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Sectoral Energy- and Labour-Productivity Convergence

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Abstract

This paper provides an empirical analysis of convergence patterns for energy- and labour-productivity developments at a detailed sectoral level for 14 OECD countries, covering the period 1970-1997. Cross-country differences of energy-productivity levels are shown to be substantially larger than cross-country differences of labour-productivity levels at all levels of sectoral aggregation. A σ-convergence analysis shows that the development of cross-country variation in productivity performance depends on the level of aggregation. Both patterns of international productivity convergence and divergence exist across sectors. Using a panel-data approach, we find in most sectors energy productivity to grow relatively fast in countries with relatively low initial productivity levels, while in several sectors this is also true for labour productivity. This evidence of β-convergence supports the hypothesis that lagging countries tend to catch up with technological leaders, in particular in terms of energy productivity. Moreover, the results show that convergence is conditional rather than unconditional, meaning that productivity levels converge to country-specific steady states. Searching for the fundamentals determining cross-country productivity differentials reveals a positive productivity effect of energy prices and economies of scale in several sectors, while wages, investment share, openness and specialisation play only a very limited role in explaining (cross-country differences in) energy- and labour-productivity growth.

Keywords: energy productivity, labour productivity, convergence, sectoral analysis

JEL codes: O13, O47, O5, Q43

1 Introduction[1]

Economies differ, and so does productivity performance. Of course, economies also interact and, hence, productivity developments are thought to be determined not only by developments within a particular country or sector, but also by what is happening in the outside world. Therefore, a key issue in understanding long-run productivity performance is whether the process of economic growth tends to involve reductions in productivity differences among countries, for example, due to capital accumulation or technology transfers. In a related paper (Mulder and de Groot 2003) we found evidence of substantial differences in energy- and labour-productivity performance across countries and across sectors. A decomposition analysis at different levels of aggregation showed that after correcting for the impact of structural changes, there remain substantial technology-driven productivity growth differentials among OECD countries. Therefore, the major question this paper deals with is whether cross-country productivity differences are persistent or whether they tend to decline over time? And if so, how quickly and by what means? By searching for the determinants of (differences in) energy- and labour productivity growth across countries and across sectors this paper provides an explanatory analysis of sectoral trends in energy- and labour-productivity performance across countries, in addition to the descriptive analysis of Mulder and de Groot (2003).

Since productivity growth is primarily driven by technological change, cross-country productivity differences suggest the existence of different technology levels among countries. By analysing productivity convergence we aim to gain insight into the potential role of international technology flows in determining cross-country productivity differentials. Since technological change is the main driving force behind economic growth, the issue of labour- or total-factor productivity convergence obviously bears important implications for the international welfare distribution, while energy-productivity convergence has become an important issue in the context of international commitments to reduce (energy-related) greenhouse gas emissions. Do energy-inefficient countries catch-up with technological 'leaders'? Do convergence patterns differ substantially across (energy-intensive and -extensive) sectors? Does energy-productivity convergence follow patterns of labour-productivity convergence? Do advanced economies converge in the long-run to a uniform (autonomous) rate of energy-efficiency improvement? We will answer these questions by carrying out an empirical analysis of energy- and labour-productivity convergence, using a new dataset that merges energy data and economic data for 13 sectors and 14 OECD countries, covering the period 1970-1997.

The concept of productivity convergence has its roots in traditional neoclassical growth theory, with its central notion of a transitional growth path to a steady state. The

