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ICT contribution to economic performance in Belgium: preliminary evidence

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Executive summary

Information and communication technologies (ICT) have become a significant economic activity in most industrialised countries, as well as an important engine of innovation. Despite the recent sharp decline in technology stocks, the closure of thousands of "dot com" firms around the world and the slump in the ICT equipment industry, ICT still account for a substantial contribution to output growth in most OECD countries. ICT are currently recognised as one of the key factors boosting productivity growth and hence business sector competitiveness.

In this paper, the impact of ICT on economic and productivity growth is investigated in the context of the Belgian economy. The analysis is conducted at aggregate and branch level. The impact of ICT on economic growth through productivity gains can be transmitted via three different channels, namely increase in the ICT capital available per worker (capital deepening), technical progress in the ICT producer sectors (TFP growth) and finally, technical progress in the ICT user sectors through spillover effects (TFP growth).

At a macroeconomic level, the empirical evidence indicates that ICT explain more than half of the productivity growth acceleration in the United States. In Europe, the impact seems weaker, due both to a less developed ICT producer sector and to a slower diffusion of ICT in the economy. The conclusions for Europe apply for Belgium as well. Nevertheless, the average annual growth contribution of ICT capital accelerated between the first and second half of the 1990s, from 0.28% to 0.36%. This evolution puts Belgium slightly above the average of the European Union.

At sector level, the analysis attempts to establish links between the evolution of productivity and the diffusion of ICT among the different economic sectors. This analysis leads to further investigation of the apparent trade-off between productivity and employment observable in Belgium and the role played by ICT investment. Several sectors appear to have carried out important ICT investment as early as 1995. Sharp productivity growth is observed for all these branches but in terms of job creation, performance has been more heterogeneous.

A detailed study of the Belgian sectors leads to the same conclusion as the one reached for other countries: ICT producer sectors account for the main part of the overall productivity acceleration while they are also job creators. The behaviour of the sectors that intensively use ICT is not so clear cut. Some ICT using service sectors have recorded both productivity and employment growth while the manufacturing industries have recorded an increase in productivity and a strong decline in employment. In the first case, spillover effects of ICT on TFP could prevail while in the second case capital deepening could be the dominant effect.

I Introduction

Information and communication technologies (ICT) have become a significant economic activity in most industrialised countries as well as an important engine of innovation and changes in the rest of the economy. Despite the recent sharp decline in technology stocks, the closure of thousands of "dot com" firms around the world and the slump in the ICT equipment industry, ICT still account for a substantial contribution to output growth in most OECD countries. ICT have been recognised as one of the key factors boosting productivity growth and hence business sector competitiveness. Various initiatives have recently been adopted at regional, national and European levels in order to meet the new challenges posed by ICT diffusion. A growing number of indicators are now available in order to assess the position of each country or region in terms of ICT development and to guide policy decisions in that field.

The current data seem to indicate that extensive ICT use is economically positive, mainly because it reinforces the acceleration of productivity gains. However, an essential question remains: what is the nature of these productivity gains, economically broad-based or purely cyclical? The fact that the surge in productivity growth in the United States has been sustained even in the midst of the recent economic slowdown could indicate that the impact of ICT is durable. Indeed, the sustained growth of American labour productivity during 2001[1], a year of recession, is in sharp contrast to the conventional pro-cyclical pattern of productivity growth.

The main objective of this paper is to use all currently available data to study this question in the context of the Belgian economy. After a brief summary of the methodology of productivity analysis and the still pending data problems, the paper analyses the Belgian situation in comparison with the United States and the European Union from a macroeconomic point of view. In a second step, the analysis is conducted at a branch level to establish links between the evolution of productivity and the diffusion of ICT products among the different economic sectors. This analysis leads to further investigation of the apparent trade-off between productivity and employment currently observed in Belgium and the role played by ICT investment.

1. Non-farm business productivity grew by 2% according to the US Bureau of Labor Statistics. For more details, see European Commission (2002a: 5).

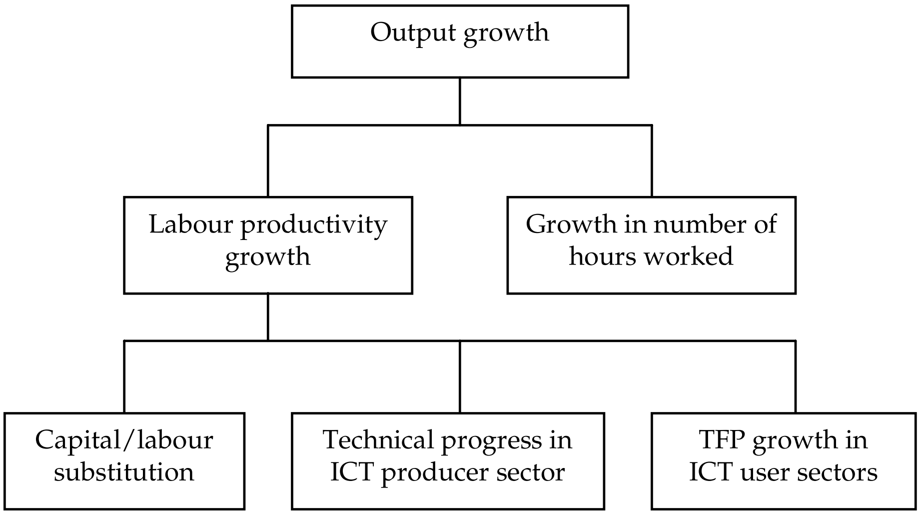
II A well-developed theoretical framework but a lack of pertinent data

The growth accounting methodology is a widely used theoretical framework for productivity analysis. Beginning from the theory of production and assuming that factors are paid their social marginal products and that production is characterised by constant returns to scale in the factor inputs, a decomposition of output growth is derived in terms of the share-weighted growth of factor inputs and total factor productivity (TFP) growth.[1] The decomposition of output growth can be expressed per hour worked. Growth of output per hour worked or average labour productivity (ALP) growth is then explained by capital deepening, the improvement in labour quality and TFP growth.

There are three main channels through which improvements in ICT are expected to affect ALP growth, when using a branch level approach. First, high rates of investment in ICT, in response to the fast decline in quality-adjusted ICT prices, contribute to ALP growth through increased capital deepening. Second, technological progress in ICT stimulates growth of TFP in the ICT producing sector and hence of aggregate TFP. Third, TFP growth may accelerate in the ICT using sector as a result of production spillovers from the ICT producing sector. This last channel, however, remains controversial. Indeed, not only is it unclear what constitutes these spillovers at the theoretical level, but measuring them is complicated by data requirements and conceptual problems. These three links between progress in ICT and growth of output are depicted in Figure 1.

1. See for instance Barro (1998) for a thorough discussion of growth accounting.

FIGURE 1 - The links between ICT and economic growth



In order to evaluate the possible economic impact of ICT in Belgium using the growth accounting framework, a capital stock of ICT assets is needed. The ICT assets distinguished here are limited to IT equipment and communications equipment.[1] Thus, software and ICT services are left out of the analysis, although software investment expenditure is discussed separately. Construction of the capital stock involves three main steps: obtaining ICT investment expenditure, obtaining an ICT investment price deflator to transform investment expenditure into constant-quality units valued at base-year prices, and calculating the ICT capital stock and rental price associated with the ICT capital services.

The first step concerns investment expenditure. Since investment data for detailed sectors in Belgium are not available on a regular basis,[2] an indirect method based on foreign trade data is used to arrive at a time series of investment expenditure of the ICT assets. Using the equilibrium condition that domestic spending (intermediate and final consumption plus investment) equals domestic supply (domestic production minus net exports), domestic spending on each ICT asset is calculated using domestic production and foreign trade data. The advantage of this method lies in the fact that foreign trade data are available on very low levels of aggregation. The resulting series is corrected by the ratio of investment spending to total domestic spending of 1995 to obtain an estimate of investment expenditure of the ICT assets from 1978 until 2000. The method of calculation of the ICT investment expenditure and the foreign trade data are discussed in detail in Annex point B and point C respectively.

