CPB Discussion Paper

No 22

November, 2003

International Comparisons of Sectoral Energy- and Labour-Productivity Performance

Stylised Facts and Decomposition of Trends

Peter Mulder and Henri L.F. de Groot

CPB Netherlands Bureau for Economic Policy Analysis
Van Stolkweg 14
P.O. Box 80510
2508 GM The Hague, the Netherlands

Telephone +31 70 338 33 80
Telefax +31 70 338 33 50
Internet www.cpb.nl

ISBN 90-5833-141-5

Table of contents

Abstract

This paper simultaneously explores trends in energy- and labour productivity for 14 OECD countries and 13 sectors over the period 1970-1997. A principal aim of this paper is to trace back macroeconomic productivity developments to developments at the level of individual sectors, in order to correct trends in technology-driven productivity improvements for the impact of structural effects. First, we document trends in macroeconomic energy- and labour productivity performance, examining the role of the Manufacturing, Services, Transport and Agricultural sector. Second, we take a closer look at the role of 10 Manufacturing sectors in driving aggregate Manufacturing energy- and labour-productivity performance. A cross-country decomposition analysis reveals that in some countries structural changes contributed considerably to aggregate energy-productivity growth while in other countries they partly offset energy-efficiency improvements. In contrast, structural changes only play a minor role in explaining aggregate labour-productivity developments. We identify for each country the percentage contribution of each sector to aggregate structural and efficiency changes. Furthermore, we find labour productivity growth to be higher on average than energy productivity growth. Over time, this bias towards labour productivity growth is increasing in the Transport, Agriculture and aggregate Manufacturing sectors, while it is decreasing in Services and most Manufacturing sectors.

Keywords: energy productivity, labour productivity, convergence, sectoral analysis
JEL-codes: O13, O47, O5, Q43

1 Introduction[1]

Economic growth depends on a number of interrelated factors such as an increase in labour force and labour productivity, accumulation of knowledge and capital, the availability of natural resources and energy, the quality of government and institutions and – probably most of all – technological change (see, for example, OECD 2003). Ever since Solow (1957) held his famous 'residual' responsible for most of the observed economic growth, broad consensus exists that long-run economic growth is caused by technology driven (total) factor productivity growth. This led economists to focus on the role of productivity and technology in their quest for understanding economic growth. The quest has not been confined to economic theorizing about growth and technological change, but includes also empirical work on the sources of economic growth. Over the last decades, a growth accounting tradition emerged measuring the contribution of various determinants to output- and productivity growth (see, for example, Kendrick 1961, Denison 1967, Jorgenson and Griliches 1967, Maddison 1991, Jorgenson 1995, Wagner and van Ark 1996, van Ark 1997, Barro 1997). This empirical research on productivity growth has focused almost exclusively on labour-, capital- and total factor-productivity growth.

However, over the last decades increasing attention is paid to the role of energy in production processes and economic growth. Energy is an essential factor that fuels economic growth and serves human well-being. Along with unprecedented economic growth, world primary energy use has grown enormously since the middle of the 19th century. The energy crisis of the 1970s and, more recently, the environmental problems associated with economic growth and increasing energy use have induced empirical research on energy-productivity or energy-intensity developments and its determinants (see, for example, Jorgenson 1984, 1986, Howarth et al. 1991, Morovic et al. 1987, 1989; Schipper and Meyers 1992, Rosenberg 1994, Miketa 2001). Moreover, it made most governments in OECD countries to strive explicitly for sustainable development, aiming to decouple economic growth and environmental pressure. In a more operational sense this implies that not only labour productivity, but also energy productivity should increase. Against this background, this paper offers international comparisons of energy- and labour-productivity developments for the period 1970-1997, distinguishing 13 sectors – including 10 Manufacturing sectors, Services, Transport and Agriculture – and 14 OECD countries. In doing so, we build upon insights from the traditional empirical growth literature as well as from the literature on energy-intensity developments.

The level of sectoral detail in our dataset allows us to trace back macroeconomic energy- and labour-productivity developments to developments at the level of individual sectors, in order to correct as much as possible for the impact of 'structural effects' on productivity trends. This is important since observed aggregate productivity trends are not directly attributable to

[1] We gratefully acknowledge useful comments by Jeroen van den Bergh, Frank den Butter, Kornelis Blok, Reyer Gerlagh, Marjan Hofkes, Ton Manders, Hein Mannaerts, Machiel Mulder, Peter Nijkamp, Sjak Smulders, Paul Tang and Herman Vollebergh on earlier versions of this paper.

technological change in individual sectors, but also the result of changes in the distribution of production factors among sectors. The latter is due to the fact that some sectors produce more value added per unit of input (energy or labour) than others, because some activities require more capital, higher labour skills and/or technology than others. Hence, understanding technology-driven productivity performance requires an assessment of productivity performance in individual sectors (see also, for example, Dollar and Wolff 1993, Wagner and van Ark 1996, Jorgenson 1984). In order to identify to what extent aggregate productivity trends are to be explained from, respectively, shifts in the underlying sector structure and efficiency improvements in individual sectors, we decompose per country changes in overall productivity performance into a so-called 'sectoral effect' and an 'efficiency effect'. In several respects, our decomposition differs from most other decomposition studies (see, for example, van Ark 1996, Unander et al. 1999), most notably by the combination of a relatively high level of sectoral detail with a wide range of countries and a simultaneous exploration of productivity performance along the two dimensions of energy and labour.

By documenting the relation between energy- and labour-productivity growth rates we touch upon the issue of the direction of technological change. The idea that the nature of technological progress might be factor-augmenting, depending on relative factor prices and substitution possibilities, goes back to Hicks (1932) and received attention in the theoretical and empirical literature on technological change and factor productivity developments ever since (see, for example, Kennedy 1962, Binswanger 1974a,b, Acemoglu 2002, Ruttan 2001). Recently, the issue has also been addressed in the context of environmental policy and energy use, examining a price- or product-standard induced bias towards energy-saving technological change (see, for example, Newell et al. 1999, Smulders and de Nooij 2003, Taheri and Stevenson 2002). An important hypothesis in this respect is that if all technological efforts are directed towards an increase in labour productivity, energy productivity improvements might slow down because of lack of resources devoted to increasing energy efficiency – and vice versa. In this paper, we provide some empirical evidence on the existence and development of a potential bias towards either energy- or labour productivity, which might reflect biases of technological change at the level of individual sectors.

The paper proceeds as follows. In section 2 we give a brief description of the data used in this study. In section 3 we document several stylised facts on the levels and trends in macroeconomic energy- and labour productivity performance, examining the role of the Manufacturing, Services, Transport and Agriculture sectors. In section 4 we take a closer look at the Manufacturing sector, not only because it is an important sector within the OECD – still responsible for about 40% of total final energy consumption and 25% of total employment – but also because it is a very heterogeneous sector in terms of production structure. Therefore, we further disaggregate the Manufacturing sector into 10 sub-sectors and examine their role in driving aggregate Manufacturing energy- and labour-productivity performance, following the same research strategy as we will use in section 3. Section 5 concludes.

2 Data

The analysis presented in this paper is based on a newly constructed database that merges energy data from the Energy Balances as they are published by the International Energy Agency (IEA) and economic data from the International Sectoral Database (ISDB) and the Structural Analysis Database (STAN), both published by the OECD. The main idea behind the construction of this database is to establish a link between economic and energy data at a detailed sectoral level. This results in the sector classification as described in Table 2.1.

Table 2.1

	Sector	Abbreviation	ISIC Rev. 2 code
1	Food and Tobacco	FOD	31
2	Textiles and Leather	TEX	32
3	Wood and Wood Products	WOD	331 [a]
4	Paper, Pulp and Printing	PAP	34
5	Chemicals	CHE	351+352 [b]
6	Non-Metallic Minerals	NMM	36
7	Iron and Steel	IAS	371
8	Non-Ferrous Metals	NFM	372
9	Machinery	MAC	381+382+383 [c]
10	Transport Equipment	MTR	384
11	Construction	CST	50
12	Services	SRV	61+62+63+72+81+82+83+90 [d]
13	Transport	TAS	71
14	Agriculture	AGR	10

[a] WOD excludes furniture since the sector WOD in the IEA Energy Balances excludes furniture

[b] CHE includes non-energetic energy consumption, i.e. using energy carriers as feedstock.

[c] MAC = Metal Products (BMA, 381) + Agricultural and Industrial Machinery (MAI, 382) + Electrical Goods (MEL, 383);

[d] SRV = Wholesale and retail trade, restaurants and hotels (RET) + Communication (COM) + Finance, insurance, real estate and business services (FNI) + Community, social and personal services (SOC).

The database covers the period 1970-1997 and includes the following countries: Australia (AUS), Belgium (BEL), Canada (CAN), Denmark (DNK), Finland (FIN), France (FRA), West-Germany (WGR), Italy (ITA), Japan (JPN), Netherlands (NLD), Norway (NOR), Sweden (SWE), United Kingdom (GBR) and the United States (USA). For a detailed description of the database we refer to Mulder (2003). In the remainder of this section we briefly highlight a few important characteristics as well as limitations of our dataset.

We measure energy productivity by gross value added per unit of final energy consumption and labour productivity by gross value added per worker (in full time equivalents).[2] Value added is the net economic output of a sector, measured by the price differential between the

[2] Alternatively, one can also make use of physical productivity indicators to measure energy- and labour productivity. We refer to Appendix B for a brief discussion on the use of physical versus economic indicators of output and, hence, productivity.

price of output and the cost of input and comprises compensation to employees, operating surplus, the consumption of fixed capital and the excess of indirect taxes over subsidies (OECD 1998). Following the IEA, energy use is defined as final energy consumption in kilo tonnes of oil equivalence (ktoe),[3] with sectoral data excluding transformation losses. Total employment is measured in full-time equivalent number of persons, including self-employed.

The value added data have been converted to constant 1990 US$, using 1990 expenditure purchasing power parities (PPP) as given by the OECD. In principle the theoretically most appropriate conversion factors for productivity comparisons at the sectoral level are to be based on a comparison of output prices by industry of origin, rather than on expenditure prices (see, for example, van Ark and Pilat 1993). Expenditure PPPs exclude the part of output that is exported, while they include imported goods produced elsewhere; they take account of differences in trade and transport margins and indirect taxes between countries; and they do not cover intermediate products. The main problem in using the production or industry-of-origin approach, however, is the limited availability of producer-price based PPPs, in particular for non-Manufacturing sectors (van Ark 1993).[4] Hence, most studies including cross-country productivity comparisons use expenditure PPPs. Moreover, for an international comparison the main issue is whether there are substantial cross-country differences with respect to the drawbacks of expenditure PPPs as outlined above. We have no a priori reason to presume that these cross-country differences are substantial. Therefore, in this study we use expenditure PPPs, enabling a systematic cross-country analysis of energy- and labour-productivity performance at a high level of sectoral detail.

In general it holds for each analysis of productivity developments that the lower the level of aggregation the better, but that an adequate distinction between factor-intensive and factor-extensive sectors is even more important. In this respect, it is to be noted that our Chemicals sector is defined at a rather aggregated level. The Chemicals sector is built up from the energy-intensive sub-sector Industrial Chemicals (ISIC 351, including basic industrial chemicals, fertilizers, pesticides and main plastic products) and the energy-extensive sub-sector Other Chemical Products (ISIC 352, including paints, drugs and medicines, cosmetics and cleaning products). Until consistent and internationally comparable energy and economic data become available for a more detailed breakdown of the chemical sector, this problem will persist and energy-productivity figures for the sector Chemicals should be interpreted with caution.

Unfortunately, for the USA the IEA Energy Balances provide no sectoral breakdown for the consumption of oil products and natural gas within Manufacturing until 1995. Instead, these volumes are included in the sector Non-Specified Industry (NSI) and, hence, they are available

[3] Hence, we do not analyze explicitly the impact of changes in fuel mix on overall energy-efficiency improvements.

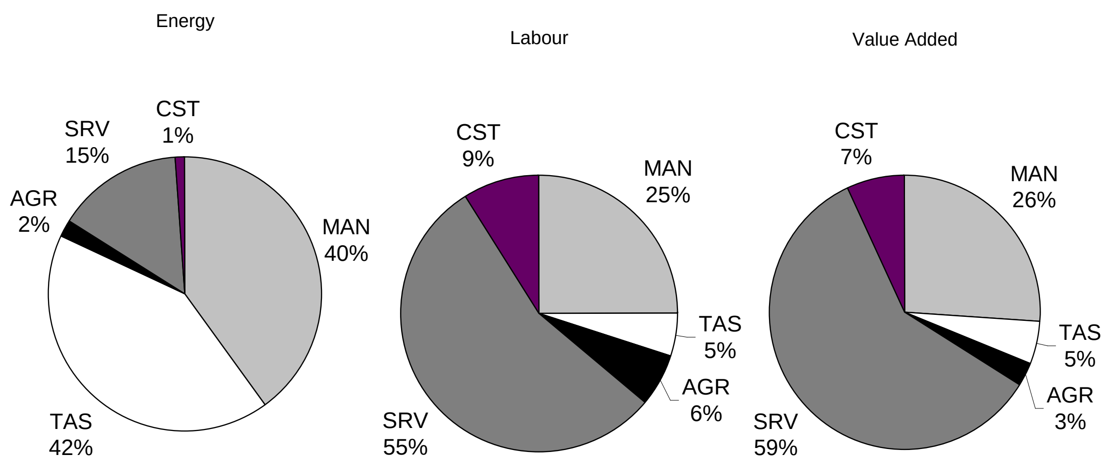
[4] This limited availability is due to some problems inherent to the industry-of-origin approach: producer prices (i.e. production values divided by output quantities) may not properly account for cross-country quality differences and imply aggregation problems for they are available only for a sample of goods (partly because of confidentiality problems), and because the production structure among countries tends to be less comparable than the consumption structure due to specialization tendencies in production according to comparative advantage (Pilat 1996).

only at the level of the aggregate Manufacturing sector. For this reason, for the different USA Manufacturing sub-sectors, we neither include data from 1995 onwards nor do we report *levels* of energy consumption. We do, however, calculate energy-productivity growth rates for the different USA Manufacturing sub-sectors, with final energy consumption defined as the sum of only Coal and Electricity consumption, under the assumption that the share of the sum of oil and gas in final energy consumption is more or less constant over time. Hence, the documented growth rates of energy productivity for the breakdown of the USA Manufacturing sector should be interpreted with caution.

3 Macroeconomic developments

In this section we explore levels and trends in macroeconomic energy- and labour-productivity performance, examining the role of the Manufacturing, Services, Transport and Agricultural sectors. We start with a brief overview of their sectoral shares in macroeconomic energy consumption, employment and GDP. The Manufacturing sector used to be the most important sector from an energy-point of view, accounting for more than 40% of the world's energy use (Schipper and Meyers 1992). In the OECD the Transport sector is nowadays at least as important as Manufacturing in terms of energy consumption. For the sum of the 14 OECD countries included in this study, the share of total final energy consumption in Transport accounted for 42% in 1990, closely followed by Manufacturing with 40%, while Services accounted for 15%, Agriculture for 2% and Construction for 1% (see Figure 3.1).

Figure 3.1 Percentage shares of non-residential final energy consumption, total employment and value added by sector in 1990. Sample of 14 OECD countries.



In Figure 3.1 we compare those shares with the sector shares of total employment and value added. Our data confirm the well-known fact that for industrialised countries the highest share of total employment and value added can be found in the Service sector (55-60%), followed by Manufacturing (25%), while Transport, Agriculture and Construction are responsible for the remaining 15-20%. These shares are more or less similar for all of the 14 OECD countries included in this study (see Table A1 in Appendix A). In sum, the Service sector plays a major role in terms of value added and total employment, while most energy is consumed in Transport and Manufacturing. For the Transport in particular there is a large contrast between the share of total energy consumption on the one hand and the share of total value added and employment on the other hand.

Within the OECD, the absolute level of energy consumption and employment grew over the last decades, but so did economic activity. In this paper we take this volume effect into account by using energy- and labour productivity as indicators to relate, respectively, final energy consumption and employment to the level of economic activity.[5] In the remaining part of this section we provide a cross-country comparison of energy- and labour-productivity *levels*, followed by a cross-country comparison of energy- and labour-productivity *growth rates.*

3.1 Comparing energy- and labour-productivity levels

To compare cross-country energy- and labour-productivity performance at the macroeconomic level, we calculated for each country the energy- and labour-productivity levels for the sum of the Manufacturing, Transport, Services and Agriculture sectors.[6] In Figure 3.2 and 3.3 we plot the development of these macroeconomic energy- and labour-productivity levels over time.

Figure 3.2 reveals a diverse picture for energy productivity with substantial cross-country differences. The highest energy-productivity levels are to be found in Italy and Japan while Canada, Finland, Norway and Sweden show the lowest levels of energy productivity. All other countries form a medium group. The USA tends to leave the group with low levels of energy productivity over time to catch-up with the medium group. Figure 3.3 shows the well-known picture for labour productivity with a leading position for the USA and other OECD countries showing a tendency to catch-up.

[5] Note that most studies analysing energy-efficiency developments use energy intensity as an indicator, being the inverse of energy productivity. We prefer to use energy productivity simply because it establishes a direct link with (the empirical literature on) labour-productivity developments.

[6] Hence, in this paper 'macroeconomic' refers to the sum of the Manufacturing, Transport, Services and Agriculture sectors and thus excludes Construction, Households and the Energy Production sector.

