \quad (4)$$

From the empirical literature on the links between knowledge stock and MFP growth[1], MFP growth may be expressed as a function of the growth of knowledge stock (SRD) and a vector of control variables specific to the sector and country (X):

$$\Delta \ln A_{it} = \theta \Delta \ln SRD_{it} + \varphi X_{it} + \mu_{it} \quad (5)$$

where θ is the elasticity with respect to the R&D and μ_{it} is a stochastic error.

When interpreting this elasticity, it should be borne in mind that it captures the effect of R&D on value added growth that is not due to labour and capital contribution, in other words only the MFP effect. As underlined by van Pottelsberghe and Guellec (2001), this means that only spillovers are estimated rather than the total effect on value added. A share of private resources devoted to R&D is indeed already included in the two factors of production, labour (L) and capital (K). Therefore, if social return is equal to private return and if private return is equal to VA share, this elasticity is to be equal to zero.

Equation (5) can be rewritten as:

$$\Delta \ln A_{it} = \beta \left(\frac{\Delta SRD_i}{Y_i} \right)_{t-1} + \varphi X_{it} + \mu_{it} \quad (6)$$

where β is the rate of return[2] of R&D, and ΔSRD_i is the net investment or increase in the stock of R&D Under the assumption of null depreciation rates, explanatory variables can be transformed into intensities (R&D expenditures over value added):

$$\Delta \ln A_{it} = \beta \left(\frac{RD_i}{Y_i} \right)_{t-1} + \varphi X_{it} + \mu_{it} \quad (7)$$

In the empirical analysis, two factors -country and sector specific- have been identified: high-skill labour (LAB) and the ICT capital (ICT) [3]. These two variables are expressed as the compensation share in the VA of their respective services. Therefore, equation (7) can be rewritten:

1 See Griliches and Lichtenberg (1984) for the formalisation of the link between R&D and productivity. These authors assume a standard value-added Cobb-Douglas function that includes the knowledge capital stock as a separable factor of production.

2 $\theta = \frac{(dY / dSRD)}{(Y / SRD)}$ becomes $\beta = \frac{dY}{dSRD}$ when the explanatory variable is intensity.

3 Owing to lack of available data, competition is not taken into account. The effect of competition on MFP growth is

$$\Delta \ln A_{it} = \beta\left(\frac{RD_i}{Y_i}\right)_{t-1} + \varphi_2\left(\frac{LAB_i}{Y_i}\right)_{t-1} + \varphi_3\left(\frac{TIC_i}{Y_i}\right)_{t-1} + \mu_{it} \qquad (8)$$

Finally, a third element is usually taken into account in the empirical studies: the interaction term between explanatory variables (R&D, LAB and ICT) and the distance to the frontier. Indeed, R&D, LAB and ICT can sustain MFP growth by innovation (direct impact) but can also facilitate the catching-up process (indirect impact) by increasing the innovation absorptive capacity of the sector behind the frontier.

For sectors i behind the frontier, the total equation of MFP growth is:

$$\begin{aligned}\Delta \ln A_{it} &= \alpha\Delta \ln A_{Ft} - \delta \ln(\frac{A_i}{A_F})_{t-1} + \beta(\frac{RD_i}{Y_i})_{t-1} + \varphi_2(\frac{LAB_i}{Y_i})_{t-1} + \varphi_3(\frac{TIC_i}{Y_i})_{t-1} \\ &- \gamma_1(\frac{RD_i}{Y_i})_{t-1}\ln(\frac{A_i}{A_F})_{t-1} - \gamma_2(\frac{LAB_i}{Y_i})_{t-1}\ln(\frac{A_i}{A_F})_{t-1} - \gamma_3(\frac{TIC_i}{Y_i})_{t-1}\ln(\frac{A_i}{A_F})_{t-1} + \mu_{it}\end{aligned} \qquad (9)$$

On the right-hand side of the equation, the first term captures the contemporaneous spillovers of MFP growth at the frontier on the MFP growth of sectors behind the frontier. The second term measures the impact of the technological gap, defined as the differential in MFP levels between sector i and the sector at the frontier. The last three terms are terms of interaction which capture the indirect effect of the explanatory variables.

The expression for MFP growth at the frontier remains exactly the same as in equation (8) ($A_{it} = A_{Ft}$). Combining equation (9) for non-frontier sectors with equation (8) for frontier sectors, one obtains a first-order difference equation for MFP growth:

$$\begin{aligned}&\Delta \ln(\frac{A_i}{A_F})_t = \alpha\Delta \ln A_{Ft} \\ &+\beta\left[\left(\frac{RD_i}{Y_i}\right)_{t-1} - \left(\frac{RD_F}{Y_F}\right)_{t-1}\right] + \varphi_2\left[\left(\frac{LAB_i}{Y_i}\right)_{t-1} - \left(\frac{LAB_F}{Y_F}\right)_{t-1}\right] + \varphi_3\left[\left(\frac{TIC_i}{Y_i}\right)_{t-1} - \left(\frac{TIC_F}{Y_F}\right)_{t-1}\right] \\ &-\left[\delta + \gamma_1\left(\frac{RD_i}{Y_i}\right)_{t-1} + \gamma_2\left(\frac{LAB_i}{Y_i}\right)_{t-1} + \gamma_3\left(\frac{TIC_i}{Y_i}\right)_{t-1}\right]\ln\left(\frac{A_i}{A_F}\right)_{t-1} + \mu_{it} - \mu_{Ft}\end{aligned} \qquad (10)$$

In steady state equilibrium, MFP in a sector i in all countries will grow at the same rate, equal to MFP growth at the frontier, and there is no longer a MFP growth differential between countries ($\Delta \ln A_{it} = \Delta \ln A_{Ft}$ and $\Delta \ln(\frac{A_i}{A_F})_t = 0$). With the equation (8), one obtains the following equation for the long-run equilibrium relative MFP level:

$$\ln\left(\frac{A_i}{A_F}\right)^*_t = \frac{\beta\left[\left(\frac{RD_i}{Y_i}\right)_t - (1-\alpha)\left(\frac{RD_F}{Y_F}\right)_t\right] + \varphi_2\left[\left(\frac{LAB_i}{Y_i}\right)_t - (1-\alpha)\left(\frac{LAB_F}{Y_F}\right)_t\right] + \varphi_3\left[\left(\frac{TIC_i}{Y_i}\right)_t - (1-\alpha)\left(\frac{TIC_F}{Y_F}\right)_t\right]}{\left[\delta + \gamma_1\left(\frac{RD_i}{Y_i}\right)_t + \gamma_2\left(\frac{LAB_i}{Y_i}\right)_t + \gamma_3\left(\frac{TIC_i}{Y_i}\right)_t\right]} \qquad (11)$$

the focus of a new research project of the Federal Planning Bureau, called REFBARIN, financed by the federal scientific policy.