Second, investment expenditure on IT and communications equipment is expressed in quality-adjusted units by means of a "harmonised" price index. This method equates the price decline in ICT assets relative to non-ICT assets in Belgium to the smoothed relative price decline recorded in the US. It is applied

1. The definition of ICT in terms of producing sectors suggested by OECD (1998) is followed. Thus, IT equipment is the product of the following NACE manufacturing classes: 3000, 3210, 3320 and 3330, while communications equipment is defined in terms of NACE 3130, 3220 and 3230. See Annex point A for the description of the NACE classes.
2. Only for 1995 is a detailed table of investment expenditure available, consisting of 320 products and 120 sectors.

because hedonic price indices, the first best instruments, are not available for Belgium. More details can be found in Annex point D.

Third, the resulting volume investment is accumulated according to the perpetual inventory method to obtain a productive capital stock of IT and communications equipment. The rental price of the capital services associated with the capital stock of each asset is needed to obtain its income share; it consists of the internal rate of return, the rate of depreciation and the expected capital gains of the asset. The internal rate of return is measured as the ex post rate that exhausts all capital income, the depreciation rate is implied by the age price profile that is consistent with the assumed age efficiency profile, and the capital gains term is measured as the current change in harmonised prices. Details about these calculations are given in Annex point E.

The growth contribution of ICT capital is then found as the product of the income share and the growth rate of the capital stock. Note that although this allows calculating the growth contribution of ICT at the macroeconomic level, the growth contribution at sectoral level necessitates sectoral ICT capital stocks, which are not yet available.

The macroeconomic growth accounting analysis pertains to the total economy. Only one output is distinguished, and total value added (GDP) is obtained from the ICN (2001 and earlier). The services of non-ICT capital are approximated by the total net capital stock minus the productive stock of ICT-capital. The use of the net capital stock, which is available from ICN (2002), is clearly an approximation for the productive stock of total capital, as the net stock is the current market valuation of the productive capital stock. Labour input is measured as hours worked in the total economy but there is no further breakdown of the labour input by type, so that the improvement in labour quality is picked up by TFP growth. Labour’s share of income is taken from the European Commission’s Ameco database.

III What can we learn from macroeconomic evidence?

During the 1990s, the US economy recorded two historical peaks: the longest expansion phase of its history (since 1854) and the lowest unemployment rate in 30 years. As is well established by now, the production and diffusion of ICT have played a major role in this productivity growth revival. The European economy has on average not been able to match the US economic performance and has also lagged behind the US in terms of ICT innovation and diffusion.

TABLE 1 - Comparison of the recent growth performance of Belgium, EU and US (%)

Average annual growth	Belgium		EU		US	
	1990-1995	1995-2001	1990-1995	1995-2001	1991-1995	1995-2001
Real GDP	1.5	2.8	1.5	2.6	2.4	3.9
Employment[a]	-0.2	1.1	-0.5	1.2	0.9	1.4
Average labour productivity per head[b]	1.7	1.6	2.0	1.4	1.5	2.5
- Capital deepening	0.9	0.4	1.0	0.4	0.4	0.8
- TFP	0.8	1.2	1.1	1.0	1.0	1.6

a. Employment measured per employed person.

b. Based on the National Accounts data, the slowdown of labour productivity growth in Belgium in the period 1995-2001 is larger, due to a negative growth rate in 2001.

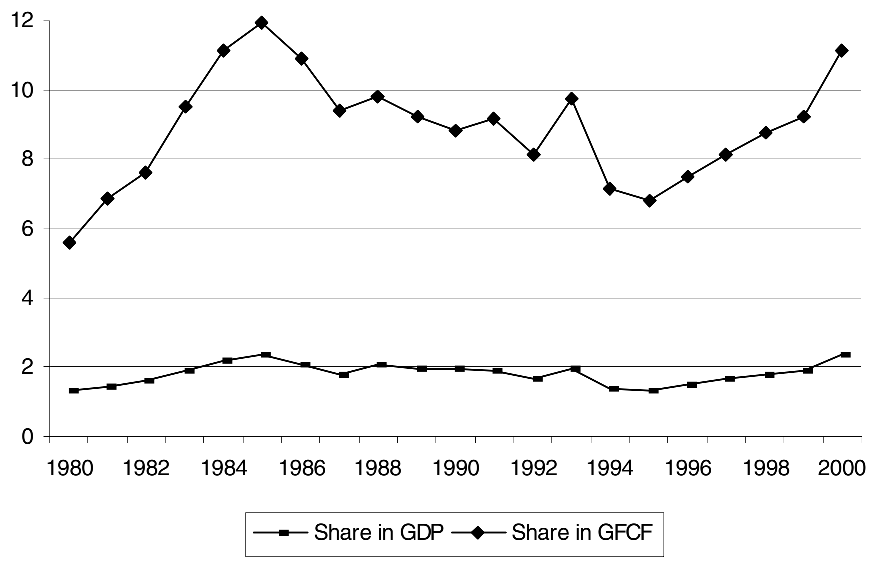
Source: European Commission (2002b).

As shown in Table 1, the growth revival of the Belgian economy was mainly due to a huge upsurge of the labour force. Unlike in the rest of Europe on average, where labour productivity gains decelerated, labour productivity growth remained constant between the first and the second half of the 1990s in Belgium. At the beginning of the nineties, the capital/labour ratio increased rapidly in most European economies, faster than in the US. However, this evolution was driven by losses in employment rather than by an acceleration of investment. In the second half of the nineties, employment growth reduced the substitution effect even if investment was more dynamic than in the previous period. While the contribution of capital deepening to growth decreased, TFP, on the contrary, was on an ascending trend in Belgium in contrast to the EU on average.

A. The role of capital deepening

Can this acceleration of output growth be linked to ICT? Turning first to the capital deepening channel, ICT investment in Belgium has increased more rapidly than total investment during the last years. Figure 2 shows that the share of ICT investment expenditure in total investment (GFCF) increased from 5.6% in 1980 to 11.1% in 2000. Likewise, the share of ICT investment expenditure in GDP rose from 1.3% in 1980 to 2.4% in 2000. In volume terms the rise is impressive: volume investment in ICT rose from 1.2% to 29.4% as a percentage of GFCF between 1980 and 2000.

FIGURE 2 - ICT investment in Belgium, current prices (%)



Source: own calculations.

TABLE 2 - Contribution of ICT capital growth in Belgium (%)

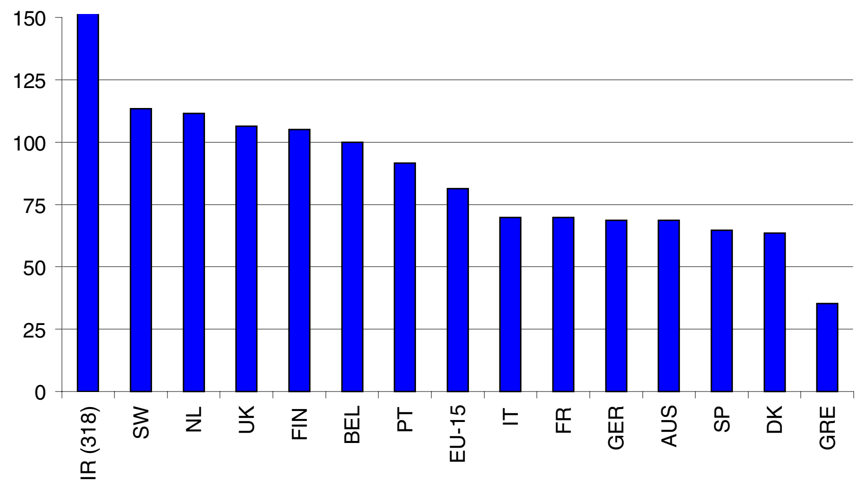
Average annual growth	1991-1995	1995-2000	acceleration
Real GDP	1.54	2.81	+1.27
Hours worked	-0.32	0.91	+1.23
Hourly labour productivity	1.86	1.89	+0.03
- Capital deepening	1.09	0.64	-0.45
of which ICT	0.29	0.34	+0.05
- TFP	0.77	1.25	+0.48
Real GDP	1.54	2.81	+1.27
- Contribution of hours	-0.21	0.58	+0.79
- Contribution of capital	0.98	0.98	+0.00
of which ICT[a]	0.28	0.36	+0.08
- TFP	0.77	1.25	+0.48

a. The growth contribution of ICT pertains only to ICT equipment and not to software. A comparison of the growth contributions in other industrialised countries may give an approximate indication about the size of the contribution of software investment in Belgium. According to OECD (2002: 24) this contribution amounts to at least 20% of the total ICT contribution in the OECD member countries for which software data is available. Based on this information, a cautious guess may put the average annual growth contribution of software in Belgium at 0.07% and 0.09% in the periods 1991-1995 and 1995-2000 respectively.