Figure 3.2 Trends in macroeconomic energy productivity development

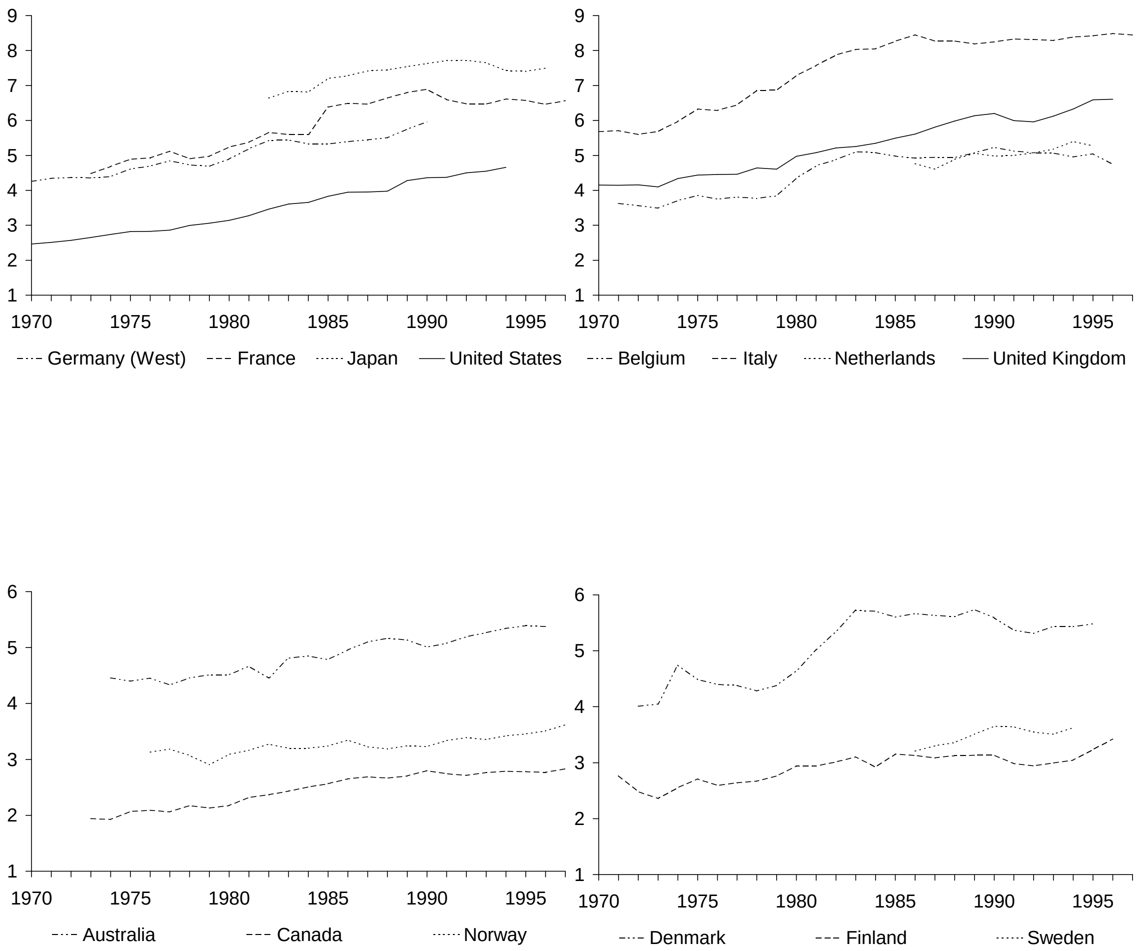
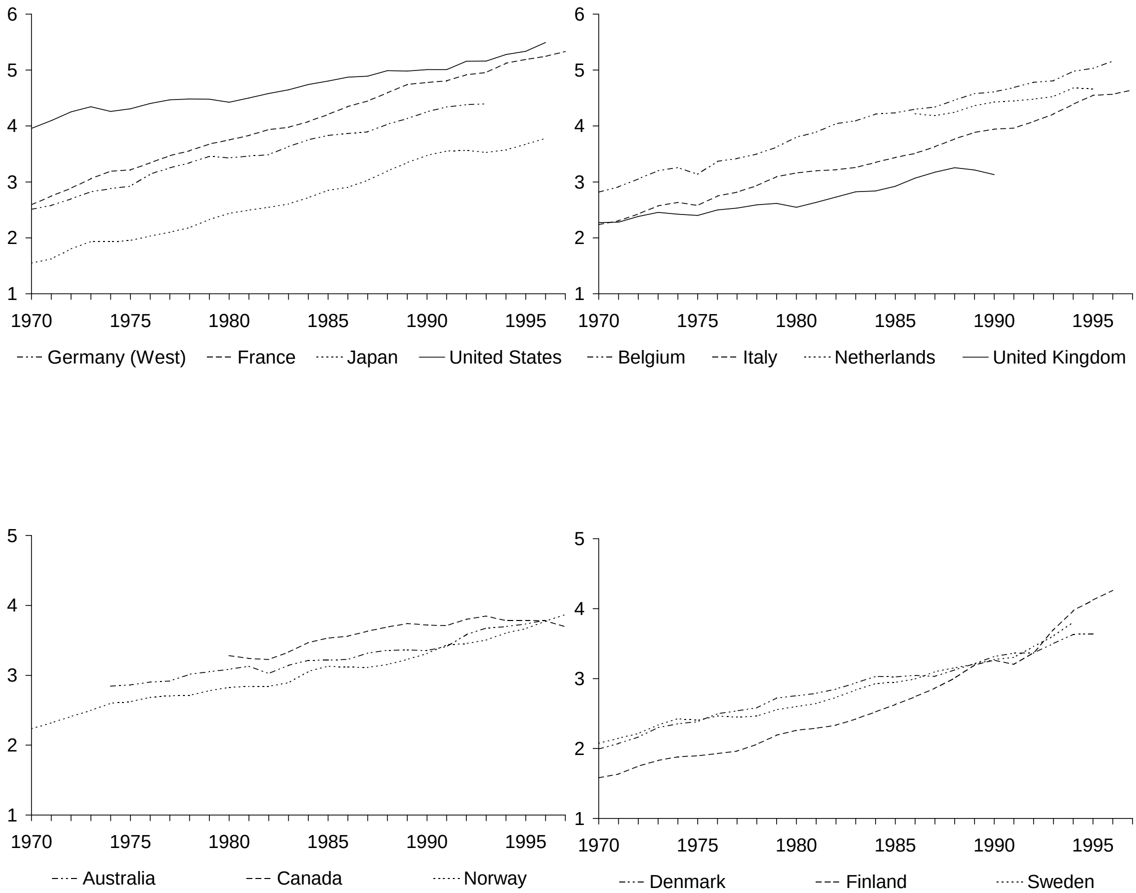


Figure 3.3 Trends in macroeconomic labour productivity development



These macroeconomic pictures raise the question whether similar cross-country productivity pattern can be found at a lower level of aggregation or whether a country's performance differs substantially across sectors? To answer this question we present in Table 3.1 a cross-country comparison of the energy- and labour-productivity levels relative to the USA for the years 1976 and 1990, for the Manufacturing, Transport, Services and Agriculture sector.

Table 3.1 **Energy- and labour productivity main sectors relative to USA (USA=100)**

	Manufacturing				Services			
	Energy		Labour		Energy		Labour	
	1976	1990	1976	1990	1976	1990	1976	1990
USA	100	100	100	100	100	100	100	100
AUS	105	71	57	54	413	244	70	72
BEL	84	93	59	84	149	130	86	91
CAN	67	51	74	69	61	52	81	77
DNK	188	185	54	49	183	94	66	77
FIN	57	55	43	64	321	141	50	69
FRA	214	172	76	85	74	123	91	106
WGR	209	175	78	73	106	104	77	98
ITA	150	166	55	74	1481	598	90	93
JPN	--	169	--	75	192	151	50	72
NLD	--	75	--	86	--	305	--	89
NOR	75	42	56	52	102	61	65	67
SWE	90	78	52	56	--	63	67	73
GBR	157	159	53	62	152	152	62	61
SD log	.44[a]	.52[a]	.22[a]	.21[a]	.84[b]	.61[b]	.21[c]	.17[c]

	Transport				Agriculture			
	Energy		Labour		Energy		Labour	
	1976	1990	1976	1990	1976	1990	1976	1990
USA	100	100	100	100	100	100	100	100
AUS	183	175	57	74	165	91	83	58
BEL	481	372	94	124	114	81	79	88
CAN	115	125	--	74	146	50	89	63
DNK	333	316	63	76	34	63	41	64
FIN	319	268	52	67	145	64	57	61
FRA	256	242	65	87	176	135	52	74
WGR	252	209	55	73	142	103	39	49
ITA	370	313	53	67	288	124	41	37
JPN	662	555	60	84	--	66	30	27
NLD	--	272	--	77	--	38	84	102
NOR	570	488	78	114	196	114	66	50
SWE	182	221	35	52	120	89	59	62
GBR	368	266	47	58	124	154	66	72
SD log	.55[c]	.47[c]	.28[d]	.25[d]	.49[a]	.32[a]	.35	.35

[a] excl. JPN and NLD, [b] excl. NLD and SWE, [c] excl. NLD, [d] excl. CAN and NLD

Concerning energy-productivity performance we find that the high energy-productivity level of Italy is mainly due to its high energy productivity in Services.[7] Japan shows a relatively high level of energy productivity in all four sectors while Canada, having an overall low level of energy productivity, displays a relatively low level of energy productivity in all four sectors. The overall picture, however, is that within most countries the energy-productivity performance can differ substantially among sectors. For example, Finland has a low energy-productivity level in Manufacturing, while the opposite is true for Services. Moreover, we find the USA to have an average level of energy productivity in Manufacturing while in Transport, Services and Agriculture the USA faces an energy-productivity disadvantage relative to most other OECD countries. Concerning labour productivity, Table 3.1 shows that the leading position of the USA holds for all four sectors, and although less pronounced than for energy productivity, there are also substantial cross-sectoral differences within most countries in terms of relative labour productivity performance.

The standard deviation of the log of relative energy- and labour-productivity performance in Table 3.1 confirms that the cross-country dispersion of energy-productivity levels is substantially larger than the cross-country dispersion of relative labour-productivity levels.[8] In terms of energy productivity the largest cross-country differences are to be found in Services, while Agriculture exhibits the largest spread in cross-country labour-productivity levels. Finally, cross-country dispersion of both relative energy- and labour-productivity levels is decreasing over time, with two exceptions: aggregate Manufacturing shows a pattern of increasing cross-country differences in energy-productivity levels while in Agriculture the relative cross-country differences in labour-productivity levels remain constant (see Mulder and de Groot 2003 for a further exploration of this issue).

3.2 Decomposing energy- and labour-productivity growth rates

As noted previously, overall productivity performance is not only the result of technology-driven productivity performance in individual sectors but also of the distribution of production factors among sectors. Therefore, we will correct trends in aggregate energy- and labour-productivity performance for the impact of shifts in sectoral energy- and employment shares, to get a better view on the role of sector-specific technology-driven productivity improvements in driving aggregate productivity growth.

[7] Although we have some reason to believe that this result might be due to poor data (see section 3.2) the relatively good energy-productivity performance of Italy in Services is also found by Schipper and Meyers (1992: 185) who document for Italy in 1973 and 1988 an energy intensity level in Services that is substantially lower than in 8 other OECD countries.

[8] The SD log of productivity (y) measures variation across countries *i* according to:

$$\sqrt{\tfrac{1}{n}\sum_{i=1}^{n}\left(\log y_i - \log \bar{y}\right)^2}\,,\ \log \bar{y} = \tfrac{1}{n}\sum_{i=1}^{n}\log y_i\ .$$

See Mulder and de Groot (2003) for further discussion.

We do so by using a decomposition- or shift-share analysis, which is based on the following definitions of, respectively, aggregate energy productivity and labour productivity:

$$\frac{Y_t}{E_t} = \sum_i \frac{Y_{i,t}}{E_{i,t}} \frac{E_{i,t}}{E_t} \quad (3.1)$$

$$\frac{Y_t}{L_t} = \sum_i \frac{Y_{i,t}}{L_{i,t}} \frac{L_{i,t}}{L_t} \quad (3.2)$$

with Y_t, E_t and L_t being respectively GDP, final energy consumption and total employment, and the subscript i denoting the sub-sector. So, equation (3.1) says that aggregate energy productivity is the sum of the energy productivity of each sub-sector (the first term at RHS) multiplied by the energy share of each sub-sector (the second term at RHS). Equation (3.2) defines the same relationship in terms of labour productivity. Building upon equation (3.1) and (3.2), we decompose aggregate energy- and labour-productivity growth into a structural effect and an efficiency effect. The structural effect is obtained by calculating aggregate energy- and labour-productivity growth insofar as it is caused by shifts in sectoral energy- and employment shares (the second term at RHS), keeping the levels of energy- and labour-productivity performance for each individual sub-sector (the first term at RHS) constant. Vice versa, the efficiency effect is obtained by calculating aggregate energy- and labour-productivity growth insofar as it is caused by changes in the energy- and labour-productivity performance within each individual sub-sector, keeping the sectoral energy- and employment shares constant. Hence, the structural effect indicates the effect of changes in the structure of production on aggregate productivity growth while the efficiency effect points to the role of technology-driven efficiency improvements.

In this paper, we perform a decomposition analysis at two levels of aggregation. In this section we decompose for each of the 14 OECD countries the average annual macroeconomic energy- and labour-productivity growth rate into a structural and an efficiency effect, examining the role of the sectors Manufacturing, Services, Transport and Agriculture. In section 4 we repeat the analysis to decompose average annual Manufacturing energy- and labour-productivity growth rates, examining the role of 10 Manufacturing sub-sectors in driving energy- and labour-productivity trends in aggregate Manufacturing. Many studies measure the relative contribution of structural and technological change to aggregate productivity growth, using so-called index number decomposition or shift-share analysis.[9] The studies differ from

[9] For early applications of this methodology to measure the impact of technological change and changes in labour and/or capital shares on aggregate (total factor productivity) growth see, for example, Maddison (1952) and Massell (1961). For recent applications, including cross-country comparisons, see Dollar and Wolff (1993), Van Ark (1996) and Fagerberg (2000). Cross-country decomposition analyses of energy use can be found, for example, in Morovic et al. (1987, 1989), Greening et al. (1997), Howarth et al. (1991), Schipper and Meyers (1992), Park et al. (1993), Eichhammer and Mannsbart (1997) and Unander et al. (1999). From these studies, only van Ark (1996) and Schipper and Meyers (1992) include non-manufacturing sectors, while with the exception of Fagerberg (2000) and Park et al. (1993) all other studies focus on OECD countries.

each other in several dimensions, including the number of sectors and countries included, the methodology (Laspeyeres, Paasche, Divisia, etc.), the area of application (TFP, capital, labour, energy), the type of indicator (quantity, intensity, productivity or elasticity) and the type of analysis (time-series or period-wise). For a lucid exposition of the methodology and a survey of studies we refer to Ang (1995a,b; 1999) and Ang and Zhang (2000) concerning energy studies, and to Syrquin (1984) concerning macroeconomic studies focussing on aggregate (total factor) productivity. The main value added of our study lies in a simultaneous exploration of productivity performance along the two dimensions of energy and labour. Moreover, compared to most existing studies our analysis comprises a relatively high level of sectoral detail for a relatively large number of countries, in particular in terms of energy-productivity developments. As a result, the changes in technology driven productivity performance at the level of individual sectors reported in this paper are relatively well specified and informative. Furthermore, contrary to most studies, in particular those focussing on energy productivity, our decomposition analysis is not confined to the Manufacturing sector, but applies also to the macroeconomic level, identifying the role of Manufacturing, Services, Transport and Agriculture in driving macroeconomic productivity growth rates. Finally, our data set enables us to apply a time-series approach whereas most cross-country studies conduct a period-wise approach, using only data for the first and the last year of a specified time period. Compared to a period-wise approach, a time-series approach yields more insight into energy-productivity development over subsequent years and, moreover, the decomposition results are less sensitive to the exact functional form used and to the values in the initial- and final year.

Several functional forms can be used for the actual decomposition. We use the so-called Refined Divisia Index method and refer to Appendix C for a motivation as well as technical details and a brief discussion of alternative decomposition methods. In Figures 3.4 and 3.5 we present the results of the decomposition of the macroeconomic energy- and labour productivity growth rates into a structural effect and an efficiency effect. Figures 3.4 and 3.5 plot for each country, respectively, the average annual macroeconomic energy- and labour-productivity growth rate as the sum of an efficiency effect and a structural effect. It is to be noted that one has to be careful with comparing the results between countries due to the different time periods used (because of data availability).