In this model, the steady state convergence occurs in terms of growth rates but not necessarily in terms of MFP levels. Indeed, the long-run equilibrium MFP level depends basically on the availability of resources that favour innovation, mainly R&D, high skilled labour and ICT capital, and each sector in each country can have these in different quantities. The sector with the largest quantities of these resources will be at the frontier (leader sector). It will have the highest level and growth rate of MFP. The other non-frontier sectors will have, from their own resources, a lower MFP growth rate than that of the frontier sector. However, thanks to the possibility to imitate the innovation implemented at the frontier, these sectors will be able to equal the frontier MFP growth rate, at the long-run equilibrium.

3. Econometric model

The econometric specification is an Equilibrium Correction Model (Griffith et al (2001)). In this model, variables converge towards stable and proportional growth rates.

Consider an ADL(1,1) model[4] in which the Belgian MFP is cointegrated with the frontier MFP,

$$\ln A_{it} = \alpha_1 \ln A_{it-1} + \alpha_2 \ln A_{Ft} + \alpha_3 \ln A_{Ft-1} + v_{it} \tag{12}$$

Under the assumptions of long run homogeneity $(\frac{\alpha_2 + \alpha_3}{1-\alpha_1} = 1)$, the equation is presented as:

$$\Delta \ln A_{it} = \alpha_2 \Delta \ln A_{Ft} - (1-\alpha_1)\ln\left(\frac{A_i}{A_F}\right)_{t-1} + v_{it} \tag{13}$$

Ignoring R&D, equation (13) is in fact equation (9), in which $\alpha_2 = o$, and $(1-\alpha_1) = \delta$. In equation (9), equation (13) is augmented with a term for the R&D intensity, the coefficient on relative MFP $(1-\alpha_1)$ is allowed to be a function of R&D intensity and a vector of control variables (LAB et TIC) is included. It is therefore clear that the coefficient of the relative MFP term measures the speed of convergence to long-run equilibrium. An explicit value for this long-run equilibrium (steady state) is given in equation (11).

By augmenting equation (13) for the R&D intensity[5] and for the two control variables, LAB and TIC, and by expressing the coefficient $(1-\alpha_1)$ as a function of these three determinants, one obtains the following econometric model for sectors behind the technology frontier:

$$\begin{aligned}\Delta \ln A_{it} = {} & \alpha \Delta \ln A_{Ft} - \delta \ln(\frac{A_i}{A_F})_{t-1} + \beta\ (\frac{RD_i}{Y_i})_{t-1} + \varphi_2 (\frac{LAB_i}{Y_i})_{t-1} + \varphi_3 (\frac{TIC_i}{Y_i})_{t-1} \\ & - \gamma_1 (\frac{RD_i}{Y_i})_{t-1} \ln(\frac{A_i}{A_F})_{t-1} - \gamma_2 (\frac{LAB_i}{Y_i})_{t-1} \ln(\frac{A_i}{A_F})_{t-1} - \gamma_3 (\frac{TIC_i}{Y_i})_{t-1} \ln(\frac{A_i}{A_F})_{t-1} + \mu_{it}\end{aligned} \tag{14}$$

For sectors at the frontier, there is no potential for technology transfer and the model is reduced to:

$$\Delta \ln A_{Ft} = \beta\ (\frac{RD_F}{Y_F})_{t-1} + \varphi_2 (\frac{LAB_F}{Y_F})_{t-1} + \varphi_3 (\frac{TIC_F}{Y_F})_{t-1} + \mu_{Ft} \tag{15}$$

4 An ADL(1,1) is an autoregressive model with one lag for the explanatory variable and one lag for the explained variable.

5 As in Griliches and Lichtenberg (1984), we make the assumption that R&D is a determinant of the long-run trend of MFP but not of the short term deviations. These deviations are primarily the results of fluctuations in capacity utilisation.

The equation for the frontier sectors is stacked together with the equation for the non-frontier sectors by putting $\Delta \ln A_{Ft}$ and $\ln(\frac{A_i}{A_F})_{t-1}$ at zero for the frontier sectors. The direct effect of R&D, LAB and ICT on MFP growth is therefore assumed to be the same for the frontier and the non-frontier sectors. In order to examine the robustness of the results, equations are estimated only for the non-frontier sectors in Annex 3.

4. Data description

4.1. Data sources

The data used in the empirical application cover 20 Belgian sectors[6] over 1987-2005. They come from the EUKLEMS database (www.euklems.net) which provides data on output, inputs and productivity at a detailed industry level for the EU Member States as well as for the US. Data used in the analysis are MFP (level and growth rate), R&D, ICT use and qualification of labour force.

MFP data come from the EUKLEMS database. MFP at the industry level is estimated by the growth accounting method using capital and labour services input in order to take into account the improvement of quality over time[7]. Accurate measures of labour and capital input contribution to growth are based on a distinction between different categories of hours worked and capital assets. The use of services input improves the estimated contribution of factors of production and therefore the MFP residual estimation in the growth accounting decomposition. A sensitivity analysis of MFP to various input measures is provided in Annex 2.