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

introduction of new or endogenous growth theories generated some degree of controversy around the issue of convergence. The Solow-Swan neoclassical growth model (Solow 1956, Swan 1956) postulates convergence of per capita income, driven by the assumption of diminishing returns to capital accumulation at the economy-wide level. The dynamics of the model imply that initial differences in per capita income and capital endowments will vanish in the long run, due to declining growth rates as countries approach the steady state. In the steady state, diminishing returns are offset by technological progress, the principal source of long-run economic growth. New or endogenous growth theory (see, e.g., Lucas 1988 and Romer 1986, 1990), yields a more diverse picture concerning patterns of convergence. In this view economic growth is ultimately driven by accumulation of knowledge or human capital, which is (at least partially) a public good. Hence, cross-country convergence depends on the extent of international knowledge spill-overs, allowing less productive countries to catch-up with more advanced economies. As such, endogenous growth theory supports the old hypothesis of the existence of an 'advantage of backwardness' (Gerschenkron 1952), suggesting that being relatively backward in productivity carries a potential for rapid advance (see, e.g., Abramovitz 1986). At the same time, endogenous growth theory suggests – contrary to exogenous growth theory – that growth differentials may persist or even increase: learning effects, externalities and market imperfections allow for economy-wide increasing returns to capital accumulation and the existence of multiple steady-states. A mixed view on convergence patterns also emerges if one takes into account the role of international trade: on the one hand trade will enhance cross-country convergence through knowledge diffusion and increasing competition, but on the other hand, it may contribute to cross-country divergence since trade advances international specialisation (Grossman and Helpman 1991).

These various approaches caused the convergence hypothesis to be the subject of extensive empirical research and debate, concentrating on the question of whether initially poor or unproductive countries indeed grow faster than rich or productive countries (see Islam 2003 for a recent survey). The stage for this convergence debate has been set by Baumol (1986), who reported a strong negative relationship between the initial level of labour productivity and its subsequent growth over a long period (1870-1979), which he argued to be strong evidence in favour of convergence. Abramovitz (1986) presented similar evidence, arguing that catch-up growth has been most prominent in the period since 1945. This position was challenged by DeLong (1988) who argued that Baumol's results suffered from a sample bias, in that his analysis has been confined to a sample of countries that have become rich and developed; if one takes a sample of countries that in 1870 seemed likely to converge, the evidence of convergence is less clear cut. In addition, a number of studies have presented evidence of income convergence across countries, by explicitly testing (augmented versions of) the Solow growth model (Barro 1991, Barro and Sala-i-Martin 1992, Mankiw et al. 1992). These empirical cross-country growth analyses raised the important question of whether countries converge to a global or rather to a local steady state, the latter implying that convergence is conditional on cross-country differences in steady-state characteristics. This idea has been formalised by Durlauf and Johnson (1992) and confirmed by several studies in this field, some of them suggesting the existence of convergence clubs: groups of countries converging to different steady states (see, for example, Barro 1991, Chatterji 1992, Chatterji et al. 1993, Quah 1997).[2]

In this paper we do not go further into this debate, but add to the existing empirical convergence analysis a systematic comparison of energy- and labour-productivity convergence at a detailed sector level. These two aspects distinguish our study from previous empirical research on cross-country patterns of convergence and divergence. By including energy-productivity developments, our analysis differs from the empirical macroeconomic convergence literature that focuses on convergence of per capita income, labour productivity and total factor productivity. To the best of our knowledge, the empirical literature on energy-intensity developments lacks empirical convergence analyses from a macroeconomic perspective.[3] By looking at cross-country convergence patters *within* sectors, our analysis differs from virtually all empirical convergence studies, which employ aggregated data. Important exceptions are sectoral studies by Dollar and Wolff (1988, 1993) and Bernard and Jones (1996a, b) who – using (partly) the same data source (OECD's ISDB) – conclude that a convergence analysis of aggregate productivity levels masks substantial differences at the sectoral level; a conclusion we also drew in Mulder and de Groot (2003), and which supports the relevance of examining sectoral patterns of productivity convergence in this paper. Our analysis, however, differs from their work in comparing labour- and energy-productivity convergence, in further disaggregating the manufacturing sector into 10 sub-sectors,[4] in using more recent data (which end in 1997 instead of, respectively, 1985 and 1987) and in carrying out a more extensive search for country- and sector-specific factors to explain productivity convergence patterns.