Source: own calculations.

As shown in Table 2, the accumulation of ICT capital resulted in an increasing contribution of ICT capital to output growth and ALP growth. Between the first and the second half of the 1990s, the average annual contribution of ICT capital to economic growth rose from 0.28% to 0.36%. Using the European Commission's (2002b)[1] results to rank the EU countries by their growth contribution of ICT capital, Figure 3 shows that Belgium is situated in the better half of the EU countries, although close to the EU average.

FIGURE 3 - Contribution of ICT to output growth in the EU – 1995-99 (Belgium = 100)



Source: European Commission (2002b).

B. The role of productivity in the ICT producing sector

The second channel by which ICT can affect economic performance is through increased productivity in the ICT producing sector. Although this sector has contributed substantially to the acceleration of TFP growth in the US, a large contribution of the ICT sector to Belgian TFP growth seems unlikely for at least two reasons.

First, the share of this sector remains small in Belgium: in 1997, the ICT sector as a whole represented 5.8% of business sector value added in Belgium, compared to 6.4% in Europe and 8.7% in the US. In particular, the share of ICT manufacturing in total value added in Belgium remains well below that of the EU average. As the strongest productivity gains are likely to be made in ICT manufacturing - cf. Moore's law - the possible contribution of the Belgian ICT sector to productivity growth is limited.[2]

1. European Commission (2002b: 42) reports absolute ICT contributions for each EU country, which are, however, not comparable to the results in Table 2 due to methodological differences.
2. These numbers are taken from OECD (2001b). Although they are somewhat dated, the international comparison of value added shares of the ICT sector given in OECD (2002: 34) seems to uphold the same picture for 1999: value added in the Belgian ICT sector stood at almost 7.5% of business sector value added, compared to 9.5% on average in the OECD and 11.0% in the US.

Second, R&D figures suggest that this growth contribution is likely to remain limited in the near future. Indeed, R&D efforts in the ICT sector are mainly carried out in manufacturing and were less important in Belgium in 2000 than in the EU and the US in 1999, when measured in percent of total R&D expenditure by the business sector according to OECD (2002). Moreover, business sector R&D as a whole represents a relatively small part of GDP in Belgium.

Box 1: Software investment

The National Bank of Belgium (2002) has estimated investment expenditure on software in Belgium for the period 1995-2000. Since the length of this period is insufficient to calculate a software capital stock for the 1990s, the software investment data of the National Bank is discussed here separately from the ICT equipment investment data.

Software is broken down into software produced on own-account and purchased software. As shown in Table B1, investment in the former amounts to 1,462.5 million euro in 2000, whereas purchased software investment in 2000 amounts to 548.7 million euro. An explanation for this divergence could be found in the assumption underlying own-account software figures that all informaticians and programmers are considered to develop own-account software. The average annual growth rate of software investment over the period 1995 is 9.6%. The harmonised price index of software investment, which allows expressing software investment in constant-quality units, is characterised by a moderate decline at an average annual rate of less than 1% over the period 1995-2000. Hence, quality-adjusted software investment at 1995 prices grew only slightly faster than investment in current prices, at 10.6% on average per annum.

How would the growth contribution of software compare to that of IT equipment? The ratio of software investment to IT equipment investment expenditure equals only 0.6 on average over the period 1995-2000. As both the level and the growth rate of software investment are significantly lower than those of IT equipment, the expected growth contribution of software investment is considerably smaller than that of IT equipment.

Table B1 - Software investment expenditure (million euro)

	1995	1996	1997	1998	1999	2000
Own-account	912.5	979.2	1013.1	1126.0	1531.1	1462.5
Purchased	360.8	362.1	529.2	714.2	578.1	548.7
Total	1273.3	1341.3	1542.3	1840.2	2109.2	2011.2

Source: National Bank of Belgium (2002).

C. The role of production spillovers

As a third link between progress in ICT and economic performance, ICT may affect economic activity through production spillovers to the ICT user sector. As seen from Tables 1 and 2, an acceleration of TFP growth has indeed been observed in Belgium, unlike in Europe on average. This could be a sign of a positive impact of ICT diffusion on user industries' TFP.

However, various arguments could qualify such a positive assessment. First, at the beginning of the 1990s, the economic recession has drawn TFP growth to a very low level. The current evolution could mainly be due to the cyclical upturn of economic growth rather than to a radical innovation affecting trend growth in the medium term. Second, Belgium is currently catching up with the more advanced European economies regarding diffusion of ICT. Until recently, the gap with other European economies was particularly large for communications equipment. One of the main reasons for its slower diffusion could be the prices of communication services in Belgium, which have long remained among the highest in Europe. Indeed, high communication prices lower the demand for communications equipment as well as for communication services by enterprises, as both are complementary. Table 3 compares the share of communications equipment in non-residential GFCF as well as the price of communication in Belgium to that of other industrialised countries.

TABLE 3 - Communications equipment and prices in Belgium: comparison to other industrialised countries - 2000

	Belgium	France	Germany	UK	US
Communications equipment[a]	2.3%	3.9%	4.8%	3.6%	8.0%
Communications price[b]	1476.8	1076.1	1177.0	1067.1	1214.9

a. Share of communications equipment in non-residential GFCF.

b. Composite basket of business telephone charges (inclusive international calls and calls to mobile networks), total charge in US $ based on PPP for 08/2000.

Sources: Colecchia and Schreyer (2001), OECD (2001c) and own calculations.

As seems to be the case for Europe as a whole, the contribution of ICT to macroeconomic growth remains weak in Belgium compared to US standards. Is Europe in a position to benefit of what appears to be a radical innovation in the US? The main reasons of the differences between Europe and the US are on the one hand the innovation capacity of the US in these fields[1] and, on the other hand, the much wider diffusion of ICT goods and services in the business sector as well as at the consumer level. To answer this question, the preliminary evidence for Belgium needs to be confirmed by further work. The crucial role played by TFP to raise potential output growth has been demonstrated in the theoretical literature. In contrast, the links between ICT diffusion and TFP gains remain to be identified more clearly. This task, required to properly evaluate the nature of the ICT revolution, faces important theoretical and practical problems.

Various analyses carried out in Europe have shown that if the macroeconomic effect is still difficult to detect at the aggregate level in the EU countries, microeconomic impacts are quite visible in some branches or type of firms. In the next section, data at branch level are used to identify which sectors are the most advanced in this field.

1. As can be illustrated by R&D figures in ICT sectors or the number of patents for ICT related products.

IV What can we learn from microeconomic evidence?

A. A comparative analysis: Belgium - United States

Using the national accounts data on 31 sectors, we compared the productivity gains of the main private business sectors in Belgium and in the United States. For this comparison, our main reference was Stiroh's (2001) analysis of American sectoral productivity evolution.

At the branch level, the number of hours worked is usually not available even in statistically advanced countries such as the United States. Therefore, the productivity of labour is calculated as the output divided by the number of employed persons in Belgium and by the number of full time equivalents in Stiroh's study. This method of measurement introduces without doubt some biases, especially for Belgium. Indeed, productivity will be underestimated for branches of activities with extensive use of part-time workers. Moreover, in the beginning of the economic revival period with a rapid increase in output, the number of hours worked tends to increase while the number of workers stays constant. Thus, hourly productivity tends to increase less rapidly (or even decrease) than productivity by worker.

Box 2: Measuring productivity

For the economy as a whole, average labour productivity is usually measured by dividing real value added by a measure of labour (hours worked, FTE or employed persons depending on availability). At the sectoral level however, the rule is not so clear and the denominator may also be real gross output. The choice between value added or gross output depends on the subject of the analysis as underlined in the OECD manual on productivity measurement (2001a).

As the current analysis attempts to identify all the effects of the ICT on the productivity growth at sectoral level, real gross output seems to be the appropriate concept. As pointed out by Stiroh (2001), firms and industries actually produce gross output from some combination of primary and intermediate inputs and the production model should match this as closely as possible. Value added is an artificial construct that reflects only primary inputs and therefore does not correspond to a well-defined output concept at the industry level. Moreover, only under specific assumptions about the separability of primary inputs from intermediate inputs does a value added production function exist and provide a valid description of the underlying production technology. This is why it seems more appropriate to use the output concept in the micro-level analysis.