Figure 3.4 Decomposition of average annual growth rate of macroeconomic energy productivity

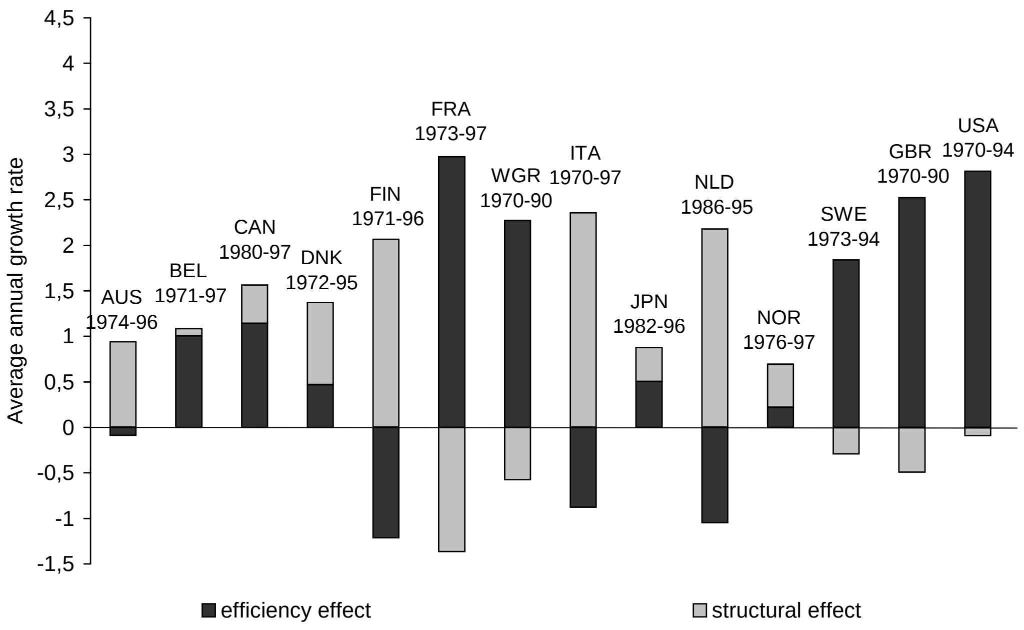
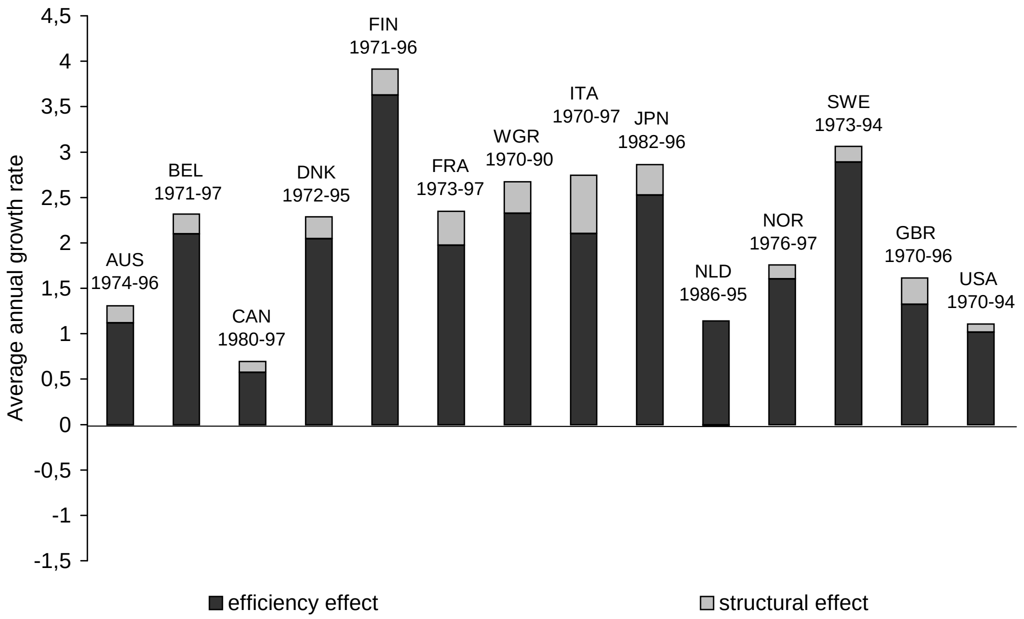


Figure 3.5 Decomposition of average annual growth rate of macroeconomic labour productivity



From Figure 3.4 it can be seen that, except for Belgium, Sweden, the United Kingdom and the United States, structural changes explain a substantial part of average annual macroeconomic energy-productivity growth rates. Structural effects even dominate efficiency effects in Australia, Denmark, Finland, Italy, the Netherlands and Norway. In most countries, the efficiency effect is positive, except for Finland, Italy and the Netherlands.

Figure 3.5 shows on the contrary, that although in all countries the effect of structural changes on macroeconomic labour-productivity growth rates is positive, it is also relatively small, implying efficiency improvements to be the main source of macroeconomic labour-productivity growth. The latter result confirms what has been known from the macroeconomic empirical growth literature (see, for example, van Ark 1996). Moreover, it can be concluded that considerable cross-country differences exist, in particular in terms of energy productivity. Finally, the figures reveal that on average macroeconomic labour-productivity growth is higher than macroeconomic energy-productivity growth, except for Canada, the United Kingdom and the USA. Using the data underlying Figures 3.4 and 3.5, we calculated the average annual growth rates of energy productivity and labour productivity for the 14 OECD countries combined, weighted for each country's share in total GDP. We found average annual growth rates of both energy- and labour productivity to be about 1.8% before correcting for structural changes, while they are, respectively, 1.7% and 1.6% after correcting for structural changes.

To see which sectors are responsible for these aggregate results, in Tables 3.2 and 3.3 we split the percentage contribution of the total efficiency effect and the total structural effect to the aggregate productivity growth rates, as presented in Figures 3.4 and 3.5 respectively, into the percentage contribution of individual sub-sectors.

Table 3.2 **Percentage contribution of efficiency effect (EFF) and structural effect (STR) by sector to average annual growth rate (g) of aggregate energy productivity per country**

	Australia 1974-96			Belgium 1971-97			Canada 1980-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
Manufacturing	-20.9	5.6	-15.3	-27.6	53.6	26.0	-1.1	18.9	17.9
Transport	4.1	8.4	12.4	13.1	-9.7	3.4	-1.2	4.6	3.4
Agriculture	0.7	0.2	0.9	9.0	-8.9	0.1	5.3	-5.0	0.4
Services	126.3	-24.3	101.9	12.6	57.9	70.5	24.1	54.3	78.4
Total %	110.2	-10.2	100.0	7.1	92.9	100.0	27.1	72.9	100.0
Total g	0.94	-0.09	0.86	0.08	1.01	1.08	0.42	1.14	1.56
	Denmark 1972-95			Finland 1971-95			France 1985-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
Manufacturing	– 47.4	65.5	18.1	-19.6	89.9	70.3	-103.8	61.4	-42.3
Transport	4.9	10.0	14.9	5.9	1.8	7.7	20.2	6.9	27.1
Agriculture	– 3.6	11.7	8.1	-9.9	-27.1	-37.0	-27.9	10.9	-17.0
Services	112.0	-53.0	58.9	259.0	-200.0	59.0	2.0	130.2	132.2
Total %	65.9	34.1	100.0	235.5	-135.5	100.0	-109.4	209.4	100.0
Total g	0.90	0.47	1.37	1.53	-0.88	0.65	-0.26	0.50	0.24
	West Germany 1970-90			Italy 1970-97			Japan 1982-96		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
Manufacturing	-24.3	38.7	14.4	-30.1	62.4	32.3	-38.7	67.0	28.3
Transport	4.9	-0.6	4.2	6.5	0.5	7.0	9.8	-1.0	8.8
Agriculture	-0.9	1.9	1.0	3.9	-7.4	-3.5	3.3	-14.0	-10.8
Services	-13.7	94.1	80.3	178.9	-114.7	64.1	68.3	5.3	73.6
Total %	-34.1	134.1	100.0	159.2	-59.2	100.0	42.7	57.3	100.0
Total g	-0.58	2.27	1.70	2.36	-0.88	1.48	0.37	0.50	0.87
	Netherlands 1986-95			Norway 1976-97			Sweden 1973-94		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
Manufacturing	-41.3	46.9	5.6	-29.7	-4.7	-34.3	-1.9	25.4	23.5
Transport	8.7	6.8	15.5	22.0	38.4	60.4	2.6	9.7	12.3
Agriculture	14.4	-4.5	10.0	28.9	-29.8	-0.9	-11.3	10.6	-0.8
Services	210.3	-141.4	69.0	47.1	27.7	74.8	8.6	73.6	65.0
Total %	192.1	-92.1	100.0	68.4	31.6	100.0	-19.2	119.2	100.0
Total g	2.18	-1.05	1.14	0.48	0.22	0.70	-0.30	1.84	1.54
	United Kingdom 1970-90			United States 1970-94					
	STR	EFF	Total	STR	EFF	Total			
Manufacturing	-34.7	47.1	12.3	-12.1	29.6	17.5			
Transport	9.6	-2.4	7.3	1.6	2.5	4.1			
Agriculture	-2.0	4.4	2.4	-0.6	3.0	2.4			
Services	2.6	75.4	78.0	7.5	68.5	76.0			
Total %	-24.5	124.5	100.0	-3.5	103.5	100.0			
Total g	-0.50	2.52	2.03	-0.10	2.81	2.72			

In Table 3.2, for each country the first column denotes per individual sector its shift in energy share, expressed as a percentage contribution to the total effect of shifts in sectoral energy shares on aggregate productivity growth (i.e. the total structural effect). The second column denotes per individual sector its change in energy-productivity performance, expressed as a percentage contribution to the total change in energy-productivity performance at a constant sector structure (i.e. the total efficiency effect). The third column denotes per individual sector its total relative contribution to aggregate productivity change, being the sum of the structural and efficiency effects. From Table 3.2 it can be concluded that the largest effects of shifts in sectoral energy shares on macroeconomic energy-productivity growth are to be found in Manufacturing and Services, with the energy share declining in Manufacturing and increasing in Services (except for West Germany and Sweden). Moreover, it can be seen that the extraordinary positive effect of structural changes on macroeconomic energy-productivity growth in Finland, Italy and the Netherlands is to be explained from a strongly increasing energy share in Services.[10] Finally, the effect of shifts in the energy share of Transport and Agriculture on macroeconomic structural change is relatively small, with small increasing energy shares in Transport and a mix of increasing and decreasing energy shares in Agriculture (decreasing in Denmark, Finland, France, West Germany, Sweden, United Kingdom and USA and increasing in other countries).

Concerning energy-efficiency improvements, Table 3.2 shows that they are mainly realised within Manufacturing. For Services, however, the picture is highly diverse with a mix of positive and negative percentage contributions to aggregate energy-efficiency improvements. Most notable is again the exceptional negative growth rate of energy productivity in Finland, Italy and the Netherlands, which drive the negative efficiency effects in these countries as plotted in Figure 3.4. The percentage contribution of Transport and Agriculture to macroeconomic energy-efficiency improvements is relatively small (except for Norway), with energy efficiency improving in Transport (except for Belgium, West Germany, Japan, Norway and the United Kingdom) while energy efficiency in Agriculture (slightly) improves in Australia, Denmark, France, West Germany, Sweden, United Kingdom and the USA and (slightly) decreases in the other countries.

[10] A closer look at the data reveals that this result is due to an exceptionally low initial level of energy consumption in Services in these countries, which then increases relatively fast over time to converge to an average level. Since we have no breakdown of energy data for the underlying sub-sectors we cannot explore this issue any further, but it might just be due to poor quality of the data. See also Ramirez et. al. (2002), who found in a detailed analysis of the Dutch Service sector for the period 1984-1998, a minor increase of energy productivity, which has been hardly affected by structural changes.

Table 3.3 Percentage contribution of efficiency effect (EFF) and structural effect (STR) by sector to average annual growth rate (g) of aggregate labour productivity per country

	Australia 1974-96			Belgium 1971-97			Canada 1980-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
Manufacturing	-32.4	28.8	-3.6	-23.7	50.0	26.3	-50.9	4.9	-46.0
Transport	-3.0	13.2	10.2	0.0	6.2	6.2	-11.1	15.3	4.2
Agriculture	-4.6	6.6	2.0	-3.1	4.6	1.5	-11.6	10.1	-1.5
Services	54.6	36.9	91.4	36.2	29.7	66.0	91.1	52.1	143.2
Total %	14.6	85.4	100.0	9.5	90.5	100.0	17.5	82.5	100.0
Total g	0.19	1.12	1.31	0.22	2.10	2.32	0.12	0.57	0.70

	Denmark 1972-95			Finland 1971-95			France 1985-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
Manufacturing	-3.7	25.6	21.9	-1.5	42.9	41.4	-24.2	45.0	20.8
Transport	2.2	11.2	13.4	2.4	6.0	8.4	2.1	5.7	7.8
Agriculture	-7.6	14.8	7.3	-8.3	11.8	3.5	-9.3	11.5	2.2
Services	19.6	37.8	57.4	14.6	32.1	46.7	44.4	24.7	69.2
Total %	10.6	89.4	100.0	7.2	92.8	100.0	13.0	87.0	100.0
Total g	0.24	2.04	2.29	0.28	3.65	3.94	0.26	1.74	2.00

	West Germany 1970-90			Italy 1970-97			Japan 1982-96		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
Manufacturing	-12.6	38.0	25.3	-11.6	42.3	30.8	-4.9	36.3	31.4
Transport	0.6	3.8	4.3	1.5	5.0	6.5	0.8	7.5	8.3
Agriculture	-3.7	5.1	1.4	-6.6	7.4	0.8	-4.4	3.3	-1.1
Services	28.8	40.1	68.9	40.1	21.8	61.9	20.1	41.2	61.3
Total %	13.0	87.0	100.0	23.4	76.6	100.0	11.7	88.3	100.0
Total g	0.35	2.32	2.67	0.64	2.10	2.75	0.33	2.53	2.86

	Netherlands 1986-95			Norway 1976-97			Sweden 1973-94		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
Manufacturing	-49.6	55.0	5.3	-19.0	19.2	0.1	-21.1	49.7	28.6
Transport	-1.1	16.7	15.6	-6.9	41.5	34.5	2.5	6.6	9.1
Agriculture	-11.2	21.2	10.0	-8.0	11.3	3.3	-2.6	4.2	1.6
Services	60.0	9.1	69.1	42.9	19.1	62.0	26.8	33.8	60.7
Total %	-1.9	101.9	100.0	8.9	91.1	100.0	5.7	94.3	100.0
Total g	-0.02	1.14	1.12	0.16	1.60	1.76	0.17	2.89	3.06

	United Kingdom 1970-90			United States 1970-94		
	STR	EFF	Total	STR	EFF	Total
Manufacturing	-57.4	64.2	6.7	-45.3	52.2	6.9
Transport	-4.5	11.8	7.3	-1.8	5.3	3.5
Agriculture	-3.6	6.0	2.4	-4.0	6.0	2.0
Services	83.7	-0.1	83.6	59.1	28.6	87.6
Total %	18.1	81.9	100.0	8.0	92.0	100.0
Total g	0.29	1.32	1.61	0.09	1.02	1.10

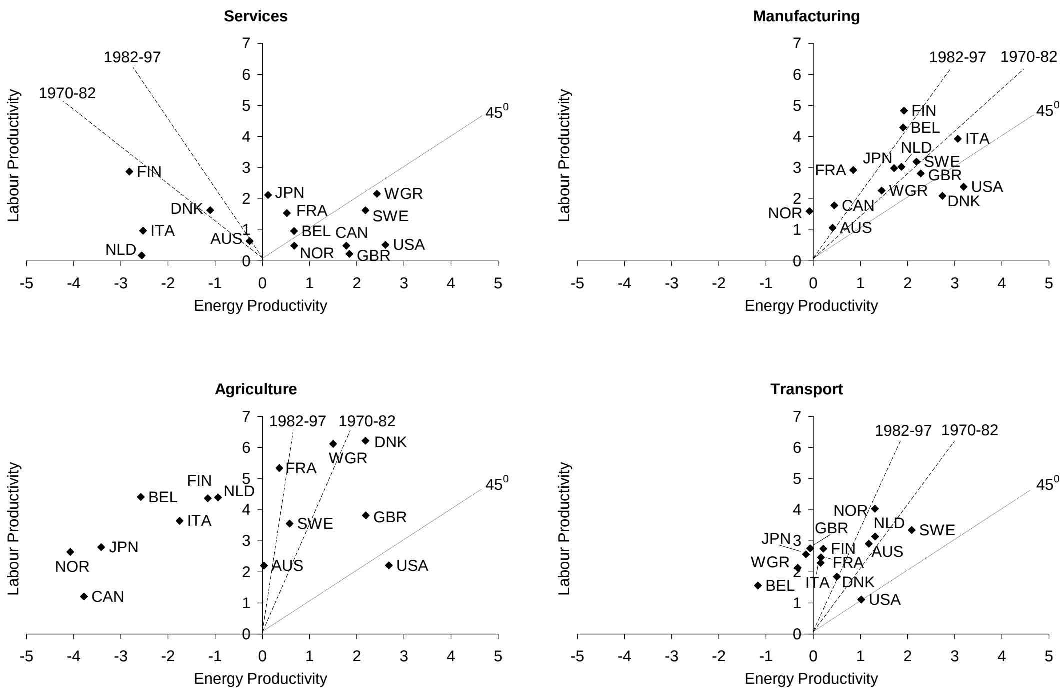
In Table 3.3 we present a similar breakdown of the total structural- and efficiency effects as in Table 3.2, but now for labour productivity. Table 3.3 shows that the relatively small impact of total structural change on macroeconomic labour-productivity growth does not imply that employment mixes have been constant over time. On the contrary, the employment mix changed considerably with a substantially decreasing employment share in Manufacturing and a substantially increasing employment share in Services. The fact that the net effect of this shift on macroeconomic labour-productivity growth is always positive confirms an employment shift from a relatively low- towards a relatively high value-added sector. Moreover, Table 3.3 also shows that in terms of shifts in employment shares, the relative contribution of Transport and Agriculture to macroeconomic structural change is small, with decreasing employment shares in Agriculture and a mix of increasing and decreasing employment shares in Transport (decreasing in Australia, Canada, Netherlands, Norway, United Kingdom and USA, constant in Belgium and increasing in other countries). Concerning the efficiency effect, Manufacturing is not only an important source for energy-efficiency improvement, but also for labour-efficiency improvement (i.e. labour productivity corrected for structural changes). Moreover, unlike energy efficiency, Services is also an important source for labour-efficiency improvement in most countries, except for the Netherlands. Similar to energy efficiency, the percentage contributions of Transport and Agriculture to macroeconomic labour-efficiency improvements are small, although positive in all countries.

3.3 Sectoral biases in productivity growth rates

So far, we found macroeconomic growth rates of labour productivity in general to be substantially higher than macroeconomic growth rates of energy productivity. Does this pattern hold also for Manufacturing, Services, Transport and Agriculture? In this section we take a closer look at the relationship between sectoral growth rates of energy- and labour productivity. Are they positively or negatively correlated to one another among the different countries? In other words, do they complement each other, or are they substitutes? And is the observed relationship between energy- and labour-productivity growth changing over time?