The notion of convergence can be understood in terms of levels and growth rates. This is acknowledged in the above mentioned macroeconomic empirical research by making a distinction between so-called σ-convergence and β-convergence (see, e.g., Barro 1991, Barro and Sala-i-Martin 1992). The former refers to a decreasing variance of cross-country differences in productivity levels, while the latter suggests a tendency of countries with relatively low initial productivity levels to grow relatively fast, building upon the proposition that growth rates tend to decline as countries approach their steady state. The concept of β-convergence can be refined by distinguishing unconditional (or absolute) convergence from conditional (or relative) convergence. As already noted, the first is said to be present if there is a

[2] For more complete surveys of the convergence debate we refer to Barro and Sala-i-Martin (1995), Broadberry (1996), Durlauf and Quah (1999), Fagerberg (1994), Economic Journal (1996) and Islam (2003). For more recent work on evidence of and driving forces behind convergence patterns see, for example, Baumol et al. (1994), van Ark and Crafts (1996), Kumar and Rusell (2002), Miller and Upadhyah (2002) and Tondl (2001) among many others.

[3] As an exception, Groenenberg (2002) analyses technological convergence in the context of commitments under the Climate Convention. Her analysis, however, is different from ours in being mainly scenario-oriented whereas we perform an empirical pooled cross-section analysis of energy-efficiency developments.

[4] Although Dollar and Wolff (1988, 1993) distinguish 28 sectors, they only present a labour-productivity convergence indicator for a few years and did not perform a regression analysis to test for convergence patterns.

tendency of per capita income or productivity to converge towards a unique steady state while the second concerns convergence towards multiple (country-specific) steady states. Obviously, σ-convergence and β-convergence are closely related. A narrowing dispersion of cross-country productivity differences implies that countries with a relatively poor initial productivity performance tend to grow relatively fast. In other words, β-convergence is a necessary condition for σ-convergence: if advanced countries grow faster than backward nations, there will be no decline in cross-country differences. However, β-convergence is not a sufficient condition for σ-convergence. As has been argued by Quah (1993), a statistically significant inverse relationship between the initial *level* and the *growth rate* of productivity performance can be consistent with constant or even increasing cross-country productivity differences – a phenomenon known as Galton's Fallacy of regression towards the mean.[5] Therefore, in this paper we will explore both patterns of σ-convergence and β-convergence.

The paper proceeds as follows. In section 2 we provide a brief description of the data used. In section 3 we compare cross-country differences of energy- and labour-productivity levels within sectors over time, by means of studying patterns of σ-convergence. In section 4 we use a panel data approach to test the proposition that sectoral growth rates of energy- and labour productivity are inversely related to their initial levels of energy- and labour productivity, indicating possible patterns of β-convergence. We start with testing for unconditional or absolute β-convergence, assuming a unique steady state among countries. In addition we will control for (unspecified) country-effects, testing for conditional or relative convergence, assuming the existence of multiple (country-specific) steady states. Finally, we try to identify the country- and sector specific fundamentals determining (differences in) energy- and labour productivity developments. Section 5 summarises and concludes.

[5] See Bernard and Durlauf (1996) and Durlauf and Quah (1999) for further discussion of empirical methodological issues of convergence tests.

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 Classification

	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).

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). Value added is the net economic output of a sector, measured by the price differential between the 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)[6], with sectoral data excluding transformation losses. Total employment is measured in full-time equivalent number of persons, including self-employed.

Moreover, the database includes data on Investment, Energy Prices, Compensation of Employees, Export and Import – all at the sectoral level. The sector-specific energy prices are constructed by dividing sector-specific expenditures on energy over total sectoral energy consumption. The sector-specific expenditures are calculated as the product of the sectoral consumption of the four main energy carriers (Coal, Natural Gas, Electricity, Oil) – available from the Energy Balances – and the (annual) price of each energy carrier at the aggregate industrial sector – available from the IEA Energy Prices and Taxes series. In addition, some missing aggregate energy price data series have been constructed. All currency-denominated variables are in 1990 US$ and have been converted by the OECD using 1990 purchasing power parities.[7] For further details on data and sector classification we refer to Mulder and De Groot (2003) and Mulder (2003).

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

[7] See Mulder and de Groot (2003) for a brief discussion on the appropriateness of using PPP's. For a discussion of this issue in empirical analysis of convergence at the sectoral level see Sørensen (2001) and Bernard and Jones (2001).