However, given the availability of data, the second section of this micro analysis devoted to a detailed study of the Belgian case, is conducted with value added rather than with output measure.

TABLE 4 - Comparison of productivity evolution: Belgium - United States - average annual growth rate 1995-1999 (%)

Sectors	Belgium	United States
Agriculture, forestry & fishing	3.7	- 0.7
Mining	2.1	2.5
Construction	2.4	- 0.8
Durable goods manufacturing	3.8	6.5
Nondurable goods manufacturing	4.2	3.3
Transportation & public utilities	3.7	2.4
Wholesale trade[a]	6.3	4.2
Retail trade		3.0
Finance, insurance & real estate	2.5	2.9
Other services	0.2	1.2
Total Private Business sector	3.6	2.4

a. Wholesale and retail trade are not available separately in Belgian statistics.

Source: Stiroh (2001) and own calculations.

As illustrated by Table 4, the Belgian productivity performance at the branch level was comparable to what was observed in the United States during the period 1995-1999. The overall evolution of productivity of the private industries was even better in Belgium than in America. This result hides divergences between services, which overall performed better in Belgium than in the US, and manufacturing which recorded a slower increase. Indeed, an important economic sector, the Durable Goods Manufacturing, recorded a clearly slower increase in its productivity. This divergence partly reflects the lack of a well-developed ICT producer sector in Belgium, as already mentioned.

In order to link this evolution of branch level productivity to the development of ICT diffusion in Belgium, the relative importance of ICT investment in the different sectors is analysed.

We analysed the structure of investment for the year 1995 and in particular, the share of ICT goods in total investment by branch (for a definition of ICT goods, see Annex point A) because it is currently the only available year. Moreover, as indicated in many studies, the effect of ICT investment on productivity takes time.[1] The main reasons usually invoked to explain this lag are the time needed for skill upgrading of workers, the time required for reorganising of activities inside firms, and by the establishment of new relations between enterprises.

In Table 5, sectors are classified according to the share of ICT goods in their total investment while their performance in terms of productivity growth for the period 1995-2000 is added. In 1995, the average share of ICT goods in total investment for private enterprises was 15.2% and the average investment rate, defined as total investment divided by value added, was 22.2%. During the period 1995-2000, the average annual growth rate of productivity of private

1. See for example Haltiwanger (2000) and Scarpetta et al. (2000).

industries was 3.95%. The sectors with a share of ICT goods equal to or higher than the average share of private enterprises (15.2%) are in bold in the Table 5.

TABLE 5 - Investment in ICT and productivity performance (%)

Sector	ICT share in investment 1995	Investment rate 1995	Average annual productivity growth rate 1995-2000
Financial Activities	46.5	10.2	5.1
Machines & Equipment Manufacturing	42.6	13.1	4.5
Coke, Refining & Nuclear Industries	39.4	21.6	3.4
Electric & Electronic Equipment Manufacturing	37.5	17.7	11.2
Leather & Shoes Industries	33.4	11.5	6.7
Transport & Communications	31.5	30.4	4.5
Cardboard & Paper Industry, Edition & Printing	24.0	21.0	2.9
Trade & Domestic Equipment Reparation	21.7	15.0	6.0
Other Manufacturing Industries	18.2	18.5	4.0
Metal Industry	17.2	13.4	4.5
Textile & Clothing Industries	15.2	16.3	7.6
Hotels & Restaurants	12.8	21.4	3.3
Rubber & Plastic Industry	12.5	18.1	4.6
Chemical Industry	12.0	18.0	6.7
Wood Industry	10.9	19.6	3.6
Food Industry	10.5	19.0	0.5
Other Mineral Products Industry	9.7	22.8	4.5
Transport Material Manufacturing	9.7	12.1	2.4
Public Utilities	8.8	35.2	4.7
Real Estate, Location & Business Services	6.4	33.5	2.4
Construction	6.1	12.0	2.6
Non Energetic Products	6.0	15.8	1.5
Fishing & Aquaculture	5.6	29.0	1.6
Agriculture	3.3	21.5	3.1

Source: ICN (2001) and own calculations.

From Table 5, it clearly appears that the sectors which have invested massively in ICT goods, are also the sectors which recorded the best performance in terms of productivity evolution. This statement has to be slightly qualified for two sectors: one is a very particular industry, subject to strict safety rules, "Coke, Refining & Nuclear Industries" and the other is a mix between high tech activities such as Edition and Printing and low tech activities such as Cardboard and Paper.

In the past, the Belgian economy has recorded high investment rates. Technical progress has been mainly embodied in new equipment. The relation between ICT investment and productivity performance could underline the relative importance of capital deepening as a channel of technical progress diffusion in Belgium.

The evolution of the productivity gains is only one possible explanation for the observed divergences in growth performance between Belgium and the United States. Indeed, even if the productivity growth rates recorded by the Belgian economy in recent years were quite close to the American performance, Belgian economic growth has clearly been weaker. The other part of the explanation could be given by a smaller increase in employment. It is thus useful to compare the evolution of productivity to the evolution of employment during the period 1995-2000 at branch level. Indeed, the productivity gains could also have been obtained by rationalisation investments leading to massive job destruction.

TABLE 6 - Productivity and employment in Belgium - average annual growth rate 1995-2000

	Productivity < 0	Productivity > 0
Employment > 0	Domestic Services (-3.3%, 4.4%)	Chemical Industry (6.7%, 0%) **Trade & Domestic Equipment Reparation** (6.0%, 0.2%) **Financial Activities** (5.1%, 0.7%) Rubber & Plastic Industry (4.6%, 1.4%) **Transport & Communications** (4.5%, 1.2%) Construction (2.6%, 0.5%) Real Estate, Location & Business Services (2.4%, 3.3%) Transport Material (2.4%, 0.2%)
Employment < 0		**Electric & Electronic equipment** (11.2%, -0.1%) **Textile & Clothing Industries** (7.6%, -3.7%) **Leather and Shoes Industry** (6.7%, -7.0%) Public Utilities (4.7%, -0.9%) **Metal Industry** (4.5%, -0.5%) **Machinery & Equipment** (4.5%, -0.6%) **Other Manufacturing** (4.0%, -2.4%) Wood Industry (3.6%, -0.9%) **Coke, Refining & Nuclear Industry** (3.4%, -2.5%) Hotels & Restaurants (3.3%, -0.5%) Agriculture (3.1%, -2.2%) **Cardboard & Paper Industry, Edition and Printing** (2.9%, -0.3%) Fishing & Aqua-culture (1.6%, -1.0%) Non-Energetic Product Extraction (1.5%, -0.9%) Non-Metal Mineral Industry (1.2%, -0.6%) Agro-alimentary Industry (0.5%, -0.2%)

In Table 6, sectors are classified according to two criteria: the evolution of productivity and of employment during 1995-2000. The exact figures are given in brackets for each sector. This classification highlights an important weakness in the recent Belgian economic evolution. In most sectors, the acceleration of productivity has been accompanied by a reduction, sometimes very sharp, of the number of jobs.

Only 8 sectors have recorded a concomitant increase in their productivity and in their employment. However, these sectors are relatively important for the Belgian economy as they accounted for 45% of total employment in 2000.

A crucial question is whether the 11 sectors identified as ICT intensive (in bold in Table 5) have a particular behaviour in terms of job creation. Once again, a dichotomy exists between services and manufacturing. Among the sectors with a concomitant increase in productivity and employment, 3 (in bold in Table 6) have made important ICT investment. These sectors improved their competitive position and increased their production capacity. These 3 sectors belong to service activities. The other 8 sectors previously classified as ICT users (in bold) are all manufacturing industries and have recorded a, sometimes strong, decline in employment. In this case, ICT investment could have been mainly used to accelerate capital deepening and restructuring of firms. This particular use of ICT would be in line with the secular trend of using technical progress to maintain competitiveness by controlling unit labour cost, which is observable in the manufacturing industries.

However, caution is needed given the high level of aggregation used in this first analysis. In particular, the analyses carried out in other countries have shown the major role played by the ICT producer sectors in the productivity performances.[1] It seems thus useful to search for confirmation of this result by using more disaggregated data.

B. A detailed analysis of the Belgian case

This analysis is based on a disaggregation of the national accounts in 60 branches. Such a disaggregation requires some sacrifices in terms of quality in productivity measurement. In particular, the output data are not yet publicly available so that productivity has been calculated from value added data for the period 1995-1999. But the main advantage offered by a wider disaggregation is the opportunity to separate the ICT producer sectors from the ICT user sectors and thus to better assess the transmission channels of ICT on the structure of the economy.