To assess these issues, we calculate the average annual growth rates of energy- and labour productivity for each sector and country for the period 1970-1997.[11] They are presented in Figure 3.6 together with 2 regression lines through the origin, estimating the cross-sectional relationship between energy- and labour productivity growth rates for, respectively, the periods 1970-1982 and 1982-1997.

Figure 3.6 Energy- and labour productivity main sectors. Average annual growth rates



[11] Note that the exact period differs per country due to data restrictions. We refer to Table A.2 in Appendix A for an overview of the periods used for each country as well as the sectoral growth rates per country (the same as in Figure 3.6 but then in table format).

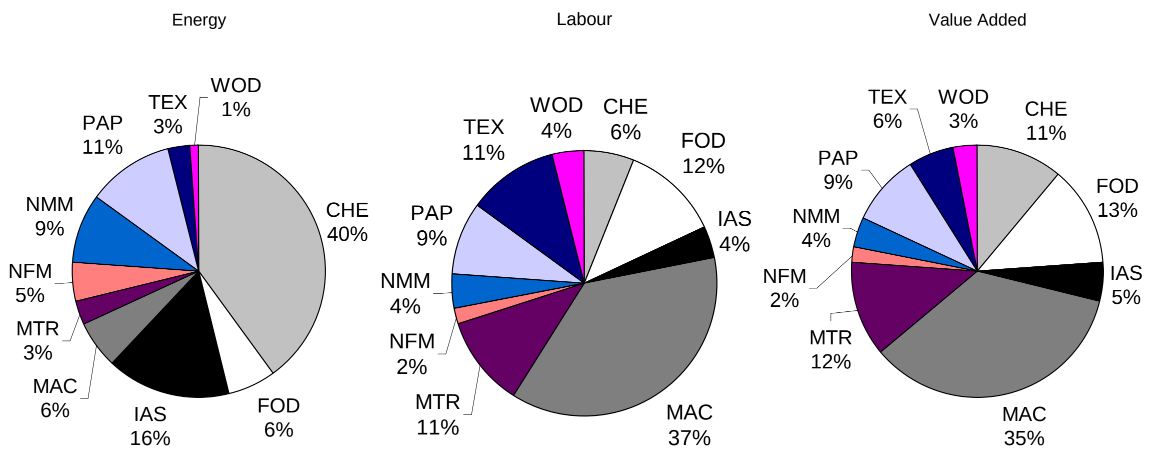
Figure 3.6 leads to the following conclusions. In Manufacturing all countries show a positive correlation between energy- and labour-productivity growth rates, suggesting manufacturing energy- and labour-productivity growth to be complements rather than substitutes. For most countries, this conclusion holds also for Services and Transport. In Agriculture, however, 7 out of the 14 countries combine a positive labour-productivity growth with a negative energy-productivity growth, suggesting energy- and labour-productivity growth to be substitutes rather than complements in these countries. Of course, the figure shows again that labour-productivity growth is in general substantially higher than energy-productivity growth. Comparing the regression lines for the period 1982-1997 and the period 1970-1982 suggests that this bias towards labour productivity growth is increasing in aggregate Manufacturing, Transport and Agriculture, while it is decreasing in Services. Insofar as the observed sectoral productivity growth rates are driven by technological progress, the (increasing) bias towards labour productivity growth suggests the existence of a (increasing) bias towards labour-augmenting technological progress in aggregate Manufacturing, Transport and Agriculture.

In the remainder of this paper we move beyond the macroeconomic level by taking a closer look at the Manufacturing sector. As already argued several times, a first prerequisite for understanding technology-driven productivity performance is to assess productivity performance at a sufficiently disaggregated sector level. Therefore, we continue by identifying cross-country productivity developments within 10 Manufacturing sub-sectors, following the same research strategy as we applied so far.

4 The Manufacturing sector in detail

In this section we further explore levels and trends in Manufacturing energy- and labour-productivity performance, examining the role of 10 Manufacturing sub-sectors: Food, Textiles, Wood, Paper, Chemicals, Non-Metallic Minerals, Iron and Steel, Non-Ferrous Metals, Machinery and Transport Equipment (see Table 2.1). We start with a brief overview of their sectoral shares in Manufacturing energy consumption, employment and GDP (see Figure 4.1). For the 14 OECD countries included in this study taken together, the sub-sector Chemicals consumed by far most energy with a share of 40% in Manufacturing final energy consumption in 1990, followed by Iron and Steel (16%), Paper, Pulp and Printing (11%) and Non-Metallic Minerals (9%).[12]

Figure 4.1 Percentage shares of manufacturing final energy consumption, total employment and value added by sector in 1990. Sample of 14 OECD countries.



In Figure 4.1 we compare those shares with the shares of total employment and value added.[13] This yields a different picture, with Machinery accounting for the largest share of Manufacturing total employment and value added (35-37%) followed by Food and Transport Equipment (each around 12%). In the previous section we found the shares of total energy consumption, employment and value added for aggregate Manufacturing to be more or less similar among the 14 OECD countries (see Table A1 in Appendix A). Within Manufacturing, however, these shares differ substantially among the different Manufacturing sub-sectors. For example, in the Netherlands, the energy-intensive Chemicals sector is responsible for 67% of

[12] These percentages are in line with IEA data of total OECD in 1997: Chemicals: 39% ; Iron and Steel: 11% ; Paper:10% ; Non-Metallic Minerals: 9%.

[13] Note that Manufacturing sector shares of value added are calculated for the sum of 12 OECD countries (excluding Australia and Canada due to lack of data).

Manufacturing energy consumption, while in the other countries this share lies between 14% and 38%. In Finland and Sweden, Paper consumes around 40% of Manufacturing energy consumption, while in the other countries this share lies in between 3% and 14%. Contrary to other countries, in Italy Textiles is responsible for a large share of total employment and value added. For a detailed overview of Manufacturing sector shares per country we refer to Table A3 in Appendix A.

4.1 Comparing energy- and labour-productivity levels

To compare cross-country energy- and labour-productivity performance at the Manufacturing level, we show in Figure 4.2 and 4.3 the aggregate Manufacturing energy- and labour-productivity levels over time, for each of the 14 OECD countries. Figure 4.2 shows that in aggregate Manufacturing two groups of countries can be identified in terms of observed levels of energy productivity. Denmark, Italy, West-Germany, France, Japan and the United Kingdom, show a high level of energy productivity while the USA, Netherlands, Belgium, Sweden, Australia, Finland, Canada and Norway display a relative low energy-productivity level.[14] Figure 4.3, confirms again the well-known leading position of the USA in terms of labour productivity, with – contrary to the macroeconomic level – no clear pattern of catching-up by other OECD countries.

[14] For the same sample of countries but using energy consumption data from partly different sources, Unander et al. (1999) distinguish 3 groups of countries for Manufacturing energy-intensity, which differs slightly from our picture in classifying the Netherlands, Sweden and the USA in a medium-group.

Figure 4.2 Trends in manufacturing energy productivity development

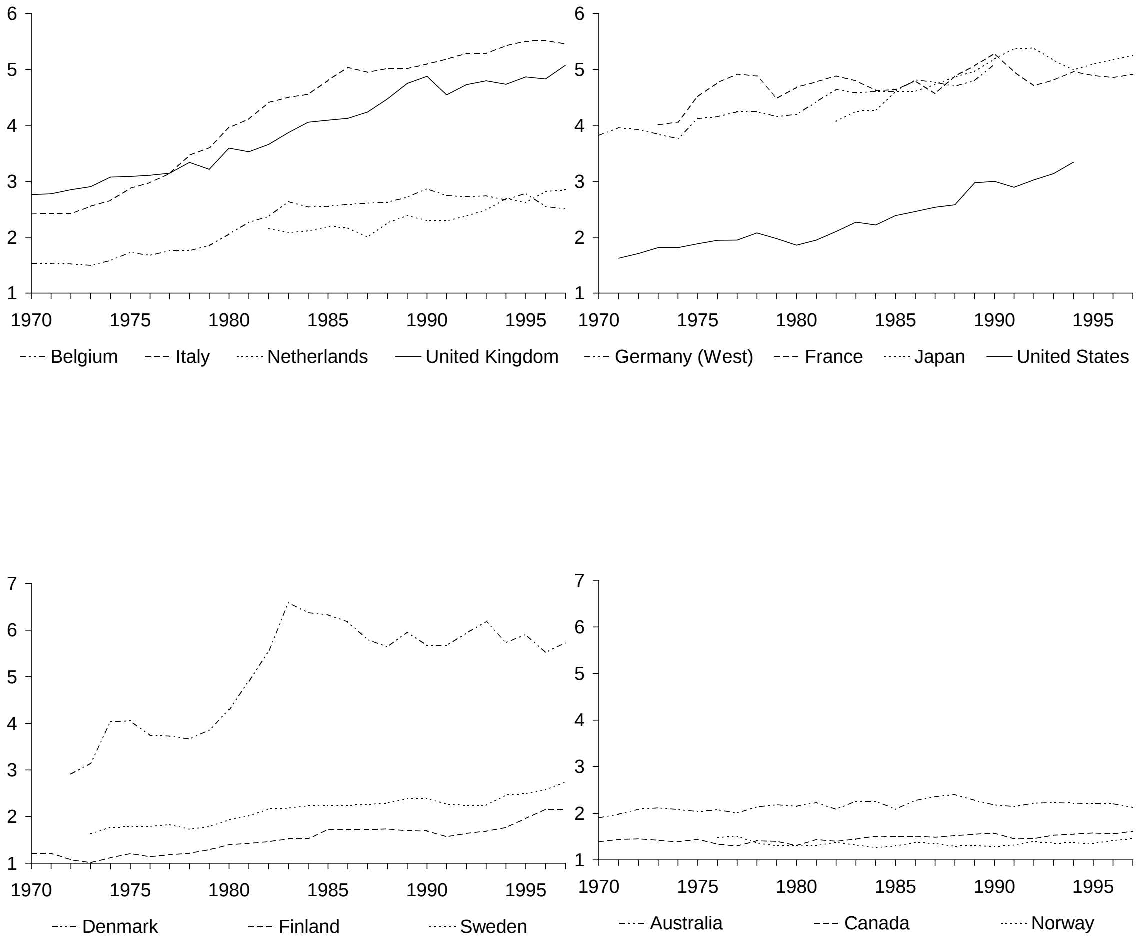
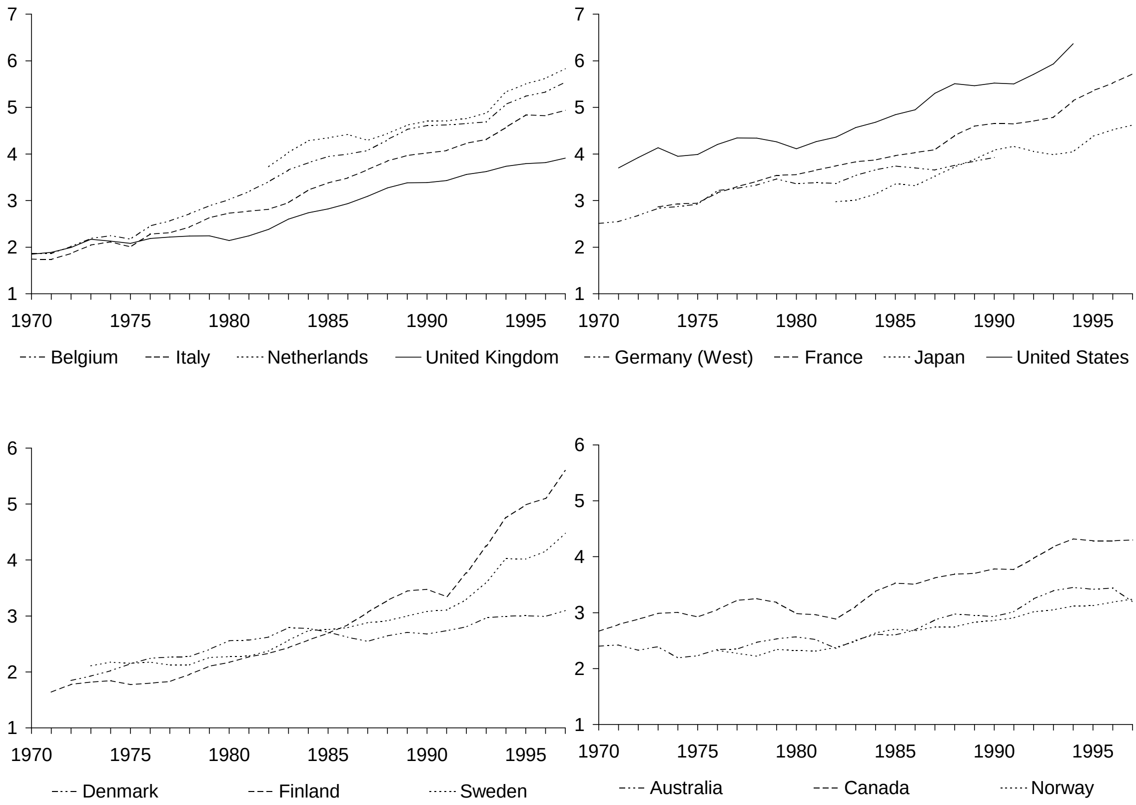


Figure 4.3 Trends in manufacturing labour productivity development



In order to see which Manufacturing sectors are driving these aggregate trends, we provide in Table 4.1 for all 10 Manufacturing sub-sectors a cross-country comparison of the energy- and labour productivity level relative to the weighted OECD average in 1976, 1982, 1990 and 1997.[15] The table reveals that the energy-productivity level in Germany and Japan lies above the OECD average in most Manufacturing sectors, while the opposite is true for Norway. For all other countries, the table shows a diverse picture with considerable cross-sector variation in relative productivity performance. For example, the Netherlands has a relatively low level of energy productivity in Chemicals, but a relatively high level in Paper and Wood. The high energy-productivity level in Denmark, as shown in Figure 4.2, is due to an extremely high energy-productivity level in Chemicals and Paper, while its energy-productivity level in Food is relatively low. A few other remarkable facts are: Finland, Norway and Sweden have low levels of energy productivity in Paper and Wood; the United Kingdom has a relatively high level of energy productivity in Chemicals, Iron and Steel and Paper, while this is relatively low in Machinery; and Italy has a very high level of energy productivity in Wood. Concerning labour productivity, Table 4.1 again confirms the well-known leading position of the USA for most

[15] Note that we do not take the USA as the reference country because the USA lacks a sectoral breakdown of oil and natural consumption at this level of disaggregation (see section 2).

Manufacturing sectors. Exceptions, however, are Non-Ferrous Metals and Non-Metallic Minerals where the USA is lagging behind some other countries.

Table 4.1 Energy- and labour productivity manufacturing sectors relative to OECD average (OECD=100)

	Chemicals				Food and Tobacco			
	Energy		Labour		Energy		Labour	
	1976	1990	1976	1990	1976	1990	1976	1990
USA	100	100	100	100	100	100	100	100
AUS	97	149	70	78	116	115	85	97
BEL	96	64	96	92	171	--	103	87
CAN	269	434	70	53	40	67	45	61
DNK	68	88	47	55	49	74	51	65
FIN	149	168	63	77	125	120	95	89
FRA	202	175	84	63	135	162	92	86
WGR	54	141	32	62	87	168	84	107
ITA	155	176	132	113	240	226	92	76
JPN	48	66	79	89	59	76	70	89
NLD	55	58	47	64	57	54	69	48
NOR	101	147	73	53	78	90	73	67
SWE	166	230	66	73	84	114	68	81
GBR	--	--	113	124	--	--	125	129
SD log	0.54[a]	0.56[a]	0.36	0.27	0.50[b]	0.42[b]	0.27	0.25

	Iron and Steel				Machinery			
	Energy		Labour		Energy		Labour	
	1976	1990	1976	1990	1976	1990	1976	1990
USA	100	100	100	100	100	100	100	100
AUS	76	58	46	80	98	118	98	94
BEL	121	55	96	76	201	--	99	86
CAN	74	96	31	54	89	116	84	55
DNK	83	50	39	69	59	94	58	82
FIN	169	129	57	63	205	100	102	98
FRA	163	127	67	65	299	215	111	85
WGR	165	128	72	96	72	102	83	95
ITA	155	154	139	137	--	179	40	91
JPN	120	70	97	85	--	100	--	90
NLD	38	18	43	55	69	61	81	66
NOR	77	85	31	48	57	68	65	64
SWE	169	130	42	62	64	68	71	65
GBR	--	--	115	100	--	--	123	125
SD log	0.45[a]	0.58[a]	0.48	0.28	0.55[c]	0.36[c]	0.30[d]	0.22[d]

excluding [a] USA [b] CAN, USA [c] CAN, JPN, NLD, USA [d] NLD

Average OECD is weighted with each country's 1990 GDP share of total GDP per sector.