To be able to calculate the technological gap for a sector i, MFP levels are required for all countries and for each year. International comparison of levels -labour productivity levels as well as MFP levels- requires the use of the Purchasing Power Parities (PPP's) to express all monetary variables on a common basis. However, in practice, estimation of MFP levels is much more complex than the estimation of the labour productivity level. Indeed, this estimation requires PPPs for each industry and each variable included in the MFP estimation in particular for each category of inputs taken into account. The set of information needed is detailed in Inklaar and Timmer (2007). Data in levels for the year 1997 have been provided to EUKLEMS members and cover 11 countries[8]. Using MFP growth rates in the March 2008 EUKLEMS release, series in levels covering the period 1987-2005 have been created for each sector in each country. These results have to been taken with caution, as comparison of MFP levels is more sensitive to national differences in output and inputs measurements than comparison of MFP growth.

R&D data cover business R&D expenditure in current prices from the Belgian Scientific Policy. These data are divided by the value added in nominal prices published in EUKLEMS database to obtain R&D intensity. In order to estimate foreign R&D impact on MFP growth, R&D intensity for the three neighbouring countries, France, the Netherlands and Germany, has been estimated from the ANBERD (CITI rev 3) database of the OECD completed by data from EUROSTAT. Foreign

6 Detail on sectors in Annex 1.
7 For more information on data construction, consult the methodological manual on the EUKLEMS website, www.euklems.net.
8 Countries covered by the analysis are Belgium, Austria, Denmark, Spain, Finland, France, the United-Kingdom, Germany, Italy, the Netherlands and the United States.

R&D intensity has been calculated only for manufacturing due to lack of reliable information for other sectors.

The ICT data are ICT capital compensation from the EUKLEMS database divided by value added in nominal terms. High skilled labour data are high skilled labour compensation from the EUKLEMS database divided by value added in nominal terms. For Belgium, high skilled workers are defined as workers that have a university diploma or equivalent.

4.2. MFP data description

Over the period considered, 7 out of 20 sectors recorded on average a slowdown in MFP growth (see Table 1). Some sectors moved from a positive MFP annual average growth rate over 1987-1994 to a negative MFP growth rate over 1995-2005. This was the case of Pulp, paper and printing (DE), Non-metallic mineral products (DI), Transport and storage (I60-63) and Post and telecommunication (I64).

By contrast, 9 sectors improved their MFP growth rate: 7 sectors in manufacturing plus Electricity (EE) and Construction (FF). In manufacturing, this evolution concerned Machinery and equipment (DK), Electrical and electronic equipment (DL) and Rubber and plastic products (DH), which recorded the fastest MFP growth over the most recent period. Finally, 4 sectors recorded a slowdown in the decrease in MFP growth over the most recent period: Coke, petroleum and nuclear industries (DF), Chemicals (DG), Trade (GG) and Hotels and restaurants (HH).

Table 1: Average annual growth rate of MFP in %

	Sector	1987-1994	1995-2005
DA	Food products, beverages and tobacco	-0.50	0.20
DB+DC	Textiles and textile products and leather and leather products	3.46	1.91
DD	Wood and wood products	2.97	2.33
DE	Pulp, paper and paper products; publishing and printing	0.93	-0.39
DF	Coke, refined petroleum products and nuclear fuel	-7.13	-5.45
DG	Chemicals, chemical products and man-made fibres	-0.81	-0.09
DH	Rubber and plastic products	2.21	4.11
DI	Other-non metallic mineral products	2.46	-0.43
DJ	Basic metals and fabricated metal products	-0.23	1.66
DK	Machinery and equipment n.e.c.	-1.54	2.46
DL	Electrical and optical equipment	0.04	2.15
DM	Transport equipment	-0.31	1.33
DN	Manufacturing n.e.c.	-0.79	1.82
EE	Electricity, gas and water supply	0.82	2.11
FF	Construction	0.11	1.10
GG	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	-2.92	-1.57
HH	Hotels and restaurants	-1.19	-0.89
I_60t63	Transport and storage	5.30	-0.83
I_64	Post and telecoms	3.37	-1.44
JJ	Financial intermediation	2.96	2.87

Source: EUKLEMS, database March 2008.

From data on MFP levels, it appears that the position of Belgian manufacturing and market services among 11 countries considered deteriorated over the period 1987-2005[9]. Table 2 shows the country with the highest level of MFP and, in brackets, the Belgian position for the 13 manufacturing industries in 1987, 1995 and 2005. The relative technological position of Belgian manufacturing clearly deteriorated. While in 1987, Belgium was among the three leaders for 8 sectors, it belonged to this group only for 4 sectors in 2005. Between 1987 and 2005, the relative technological position of Belgium improved for 3 sectors: Textile (DB+DC) which has been strongly restructured; Rubber and plastics (DH), for which the improvement has been visible since the mid-nineties; and Other non-metallic industries (DI). The relative technological position deteriorated for 7 sectors.

Table 2: Country with the highest MFP level and relative position of Belgium - Manufacturing

	Sectors	1987	1995	2005
DA	Food products, beverages and tobacco	DK (2)	NL (4)	FI (4)
DB+DC	Textiles and textile products and leather and leather products	ES (7)	ES (5)	US (3)
DD	Wood and wood products	ES (4)	ES (6)	FR (4)
DE	Pulp, paper and paper products; publishing and printing	ES (2)	**BE**	FI (2)
DF	Coke, refined petroleum products and nuclear fuel	DE (3)	UK (4)	NL (6)
DG	Chemicals, chemical products and man-made fibres	AU (2)	FR (6)	NL (9)
DH	Rubber and plastic products	IT (3)	**BE**	**BE**
DI	Other non-metallic mineral products	NL (5)	ES (2)	ES (2)
DJ	Basic metals and fabricated metal products	ES (4)	NL (8)	NL (6)
DK	Machinery and equipment n.e.c.	IT (2)	IT (9)	FR (6)
DL	Electrical and optical equipment	**BE**	NL (4)	US (5)
DM	Transport equipment	US (5)	US (9)	US (5)
DN	Manufacturing n.e.c.	UK (3)	DK (5)	UK (5)

Source: FPB estimations from the EUKLEMS database.