3 σ-Convergence

This section deals with the notion of convergence in terms of levels. Do cross-country differences in energy- and labour-productivity levels decrease over time? Are patterns of energy-productivity convergence similar to those of labour-productivity convergence? And to what extent do the results depend on the level of aggregation? To answer these questions we calculated for each sector the unweighted cross-country standard deviation for the log of energy- and labour productivity, σ, among the 14 OECD countries[8] (insofar as data are available). Figure 3.1 presents the degree of variation in 'macroeconomic' energy- and labour-productivity levels, being the sum of aggregate Manufacturing, Transport, Services and Agriculture.[9] The figure shows that cross-country differences in energy-productivity levels are substantially larger than cross-country differences of labour-productivity levels. Moreover, it can be seen that over time the standard deviation of the log of energy-productivity performance is increasing, indicating σ-divergence, while the opposite is true for cross-country labour-productivity performance, displaying a pattern of σ-convergence.

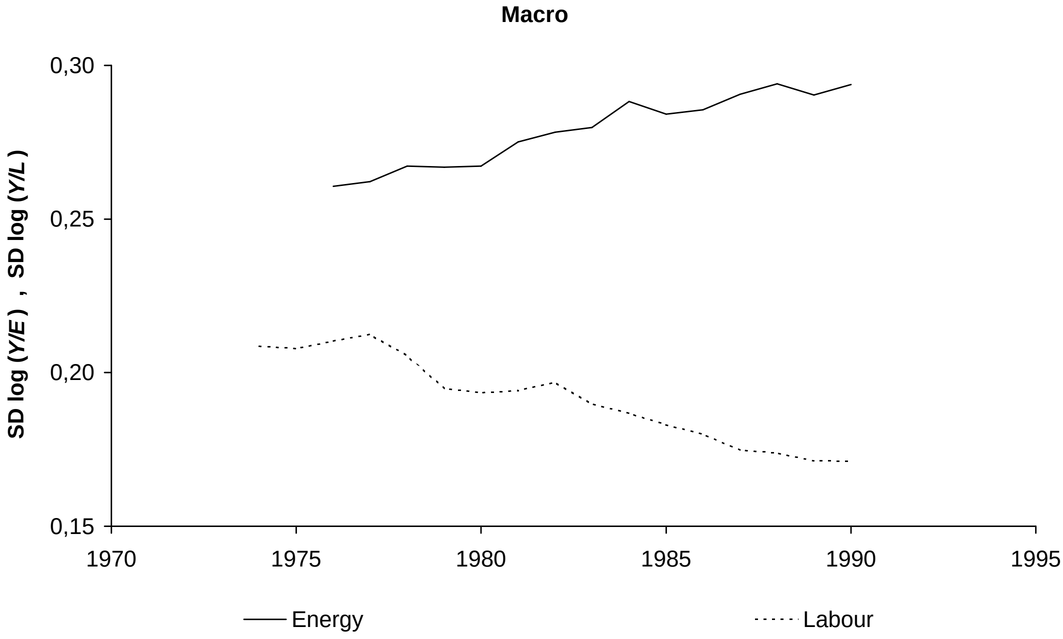
[8] In the literature on convergence analysis, two measures for σ-convergence are used interchangeably: 1) the SD log of per capita income or productivity (*y*) and 2) the coefficient of variation which equals the SD of per capita income or productivity divided by the sample average. They are defined, respectively, as:

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

Dalgaard and Vastrup (2001) show that these measures lead to different conclusions when applied to the data set from the Penn World Table used in Jones (1997) caused by the fact that the measures assign different weights to individual countries' performance. We have therefore used both measures in our convergence analysis, finding both measures to yield an identical pattern of convergence, although with small differences in the size of cross-country variance. Details are available upon request. Here, we only present the result of the SD log-measure (1).

[9] Due to limited data availability the calculation of cross-country dispersion, as shown in Figure 1, excludes Canada, Japan, the Netherlands and Sweden.