Table 4.1 Continued

	Transport Equipment				Non-Ferrous Metals			
	Energy		Labour		Energy		Labour	
	1976	1990	1976	1990	1976	1990	1976	1990
USA	100	100	100	100	100	100	100	100
AUS	153	134	81	106	143	156	126	165
BEL	92	--	92	93	87	31	171	113
CAN	76	91	65	54	--	--	46	48
DNK	131	161	--	63	111	77	80	103
FIN	198	193	81	90	133	125	174	159
FRA	91	111	99	89	196	163	117	78
WGR	319	335	63	91	113	108	99	102
ITA	252	171	66	102	249	193	227	152
JPN	195	106	65	74	111	51	256	168
NLD	83	69	60	58	35	20	137	96
NOR	86	96	--	57	112	72	92	72
SWE	79	142	51	83	100	98	67	66
GBR	--	--	135	113	--	--	140	113
SD log	0.49[b]	0.41[b]	0.26[e]	0.22[e]	0.47[f]	0.68[f]	0.47	0.37

	Non-Metallic Minerals				Paper, Pulp and Printing			
	Energy		Labour		Energy		Labour	
	1976	1990	1976	1990	1976	1990	1976	1990
USA	100	100	100	100	100	100	100	100
AUS	46	97	79	119	265	227	55	84
BEL	157	138	136	103	54	30	88	85
CAN	93	76	92	70	611	322	74	61
DNK	68	63	65	86	33	33	47	84
FIN	222	143	126	137	341	182	82	93
FRA	148	139	107	100	290	188	68	76
WGR	119	136	93	98	229	262	59	103
ITA	121	135	63	88	--	185	66	98
JPN	115	118	--	111	360	288	72	93
NLD	65	88	100	79	83	56	56	62
NOR	86	96	84	82	37	31	58	71
SWE	123	128	79	75	290	374	65	82
GBR	--	--	118	105	--	--	126	112
SD log	0.41[a]	0.26[a]	0.23	0.19	0.97[g]	0.97[g]	0.24	0.18

excluding [a] USA [b] CAN, USA [e] FIN, SWE [f] DNK, USA [g] JPN, USA

Average OECD is weighted with each country's 1990 GDP share of total GDP per sector.

Table 4.1	continued (2)							
	Textiles and Leather				Wood and Wood Products			
	Energy		Labour		Energy		Labour	
	1976	1990	1976	1990	1976	1990	1976	1990
USA	100	100	100	100	100	100	100	100
AUS	328	124	82	108	145	145	39	44
BEL	--	--	107	91	130	--	100	86
CAN	130	112	95	74	129	102	95	56
DNK	176	145	66	69	41	56	65	77
FIN	151	170	118	116	--	--	83	91
FRA	149	108	107	98	185	217	111	75
WGR	191	216	115	109	803	756	89	80
ITA	85	115	55	46	--	--	48	52
JPN	131	134	108	108	402	300	134	89
NLD	90	95	62	66	87	62	90	66
NOR	112	64	105	82	76	67	109	87
SWE	106	139	91	83	--	--	88	59
GBR	--	--	99	110	--	--	124	106
SD log	0.36[b]	0.30[b]	0.24	0.26	0.89[h]	0.85[h]	0.34	0.25

excluding [b] CAN, USA [h] CAN, FRA, JPN, GBR, USA

Average OECD is weighted with each country's 1990 GDP share of total GDP per sector.

Looking at the standard deviation of the log of relative energy productivity in Table 4.1 leads to the conclusion that also at the level of Manufacturing sub-sectors the cross-country differences in energy productivity are substantially larger than cross-country differences in labour productivity. In the previous section we found the cross-country dispersion of energy productivity to be increasing over time at the level of aggregate Manufacturing. From Table 4.1 it can be concluded, however, that this result does not apply to all Manufacturing sectors: we find cross-country dispersion of energy productivity to be increasing only in the energy-intensive sectors Chemicals, Iron and Steel and Non-Ferrous Metals, while it is (more or less) constant in Chemicals, Paper and Wood and decreasing in the other sectors. Overall, the cross-country differences in labour-productivity performance seem to be slightly decreasing. Again, we refer to Mulder and de Groot (2003) for a further exploration of this issue.

4.2 Decomposing energy- and labour-productivity growth rates

To get a more precise view of the role of sector-specific technology driven productivity improvements in driving the observed trends in Manufacturing energy- and labour-productivity performance, we have to correct the latter for the impact of shifts in sectoral energy- and employment shares. Hence, in this section we decompose average annual Manufacturing energy- and labour-productivity growth rates into a structural- and an efficiency effect, examining the role of the 10 Manufacturing sub-sectors. Again, we use the Refined Divisa Method for the actual decomposition (see Appendix C). The results are presented in Figures 4.4 and 4.5.[16] Figure 4.4 shows that in all 12 OECD countries energy-efficiency improvements are the main driving force behind aggregate Manufacturing energy-productivity growth, although in most countries there is also a substantial effect from shifts in sectoral energy shares on aggregate Manufacturing energy-productivity growth. This structural effect is mixed: it is positive in Belgium (41%), Denmark (11%), France (47%), West-Germany (20%), Italy (37%), Japan (33%) and the USA (35%), indicating a shift towards a less energy-intensive Manufacturing structure, while it is negative in Finland (-50%), the Netherlands (-30%), Norway (-960%) and Sweden (-12%), indicating a shift towards a more energy-intensive Manufacturing structure. In Norway the large structural change even dominates the energy-efficiency improvements.

This overall picture accords well with other cross-country studies decomposing Manufacturing energy use in OECD countries (Greening et al. 1997, Howarth et al. 1991, Eichhammer and Mannsbart 1997 and Unander et al. 1999), although our structural effects in Finland, France and Italy are relatively high as compared to these studies. This might well be due to differences in data, period and decomposition method between the other studies and ours.[17] Concerning labour-productivity growth, Figure 4.5 shows that in all 12 OECD countries the effect of shifts in sectoral employment shares on aggregate Manufacturing labour-productivity growth is positive, but also very small; almost all aggregate Manufacturing labour-productivity growth is to be explained from labour productivity improvements in individual sectors. This result confirms what has been known from empirical labour-productivity analyses for the Manufacturing sector (see, for example, Dollar and Wolff 1993 and Fagerberg 2000). Similar to the conclusions drawn at the macroeconomic level, considerable cross-country differences also exist at the level of Manufacturing, in particular in terms of energy productivity. Moreover, except for Denmark and the USA, the average manufacturing labour-productivity growth is again higher than manufacturing energy-productivity growth. We calculated that for the 12 OECD countries taken together the weighted average annual growth rates of Manufacturing energy- and labour productivity are, respectively, 2.25% and 2.69%, while they drop to, respectively, 1.57% and 2.53% after being corrected for the impact of structural changes.

[16] Due to limited data availability, Australia and Canada are excluded from the analysis. Moreover, for the same reason in France, Japan, United Kingdom and USA the sector Wood and in Denmark the sector Non-Ferrous Metals are excluded from the decomposition analysis.

[17] The results depend to some extent also on the level of aggregation. As noted in section 2, the higher the level of dis-aggregation the better, but even more important is an adequate distinction between factor-intensive and factor-extensive sectors in order to reduce the likelihood of efficiency-performance figures being biased by the impact of intra-sectoral structural changes. However, in a European cross-country decomposition analysis of energy-efficiency in the Manufacturing industry, Eichhammer and Mannsbart (1997) concluded that, apart from data-related methodological problems, an analysis at a 2-digit level suffices to isolate the main structural effects on aggregate productivity developments. After disaggregating several energy-intensive sectors to a 4-digit level, they found intra-sectoral structural changes to be responsible for at maximum 10% of the observed aggregate energy-intensity changes.

Figure 4.4 **Decomposition of average annual growth rate of macroeconomic energy productivity**

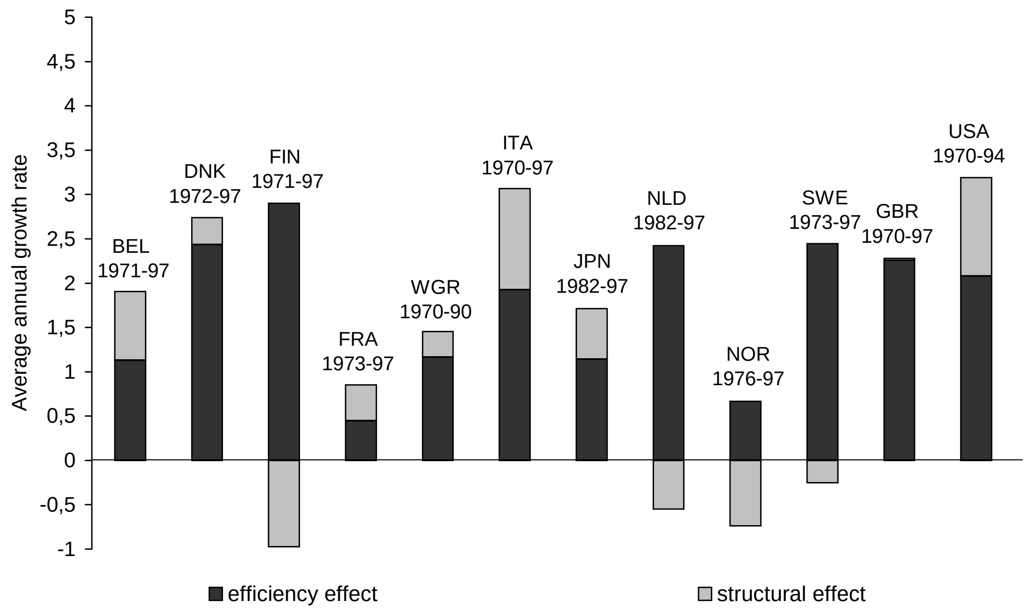
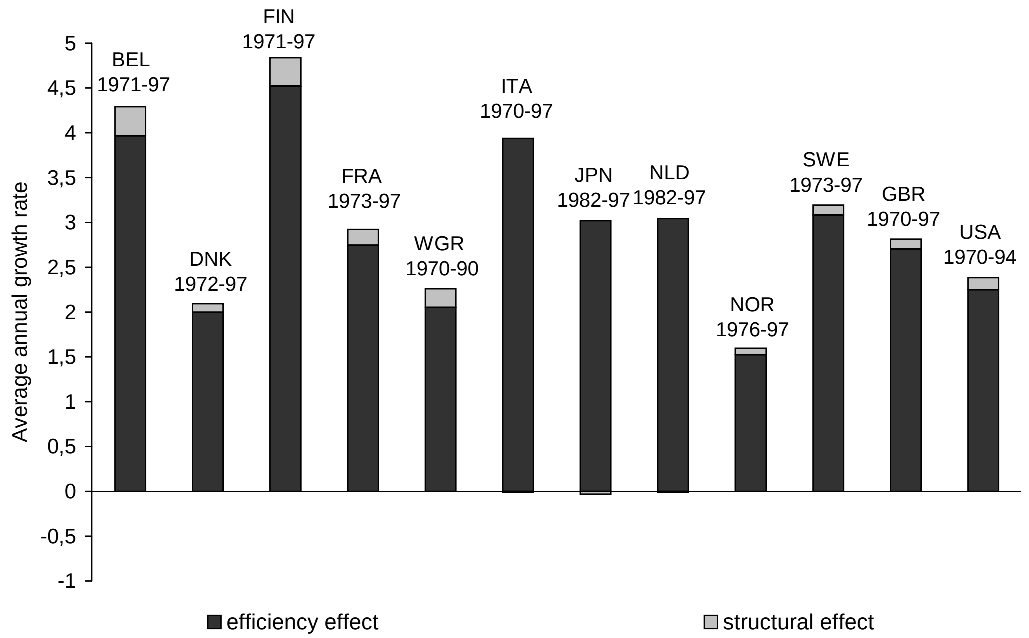


Figure 4.5 **Decomposition of average annual growth rate of macroeconomic labour productivity**



To see which sectors are responsible for these aggregate results, in Table 4.2 we split the percentage contribution of the total efficiency- and structural effects to aggregate Manufacturing energy-productivity growth rates, as presented in Figure 4.4, into the percentage contribution of individual sub-sectors for each country. The interpretation of the figures is similar to Table 3.2.

Table 4.2 Percentage contribution of structural effect (STR) and efficiency effect (EFF) by sector to average annual growth rate (g) of aggregate energy productivity in manufacturing per country

	Belgium 1971-97			Denmark 1972-97			Finland 1971-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
CHE	13.5	14.9	28.5	-2.7	20.7	18.0	1.4	5.2	6.6
FOD	15.6	-3.8	11.8	10.9	10.6	21.4	-13.6	13.5	-0.1
IAS	-4.8	4.7	-0.1	-1.3	2.8	1.5	2.1	4.6	6.6
MAC	-24.4	39.2	14.7	7.3	31.1	38.5	-17.0	88.2	71.2
MTR	16.5	-5.4	11.1	-4.8	1.5	-3.3	-11.6	12.0	0.4
NFM	-1.7	5.5	3.8	--	--	--	0.6	1.3	1.9
NMM	-3.6	5.9	2.3	-3.1	1.5	-1.7	-5.3	5.8	0.5
PAP	12.6	-6.6	6.0	1.0	5.7	6.7	5.3	9.9	15.2
TEX	10.2	-12.4	-2.2	-7.1	6.7	-0.4	-12.4	4.7	-7.7
WOD	1.0	0.2	1.2	3.1	-0.3	2.9	-6.2	7.2	1.0
NSI	5.9	17.0	22.9	7.8	8.6	16.4	5.9	-1.4	4.4
MAN %	40.8	59.2	100.0	11.1	88.9	100.0	-50.8	150.8	100.0
MAN g	0.78	1.13	1.91	0.30	2.43	2.74	-0.98	2.90	1.93

	France 1971-97			West Germany 1970-90			Italy 1970-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
CHE	8.4	25.3	33.7	12.6	3.4	16.0	-0.8	10.8	10.0
FOD	17.8	2.2	20.0	0.1	5.0	5.1	4.7	5.5	10.2
IAS	-12.5	9.6	-2.9	-9.1	9.3	0.2	-1.0	1.6	0.6
MAC	66.7	-36.4	30.3	16.3	20.0	36.3	9.8	22.5	32.3
MTR	-10.9	13.9	3.0	9.6	15.7	25.2	6.4	-3.5	2.9
NFM	-5.1	7.9	2.8	1.5	2.7	4.2	0.1	0.4	0.5
NMM	0.3	-2.9	-2.5	-3.2	5.2	2.1	-2.1	8.8	6.7
PAP	20.1	-13.1	7.0	4.2	0.0	4.2	3.8	3.8	7.6
TEX	-37.4	17.5	-19.9	-4.3	-0.8	-5.0	4.7	9.7	14.4
WOD	--	--	--	-1.0	1.6	0.5	1.8	-1.4	0.4
NSI	0.1	28.4	28.5	-6.9	18.1	11.2	9.8	4.5	14.4
MAN %	47.6	52.4	100.0	19.8	80.2	100.0	37.2	62.8	100.0
MAN g	0.40	0.45	0.85	0.29	1.16	1.45	1.14	1.92	3.07

Table 4.2 continued

	Japan 1982-97			Netherlands 1982-97			Norway 1976-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
CHE	8.4	1.1	9.4	-3.3	32.9	29.6	106.6	182.1	288.7
FOD	-6.1	-7.5	-13.6	-2.8	15.3	12.5	-342.3	140.9	-201.4
IAS	-5.5	9.2	3.7	3.5	-3.5	0.0	-45.4	33.9	-11.5
MAC	45.2	52.6	97.9	17.8	10.4	28.3	-514.5	938.9	424.4
MTR	12.4	-3.2	9.2	-3.4	5.7	2.3	-154.9	-171.6	-326.5
NFM	-0.5	0.6	0.1	-0.2	0.2	0.0	13.8	55.6	69.4
NMM	-2.7	4.0	1.3	1.2	2.5	3.7	-126.6	80.6	-46.0
PAP	0.3	0.6	0.9	-3.1	13.8	10.7	90.6	22.7	113.3
TEX	-17.6	6.2	-11.4	-1.5	0.3	-1.2	-117.8	39.0	-78.8
WOD	--	--	--	-0.6	1.5	0.9	63.5	-106.1	-42.6
NSI	-0.6	13.0	2.4	-37.0	50.2	13.2	68.9	-357.8	-288.9
	-------	-------	-------	------	-------	-------	-------	-------	-------
MAN %	33.3	66.7	100.0	-29.5	129.5	100.0	-958.1	858.1	-100.0
MAN g	0.57	1.14	1.71	-0.55	2.42	1.87	-0.74	0.67	-0.08

	Sweden 1973-97			United Kingdom 1970-97			United States 1970-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
CHE	1.2	10.6	11.9	6.2	14.3	20.5	8.3	6.6	14.9
FOD	-2.1	7.1	5.0	5.4	10.0	15.4	2.7	5.0	7.7
IAS	-2.4	6.6	4.2	-3.1	3.4	0.3	-4.4	4.8	0.4
MAC	-22.5	80.7	58.2	-2.2	29.0	26.8	27.0	19.3	46.3
MTR	4.0	1.2	5.1	-3.3	13.2	9.9	-1.3	7.9	6.6
NFM	-0.1	1.7	1.6	0.0	0.6	0.6	0.1	0.9	1.0
NMM	-5.3	3.4	-1.8	-3.7	5.8	2.1	2.3	-0.7	1.6
PAP	3.1	7.1	10.2	2.9	8.6	11.5	3.3	6.2	9.4
TEX	-5.0	0.8	-4.1	-2.7	3.5	0.8	0.7	4.3	5.1
WOD	6.4	-5.1	1.4	--	--	--	--	--	--
NSI	11.0	-2.7	8.3	1.4	10.6	12.1	-3.9	10.9	7.0
	-------	-------	-------	-------	-------	-------	-------	-------	-------
MAN %	-11.6	111.6	100.0	1.0	99.0	100.0	34.8	65.2	100.0
MAN g	-0.25	2.44	2.19	0.02	2.26	2.28	1.11	2.08	3.19

From Table 4.2 it can be concluded that, except for France, the aggregate Manufacturing energy-productivity improvements are to a large extent realised within the Machinery sector, followed by Chemicals.[18] Looking into the sources of structural changes yields a more diverse picture. In Belgium, the substantial positive structural effect on aggregate Manufacturing energy-productivity growth is mainly caused by a shift of energy share from Machinery, Iron and Steel, Non-Ferrous Metals and Non-Metallic Minerals towards Chemicals, Food, Transport Equipment and Paper. The small positive structural effect in Denmark is mainly the result of a relatively small increasing energy share in Food and Machinery and decreasing energy shares in Textiles, Transport Equipment, Non-Metallic Minerals and Iron and Steel, while the role of Non-Ferrous Metals is unclear due to lack of data. The substantial negative impact of structural changes on aggregate Manufacturing energy-productivity growth in Finland is to a large extent caused by a shift in energy share from Machinery, Food, Transport Equipment and Textiles towards Paper, Non-Specified Industry, Iron and Steel and Chemicals. In France the positive structural effect is mainly due to a shift of energy shares from Textiles, Iron and Steel and Transport Equipment towards Machinery, Paper and Food. In West Germany the positive structural effect is mainly caused by an increasing energy share in Machinery and Chemicals at the cost of a decreasing energy share in Iron and Steel, Textiles and Non-Metallic Minerals. The positive structural effect in Italy has been mainly due to a shift of energy shares from Non-Metallic Minerals and Iron and Steel towards Machinery, Non-Specified Industry, Food and Textiles. In Japan the structural changes towards a less energy-intensive Manufacturing structure were mainly driven by a shift towards Machinery and Transport Equipment, while energy shares decreased in Textiles, Foods, Iron and Steel and Non-Metallic Minerals. The negative structural effect in the Netherlands is the result of a shift in energy shares from Non-Specified Industry, Chemicals, Transport Equipment and Paper towards Machinery and Iron and Steel. The major negative structural effect in Norway is mainly driven by a shift in energy shares towards Chemicals and Paper at the cost of decreasing energy shares in Machinery, Food, Transport Equipment and Non-Metallic Minerals. The negligible impact of structural changes in the United Kingdom is mainly due to the fact that a slight increase in energy shares in Chemicals, Food and Paper outweigh a slight decrease in energy shares in Non-Metallic Minerals, Transport Equipment and Iron and Steel. In the USA a shift in energy share from Iron and Steel towards Machinery and Chemicals has been the main driving force behind the role of structural changes in improving aggregate Manufacturing energy-productivity improvement.