The same kind of analysis was implemented for the 5 market services industries. Table 3, constructed in the same way as Table 2, presents the leader country and, in brackets, the relative position of Belgium. The results have to be interpreted with more caution than in the case of manufacturing. On the one hand, value added in services is less accurately estimated than in manufacturing, and on the other hand, inputs and outputs measurement practices vary more widely from one country to another.

Table 3: Country with the highest MFP level and relative position of Belgium – market services

	Sectors	1987	1995	2005
GG	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods	**BE**	DK (2)	DK (5)
HH	Hotel and restaurant	FR (4)	DE (3)	US (5)
I_60t63	Transport and storage	NL (11)	NL (11)	NL (11)
I_64	Post and telecoms	UK (2)	UK (2)	UK (9)
JJ	Financial intermediation	ES (7)	NL (2)	ES (2)

Source: FPB estimations from the EUKLEMS database.

9 Annex 5 presents the evolution of the MFP gap between the Belgian sectors and the leading sectors.

From Table 3, the decline in the relative technological position of Belgium is also visible in the services industries. While Belgium was the leader for Trade (GG) in 1987, it fell back to the fifth position in 2005. Belgium succeeded in improving its relative position solely for one services industry: financial services (JJ), with second place since the mid-nineties.

4.3. R&D, ICT and high skilled labour force data description

For each sector, Table 4 shows average R&D expenditure, ICT capital compensation and high skilled labour compensation in percentage of value added for two periods: 1987-1994 and 1995-2005.

In Belgium, R&D expenditure is clearly concentrated in few sectors. Two sectors in manufacturing are particularly intensive in R&D with an intensity much higher than in other sectors: Chemicals (DG), which includes drugs and medicines, and Electrical and electronic equipment (DL). Machinery and equipment (DK), Rubber and plastics (DH) and Transport equipment (DM) are also relatively R&D intensive although their performances are far below the two mostly intensive sectors. The non-manufacturing sectors recorded particularly low levels of R&D intensity. Finally, only one sector, Paper industry (DE) recorded on average a decrease in its R&D intensity over the most recent period.

Table 4: R&D expenditure, ICT capital compensation and high skilled labour compensation, in % of nominal value added – average intensity (in %)

	R&D		ICT		HS labour (LAB)	
	1987-1994	1995-2005	1987-1994	1995-2005	1987-1994	1995-2005
DA	0.91	1.61	2.96	2.59	5.08	7.26
DB	1.31	2.35	3.68	2.92	5.81	8.09
DD	0.73	0.74	2.83	2.58	10.38	12.88
DE	1.06	0.99	8.27	8.15	9.19	12.46
DF	2.41	3.28	7.78	6.87	7.36	8.51
DG	12.81	14.59	3.92	5.23	7.90	10.93
DH	2.74	4.67	4.95	3.44	8.77	12.79
DI	1.82	2.48	2.34	2.01	8.61	12.55
DJ	2.28	2.85	3.59	3.26	10.05	14.50
DK	5.26	6.45	5.38	4.17	10.50	12.56
DL	19.22	20.27	9.73	9.07	10.35	13.48
DM	2.78	4.16	1.94	2.09	10.34	13.87
DN	1.43	2.06	2.90	2.63	6.33	8.26
EE	0.15	0.47	2.74	4.23	7.42	9.23
FF	0.30	0.44	1.35	1.23	3.11	4.60
G	0.04	0.13	5.42	5.58	8.13	10.06
HH	0.01	0.06	2.71	2.15	10.43	12.43
I_60-63	0.11	0.25	2.50	5.01	3.87	6.42
I_64	0.10	0.95	17.80	24.55	2.19	7.16
JJ	0.15	0.20	12.30	10.62	16.65	21.22
Total	1.24	1.49	3.99	4.58	10.65	14.11

Source: FPB estimations from the EUKLEMS database and Scientific Policy.

Remarks: The I_64 sector only includes telecoms for R&D data. The total corresponds to the sum of all industries and corresponds to the total business R&D expenditure.

ICT use, measured by the share of this kind of capital compensation in the value added, is more homogeneously distributed across sectors even if the ICT intensities of Post and telecoms (I_64) and Financial services (JJ) are largely higher than the intensities of other sectors. Most sectors recorded a decrease in ICT intensity over the most recent period and only 6 sectors increased on average their ICT intensity.

Over the most recent period, Financial services (JJ) have devoted the largest share of its value added to the compensation of highly skilled labour. It is followed by Metal products (DJ), Transport equipment (DM) and Electrical and electronic equipment (DL). All sectors increased their share of high skilled labour compensation over the period. For all sectors, with the exception of Post and telecoms (I_64), the share of the VA attributed to high skilled labour compensation is higher than the share attributed to ICT capital compensation.

5. Results

5.1. Main results

The results of econometric regressions over the whole period, 1987-2005, for the 20 sectors and for manufacturing, are presented in Table 5. Only the reduced forms of the equation, obtained by the successive removal of non-significant variables, are presented in the Table 5.

The technological gap, measured by the differential in MFP levels between the Belgian sector and the leader, has a significant impact on the MFP growth of Belgian sectors[10]. The sectors that are further behind the frontier experience higher rates of MFP growth. This catching-up effect is stronger for manufacturing than for the whole economy; imitation may have been facilitated by the international openness of these sectors. By contrast, the frontier MFP growth term is not statistically significant, indicating the absence of spillovers.

Table 5: Results for the whole period

$\Delta \ln A_{it}$	Economy	Manufacturing
$\ln\left(\frac{A_i}{A_F}\right)_{t-1}$	-0.094*** (-3.651)	-0.141*** (-4.526)
$\Delta \ln A_{Ft}$	0.017 (0.365)	0.031 (0.590)
$\left(\frac{LAB_i}{Y_i}\right)_{t-1}$	0.013*** (3.193)	0.012* (1.789)
$\left(\frac{TIC_i}{Y_i}\right)_{t-1}$	-0.007*** (-2.569)	0.020*** (3.128)
Time dummies	Yes	Yes
Nbr. obs.	360	234
R^2	0.265	0.329

Estimation method: Panel OLSQ with fixed effect (Hausman-test), LM test for time dummies, heteroscedasticity robust test, Serial correlation of residuals test.