The definition of ICT producer sectors follows the OECD definition as close as possible and includes sectors with the NACE code 30 to 33 for manufacturing, and 64 and 72 for services. It is henceforth wider than that of Table 10 in Annex point A, since it is determined at the NACE 2-digit level.

The sectors belong to the group of ICT users if the share of ICT in their 1995 investment was above or close to the average share of the private sector (15.2%). This is a definition of the ICT user sector sensu lato. The exact composition of this group is available in Table 11 in Annex point A.

1. An exhaustive survey of these analyses is available in Vijselaar and Albers (2002).

Box 3: ICT sectors in some other studies

There is no internationally accepted definition of ICT sectors. Given the availability of indicators, each country determines industries which have to be classified as ICT intensive. On the whole, the main Belgian sectors identified as ICT intensive based on their 1995 investment are comparable to sectors identified in analyses carried out in other countries.

Based on three criteria[a] and a 60 sector decomposition of the economy, the Centraal Planbureau[b] has classified activities in the Netherlands in three categories:

- ICT sectors: electronic industry, telecommunication and informatics services,
- ICT intensive sectors: paper & edition, metal products, trade, financial activities and business services broadly defined (without informatics services),
- ICT extensive sectors: all other sectors of which agriculture, food, textile, wood, chemical industries, construction and transport.

Based on ICT investment data disaggregated by sectors for four countries (USA (1992), Canada (1996), Netherlands (1995) and UK (1998)), OECD[c] has established a list of ICT user sectors. For manufacturing, this list includes paper & edition, electronic equipment, and machines & equipment. For services, it takes into account communications, trade, financial activities and business services.

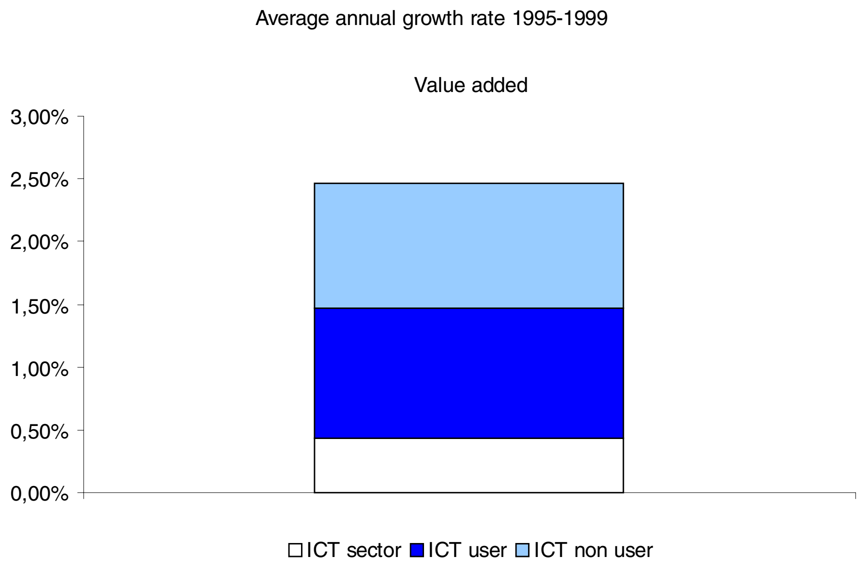
Defining ICT user sectors as those which have a relatively high ratio of ICT investment to industry output and a relatively high share in the overall ICT capital stock, the European Central Bank[d] has established a classification of ICT producing and using industries including the following sectors[e]:

- ICT producing sectors: office, accounting and computing machinery (code 30), radio, television and communication equipment (code 32), post and telecommunications (code 64) and computer and related activities (code 72),
- ICT using sectors: chemicals and chemical products (code 24), electrical machinery and apparatus (code 31) and medical, precision and optical instruments (code 33), financial activities (code 65, 66, 67), renting of machinery and equipment (code 71), research and development (code 73) and other business activities (code 74).

a. ICT capital in total capital stock, ICT capital/output ratio and ICT capital per worker ratio.
b. van der Wiel (2001).
c. Pilat and Lee (2001).
d. Vijselaar and Albers (2002).
e. The study covers Finland, France, Germany, Italy and the Netherlands.

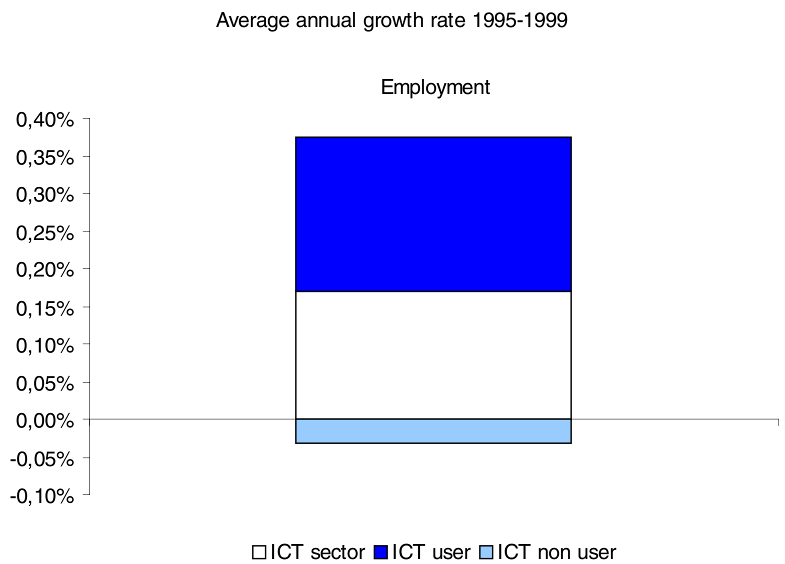
The sectoral disaggregation allows to underline the important contribution of ICT producer and user sectors to the growth of private business sector value added during the period 1995-1999. They accounted for respectively 18% and 42% of the value added average annual growth rate during this period as illustrated by Figure 4.

FIGURE 4 - Contribution to the growth of private business sector value added



The major role played by ICT sectors is even more evident when the employment evolution is considered. Between 1995 and 1999, the private business sector increased its employment at an average annual growth rate of 0.34%. Half of this increase was due to job creations in ICT producer sectors. By contrast, non ICT user sectors destroyed employment during the same period, as illustated by Figure 5.

FIGURE 5 - Contribution to the growth of private business sector employment



In order to better characterise the impact of ICT production and diffusion on the economy, the analysis also takes into consideration the evolution of productivities. Table 7 presents the comparative evolution of productivity and employment for sectors classified according to their use of ICT. The main conclusion of this comparison is that in Belgium, as in other countries for which such analysis has been carried out, the ICT producer sectors account for the major part of productivity gains recorded by the economy as a whole. These sectors have been able to increase both their productivity and their employment faster than the private sector on average.

TABLE 7 - Productivity and employment, ICT producer, user and non user sectors - average annual growth rate 1995-1999 (%)

Sector	Productivity	Employment
Private Business sector	2.1	0.3
ICT producer sectors	2.8	2.5
ICT user sectors	2.0	0.4
Non ICT user sectors	2.1	-0.1

When taken separately from the ICT producers, the ICT user sectors exhibit a different trade-off between productivity and employment than the non-ICT user sectors as they have recorded a slower increase in their productivity but an increase in their employment. However, the distinction between manufacturing and service industries shows that this overall picture is mainly driven by the behaviour of services. Indeed, the ICT user service sectors have recorded a concomitant increase in their productivity and employment while the ICT user manufacturing sectors have recorded an increase in their productivity but a strong decline in their employment, as illustrated by Table 8. In the first case, spillover effects of ICT on TFP could prevail while in the second case capital deepening could be the dominant effect.

TABLE 8 - Productivity and employment, manufacturing and services - average annual growth rate 1995-1999 (%)

Sector	Productivity	Employment
Manufacturing	4.2	-1.0
ICT producers	6.6	-0.8
ICT users	4.3	-1.7
Non ICT users	3.7	-0.6
Services	1.2	1.0
ICT producers	1.1	4.1
ICT users	1.2	1.1
Non ICT users	1.3	0.2

These results depend on the definition of ICT user sectors chosen for the analysis. In Table 9, we have recalculated the productivity and employment growth rates for ICT user sectors defined very strictly (as sectors having invested more than 30% in ICT goods in 1995). If the overall conclusion concerning a better trade-off between productivity and employment for ICT user sectors is maintained, the ICT user manufacturing sectors are in a worse situation as they continue to destroy more employment than non ICT user sectors but with a very slight increase in their productivity. The picture is better for ICT user service sectors as they record a clearly faster increase in their productivity and employment than the non ICT user service sectors.