[18] Note that in France, Norway and in particular in the Netherlands a substantial part of the efficiency improvement is realised within the sector Non-Specified Industry (NSI). The same holds for structural changes in Italy, Norway and, again particularly, in the Netherlands. NSI contains rubber (355) and plastic products (not classified elsewhere) (356), furniture (332) and professional, scientific, measuring and controlling equipment (not classified elsewhere), photographic and optical goods (385). Furthermore, it contains energy consumption for which no sectoral breakdown can be given. Whereas NSI is rather unimportant in most countries with an average share of 2% of total energy consumption, in the countries mentioned before the share of NSI in Manufacturing GDP is on average about 12%. In sum, one should read the results with caution since an efficiency improvement and a changing energy share in NSI is partly due to developments in the above mentioned sectors (ISIC 355, 356, 332 and 385) and might be partly due to data inaccuracy.

These findings confirm that in general a positive effect of total structural change on aggregate Manufacturing energy-productivity growth is to a large extent driven by a shift in energy shares from low-value added (energy-intensive) sectors – such as Iron and Steel, Non-Ferrous Metals and Non-Metallic Minerals – to higher value added (capital- and/or technology-intensive) industries – such as Machinery, Transport Equipment, Textile and Food – while the opposite is true in case of an overall negative structural effect. Our results suggest, however, a few exceptions to this picture. For example, Belgium realises an overall positive effect of structural changes on aggregate Manufacturing energy-productivity growth in spite of a substantial decreasing energy share in the high value added Machinery sector, while the same applies for France and Japan with respect to Textiles. Moreover, Belgium, West Germany, Japan and the USA, combine an increasing energy share in the energy-intensive Chemical sector with an overall positive structural effect while the Netherlands combine a decreasing energy share in Chemicals with an overall negative structural effect. A similar story is true for the Paper sector: Belgium and France combine a substantial increase in energy share in the energy-intensive sector Paper with an overall positive structural effect, while the opposite is true for the Netherlands, which realises an overall negative structural effect in spite of a shift away from Paper. Of course, these counterexamples can be explained from the simple fact that shifts in energy shares in one sector are sufficiently compensated by shifts in other sectors. Moreover, they might be due to data limitations, partly because in some countries (in particular Italy and the Netherlands) a significant role is played by Non-Specified Industry and partly because of the fact that the 2- and 3-digit sector definitions that were used hide heterogeneity in production structure at the 4-digit level.[19]

Finally, In Table 4.3 we present a similar breakdown of the total structural- and efficiency effect as in Table 4.2, but now for labour productivity.

[19] Recall that the Chemicals sector is built up from the energy-intensive sub-sector Industrial Chemicals (ISIC 351) and the energy-extensive sub-sector Other Chemical Products (ISIC 352). Similarly, the Paper sector is built up from the energy-intensive Paper and Pulp sector (ISIC 341) and the energy-extensive Printing sector (ISIC 342. Hence, the observed shifts in energy shares might be characterised as intra-sectoral shifts (see footnote 16). For example, it is known that in the Netherlands the share of Industrial Chemicals in the Chemical industry has been substantially reduced over time (CPB 2000: 63-68). As noted before, until consistent and internationally comparable energy and economic data become available for a more detailed breakdown of these sectors, the decomposition results should be interpreted with caution.

Table 4.3 **Percentage contribution of structural effect (STR) and efficiency effect (EFF) by sector to average annual growth rate (g) of aggregate labour productivity in manufacturing per country**

	Belgium 1971-97			Denmark 1972-97			Finland 1971-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
CHE	7.8	13.2	20.9	6.4	14.3	20.7	2.0	4.1	6.1
FOD	3.0	11.5	14.5	-5.3	27.9	22.6	-0.9	7.9	7.1
IAS	-3.5	6.3	2.8	-0.7	2.3	1.6	0.5	3.9	4.5
MAC	-0.2	17.9	17.7	16.3	24.3	40.7	11.4	35.1	46.5
MTR	4.0	6.3	10.3	-3.3	-2.6	-5.9	-2.2	5.5	3.2
NFM	-1.2	4.2	3.0	--	--	--	0.3	1.2	1.5
NMM	-1.2	5.5	4.3	-5.3	1.3	-4.0	-0.7	3.3	2.5
PAP	1.4	5.0	6.5	-1.6	6.6	5.0	-2.3	20.0	17.7
TEX	-5.8	9.6	3.7	-8.8	6.8	-2.0	-4.6	4.2	-0.4
WOD	0.1	0.9	0.9	1.1	1.7	2.7	-1.9	6.6	4.7
NSI	3.2	12.0	15.3	5.8	12.9	18.7	5.0	1.7	6.7
	-------	-------	-------	------	-------	-------	-------	-------	-------
MAN %	7.6	92.4	100.0	4.6	95.4	100.0	6.6	93.4	100.0
MAN g	0.33	3.96	4.29	0.10	2.00	2.09	0.32	4.52	4.84

	France 1971-97			West Germany 1970-90			Italy 1970-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
CHE	2.1	13.7	15.8	1.8	11.6	13.4	-0.6	9.6	9.1
FOD	5.8	9.7	15.5	-1.3	8.7	7.4	0.1	10.4	10.5
IAS	-1.6	3.5	1.9	-4.2	6.5	2.3	-1.5	3.1	1.6
MAC	2.1	25.3	27.4	7.9	27.6	35.5	2.7	28.2	30.9
MTR	0.1	9.0	9.1	11.7	8.2	19.9	-0.9	4.9	4.0
NFM	-0.3	2.4	2.1	0.9	2.5	3.4	-0.7	1.3	0.7
NMM	-1.4	3.8	2.3	-2.4	5.2	2.8	-0.6	7.3	6.7
PAP	3.1	4.2	7.3	0.0	4.4	4.4	0.7	6.6	7.2
TEX	-6.8	6.0	-0.9	-8.3	6.9	-1.4	-0.1	15.0	15.0
WOD	--	--	--	-0.8	1.7	0.9	-1.2	2.0	0.9
NSI	3.0	16.4	19.4	4.2	7.4	11.6	1.6	11.8	13.4
	-------	-------	-------	-------	-------	-------	-------	-------	-------
MAN %	6.0	94.0	100.0	9.2	90.8	100.0	-0.3	100.3	100.0
MAN g	0.18	2.74	2.92	0.21	2.05	2.26	-0.01	3.94	3.93

Table 4.3	**continued**								
	Japan 1982-97			Netherlands 1982-97			Norway 1976-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
CHE	0.3	8.8	9.2	-1.8	25.9	24.1	0.2	20.9	21.0
FOD	4.5	-7.1	-2.7	-2.0	16.5	14.6	10.9	-3.3	7.6
IAS	-2.8	7.7	4.9	-1.5	2.6	1.1	-4.3	6.7	2.4
MAC	4.0	66.7	70.6	2.8	24.7	27.5	10.0	35.5	45.5
MTR	-0.7	10.1	9.4	-1.0	4.4	3.5	-12.9	8.1	-4.8
NFM	-0.2	1.1	0.9	-0.7	1.1	0.5	-0.7	9.4	8.6
NMM	-1.6	3.9	2.3	0.2	3.5	3.6	-2.1	4.2	2.0
PAP	1.2	2.5	3.6	3.4	7.5	10.9	10.8	11.0	21.8
TEX	-8.3	3.7	-4.6	-1.0	1.4	0.4	-5.8	4.5	-1.2
WOD	--	--	--	0.4	0.7	1.1	-3.6	6.9	3.4
NSI	2.5	3.8	6.4	0.7	12.2	12.8	2.3	-8.6	-6.3
	-------	-------	-------	------	-------	-------	-------	-------	-------
MAN %	-1.2	101.2	100.0	-0.5	100.5	100.0	4.7	95.3	100.0
MAN g	-0.04	3.94	2.98	-0.01	3.04	3.03	0.08	1.52	1.60

	Sweden 1973-97			United Kingdom 1970-97			United States 1970-97		
	STR	EFF	Total	STR	EFF	Total	STR	EFF	Total
CHE	4.6	6.0	10.6	0.4	18.3	18.7	1.0	15.9	16.8
FOD	-0.3	6.8	6.5	1.2	13.9	15.1	-0.4	7.1	6.7
IAS	-2.5	6.6	4.0	-3.2	4.1	1.0	-4.5	3.8	-0.7
MAC	4.5	45.4	49.8	2.1	24.8	26.9	0.8	52.2	53.0
MTR	1.2	6.2	7.4	-2.6	13.0	10.3	1.4	4.0	5.4
NFM	-0.4	1.9	1.6	-0.8	1.4	0.7	-0.3	1.0	0.7
NMM	-1.3	0.9	-0.4	0.0	2.4	2.4	-0.6	1.9	1.2
PAP	0.9	10.6	11.5	5.2	6.2	11.4	6.4	2.4	8.8
TEX	-4.1	2.2	-1.9	-4.2	6.1	1.9	-3.0	8.0	5.0
WOD	-1.9	4.8	2.8	--	--	--	--	--	--
NSI	2.8	5.3	8.1	5.9	5.9	11.7	5.1	-2.0	3.1
	-------	-------	-------	-------	-------	-------	-------	-------	-------
MAN %	3.4	96.6	100.0	4.0	96.0	100.0	5.8	94.2	100.0
MAN g	0.11	3.08	3.19	0.11	2.70	2.82	0.14	2.25	2.39

Table 4.3 shows that, as for energy productivity, the aggregate Manufacturing labour-productivity improvements are to a large extent realised within the Machinery sector. Moreover, the table shows that, although in all countries there is only a very limited impact of structural changes on aggregate Manufacturing labour-productivity growth, this does not imply that there were no changes in employment mix. It can be seen that the main structural change consisted of a decreasing employment share of the labour-intensive sector Textiles (except for Italy) and an increasing employment share of the capital/technology intensive sector Machinery (except for Belgium). Moreover, in most countries this shift is accompanied by a shift in employment from Iron and Steel towards Chemicals, Food and Paper.

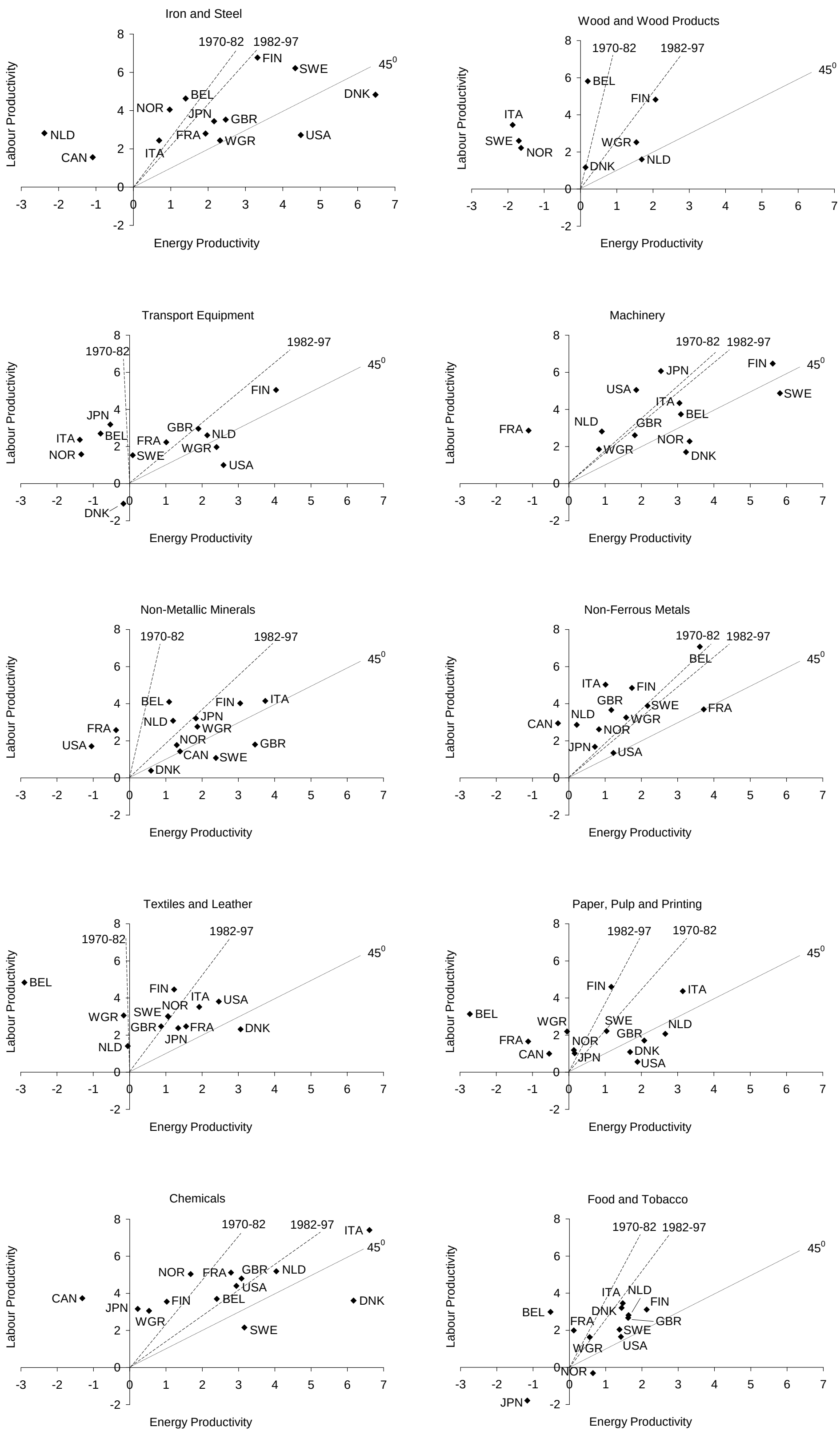
4.3 Sectoral biases in productivity growth rates

For aggregate Manufacturing we found in the previous section that although growth rates of labour productivity are substantially higher than growth rates of energy productivity, they nevertheless complement each other and that the bias towards labour productivity growth is increasing over time. Do these conclusions also apply to the individual Manufacturing sectors? To examine this issue we provide below some empirical evidence on the existence and development of potential sectoral biases towards either energy- or labour productivity for each Manufacturing sector.

For each Manufacturing sector we calculated average annual growth rates of energy- and labour productivity per country for the period 1970-1997. They are presented in Figure 4.6 together with 2 regression lines through the origin, estimating the relationship between energy- and labour-productivity growth rates for, respectively, the periods 1970-1982 and 1982-1997.[20] This leads to the following three conclusions. First, overall a positive correlation exists between energy- and labour productivity growth rates, suggesting energy- and labour-productivity growth to be complements. There are, however, several exceptions. In several sectors, most notable in Transport Equipment, and Paper and Wood, several countries combine a positive labour-productivity growth rate with a negative growth rate in energy productivity. Second, also at this disaggregated level labour-productivity growth is in general higher than energy-productivity growth, suggesting the existence of a bias towards labour-augmenting technological change. Third, over time, this bias towards labour-productivity growth is decreasing in all Manufacturing sectors except for Paper: in this sector the regression line for the period 1982-1997 is steeper than those for the period 1970-1982. This result is in contrast with the increasing bias towards labour-productivity growth which we found at the level of aggregate Manufacturing and, hence, underlines the relevance of productivity analysis at a disaggregated level.

[20] Note that the exact period differs for each country due to data restrictions. We refer to Tables A4 and A5 in Appendix A for an overview of the periods used per country, the sectoral growth rates per country (the same as in Figure 4.6 but then in tabular format) as well as the weighted average sectoral growth rates for the sum of the OECD countries included in this study.