Figure 3.1 **Standard deviation of log energy- and labour productivity at the macroeconomic level (including aggregate Manufacturing, Transport, Services and Agriculture)**



In Mulder and De Groot (2003) we found that the level of aggregation matters in examining productivity trends because of the existence of substantial sectoral heterogeneity in productivity performance. Of course, this suggests that convergence patterns may vary among sectors. And indeed, in two studies on cross-country productivity convergence across industries, Bernard and Jones (1996a, b) found aggregate outcomes to mask important variation in sectoral productivity movements. Hence, we continue by examining the development of cross-country productivity differentials within different sectors.

In Figures 3.2a and 3.2b we present the standard deviation of the log of, respectively, energy- and labour productivity for aggregate Manufacturing, Transport, Services and Agriculture.[10]

[10] Due to limited data availability, the following countries are not included in the calculation of cross-country dispersion, shown in Figure 3.2. Manufacturing: Japan, the Netherlands; Agriculture: Japan, the Netherlands; Services: the Netherlands, Sweden; Transport: Canada, the Netherlands.

Figure 3.2a Standard deviation of log energy productivity in main sectors

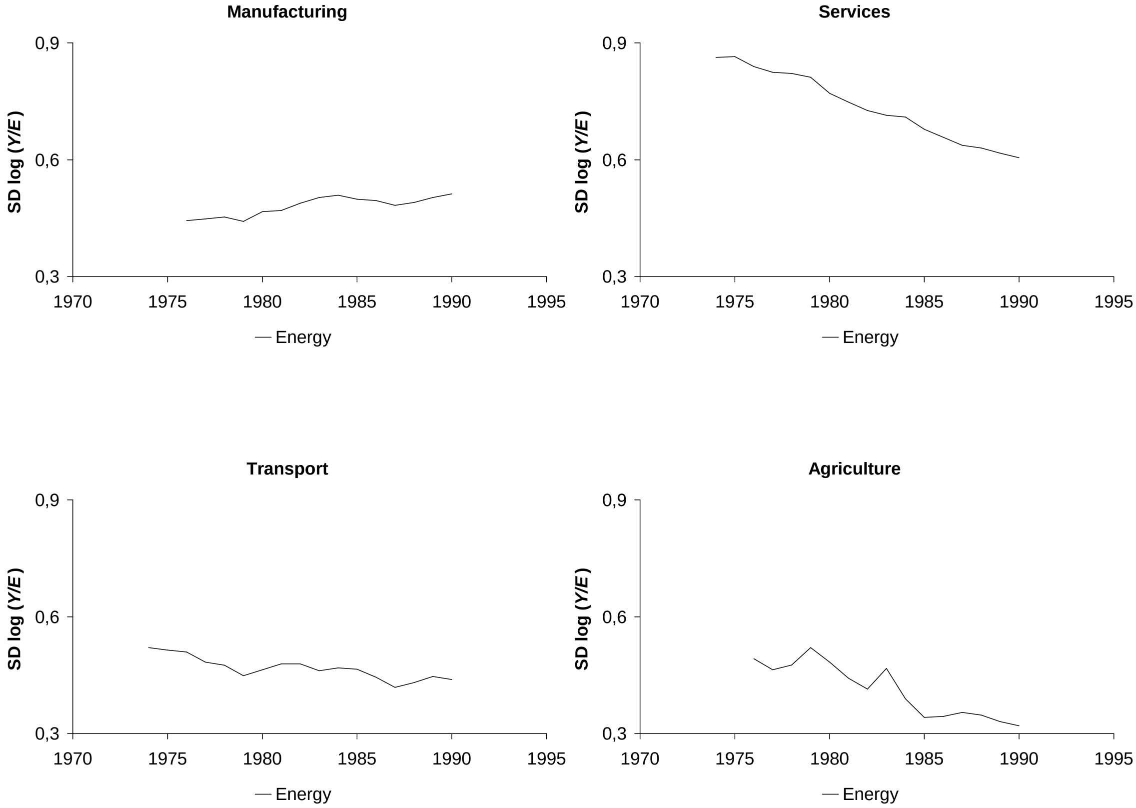


Figure 3.2b Standard deviation of log labour productivity in main sectors

From Figure 3.2a it can be seen that only Manufacturing resembles the macroeconomic pattern of σ-divergence for energy productivity. Transport, Agriculture and in particular Services display evidence of σ-convergence. Note that the level of cross-country variation is relatively high in Services, which is to a large extent due to the exceptional and so far unexplained energy-productivity performance of Finland and Italy.[11] Figure 3.2b shows that the macroeconomic pattern of σ-convergence for labour productivity is only evident in Services and to a lesser extent in the Agriculture sector. At the same time, variation in cross-country productivity differentials remains overall fairly constant within aggregate Manufacturing and Transport (although with fluctuations over time).