***, **, *: significant at 1%, 5%, 10%. t- test value in brackets.

Among the three determinants of MFP growth, high skilled labour intensity has a significant positive effect for the whole economy as well as for manufacturing. The increasing use of better skilled workers has improved the productive efficiency of Belgian companies.

ICT intensity has a differentiated effect depending on whether one considers the whole economy or manufacturing. For manufacturing, the effect is significantly positive. The increase in ICT use has improved the productive efficiency of manufacturing. By contrast, for the whole economy,

10 The values of the relative MFP level coefficient are close to the highest values found by Griffith et al. (2001).

the effect of ICT intensity is very weak and slightly negative. This could be explained by the observation often made in the empirical literature that ICT investments have to be complemented by intangibles investments and production process reorganization to fully produce efficiency gains fully. The non-manufacturing sectors, having invested in ICT later than manufacturing, could still be, during the considered period, at the reorganisation stage, leading to efficiency losses.

R&D intensity has no significant effect for manufacturing or the whole economy. This observation, which may be surprising at first sight, is easier to understand if one remembers the highly industrial concentration of R&D intensity in Belgium. Pharmaceutical laboratories and informatics and telecoms research centres implement research that will generate productive applications all over the world but not necessary in Belgium. This is more likely as these laboratories and research centres belong to multinationals.

The interaction term between these three explanatory variables and the technological gap gives no significant result. For the whole economy as well as for manufacturing, there are no indirect effect of R&D, ICT and high skilled labour on MFP growth.

Annex 4 contains the results of alternative regressions designed to pinpoint the effect of R&D, ICT and high skilled labour on MFP growth, for sectors grouped according to their level of intensity. Globally, the results confirm those obtained in Table 5. However, when three groups of sectors are distinguished according to the level of R&D intensity, R&D intensity has no effect on MFP growth except in the highly R&D intensive group. For this group, the R&D intensity has a significant negative effect, meaning that its rate of return is negative. As this group is dominated by multinationals, this negative rate of return is compatible with R&D improving foreign MFP growth but limiting the resources available to increase domestic MFP. The results based on two categories of high skilled labour intensive sectors (low and high) show a higher coefficient for high skilled labour for the sectors with low intensity. Finally, when three groups of sectors are distinguished according to their ICT intensity (low – medium – high), ICT intensity has a significant negative coefficient for low and highly ICT intensive sectors, which are mainly services sectors, and a significant positive coefficient for medium ICT intensive sectors, which are all from manufacturing and which started their ICT investment earlier.

Table 6 presents the same kind of results but for the most recent period, 1995-2005. The coefficient of the technological gap is still highly significant and higher than the coefficient estimated for the whole period for the total economy as well as for manufacturing. Potential imitation of the leader technology is more and more important for increasing the Belgian MFP. This evolution might be linked to the deterioration of the relative technological position of the country, as shown in section 4. Belgian sectors are more and more successful in imitating new foreign technologies but are no longer able to move the productive frontier up when they are the leaders.

The importance of mobilising a high skilled labour force to increase MFP is also higher over the most recent period. The value of the coefficient almost doubled for the whole economy and almost tripled for manufacturing, while all sectors increased their high skilled labour intensity over the most recent period. Holding a high level of qualifications appears to be more and more crucial to sustaining long-run economic growth. A higher coefficient is still observed for the low high skilled labour intensive sectors (see results in Annex 4).

ICT intensity is no longer significant for the whole economy, leading to the view that over the most recent period, the implementation of these technologies in market services was no longer damaging to MFP growth. By contrast, ICT intensity is slightly more positive for manufacturing. The coefficient estimated per group of ICT intensive sectors is still positive for the medium ICT intensive group and no longer significant for the two other groups (low and high).

Table 6: Results for the period 1995-2005

$\Delta \ln A_{it}$	Economy	Manufacturing
$\ln\left(\frac{A_i}{A_F}\right)_{t-1}$	-0.143*** (-3.600)	-0.201*** (-4.458)
$\Delta \ln A_{Ft}$	0.064 (1.052)	0.018 (0.276)
$\left(\frac{LAB_i}{Y_i}\right)_{t-1}$	0.024*** (4.618)	0.034*** (4.456)
$\left(\frac{RD_i}{Y_i}\right)_{t-1}$	-0.018*** (-4.521)	-0.017*** (-2.825)
$\left(\frac{TIC_i}{Y_i}\right)_{t-1}$		0.027**(2.300)
Time dummies	Yes	Yes
Nbr obs.	200	130
R^2	0.466	0.548

Estimation method: Panel OLSQ with fixed effect (Hausman test), LM test for time dummies, heteroscedasticity robust test, serial correlation of residuals test.

***, **, *: significant at 1%, 5%, 10%. t- test value in brackets.

Finally, R&D intensity has a significant coefficient but one that is negative. As is the case for the whole period, this link is in fact observed for the highly R&D intensive sectors (see results in Annex 4). For the two other groups of sectors, R&D intensity has no significant impact on MFP growth. Over the most recent period, R&D intensity increased in most of the sectors while many sectors have recorded a slowdown in their MFP growth. If the assumption of disconnection between R&D realised in Belgium and Belgian production functions is confirmed, this negative coefficient could be a sign of a crowding-out of R&D linked to domestic production in favour of R&D with more international applications.

5.2. Results with foreign R&D intensity

While Belgian R&D does not seem to increase Belgian MFP, it appears interesting to check the effect of foreign R&D on the productive efficiency of Belgian sectors. In order to check this possibility, the average R&D intensity is considered at industry level for three neighbouring countries: France, Germany and the Netherlands. The availability of data limits the investigation to manufacturing over the period 1987 to 2004.

Table 7 presents the results of the same regressions with the exception that domestic R&D intensity is replaced by the average foreign R&D intensity for the three countries.