Figure 4.6 Energy- and labour productivity main sectors. Average annual growth rate



5 Conclusions

Technological change plays a crucial role in decoupling economic growth and environmental pressure. Technology-driven productivity growth is an important source of economic growth and plays an important role in realising this decoupling, for example, through increasing energy productivity. In this paper, we empirically examined the energy- and labour-productivity performance in 14 OECD over the last decades. A principal aim of this paper was to trace back macroeconomic productivity developments to developments at the level of individual sectors, in order to correct as much as possible for the impact of structural effects on productivity trends. Our analysis covered the period 1970-1997 and distinguished 13 sectors, including 10 Manufacturing sectors, Services, Transport and Agriculture. The research has been split into two parts: one focusing on the macroeconomic level and the other taking a closer look at the manufacturing sector.

At the macroeconomic level, we found a diverse picture for trends in energy productivity with substantial cross-country differences. Italy and Japan show a high energy-productivity level while Canada, Finland, Norway and Sweden display a relatively low level of overall energy productivity. All other countries form a medium group. The USA tends to leave the lagging group over time to catch-up up with the medium group. At the level of aggregate Manufacturing two groups of countries can be identified. Denmark, Italy, West-Germany, France, Japan and the United Kingdom all show a relatively high energy-productivity level, while the opposite holds for the USA, Netherlands, Belgium, Sweden, Australia, Finland, Canada and Norway. For labour productivity we found the well-known leading position for the USA, with other OECD countries showing a clear tendency to catch-up at a macroeconomic level, while the latter is less clear cut at the manufacturing level.

A decomposition analysis revealed that, both at a macroeconomic level and at the manufacturing level, in most countries structural changes explain a substantial part of energy-productivity growth rates while they explain only a small part of labour-productivity growth rates. At the macroeconomic level the dominating structural change consists of a shift in energy- and employment shares from Manufacturing towards Services, while at the manufacturing level the positive structural effects are to a large extent driven by a shift of energy shares from low-value added (energy-intensive) sectors (such as Iron and Steel, Non-Ferrous Metals and Non-Metallic Minerals) to higher value added (capital- and/or technology-intensive) industries (such as Machinery, Transport Equipment, Textile and Food) – while the opposite is true in case of an overall negative structural effect. Macroeconomic energy-efficiency improvements are mainly realised within Manufacturing, while for Services the picture is highly diverse with a mix of positive and negative percentage contributions to aggregate energy efficiency improvements. In terms of labour-productivity improvements, the main macroeconomic efficiency improvements are not only realised within Manufacturing, but also within Services. Within Manufacturing, the Machinery sector is the main source for both energy- and labour productivity improvements. Finally, although the total structural effect on aggregate Manufacturing labour-productivity growth is small, there have been changes in employment mix, the main shifts include a decreasing employment share of the labour-intensive sector Textiles (except for Italy) and an increasing employment share of the capital/technology intensive sector Machinery (except for Belgium). Furthermore, in most countries this shift is accompanied by a shift in employment from Iron and Steel towards Chemicals, Food and Paper.

An exploration of the relationship between energy- and labour-productivity growth rates revealed this relationship, with some exceptions, to be positive in most sectors, suggesting energy- and labour-productivity growth to be complements rather than substitutes. For most countries, this conclusion holds also for Services and Transport. This may suggest that technological change is embodied in new capital goods which perform better than older capital goods in multiple dimensions, including a better performance in terms of both labour- and energy productivity. This hypothesis assumes that knowledge is more or less a public good as a result of which the most recent capital goods embody state-of-the art technology in different dimensions. If this is true, firms and sectors investing in new capital goods in order to expand or replace existing production facilities or to increase labour productivity, invest at the same time in energy-saving technological change. However, more precise conclusions concerning these issues require a better insight in the nature of technological change through microeconomic research (see, for example, Newell et al. 1999), which is beyond the scope of this paper.

Furthermore, we found labour-productivity growth rates in general to be substantially higher than energy-productivity growth while this bias towards labour-productivity growth increased in aggregate Manufacturing, Transport and Agriculture and decreased in Services as well as in most manufacturing sectors. The latter result underlines the relevance of productivity analysis at a disaggregated level.

Finally, we found that at several levels of aggregation cross-country differences in energy-productivity levels are substantially larger than cross-country differences in labour-productivity levels. However, our results suggest that whether these cross-country productivity differences tend to be decreasing or increasing over time, depends on the level of aggregation.

References

Acemoglu, D., 2002, Directed Technical Change, *Review of Economic Studies*, 69, pp. 781-809.

Ang, B.W., 1995a, Decomposition Methodology in Industrial Energy Demand Analysis, *Energy*, 20, pp. 1081-95.

Ang, B.W., 1995b, Multilevel Decomposition of Industrial Energy Consumption, *Energy Economics*, 17, pp. 39-51.

Ang, B.W., 1999, Decomposition Methodology in Energy Demand and Environmental Analysis, in J.C.J.M. van den Bergh (ed.), *Handbook of Environmental and Resource Economics*, Cheltenham: Edward Elgar, pp. 1146-1163.

Ang, B.W. and F.Q. Zhang, 2000, A Survey of Index Decomposition Analysis in Energy and Environmental Studies, *Energy*, 25, pp. 1149-1176.

Ark, B. van, 1993, International Comparisons of Output and Productivity, Monograph Series no.1, Groningen: Growth and Development Centre.

Ark, B. van, 1996, Sectoral Growth Accounting and Structural Change in Post-War Europe, in B. van Ark and N. Crafts (eds), *Quantitative Aspects of Post-War European Economic Growth*, Cambridge: Cambridge University Press, pp. 84-164.

Ark, B. van, 1997, *Economic Growth in the Long Run. A History of Empirical Evidence*, The International Library of Critical Writings in Economics 76, 3 Volumes, Cheltenham: Edward Elgar.

Ark, B. van and D. Pilat, 1993, Productivity Level in Germany, Japan, and the United States: Differences and Causes, *Brookings Papers on Economic Activity: Microeconomics*, 2, pp. 1-46.

Barro, R.J., 1997, *Determinants of Economic Growth: A Cross-Country Empirical Study*, Cambridge MA: MIT Press.

Binswanger, H.P., 1974a, The Measurement of Technical Change Biases with Many Factors of Production, *American Economic Review*, 64, pp. 964-976.

Binswanger, H.P., 1974b, A Microeconomic Approach to Induced Innovation, *Economic Journal*, 84, pp. 940-958.

CPB, 2000, *Naar een Efficiënter Milieubeleid*, Den Haag: Sdu Uitgevers.

Denison, E.F., 1967, *Why Growth Rates Differ*, Washington DC: Brookings.

Dollar, D. and E.N. Wolff, 1993, *Competitiveness, Convergence, and International Specialization*, Cambridge MA: MIT Press.

Eichhammer, W. and W. Mannsbart, 1997, Industrial Energy Efficiency: Indicators for a European Cross-Country Comparison of Energy Efficiency in the Manufacturing Industry, *Energy Policy*, 25, pp. 759-772.

Fagerberg, J., 2000, Technological Progress, Structural Change and Productivity Growth, *Structural Change and Economic Dynamics*, 11, pp. 393-411.

Greening, L.A., W.B. Davis and L. Schipper, 1997, Comparison of Six Decomposition Methods: Application to Aggregate Energy Intensity for Manufacturing in 10 OECD Countries, *Energy Economics*, 19, pp. 375-90.

Hicks, J.R., 1932, *The Theory of Wages* (2nd ed. 1966), London: Macmillan.

Howarth, R.B., L. Schipper, P.A. Duerr and S. Strøm, 1991, Manufacturing Energy Use in 8 OECD Countries, *Energy Economics*, 13, pp. 135-42.

Jorgenson, D.W., 1984, The Role of Energy in Productivity Growth, *Energy Journal*, 5, pp. 11-26.

Jorgenson, D.W., 1986, The Great Transition: Energy and Economic Change, *Energy Journal*, 7, pp. 1-13.

Jorgenson, D.W., 1995, *Productivity, Vol 2: International Comparisons of Economic Growth*, Cambridge MA: MIT Press.

Jorgenson, D.W. and Z. Griliches, 1967, The Explanation of Productivity Change, *Review of Economic Studies*, 34, pp. 249-282.

Kendrick, J.W., 1961, *Productivity Trends in the United States*, Princeton: Princeton University Press.

Kennedy, C., 1962, The Character of Improvements and Technical Progress, *Economic Journal*, 72, pp. 899-911.

Maddison, A., 1952, Productivity in an Expanding Economy, *Economic Journal*, 62, pp. 584-594.

Maddison, A., 1991, *Dynamic Forces in Capitalist Development*, Oxford: Oxford University Press.

Massell, B.F., 1961, A Disaggregated View of Technical Change, *Journal of Political Economy*, 69, pp. 547-557.

Miketa, A., 2001, Analysis of Energy Intensity Developments in Manufacturing Sectors in Industrialized and Developing Countries, *Energy Policy*, 29, pp. 769-775.

Morovic, T., F.J. Gründing, F. Jäger, E. Jochem, W. Mannsbart, H. Poppke, M. Schön and I. Tötsch, 1987, *Energy Conservation Indicators*, Berlin: Springer Verlag.

Morovic, T., G. Gerritse, G. Jaeckel, E. Jochem, W. Mannsbart, H. Poppke and B. Witt, 1989, *Energy Conservation Indicators II*, Berlin: Springer Verlag.

Mulder, P., 2003, Description Sectoral Database OECD with Energy, CPB Memorandum, The Hague: CPB Netherlands Bureau for Economic Policy Research, forthcoming.

Mulder, P. and H.L.F. de Groot, 2003, Sectoral Energy- and Labour Productivity Convergence, CPB discussion paper no. 23, The Hague: CPB Netherlands Bureau for Economic Policy Research.

Newell, R.G., A.B. Jaffe and R.N. Stavins, 1999, The Induced Innovation Hypothesis and Energy-Saving Technological Change, *Quarterly Journal of Economics*, 114, pp. 941-975.

OECD, 1998, *ISDB: International Sectoral Database Description*, Paris: OECD.

OECD, 2003, *The Sources of Economic Growth in OECD Countries*, Paris: OECD.

Park, S.H., B. Dissmann and K.Y. Nam, 1993, A Cross-Country Decomposition Analysis of Manufacturing Energy Consumption, *Energy*, 18, pp. 843-858.

Pilat, D., 1996, Labour Productivity Levels in OECD Countries: Estimates for Manufacturing and Selected Service Sectors, OECD Economics Department Working Paper, no 169, Paris: OECD.

Ramirez, A., M. Patel and K. Blok, 2002, An Analysis of the Dutch Service Sector: Energy Consumption and Trends, Utrecht: Copernicus Institute, Department of Science, Technology and Society, Utrecht University.

Rosenberg, N., 1994, Energy-Efficient Technologies: Past and Future Perspectives, in: N. Rosenberg (ed.), *Exploring the Black Box. Technology, Economics and History*, Cambridge: Cambridge University Press, pp. 161-189.

Ruttan, V.W., 2001, *Technology, Growth, and Development. An Induced Innovation Perspective*, Oxford: Oxford University Press.

Schipper, L. and S. Meyers, 1992, *Energy Efficiency and Human Activity: Past Trends and Future Prospects*, Cambridge: Cambridge University Press.

Smulders, S. and M. de Nooij, 2003, The Impact of Energy Conservation on Technology and Economic Growth, *Resource and Energy Economics*, 25, pp. 59-79.

Solow, R.M., 1957, Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, 39, pp. 312-320.

Syrquin, M., 1984, Resource Allocation and Productivity Growth, in: M. Syrquin, L. Taylor and L.E. Westphal (eds), *Economic Structure Performance – Essays in Honor of Hollis B. Chenery*, Orlando: Academic Press, pp. 75-101.

Taheri, A.A. and R. Stevenson, 2002, Energy Price, Environmental Policy, and Technological Bias, *Energy Journal*, 32, pp. 85-107.

Unander, F., S. Karbuz, L. Schipper, M. Khrushch and M. Ting, 1999, Manufacturing Energy Use in OECD Countries: Decomposition of Long Term Trends, *Energy Policy*, 27, pp.769-778.

Wagner, K. and B. van Ark, 1996, *International Productivity Differences: Measurement and Explanation.* Contributions to Economic Analysis (Vol. 233), Amsterdam: Elsevier.

Appendix A

Table A.1 Percentage shares of total Energy Consumption (E), Employment (L) and GDP (Y) by sector in 1990

	AUS			BEL			CAN			DNK			FIN			FRA			WGR		
	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y
MAN	40	19	16	50	26	26	42	21	22	27	30	25	61	27	29	38	27	28	46	40	37
SRV	7	63	67	13	56	57	18	60	61	17	45	53	5	42	44	17	50	57	16	42	50
TAS	48	5	6	35	6	8	36	5	5	48	8	9	27	7	7	41	5	5	37	5	4
CST	2	7	7	--	9	7	1	8	9	2	10	8	1	12	12	1	10	7	--	9	7
AGR	3	6	4	2	3	2	3	5	3	7	8	6	6	12	8	3	8	4	2	4	2
	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
TOT	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

	ITA			JPN			NLD			NOR			SWE			GBR			USA		
	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y
MAN	49	27	28	49	26	29	55	22	24	50	21	18	50	31	29	39	26	28	33	20	22
SRV	4	46	55	14	47	50	5	57	59	15	51	54	17	46	51	12	55	54	16	66	66
TAS	43	6	5	31	6	7	30	6	5	31	9	16	31	7	6	47	7	7	50	4	4
CST	--	9	8	2	11	11	1	9	7	2	10	7	--	10	10	1	9	9	--	7	5
AGR	4	12	4	4	10	3	9	6	5	2	9	5	2	6	4	1	3	2	1	3	2
	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
TOT	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table A.2 Average Annual Growth Rates of Energy Productivity (E) and Labour Productivity (L) in 5 sectors

		AUS	BEL	CAN	DNK	FIN	FRA	GBR	ITA	JPN	NLD	NOR	SWE	GBR	USA	OECD
		70-97	71-97	70-97	72-97	71-97	73-97	70-90	70-97	82-97	82-97	76-97	73-97	70-97	70-94	
MAN	E	0.41	1.91	0.45	2.74	1.93	0.85	1.45	3.07	1.71	1.87	-0.08	2.19	2.28	3.19	2.25
	L	1.06	4.29	1.79	2.09	4.84	2.92	2.26	3.93	2.98	3.03	1.60	3.19	2.82	2.39	2.69
		74-96	70-96	73-97	70-95	70-96	70-97	70-90	70-97	82-96	86-95	76-95	70-94	70-96	70-96	
TAS	E	1.18	-1.17	0.60	0.50	0.22	0.16	-0.33	0.16	-0.06	1.31	1.31	2.09	-0.15	1.02	0.39
	L	2.91	1.56	--	1.84	2.75	2.47	2.13	2.29	2.76	3.14	4.03	3.35	2.56†	1.11	2.03
SRV	E	-0.27	0.67	1.78	-1.05^	-2.82#	0.52º	2.43	-2.53	0.12	-2.56	0.76	2.18*	1.85	2.61	1.45
	L	0.64	0.96	0.49	1.63	2.87	1.54	2.16	0.97	2.12	0.18	0.48	1.63	0.22†	0.52	0.98
AGR	E	0.04	-2.58	-3.78	2.18	-1.16	0.36	1.50	-1.75	-3.42	-0.94	-4.07	0.58	2.19	2.68	0.18
	L	2.21	4.41	1.21	6.22	4.37	5.34	6.12	3.64	2.80	4.40	2.65	3.56	3.82	2.21	3.23
CST	E	-0.34	0.51	--	--	1.17	--	-1.59	-4.89	-0.37	-0.31	--	4.41	1.17	--	-0.42
	L	1.53	1.30	0.46	-0.32	2.23	1.49	1.41	0.74	1.43	0.07	--	2.70	--	-1.25	0.39

*1986-1994 † 1970-1990 ^1972-1995 #1970-1995 º1985-1997. The OECD average is weighted with each country's 1990 GDP share of total GDP per sector.

Table A.3 Percentage shares of total Manufacturing Energy Consumption (E), Employment (L) and GDP (Y) by sector, in 1990

	AUS			BEL			CAN			DNK			FIN			FRA			WGR		
	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y
CHE	17	4	--	35	10	14	--	4	--	14	5	9	17	5	7	37	7	9	36	7	10
FOD	12	12	--	6	14	15	--	12	--	27	17	21	4	12	12	9	13	13	6	9	11
IAS	12	3	--	27	5	5	--	2	--	5	1	1	11	3	3	14	4	3	22	5	5
MAC	2	19	--	3	24	21	--	20	--	8	34	30	3	26	27	8	29	26	4	37	34
MTR	1	8	--	2	10	11	--	11	--	2	5	5	0	6	5	2	12	11	4	11	12
NFM	33	2	--	3	2	3	--	2	--	3	0	0	2	1	1	4	1	2	4	2	2
NMM	12	4	--	12	5	6	--	3	--	21	4	4	9	5	5	10	3	4	9	4	4
PAP	7	10	--	3	8	7	--	15	--	7	10	11	41	18	21	8	8	8	5	5	5
TEX	2	8	--	2	12	7	--	9	--	3	7	5	1	8	4	3	10	6	2	6	4
WOD	1	5	--	0	2	1	--	5	--	4	3	2	6	8	7	2	2	2	1	2	1
NSI	0	25	--	7	8	10	--	16	--	4	13	12	8	9	9	3	11	16	7	11	12
	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
MAN	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

	ITA			JPN			NLD			NOR			SWE			GBR			USA		
	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y	E	L	Y
CHE	34	5	7	31	3	9	67	9	15	27	5	10	15	5	7	32	6	11	--	6	11
FOD	5	8	10	4	10	11	8	17	16	6	18	16	4	9	10	10	11	13	--	9	11
IAS	14	2	3	20	3	6	8	2	3	19	2	3	9	3	3	12	3	3	--	2	3
MAC	7	26	27	6	36	38	3	31	26	3	25	25	6	35	31	10	32	26	--	27	27
MTR	1	7	8	2	8	11	1	7	5	1	8	8	2	13	11	3	10	12	--	10	10
NFM	2	1	1	3	1	2	3	1	1	23	4	6	3	1	1	3	1	1	--	1	1
NMM	18	7	7	9	4	4	5	4	4	4	3	0	5	3	3	9	4	4	--	3	2
PAP	5	5	6	8	2	3	3	12	11	14	16	17	44	14	15	5	10	11	--	12	12
TEX	5	23	16	3	7	2	1	6	3	0	4	2	1	3	2	3	10	6	--	10	5
WOD	0	3	2	--	3	1	0	2	2	3	6	5	6	6	6	0	2	1	--	4	3
NSI	9	13	13	14	22	13	0	9	14	0	10	7	4	8	9	12	12	11	--	15	15
	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
MAN	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Sum sectors might differ slightly from 100 due to rounding.