TABLE 9 - Productivity and employment evolution - average annual growth rate 1995-1999 (%) - ICT user sectors sensu stricto

Sector	Productivity	Employment
ICT user sectors	2.22	1.83
- Manufacturing[a]	0.85	-1.10
- Services[b]	2.41	2.38
Non ICT user sectors	1.95	-0.35
- Manufacturing	4.40	-1.03
- Services	0.67	0.05

a. Sectors are Machinery & Equipment (29), Coke, Refining & Nuclear Industry (23), Leather & Shoes Industry (19) and Edition, Printing & Reproduction (22).

b. Sectors are R&D (73), Financial Activities (J) and Other Business Services (74).

This sensitivity analysis could be an additional indication that the impact of ICT has occured more through a capital deepening effect for the manufacturing sectors and through an increase in TFP for the service sectors. Indeed, the slight increase in productivity of manufacturing sectors classified as the most intensive users of ICT, could be partly explained by the fact that ICT investment per se does not automatically lead to growth of productivity but organisational changes are needed to allow a boost of productivity. These reorganisations have perhaps been easier to implement in the intensive ICT user service sectors, especially for those simultaneously facing a move towards liberalisation.

As concluded by the macroeconomic study, this branch level analysis also highlights the need for further research on the links between ICT diffusion and TFP in order to correctly evaluate the true nature of the current technological revolution.

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VI Annex

A. Definitions

TABLE 10 - ICT investment assets

NACE class	Description
	IT equipment
3000	Office, accounting and computing machinery
3210	Electronic valves and tubes and other electronic components
3320	Instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment
3330	Industrial process control equipment
	Communications equipment
3130	Insulated wires and cable
3220	Television and radio transmitters and apparatus for line telephony and line telegraphy
3230	Television and radio receivers, sound and video recording or reproducing apparatus and associated goods
	Software
7200	Computer advice, advice about and delivery of software, data processing and databases

TABLE 11 - The ICT user sectors as defined by the share of ICT investment in their total investment in 1995

NACE code & description	ICT Investment in total investment 1995 (%)
73. R&D	72.6
J. Financial activities	46.5
29. Machinery & equipment	42.6
23. Coke, refining & nuclear Industry	39.4
74. Other Business services	33.8
19. Leather & shoes Industry	33.4
22. Edition, printing & reproduction	33.1
51. Wholesale trade	26.2
18. Clothing Industry	21.0
52. Retail trade	18.8
36. Furniture Industry	18.7
27. Metallurgy	18.4
35. Other Transport materials	17.3
37. Recycling activities	16.9
28. Work on metal product	16.0
16. Tobacco Industry	16.0
71. Renting	14.3
17. Textile Industry	14.2

B. ICT data construction and assumptions

The construction of the macroeconomic ICT investment data is discussed hereafter. For each ICT asset (i = IT equipment or communications equipment), the investment series are calculated from the equilibrium condition that domestic use equals domestic supply, implying that

$$CJ_i + C_i + I_i = Q_i + M_i - X_i$$

abstracting from margins, net taxes and changes in stocks. Here, CJ_i denotes intermediate consumption, C_i is final consumption and I_i is investment. Q_i, M_i and X_i respectively stand for domestic production, imports and exports of the asset. Because total supply ($Q_i + M_i$) is measured at basic prices whereas the use ($CJ_i + C_i + I_i + X_i$) is measured in acquisition prices, the accounting is only exact when margins (W_i), net taxes (T_i - S_i) and changes in stocks (DS_i) are taken into account. Then,

$$CJ_i + C_i + I_i + DS_i = Q_i + M_i - X_i + W_i + (T_i - S_i) .$$

Indeed, unlike data on investment I_i, detailed data on imports M_i and exports X_i are readily available. These data are discussed in the next subsection. Detailed production data Q_i are available for the period 1994-2000[1] and the growth rate of imports of each asset is used to backcast production until the initial period for

1. From the National Institute for Statistics.

each ICT asset. For IT hardware, the ratio Q_i/M_i = 0.27 on average for 1994-2000. For communications equipment, this ratio is larger: 0.93.[1]

The series (Q_i + M_i - X_i) is subsequently corrected to arrive at investment, by multiplying it by the ratio of investment to domestic supply

$$\frac{I_i}{Q_i + M_i - X_i} = \frac{I_i}{CJ_i + C_i + I_i + DS_i - (T_i - S_i) - W_i}$$

of 1995, obtained from the investment table of the input-output tables. This ratio equals 0.97 for IT hardware en 0.36 for communications equipment.[2] Thus, the time series of domestic supply calculated from ICT foreign trade data and production data is adjusted by these respective 1995 ratios.

The investment expenditure series for IT equipment and communications equipment are then transformed into base year efficiency units using the harmonised price indices described in point D. The real investment series are accumulated according to the perpetual inventory method to obtain the capital stock of each asset, as described in point E.

The growth contribution of ICT capital is the aggregate of the growth contributions of each ICT asset and equals the weighted sum of the growth rates of the capital stock of each asset. Using the Törnqvist index number formula, the weights are given by the average of the current period and previous period income share of each asset, as e.g. in Colecchia and Schreyer (2001: 14).

C. Foreign trade data

The foreign trade data of ICT that is used to approximate ICT investment, is taken from the OECD International Trade in Commodities Statistics (ITCS). These statistics are classified according to the Standard International Trade Classification (SITC). For 1990-1998, the trade data are available in its third revision (SITC Rev. 3), which corresponds to ISIC Rev. 3 and hence to NACE-BEL. Historical series for 1961-1990 are only available in SITC Rev. 2, which does not correspond to the third revision. However, by comparing headings and values of entries at the most detailed level for the year 1990, in which data are available in both SITC Rev. 2 and Rev. 3, almost the entire ICT definition could be derived in terms of SITC Rev. 3 from the data in SITC Rev. 2 for the period 1961-90.

Table 12 gives the definition of ICT equipment in terms of NACE-BEL, as presented in Table 10 and the corresponding SITC Rev. 3 classification. The basic heading 76381 (in italics) belongs to both the ICT product with NACE-BEL code 3220 and 3230. However, since it cannot be broken down further, it is assigned entirely to

1. With regard to these average ratios, it must be noted that domestic production per euro of imports of both IT equipment and communications equipment declined over the given period.
2. The share of investment in domestic supply of communications equipment is much lower than that of IT equipment. This difference is mainly attributable to the fact that domestic production of communications equipment relative to investment is much larger than that of IT equipment. Moreover, for communications equipment, intermediate consumption per euro of investment is much larger, and margins per euro of investment are much lower than in the case of IT equipment.

NACE-BEL 3230 based on the heading's description (video recording or reproducing apparatus). The table shows the correspondence of the NACE-BEL classes with the SITC at the most aggregated level.[1]

TABLE 12 - Correspondence of NACE-BEL and SITC Rev. 3

NACE-BEL	3000	3130	3210	3220	3230	3320	3330
SITC Rev. 3	726.55	773	772.2	763.81	761	764.83	874.69
	75		772.3	764.1	762	871.3	
			776	764.3	763	873	
			778.6	764.82	764.2	874[a]	
				764.91			

a. Except the basic heading 874.69

Table 13 gives the derived correspondence between the second and third revision of the SITC, together with import and export values of 1990 (in 1,000 USD), the only year in which data are available in both revisions. Almost all the SITC revision 3 entries in part (a) of the table have a counterpart in revision 2 in part (b) of the table. For most codes the headings as well as the values correspond between revision 2 and 3, as is the case for division 75, groups 761, 762, 763 and 776, subgroups 764.3, 772.2, 772.3, 773.1 and basic headings 764.81, 764.82, 764.83, 764.91, 764.92 and 764.99.

In a few cases, the headings do not correspond but the values of different codes are identical, thus allowing to match these codes. This way, subgroups 778.6 and 871.3 in revision 3 correspond respectively with headings 778.84 and 871.03 in revision 3.