Table 7: Results for manufacturing with foreign R&D intensity

$\Delta \ln A_{it}$	1987-2004	1995-2004
$\ln\left(\frac{A_i}{A_F}\right)_{t-1}$	-0.139*** (-4.200)	-0.191*** (-4.149)
$\Delta \ln A_{Ft}$	0.049 (0.865)	0. 043 (0.688)
$\left(\frac{LAB_i}{Y_i}\right)_{t-1}$	0.011* (1.701)	0.033*** (3.935)
$\left(\frac{RE_i}{YE_i}\right)_{t-1}$	0.012*** (3.468)	0.014* (1.672)
$\left(\frac{TIC_i}{Y_i}\right)_{t-1}$	0.026*** (3.715)	0.032** (2.494)
$\ln\left(\frac{A_i}{A_F}\right)_{t-1} \times \left(\frac{RE_i}{YE_i}\right)_{t-1}$		0.012*** (2.702)
Time dummies	Yes	No
Nbr obs.	221	130
R^2	0.377	0.515

Estimation method: Panel OLSQ with fixed effect (Hausman test), LM test for time dummies, heteroscedasticity robust test, serial correlation of residuals test.

***, **, *: significant at 1%, 5%, 10%. t- test value in brackets.

The results show the importance of foreign R&D in improving the productive efficiency of the Belgian sectors. Over the whole period, the rate of return of foreign R&D was positive.

Over the most recent period, ICT and high skilled labour intensity's coefficients have strongly increased, while this is not the case for the foreign R&D intensity's coefficient. Moreover, the positive effect of foreign R&D intensity seems to be focused on sectors near the technology frontier. Indeed, the interaction term is significant and positive which means that the sectors benefiting most from foreign R&D are those that benefit least from the catching up effect.

The positive effect of foreign R&D on MFP growth might be explained by the small size of the Belgian economy and by the integration of its production functions into the functions of the three neighbouring countries.

6. Conclusions

Covering 20 Belgian industries over 1987-2005, this working paper studies the link between MFP growth and three determinants usually identified in the empirical literature: R&D, a high skilled labour force and ICT use. This analysis is conducted within the Aghion-Howitt framework in which the MFP growth of an industry depends on the distance to the world technology frontier.

Using an equilibrium correction model, the paper shows that the technological gap, measured by the difference in MFP levels, influences the growth of all Belgian sectors. The further the industry is behind the technology frontier, the faster its MFP grows. This catching-up process based on imitation is more present in manufacturing than in other industries, due probably to the importance of the international openness of manufacturing. This process was also more active during the most recent period, 1995-2005, for both the whole economy and manufacturing. This might be linked to the downgrading of the relative technological position of Belgium over the period considered. Belgian industries are more able to imitate foreign new technologies than to generate by themselves innovations that lead to the moving-up of the world technology frontier.

The results do not sustain the presence of spillover from the MFP growth of a foreign industry at the frontier onto the same Belgian industry.

Concerning the three determinants of MFP growth, the results show that the use of a high skilled labour force improves productive efficiency in Belgian companies. The positive impact of human capital has increased over time as it is higher during the most recent period, 1995-2005, than during the whole period. The continuous availability of enough high skilled workers is therefore a crucial condition for sustaining long term economic growth.

By contrast, ICT capital integration in production functions has a different effect according to the industry taken into consideration. In manufacturing, ICT increases productive efficiency. As for human capital, the positive effect of ICT capital has increased over time and is higher over the most recent period. At the opposite, for the whole economy, ICT intensity had a slightly negative impact on MFP growth over 1987-2005 and had no significant impact over the most recent period. As underlined by some recent studies, productivity gains associated with ICT capital appear only progressively and are conditioned to the presence of complementary intangible investments. The non-manufacturing industries having invested later in ICT, they could still be, particularly at the beginning of the period, in a stage of adaptation of their production processes to these new technologies.

R&D intensity had no significant effect on MFP growth over the period 1987-2005. The results for the most recent period even show a negative effect of R&D intensity on MFP growth. These counterintuitive results at first sight might be explained by the concentration of Belgian R&D in a limited number of industries dominated by multinationals. Research carried out in Belgium promotes the productive efficiency of the countries where it is implemented. However, it has to be remembered that this analysis only takes into consideration business R&D expenditure and not total R&D expenditure which also includes R&D in universities and public research centres. By contrast, foreign R&D, measured as the average R&D intensity of the three neighbouring countries, has a positive impact on the productive efficiency of Belgian manufacturing. These two opposite impacts of R&D could be interpreted as a consequence of the small size of the Belgian economy and of the strong European integration of its production functions. These results also underline the importance, for a small open country, of the implementation of an innovation strategy at the European level. This coordination of national efforts allows all countries, including the smallest ones, to take advantage of these efforts to improve their productive efficiency and therefore to improve their competitiveness.

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8. Annexes

8.1. Industry description

DA	Food products, beverages and tobacco
DB+DC	Textiles and textile products and leather and leather products
DD	Wood and wood products
DE	Pulp, paper and paper products; publishing and printing
DF	Coke, refined petroleum products and nuclear fuel
DG	Chemicals, chemical products and man-made fibres
DH	Rubber and plastic products
DI	Other non-metallic mineral products
DJ	Basic metals and fabricated metal products
DK	Machinery and equipment n.e.c.
DL	Electrical and optical equipment
DM	Transport equipment
DN	Manufacturing n.e.c.
EE	Electricity, gas and water supply
FF	Construction
GG	Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods
HH	Hotels and restaurants
I_60-63	Transport and storage
I_64	Post and telecoms
JJ	Financial intermediation

8.2. Sensitivity analysis of MFP growth to inputs measures

In the framework of growth accounting theory, MFP is calculated as a residue by subtracting from VA growth the contribution of labour and capital, weighted by the respective share of their costs in the VA. In the absence of perfect statistical measures of labour and capital, MFP also includes in addition to pure technical progress, the different measurement errors.