Table A.4 Manufacturing sectors Energy Productivity Average Annual Growth Rates

	AUS	BEL	CAN	DNK	FIN	FRA	WGR	ITA	JPN	NLD	NOR	SWE	GBR	USA	OECD
	70-97	71-97	70-97	72-97	71-97	73-97	70-90	70-97	82-97	82-97	76-97	73-97	70-97	70-94	
MAN	0.41	1.91	0.45	2.74	1.93	0.85	1.45	3.07	1.71	1.87	-0.08	2.19	2.28	3.19	2.25
CHE	--	2.4	-1.31	6.17	1.02	2.79	0.53	6.61	0.22	4.04	1.68	3.16	3.08	2.94	2.26
FOD	--	-0.52	--	1.44	2.13	0.12	0.56	1.47	-1.16	1.63	0.65	1.38	1.62	1.42	0.64
IAS	--	1.4	-1.09	6.48	3.32	1.93	2.32	0.69	2.47	-2.38	0.97	4.33	2.16	4.48	2.67
MAC	--	3.09	--	3.23	5.62	-1.11	0.83	3.05	2.54	0.91	3.33	5.82	1.82	1.86	1.80
MTR	--	-0.80	--	-0.17	4.04	1.01	2.40	-1.37	-0.53	2.14	-1.33	0.09	1.9	2.59	1.35
NFM	--	3.61	-0.3	--	1.74	3.72	1.58	1.01	0.72	0.22	0.83	2.17	1.17	1.23	1.31
NMM	--	1.09	1.39	0.59	3.05	-0.37	1.87	3.74	1.83	1.20	1.30	2.38	3.46	-1.05	1.30
PAP	--	-2.73	-0.54	1.69	1.17	-1.12	-0.05	3.14	0.16	2.66	0.14	1.04	2.08	1.89	1.31
TEX	--	-2.90	--	3.06	1.23	1.56	-0.16	1.92	1.34	-0.05	1.06	1.07	0.87	2.46	1.59
WOD	--	0.2	--	0.14	2.07	--	1.54	-1.87	--	1.69	-1.64	-1.70	--	--	-0.01

The OECD average is weighted with each country's 1990 GDP share of total GDP per sector.

Table A.5 Manufacturing sectors Labour Productivity Average Annual Growth Rates.

	AUS	BEL	CAN	DNK	FIN	FRA	WGR	ITA	JPN	NLD	NOR	SWE	GBR	USA	OECD
	70-97	71-97	70-97	72-97	71-97	73-97	70-90	70-97	82-97	82-97	76-97	73-97	70-97	70-94	
MAN	1.06	4.29	1.79	2.09	4.84	2.92	2.26	3.93	2.98	3.03	1.60	3.19	2.82	2.39	2.69
CHE	--	3.70	3.74	3.61	3.55	5.12	3.06	7.41	3.16	5.19	5.04	2.16	4.80	4.40	4.22
FOD	--	2.99	1.34	3.21	3.12	1.99	1.63	3.46	-1.79	2.81	-0.31	2.04	2.67	1.65	1.25
IAS	--	4.63	1.56	4.83	6.77	2.80	2.44	2.44	3.53	2.82	4.05	6.22	3.44	2.72	3.03
MAC	--	3.74	1.90	1.70	6.47	2.86	1.85	4.34	6.07	2.81	2.28	4.87	2.61	5.05	4.40
MTR	--	2.70	2.54	-1.08	5.05	2.23	1.97	2.37	3.19	2.61	1.58	1.53	2.96	1.00	2.02
NFM	--	7.07	2.95	4.28	4.85	3.70	3.26	5.03	1.68	2.86	2.62	3.89	3.66	1.35	2.41
NMM	--	4.10	1.43	0.39	4.02	2.58	2.76	4.15	3.21	3.08	1.77	1.08	1.80	1.71	2.71
PAP	--	3.14	1.00	1.09	4.60	1.66	2.20	4.37	1.02	2.07	1.19	2.22	1.71	0.56	1.27
TEX	--	4.84	2.73	2.32	4.46	2.47	3.06	3.52	2.38	1.41	3.02	3.00	2.47	3.81	3.28
WOD	--	5.81	1.98	1.17	4.82	4.10	2.52	3.46	0.31	1.60	2.22	2.60	0.66	0.95	1.53

The OECD average is weighted with each country's 1990 GDP share of total GDP per sector.

Appendix B

Essentially, one can use two types of indicators to measure energy productivity, each measuring economic activity (output or production) in a different way. An *economic indicator* measures economic activity in monetary values, while a *physical indicator* measures economic activity in terms of physical production. The most common unit of monetary value is value added (GDP)[21] while physical production is usually expressed in terms of physical volume of production (weight and number of products). Both types of indicator have their advantages and disadvantages (see, for example, Phylipsen et al. 1997, 1998). The main advantage of using a physical indicator, or so-called Specific Energy Consumption (SEC), is that it measures a direct relationship between the volume of production and energy consumption (e.g. MJ/tonne). An economic indicator does not measure such a direct relationship, since it measures not only SEC but also changes in the mix and characteristics of products and feedstock as well as changes in market-based product prices. In addition, since physical indicators are necessarily developed at a lower level of aggregation than economic indicators – because of the use of physical units of production – the influence of the structure of output on the aggregate energy productivity performance is by definition of less importance. But physical indicators also have their problems. The three most important disadvantages are inherent difficulties of aggregation (how to add up different levels of energy services in physical terms), lack of useful physical indicators of economic activity (in particular in the energy-extensive sectors), and limited data availability. Especially in sectors with a large variety of products and a large degree of processing, using physical indicators requires a large amount of data.

Although not many systematic comparisons between physical and economic indicators have been made so far, there is some evidence of substantial differences between the two indicators at the sector level, especially in the short run (Farla and Blok 2000, Freeman et al. 1997, Worrell et al. 1997). It is to be noted, however, that in general a value added based energy intensity seems to follow the SEC better than other economic indicators (Worrell et al. 1997). An important criterion in choosing between the two different approaches is the research question at hand. If one is primarily interested in the relationship between energy consumption and volume of production at the process level, one may not want to use economic indicators since they do not always adequately capture physical developments at such a micro level. If one is primarily interested in the relationship between energy use and economic growth (measured in terms of GDP), an economic indicator might be most suitable to examine energy productivity developments.

We have chosen in this study to use an economic indicator, measuring energy productivity by gross value added per unit of final energy consumption. The main reason is that lack of

[21] Alternative, and less common, value-based measures for economic activity are gross output, value of shipments and value of production. Apart from the fact that these measures are not reported in the ISDB or STAN databases, value added is an appropriate measure of economic activity because it measures incremental value added by a sector and thus avoids double counting of production.

physical production data would prevent us from conducting a systematic cross-country analysis for a broad range of sectors. Moreover, we adopt a macroeconomic view, examining the role of two production factors in driving aggregate productivity developments. In addition, since we compare trends in energy- and labour productivity, using gross value added to measure economic activity establishes a link with the existing empirical literature focussing on labour- and total factor productivity developments. What is more, our disaggregated level of analysis includes sufficient sectoral detail to account for the main part of structural changes on aggregate productivity growth and, hence, provides a reasonable indication of energy-efficiency developments. Furthermore, the latter is also true because we perform a long-term analysis, which is not so much biased by short-run fluctuations in value added figures. Finally, our analysis does not include developing countries and centrally planned economies, limiting measurement errors for the value added indicator due to black, grey or missing markets.

Appendix C

This Appendix provides technical details and a brief discussion of alternative decomposition methods and their relation to one another. Moreover, the choice for the decomposition method used in this paper will be motivated. Index number decomposition analysis is a methodology to decompose changes in an aggregate indicator into contributions from several specified factors. In this paper we decompose changes in the aggregate energy- and labour productivity into a contribution from an ‘efficiency effect’ and a contribution from a ‘structural effect’. The efficiency effect captures the net effect of changes in sectoral energy- or labour productivity on the change in aggregate energy- or labour productivity, holding the sector mix constant. The structural effect captures the net effect of changes in sector mix on the change in aggregate energy- or labour productivity, holding sectoral energy- or labour-productivity levels constant. Therefore, this methodology is sometimes referred to as shift-share analysis.

In the context of decomposing aggregate energy- and labour productivity the methodology is based on the following definitions:

$$\frac{Y_t}{E_t} = \sum_i \frac{Y_{i,t}}{E_{i,t}} \frac{E_{i,t}}{E_t} \tag{C.1}$$

$$\frac{Y_t}{L_t} = \sum_i \frac{Y_{i,t}}{L_{i,t}} \frac{L_{i,t}}{L_t} \tag{C.2}$$

with $Y_{i,t}$, $E_{i,t}$ and $L_{i,t}$ being respectively GDP, final energy consumption and total employment of sector *i*. Similar, Y_t, E_t and L_t are respectively aggregate GDP, aggregate final energy consumption and aggregate total employment. So, equation (C.1) says that the aggregate energy productivity is the sum of each sector’s energy productivity level – the first term at RHS – multiplied by its energy share – the second term at RHS. Equation (C.2) defines the same relationship in terms of labour productivity.

For convenience we define $I_E = \frac{Y}{E}$, $I_L = \frac{Y}{L}$ and $S_{Ei} = \frac{E_i}{E}$, $S_{Li} = \frac{L_i}{L}$, such that (C.1) and (C.2) can be summarized by

$$I_{p,t} = \sum_i I_{pi,t} S_{pi,t} \quad \text{with } p = E,L \tag{C.3}$$

which says that the aggregate productivity index is the product of the sum of each sectors’ energy-productivity level multiplied by its factor share. For the actual decomposition of aggregate productivity I into an efficiency index I_i and a structural index S_i several methods and functional forms can be used, requiring a choice with respect to four issues (Ang 1995a).

1. Additive or multiplicative technique

An additive technique builds upon the equation $\Delta I = \Delta I_i + \Delta S_i$ with $\Delta I = I_T - I_0$, $\Delta I_i = I_{i,T} - I_{i,0}$ and $\Delta S_i = S_{i,T} - S_{i,0}$. A multiplicative technique builds upon the equation $\Delta I = \Delta I_i \cdot \Delta S_i$ with $\Delta I = I_T / I_0$, $\Delta I_i = I_{i,T} / I_{i,0}$ and $\Delta S_i = S_{i,T} / S_{i,0}$.

2. The decomposition method

To actually calculate the Efficiency Effect and the Structural Effect, essentially three methods exist: (1) the General Parametric Divisia Method 1, (2) the General Parametric Divisia Method 2 and (3) the Refined Divisia Method. An important distinguishing feature of the RDM is that it leaves no residual term, i.e. there is no part of the change in aggregate change left as unexplained. Below, we present the three methods (for energy-productivity), applying the additive technique and with 0 as the initial year and T as the final year of the decomposition period:

a. General Parametric Divisia Method 1 (PDM 1)

$$\Delta I_i = \sum \left\{ \frac{Y_0}{E_{i,0}} + \alpha \left(\frac{Y_T}{E_{i,T}} - \frac{Y_0}{E_{i,0}} \right) \right\} * \ln \left(\frac{I_{i,T}}{I_{i,0}} \right)$$

$$\Delta S_i = \sum \left\{ \frac{Y_0}{E_{i,0}} + \beta \left(\frac{Y_T}{E_{i,T}} - \frac{Y_0}{E_{i,0}} \right) \right\} * \ln \left(\frac{S_{i,T}}{S_{i,0}} \right)$$

b. General Parametric Divisia Method 2 (PDM 2)

$$\Delta I_i = \sum \left\{ S_{i,0} + \alpha \left(S_{i,T} - S_{i,0} \right) \right\} * \left(I_{i,T} - I_{i,0} \right)$$

$$\Delta S_i = \sum \left\{ I_{i,0} + \beta \left(I_{i,T} - I_{i,0} \right) \right\} * \left(S_{i,T} - S_{i,0} \right)$$

c. Refined Divisia Method (RDM)

$$\Delta I_i - \sum \left\{ \frac{\left(\frac{Y_T}{E_{i,T}} - \frac{Y_0}{E_{i,0}} \right)}{\ln \left(\left(\frac{Y_T}{E_{i,T}} \Big/ \frac{Y_0}{E_{i,0}} \right) \right)} \right\} * \ln \left(\frac{I_{i,T}}{I_{i,0}} \right)$$

$$\Delta S_i - \sum \left\{ \frac{\left(\frac{Y_T}{E_{i,T}} - \frac{Y_0}{E_{i,0}} \right)}{\ln\left(\left(\frac{Y_T}{E_{i,T}} \Big/ \frac{Y_0}{E_{i,0}} \right) \right)} \right\} * \ln\left(\frac{S_{i,T}}{S_{i,0}} \right)$$

3. The functional form

For the RDM no additional specification has to be made. The exact form of the decomposition method in case of PDM1 and PDM2, however, depends on the parameter values chosen. The choice of the parameter value implies giving weight to the start and end year of the decomposition period. Three parameter values are most widely used, specifying three decomposition methods:

a. Laspeyres index (α=β=0), giving all weight to base year 0:

$$\text{PDM1}\ \Delta I_i = \sum \left\{ \frac{Y_0}{E_{i,0}} \right\} * \ln\left(\frac{I_{i,T}}{I_{i,0}} \right) \quad \text{PDM1}\ \Delta I_i = \sum \left\{ \frac{Y_0}{E_{i,0}} \right\} * \ln\left(\frac{S_{i,T}}{S_{i,0}} \right)$$

$$\text{PDM2}\ \Delta I_i = \sum S_{i,0} * \left(I_{i,T} - I_{i,0} \right) \quad \text{PDM2}\ \Delta S_i = \sum I_{i,0} * \left(S_{i,T} - S_{i,0} \right)$$

b. Marshall-Edgeworth of Divisia-Törnqvist (α=β=0.5), giving equal weight to base 0 and end year *T*:

$$\text{PDM1}\ \Delta I_i = \sum \left\{ 0.5 * \left(\frac{Y_0}{E_{i,0}} + \frac{Y_T}{E_{i,T}} \right) \right\} \ln\left(\frac{I_{i,T}}{I_{i,0}} \right)$$

$$\text{PDM1}\ \Delta S_i = \sum \left\{ 0.5 * \left(\frac{Y_0}{E_{i,0}} + \frac{Y_T}{E_{i,T}} \right) \right\} \ln\left(\frac{S_{i,T}}{S_{i,0}} \right)$$

$$\text{PDM2}\ \Delta I_i = \sum \left\{ 0.5 * \left(S_{i,0} + S_{i,T} \right) \right\} * \left(I_{i,T} - I_{i,0} \right)$$

$$\text{PDM2}\ \Delta S_i = \sum \left\{ 0.5 * \left(I_{i,0} + I_{i,T} \right) \right\} * \left(S_{i,T} - S_{i,0} \right)$$

c. Paasche index (α=β=1), giving all weight to end year *T*:

$$\text{PDM1}\ \Delta I_i = \sum \left\{ \frac{Y_T}{E_{i,T}} \right\} * \ln\left(\frac{I_{i,T}}{I_{i,0}} \right) \quad \text{PDM1}\ \Delta S_i = \sum \left\{ \frac{Y_T}{E_{i,T}} \right\} * \ln\left(\frac{S_{i,T}}{S_{i,0}} \right)$$

$$\text{PDM2}\ \Delta I_i = \sum S_{i,T} * \left(I_{i,T} - I_{i,0} \right) \quad \text{PDM2}\ \Delta S_i = \sum I_{i,T} * \left(S_{i,T} - S_{i,0} \right)$$

Alternatively, it has been proposed that the parameter value are made 'endogenous' by equating the formula of PDM1 to that of PDM2 for each estimated effect, a method referred to as the Adaptive Weighting Parametric Divisia Method (AWT-PDM). This 'smoothing' process makes the decomposition results independent of a (somewhat arbitrary) choice for PDM1 or PDM2.

4. A period-wise or a time-series analysis

A time-series approach uses yearly data to define base year 0 and end year T while a period-wise approach uses data for the first and the last year of a specified time period only.

In this study we have chosen for time-series analysis, the additive technique and the Refined Divisia Method. The latter implies that no additional choice needs to be made with respect to the parameter values α and β. We have chosen to use a time-series approach because it yields more insight into energy productivity developments over subsequent years - and our database contains yearly data. Moreover, the decomposition results given by time-series analysis are less dependent on the decomposition method used, as compared to period-wise decomposition. We have chosen to use the additive technique because we are interested in decomposing the absolute change in energy- and labour productivity, rather than a relative change. Finally, we have chosen to use the RDM because this method gives, contrary to the other methods, perfect decomposition irrespective of the pattern exhibited by the data and leaving no residual term. Moreover, this method has the advantage that it can handle the value zero in the data set effectively, while the other methods cannot. For further details on decomposition methodology and a systematic survey in energy studies we refer to Ang (1995a, 1999) and Ang and Zhang (2000).