Comparing Figures 3.2a and 3.2b shows again that in each sector the cross-country variation of energy productivity is substantially larger than of labour productivity. These results do not change when the United States is removed from the sample. Moreover, they accord well with the findings of Bernard and Jones (1996a), who suggest “that international flows, associated mostly with Manufacturing, may not be contributing substantially to convergence either through capital accumulation or technological transfer” (Bernard and Jones 1996a:1230). Our analysis suggests that this conclusion holds even stronger for energy-productivity performance across countries, where international flows cannot prevent an increase in cross-country differences of productivity levels.

This raises the question as to what the determinants of these cross-country productivity differences are. In our search for an answer we subsequently take two steps. First, we go one step further in the σ-convergence analysis than Bernard and Jones (1996a, b) by examining productivity convergence for a breakdown of aggregate Manufacturing in order to see to whether the energy-productivity divergence and the lack of labour-productivity convergence observed in aggregate Manufacturing is also found within the different Manufacturing sub-sectors. Second, we perform a β-convergence analysis to test whether a statistically significant negative relationship exists between the initial level and the growth rate of productivity performance. Moreover, we will try to explain (persistent) differences in cross-country productivity growth by examining the role of different country-specific variables in driving energy- and labour-productivity growth at the sectoral level. The latter is the subject of section 4. Below we continue with a σ-convergence analysis for a breakdown of aggregate Manufacturing into 10 sub-sectors.

[11] Excluding Finland and Italy from the sample for Services reduces the cross-country dispersion by about 40% while leaving the pattern of σ-convergence unchanged. Note that the Netherlands also exhibits an exceptional development of energy-productivity performance in Services, but has already been excluded form the sample used in Figure 2a. For further details see Mulder and de Groot (2003).

In Figures 3.3a and 3.3b we present the standard deviation of the log of, respectively, energy- and labour productivity for each of the 10 Manufacturing sub-sectors included in our dataset.[12] Figure 3.3a reveals that the pattern of divergence in cross-country energy-productivity performance at the level of aggregate Manufacturing is to be found only in Iron and Steel and Non-Ferrous Metals. On the contrary, Food, Machinery, Non-metallic Minerals (until 1980) and Textiles all display evidence of (strong) σ-convergence. Cross-country productivity differences remain more or less constant in Non-Metallic Minerals (after 1980), Chemicals, Transport Equipment, Paper and Wood.

From Figure 3.3b it can be seen that the lack of labour-productivity convergence in aggregate Manufacturing is the result of mixed convergence patterns in different manufacturing sectors. Chemicals, Iron and Steel, Non-ferrous Metals and Wood exhibit (strong) convergence, while Machinery shows the opposite pattern of divergence. The sectors Food, Non-Metallic Minerals, Textile, Paper and Transport Equipment display no clear evidence for either convergence or divergence, although the latter shows substantial fluctuations over time. Moreover, it is to be noted that in Chemicals, Iron and Steel, Non-Ferrous Metals and Non-Metallic Minerals convergence of labour-productivity performance is particularly strong during the first half of the 1980s.

[12] Due to limited data availability, the following countries are excluded from the calculation of cross-country dispersion, shown in Figure 3. Food: Australia and Canada; Iron and steel: Japan; Machinery: Canada, Japan, the Netherlands; Transport Equipment: Canada; Non-Ferrous Metals: Denmark; Paper: Australia, Japan; Textile: Canada; Wood: Canada, France, Japan, United Kingdom, United States.