The table below analyses the effects on the measure of MFP the improving the estimation of the contribution of inputs, labour and capital. The first column of the table gives a basic measure of the average annual growth rate of MFP over the period 1995-2005. The basic measure is estimated by using the number of persons engaged for the contribution of labour and capital stocks for the contribution of capital. The second column shows the effects on MFP growth of the use of hours worked instead of persons engaged as the measure of labour contribution. The third column gives the effects of the distinction between different types of labour (labour composition effect). The fourth column shows the effects of the estimation of the flow of services produced by each type of capital asset rather than capital stocks. Finally, the last column provides the final measure of MFP used in the empirical analysis.

Table 8: MFP growth rate sensitivity to different measures of inputs, average annual growth rate (Δ ln in %), 1995-2005

	MFP growth rate: basic measure	Effect of hours worked	Labour composition effect	Capital services effect	MFP growth rate: final measure
DA	0.56	0.18	-0.35	-0.19	0.20
DB	2.50	-0.03	-0.49	-0.09	1.90
DD	2.89	0.09	-0.33	-0.35	2.30
DE	0.49	0.14	-0.34	-0.67	-0.39
DF	-4.47	0.02	-0.39	-0.77	-5.61
DG	0.54	0.14	-0.35	-0.41	-0.09
DH	4.30	0.27	-0.41	-0.13	4.03
DI	0.03	0.04	-0.37	-0.13	-0.43
DJ	2.37	0.05	-0.42	-0.35	1.65
DK	2.94	0.03	-0.32	-0.22	2.43
DL	2.89	0.17	-0.34	-0.59	2.13
DM	1.97	-0.03	-0.38	-0.23	1.32
DN	2.28	0.13	-0.40	-0.22	1.80
EE	2.67	0.07	-0.04	-0.61	2.09
FF	0.92	0.28	-0.01	-0.08	1.10
G	-0.64	0.03	-0.38	-0.60	-1.59
HH	-0.26	0.12	-0.37	-0.39	-0.90
II_60-63	0.06	0.05	-0.26	-0.68	-0.83
II_64	2.00	0.13	-0.47	-3.11	-1.45
JJ	3.71	0.17	-0.13	-0.93	2.83

Source: FPB estimations from the EUKLEMS database

8.3. Sensitivity analysis of results: non-frontier industries

To check the robustness of the results, the basic equation was tested for a subset of industries: the industries that were never at the technological frontier between 1987 and 2005. This subset is composed of the total economy except for Textiles (DB), Paper (DE), Rubber and plastic products (DH), Electrical and optical equipment (DL), Trade (GG), Post and telecoms (I_64) and Financial intermediation (JJ).

The results are relatively close to those obtained for the whole economy. The coefficients of significant variables take values between those observed for the whole economy and those observed for manufacturing. The only difference concerns the ICT intensity which has a negative coefficient for the whole economy over the whole period (1987-2005) and which ceases to be significant if only the non-frontier industries are taken into account. This would imply that ICT intensity is essentially a determinant factor for the technological leader sectors.

Table 9: Results of econometric analysis

$\Delta \ln A_{it}$	1987-2005	1995-2005
$\ln\left(\frac{A_i}{A_F}\right)_{t-1}$	-0.124*** (-4.005)	-0.154*** (-3.717)
$\Delta \ln A_{Ft}$	0.030 (0.621)	0.019 (0.286)
$\left(\frac{LAB_i}{Y_i}\right)_{t-1}$	0.012* (1.847)	0.030*** (3.903)
$\left(\frac{RD_i}{Y_i}\right)_{t-1}$		-0.020** (-2.317)
Time dummies	Yes	Yes
Nbr obs.	234	130
R^2	0.320	0.512

Estimation method: Panel OLSQ with fixed effect (Hausman test), LM test for time dummies, heteroscedasticity robust test, serial correlation of residuals test.

***, **, *: significant at 1%, 5%, 10%. t- test value in brackets.

8.4. Sensitivity analysis of results: industries' groups by intensity class

Table 10: Results of regressions over 1987-2005

$\Delta \ln A_{it}$	1 Basic model of the analysis	2	3	4
$\ln\left(\frac{A_i}{A_F}\right)_{t-1}$	-0.094*** (-3.651)	-0.102*** (-3.919)	-0.094*** (-3.613)	-0.139*** (-5.064)
$\Delta \ln A_{Ft}$	0.017 (0.365)	0.019 (0.412)	0.019 (0.395)	0.029 (0.633)
$\left(\frac{LAB_i}{Y_i}\right)_{t-1}$	0.013*** (3.193)	0.015*** (3.518)		0.015*** (3.615)
$\left(\frac{TIC_i}{Y_i}\right)_{t-1}$	-0.007*** (-2.569)	-0.007** (-2.258)	-0.008*** (-2.638)	
$\left(\frac{RD_i}{Y_i}\right)_{t-1}$ * DRD - low		-0.026 (-1.182)		
$\left(\frac{RD_i}{Y_i}\right)_{t-1}$ * DRD - medium		-0.005 (-0.604)		
$\left(\frac{RD_i}{Y_i}\right)_{t-1}$ * DRD - high		-0.009* (-1.953)		
$\left(\frac{LAB_i}{Y_i}\right)_{t-1}$ * DLAB - low			0.016*** (2.618)	
$\left(\frac{LAB_i}{Y_i}\right)_{t-1}$ * DLAB - high			0.013*** (3.169)	
$\left(\frac{TIC_i}{Y_i}\right)_{t-1}$ * DTIC - low				-0.013*** (-2.582)
$\left(\frac{TIC_i}{Y_i}\right)_{t-1}$ * DTIC - medium				0.020*** (3.035)
$\left(\frac{TIC_i}{Y_i}\right)_{t-1}$ * DTIC - high				-0.016*** (-4.468)
Time Dummies	Yes	Yes	Yes	Yes
Nbr obs.	360	360	360	360
R^2	0.265	0.275	0.266	0.310

Estimation method: Panel OLSQ with fixed effect (Hausman test), LM test for time dummies, heteroscedasticity robust test, serial correlation of residuals test.