Notice in the table that the sum of the values of SITC groups 873 and 874 is the same in 1990 in revision 2 and 3, although taken separately the value of both groups differs between revisions 2 and 3.[2] However, this does not constitute a problem because groups 873 and 874 both belong to the ICT product defined by NACE-BEL class 3320.

Basic heading 874.69 in revision 3 constitutes an ICT product by itself (NACE-BEL 3330), while it is part of group 874. Judging from the heading's definitions (not displayed here), the items of heading 874.69 in revision 3 were previously added to subgroup 874.9, which does not allow to retrieve it since it has no further breakdown. Hence, the ICT products defined by NACE-BEL 3330 and NACE-BEL 3320 cannot be separated until 1990. This does not matter, however, since both NACE-BEL classes belong to the same ICT product, viz. IT equipment.

Similarly, group 764 corresponds in SITC revision 2 and 3, but its subgroups, 764.1 and 764.2, do not. Again this does not influence the data series between the two

1. The detailed correspondence, as found e.g. at Eurostat (see http://europa.eu.int/comm/eurostat/ramon), is not presented here in order to conserve space.
2. This cannot be solved by analysing the definitions of the basic headings, since this observed difference consist of the parts of 873 that is accounted for by subgroup 874.9 in revision 2 (in italics). It is impossible to retrieve this part because subgroup 874.9 has no further breakdown.

revisions, since both subgroups belong to the same asset, viz. communications equipment.

TABLE 13 - Correspondence between SITC Rev. 3 and Rev. 2

		Import	Export
	(a) SITC Revision 3		
72655	Offset printing machinery, sheet fed, office type	205.7	1,633.0
75	Office machines and auto. data processing machines	2,531,084.1	1,235,221.8
761	Television receivers, whether or not combined	361,293.9	724,015.7
762	Radio-broadcast receivers, whether or not combined	241,314.6	154,172.3
763	Sound recorders or reproducers; television recorders	207,906.2	238,371.0
7641	Electrical apparatus for line telephony or teleg.	258,444.6	119,913.5
7642	Microphones; loudspeakers; headphones; amplifiers	111,406.2	135,796.8
7643	Transmission apparatus for radio-broadcasting, etc.	48,541.4	26,809.2
76481	Reception appar. for radio-teleph., -telegr., n.e.s.	9,765.9	16,609.1
76482	Television cameras	99,668.1	27,991.3
76483	Radar, radio-navigat. aid, -remote control apparatus	32,763.3	42,353.3
76491	Parts & accessories for apparatus of heading 7641	105,427.8	358,690.9
76492	Parts & accessories for apparatus of heading 7642	18,377.2	2,189.7
76499	Parts & accessories for apparatus of group 763	26,746.4	102,564.1
7722	Printed circuits	58,453.70	99,313.3
7723	Electrical resistors, other than heating resistors	20,543.4	56,132.8
7731	Insulated wire, cable & other insulated conductors	323,514.4	350,629.8
776	Cathode valves & tubes; diodes; integrated circuits	490,625.5	146,749.4
7786	Electric capacitors, fixed, variables or adjustable	58,137.8	82,615.3
8713	Microscopes (non-optical) ; diffract. apparat., n.e.s.	3,488.8	667.6
873	Meters & counters, n.e.s.	74,446.2	22,947.6
874	Measuring, analysing & controlling apparatus, n.e.s.	768,575.3	423,922.2
87469	Parts & accessories for instruments of 8746	11,141.0	1,558.6
	(b) SITC Revision 2		
75	Office machines & auto. data processing equipment	2,531,084.1	1,235,221.8
761	Television receivers	361,293.9	724,015.7
762	Radio-broadcast receivers	241,314.6	154,172.3
763	Gramophones, dictating, sound recorders etc	207,906.2	238,371.0
7641	Elect.line telephonic & telegraphic apparatus	263,559.5	121,668.1
7642	Microphones, loudspeakers, amplifiers	106,291.3	134,042.2
7643	Radiotelegraphic & radiotelephonic transmitters	48,541.4	26,809.2
76481	Radiotelephonic or radiotelegraphic receivers	9,765.9	16,609.1
76482	Television cameras	99,668.1	27,991.3
76483	Radio navigational aid apparatus, radar apparatus	32,763.3	42,353.3
76491	Parts of apparatus of 764.1-	105,427.8	358,690.9
76492	Parts of apparatus of 764.2-	18,377.2	2,189.7
76499	Parts of apparatus of 763--	26,746.4	102,564.1
7722	Printed circuits and parts thereof	58,453.7	99,313.3
7723	Resistors, fixed or variable and parts	20,543.4	56,132.8
7731	Insulated, elect.wire, cable, bars, strip and the like	323,514.4	350,629.8
776	Thermionic, cold \& photo-cathode valves, tubes, parts	490,625.5	146,749.4
77884	Elect.capacitors, condensers, fixed or variable	58,137.8	82,615.3
87103	Microscopes \& diffraction apparatus	3,488.8	667.6
873	Meters and counters, n.e.s.	60,202.5	18,142.8
874	Measuring, checking, analysing instruments	782,819.0	428,727.0
8749	*8749 Parts, n.e.s. acc. for 873--, 8743-, 87454, 8748*	173,354.4	126,509.9

Nevertheless, one deviation between both revisions remains: the basic heading 726.55 in SITC revision 3 has no counterpart in revision 2. However, it concerns a value small enough to be safely ignored, since it amounts to an underestimation of the revision 2 data by 0.02 percent (919,350 USD) on average for imports and exports in 1990.

In short, the ICT trade time series going back before 1990 are obtained with the qualification that a negligible error remains between revision 2 and 3, due to basic heading 726.55. Disregarding this minor deviation, trade series are obtained for the period 1960-1998. However, before 1978, until when SITC Rev. 1 has been in use, a number of assets have missing values, causing a break in the series. Therefore, the series are limited to the period 1978-1998. The trade data for the years 1999-2000 are obtained using the growth rates of the Prodcom foreign trade data for the corresponding assets, obtained from the NIS and available for 1994-2000.

D. Harmonised price data

Since no hedonic indices are constructed for the producer price index in Belgium a solution consists of using harmonised deflators for each of the ICT capital goods in order to arrive at quality-adjusted price indices. According to Schreyer (2001: 12), at least three methods are used, each taking the US hedonic indices as a benchmark.

First, the US deflator for the ICT good can simply be used for the ICT good in Belgium. This is the most direct way of transposing a price index between two countries. It is based on the assumption that nominal prices of ICT goods change at the same rate in different countries: a 20 percent fall in computer prices in the US translates into a 20 percent decline in the same price in Belgium.

If $P_{US,ICT}$ represents the US price index for the ICT good and $PH1_{B,ICT}$ the harmonised price index for the same good in Belgium, then:

$$PH1_{B,\,ICT} = P_{US,\,ICT} \cdot$$

This simple method ignores the possibility that different countries can have different changes in the overall price level. The second measure allows controlling for that possibility and is therefore more widely used. In this case, the assumption is made that the relative price change of the ICT good under consideration should be the same across countries. The relative price is expressed as the price index of the ICT good divided by the price index for non-ICT goods. Let $P_{i,O}$ be the price of non-ICT goods for country i. Then the harmonised price index of Belgium is given by:

$$PH2_{B,\,ICT} = \frac{P_{B,\,O}P_{US,\,ICT}}{P_{US,\,O}} .$$

Thus, by correcting the producer price index of investment in Belgium by the relative price index of US ICT and other investment, the harmonised deflator is made independent of the overall price level of both countries.

Third, the Belgian ICT price index can be approximated by the product of the US hedonic ICT price index and the appropriate exchange rate, assuming that the law of one price holds for the ICT capital goods. If E is the euro/dollar exchange rate, the harmonised price index becomes:

$$PH3_{B, ICT} = P_{US, ICT}E .$$

Although all three methods are used in the literature, the second method is preferred here over the last because it is not sensitive to exchange rate volatility. Adjusting by the current exchange rate may imply an exaggeration of the pass-through from US prices into Belgian prices. To the extent that exchange rate changes are not fully passed on to consumers, the price change in domestic currency will be biased. Whichever method is chosen, when the harmonised price index is carefully constructed, it is the appropriate tool to convert capital expenditure on different vintages into a common efficiency-weighted or constant-quality unit.