Variables: DRD: DRD-low: dummy is equal to 1 if R&D intensity < 1%; DRD-medium: dummy is equal to 1 if R&D intensity is between 1% and 10%, DRD-high: dummy is equal to 1 if R&D intensity> 10% (high).

DLAB: DLAB-low: dummy is equal to 1 if high skilled labour intensity < 10%, DLAB-high dummy is equal to 1 if high skilled labour intensity is > 10%.

DTIC: DTIC-low: dummy is equal to 1 if ICT intensity <4%, DTIC-medium: dummy is equal to 1 if ICT intensity is between 4% and 10%, DTIC-high: dummy is equal to 1 if ICT intensity > 10%.

***, **, *: significant at 1%, 5%, 10%. t- test value in brackets.

Table 11: Results of regressions over 1995-2005

$\Delta \ln A_{it}$	1 Basic Model of the analysis	2	3	4
$\ln\left(\frac{A_i}{A_F}\right)_{t-1}$	-0.143*** (-3.600)	-0.144*** (-3.575)	-0.140*** (-3.440)	-0.180*** (-4.225)
$\Delta \ln A_{Ft}$	0.064 (1.052)	0.067 (1.088)	0.079 (1.253)	0.053 (0.903)
$\left(\frac{LAB_i}{Y_i}\right)_{t-1}$	0.024*** (4.618)	0.025*** (4.387)		0.023*** (4.847)
$\left(\frac{RD_i}{Y_i}\right)_{t-1}$	-0.018*** (-4.521)		-0.018*** (-4.170)	-0.014*** (-2.590)
$\left(\frac{RD_i}{Y_i}\right)_{t-1}$ * DRD - low		-0.034 (-1.630)		
$\left(\frac{RD_i}{Y_i}\right)_{t-1}$ * DRD - medium		-0.013 (-1.105)		
$\left(\frac{RD_i}{Y_i}\right)_{t-1}$ * DRD - high		-0.019*** (-5.135)		
$\left(\frac{LAB_i}{Y_i}\right)_{t-1}$ * DLAB - low			0.029*** (3.833)	
$\left(\frac{LAB_i}{Y_i}\right)_{t-1}$ * DLAB - high			0.019*** (3.246)	
$\left(\frac{TIC_i}{Y_i}\right)_{t-1}$ * DTIC - low				-0.009 (-0.958)
$\left(\frac{TIC_i}{Y_i}\right)_{t-1}$ * DTIC - medium				0.023* (1.843)
$\left(\frac{TIC_i}{Y_i}\right)_{t-1}$ * DTIC - high				-0.006 (-1.055)
Time Dummies	Yes	Yes	Yes	Yes
Nbr obs.	200	200	200	200
R^2	0.466	0.469	0.470	0.488

Estimation method: Panel OLSQ with fixed effect (Hausman test), LM test for time dummies, heteroscedasticity robust test, serial correlation of residuals test.

Variables: DRD: DRD-low: dummy is equal to 1 if R&D intensity < 1%; DRD-medium: dummy is equal to 1 if R&D intensity is between 1% and 10%, DRD-high: dummy is equal to 1 if R&D intensity> 10% (high).

DLAB: DLAB-low: dummy is equal to 1 if high skilled labour intensity < 10%, DLAB-high dummy is equal to 1 if high skilled labour intensity is > 10%.

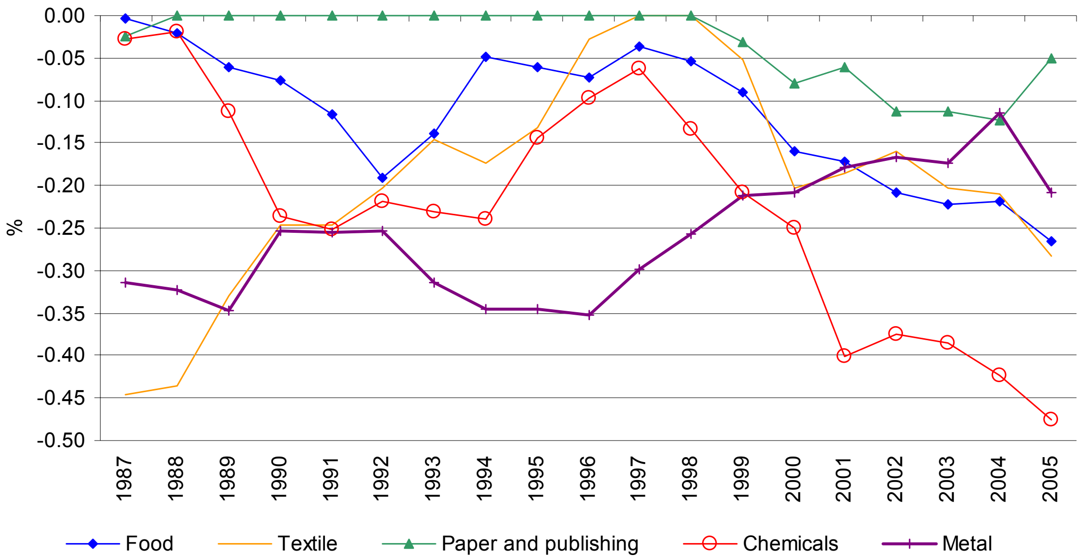
DTIC: DTIC-low: dummy is equal to 1 if ICT intensity <4%, DTIC-medium: dummy is equal to 1 if ICT intensity is between 4% and 10%, DTIC-high: dummy is equal to 1 if ICT intensity > 10%.

***, **, *: significant at 1%, 5%, 10%. t- test value in brackets.

8.5. Evolution of technological gap for the main manufacturing and market services sectors

The following graphs give the evolution of the technological gap for 5 manufacturing and market services sectors over 1987-2005. This gap is calculated as the difference in MFP levels, taken in logarithms, between the Belgian sector and the frontier sector. When this difference is null, this means that the Belgian sector is the frontier sector.

Graph 1 Evolution of technological gap - 5 manufacturing sectors



Graph 2 Evolution of technological gap - 5 market services sectors