FIGURE 6 - Harmonised IT hardware prices indices (1995=100)

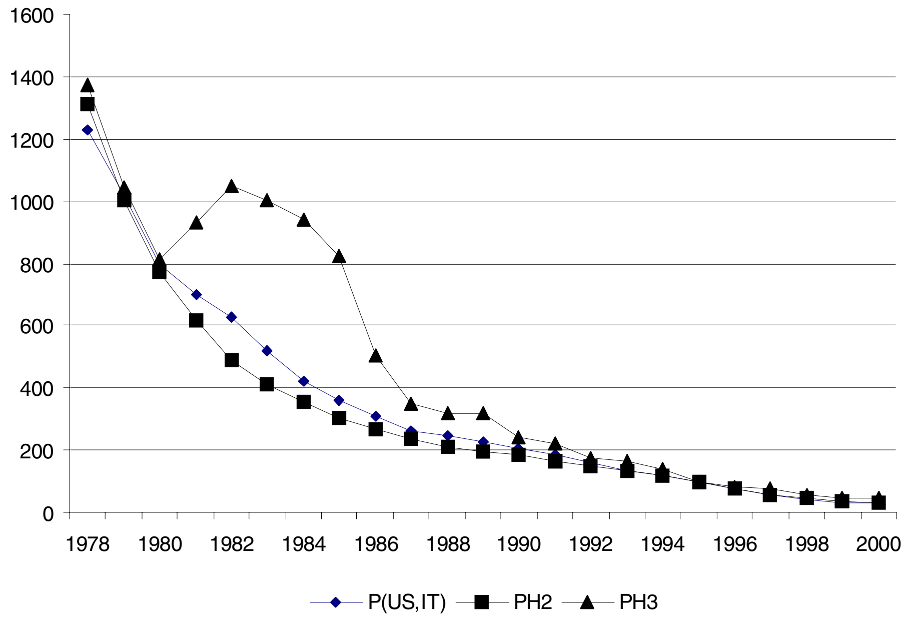

Figure 6 compares the harmonised price indices of IT equipment in Belgium and the US. The Belgian IT equipment price index is calculated by correcting the US hedonic price index either for the euro/dollar exchange rate (PH3), or by correcting the Belgian price index of private investment by the ratio of US ICT and private investment prices, where the US price ratio is smoothed by a 5-year moving average (PH2). The latter has the disadvantage that non-ICT investment prices are not available and need to be approximated by private investment prices, comprising both ICT and non-ICT investment prices. However, this is unlikely to make a big difference, since ICT investment spending is still a relatively small portion of total investment spending. Moreover, as the figure shows, the harmonised price index based on the exchange rate is characterised by a particular evolution in the early 1980s, that would show up throughout the rest of the calculations. Therefore, the series based on the investment price differential is preferred.

E. Perpetual inventory method

The capital stock of asset type i in period t is

$$K_{i,t} = \sum_{s=0}^{T} h_{i,s} F_{i,s} I_{i,t-1-s}$$

where $I_{i,t-1}$ is investment expenditure on asset i in year t-1, which becomes part of the capital stock at the beginning of year t. Furthermore, T is the maximum service life, $h_{i,s}$ is an age-efficiency profile, and $F_{i,s}$ is a retirement function that gives the proportion of assets of age s still in service at time t. Ideally, the ICN (2002: 20) is followed in specifying a bell-shaped (lognormal) *retirement function*. However, to save (L) observations it was opted to make the simplifying assumption that the asset's mortality is characterised by simultaneous exit (deterministic mortality):

$$FS_{i,s} = \begin{cases} 1 & i = 1 \ldots L \\ 0 & \text{otherwise} \end{cases}$$

where L denotes the average service life, assumed equal to 5 years for IT equipment and 11 years for communications equipment.[1] If $F_{i,s} = FS_{i,s}$, the capital stock becomes

$$K_{i,t} = \sum_{s=0}^{L} h_{i,s} I_{i,t-1-s}.$$

Because the age-efficiency pattern attributes a smaller weight to the assets of a particular vintage as they live longer, the capital stock will be overestimated if assets overall are assumed to live shorter than they do in reality. Hence, the assumption that the survival function equals $F_{i,s} = FS_{i,s}$ implies overestimation of the capital stock, relative to a more realistic bell-shaped mortality pattern with survival function $F_{i,s} = FN_{i,s}$. Indeed, with simultaneous exit at the average service life L all the assets of a particular vintage survive before L is reached, after which none survives. If $F_{i,s} = FN_{i,s}$, however, some assets break down before L is reached and a number of assets survive thereafter.

Regarding the choice of the *age-efficiency profile*, two common profiles are the hyperbolic and the geometric age-efficiency profile. Although the geometric pattern is appealing because it simplifies the calculations, the hyperbolic profile is often regarded as more realistic.[2] Assets with a hyperbolic age-efficiency profile lose relatively more of their productive value towards the end of their service life, whereas assets with a geometric deterioration lose relatively more productive

1. The length of the average service lives of IT and communications equipment follows the assumptions of the US Bureau of Economic Analysis.
2. Several official institutions prefer a hyperbolic profile over a geometric profile (e.g. US Bureau of Labor Statistics and Australian Bureau of Statistics, as reported in OECD, 2001a). Moreover, the hyperbolic pattern is applied to construct capital stocks of ICT assets in a number of studies (e.g. Colecchia and Schreyer, 2001).

value in the beginning of their service life. In the calculations presented here, a hyperbolic age-efficiency profile is used, specified by:

$$h_{i,t} = \frac{T - t}{T - \beta t}.$$

Here β is set to 0.8 and the maximum service life T = 1.5L, as in Colecchia and Schreyer (2001). ICN (2002: 19) assumes that T = 2L for its calculation of the stock of non-ICT assets, but judging from the low resulting depreciation rates (cf. infra) this seems too long for ICT equipment. Several other relations between average and maximum service life are found in the literature. For instance, van der Wiel (2001) and Vijselaar and Albers (2002) take T = L in the above formula, Meinem et al. (1998)[1] assume that $T = L\beta^2/[\beta + (1-\beta)\log(1-\beta)]$ and Mohr and Gilbert (1996)[2] take the expected value of the hyperbolic function for all possible service lives between 0.5L and 1.5L. It must be remarked that the results are sensitive to the choice of T. Variations in the value of β, on the other hand, have a negligible impact on the results.

The *user cost* of each ICT capital asset is needed to obtain the share of the asset in total income. It is given by

$$\mu_{i,t} = \left(r_t + \delta_{i,t} + \frac{q_{i,t} - q_{i,t-1}}{q_{i,t}}\right) q_{i,t}$$

and depends on the internal rate of return r_t, the asset's depreciation rate $\delta_{i,t}$ and the change in market value of the asset $(q_{i,t}-q_{i,t-1})/q_{i,t}$. The latter is obtained as a 5-year moving average of the harmonised price indices.

The rate of *depreciation* is calculated as follows. Once the functional form of the age-efficiency profile has been decided on, the age-price profile can directly be derived from it, using the result that the value of an asset depends on the expected stream of revenue provided over its service life. The age-price profile is used to calculate the net capital stock, in the same way as the age-efficiency profile is applied to calculate the productive stock. Since the change in the net stock consists of investment minus depreciation, the amount of depreciation is readily derived, and the depreciation rate is calculated as the ratio of the level of depreciation and the net stock.[3] More details can be found in OECD (2001a). As suggested there, the real discount rate needed for the calculation of the age-price profile has been set to 0.04.

The nominal or internal *rate of return* can be calculated as the ex-post rate that exhausts all non-labour income in the production account. That is, solve for r_t:

$$P_tQ_t - w_tL_t = \sum_i u_{i,t}K_{i,t} = r_t\sum_i q_{i,t}K_{i,t} + \sum_i\left[d_{i,t} - \frac{q_{i,t} - q_{i,t-1}}{q_{i,t}}\right]q_{i,t}K_{i,t}.$$

1. See G. Meinem, P. Verbiest and P. de Wolf, Perpetual Inventory Method. Service Lives, Discard Patterns and Depreciation Methods, Statistics Netherlands, Department of National Accounts, July, 1998, p. 50.
2. Mohr, M. and C. Gilbert (1996), “Capital Stock Estimates for Manufacturing Industries: Methods and Data”, Industrial Output Section, Stop 82, Division of Research and Statistics, Board of Governors of the Federal Reserve System, March.
3. The net capital stock is calculated from investment at constant prices, so that depreciation is also measured at constant prices. Hence it only measures the effects of ageing and not of revaluation.