**Figure 3.3a	Standard deviation of log energy productivity in Manufacturing sectors**

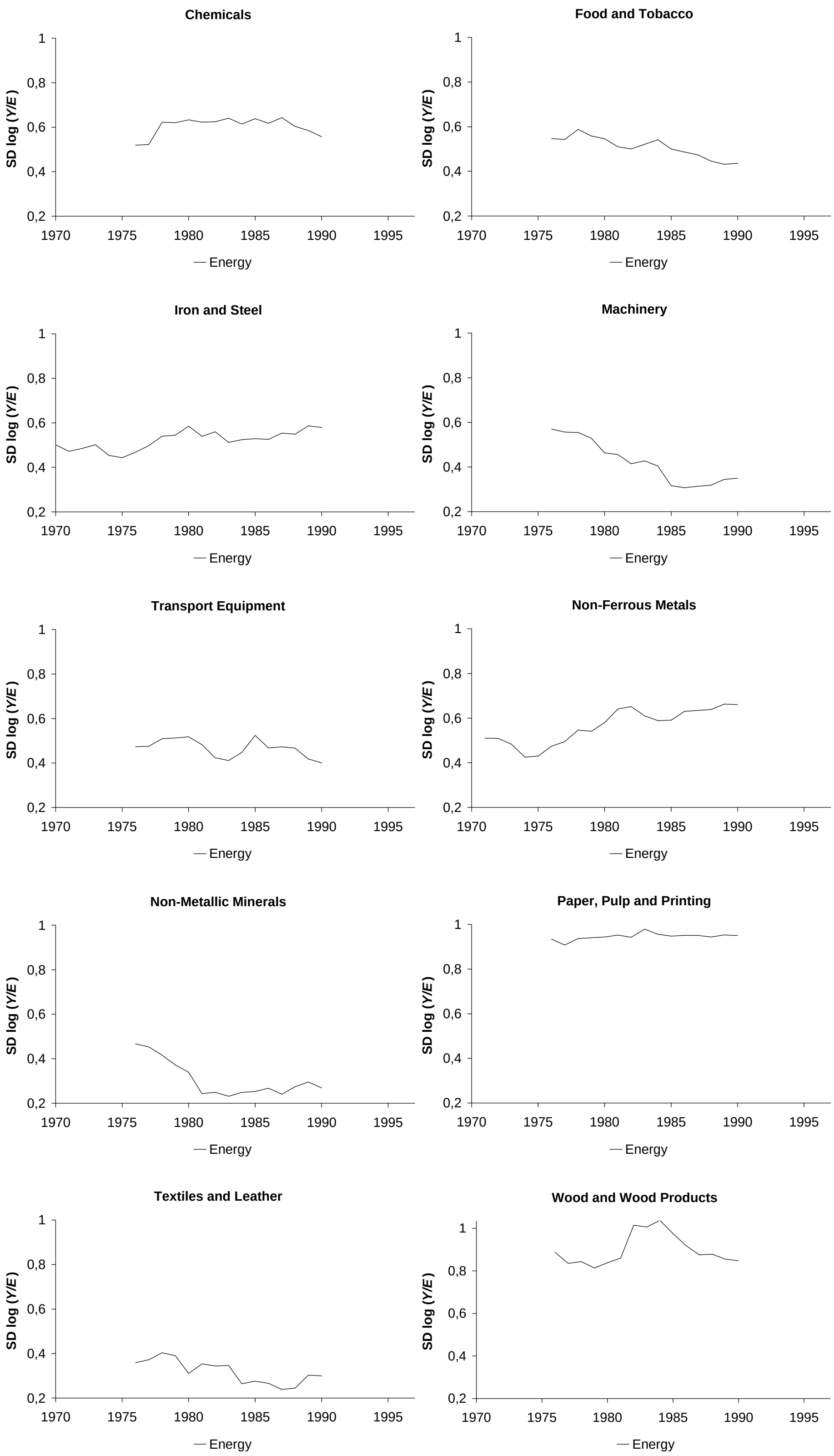
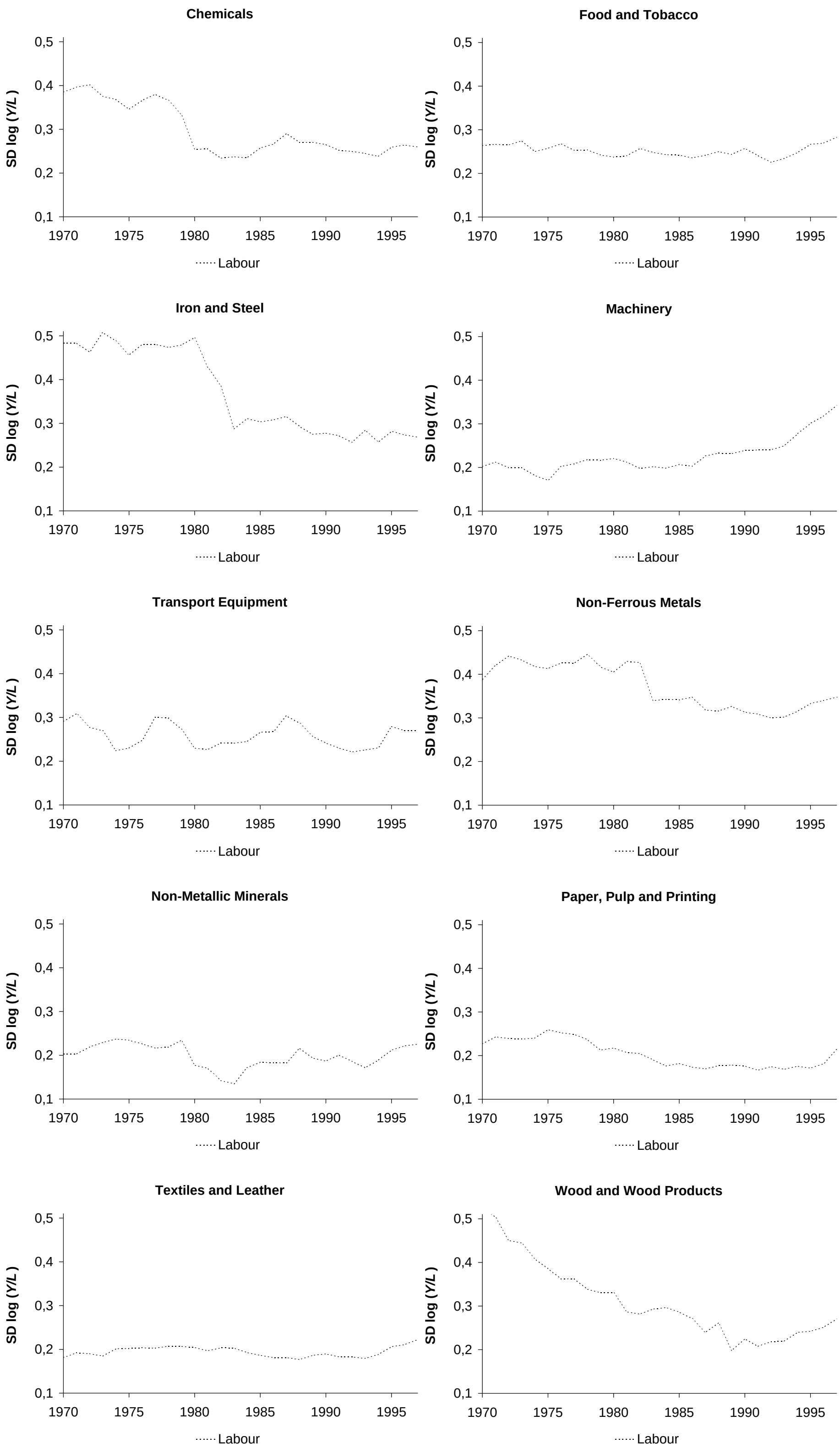


Figure 3.3b Standard deviation of log labour productivity in Manufacturing sectors



In conclusion, we found cross-country variation of energy-productivity performance to be substantially higher than of labour-productivity performance at all levels of sectoral aggregation, and in particular in Services, Chemicals, Paper, Wood and at an ever increasing rate also in Iron and Steel and Non-Ferrous Metals. In Machinery, however, cross-country variation of energy- and labour-productivity differences has strongly converged, resulting in a relatively small – although persistent – difference in the degree of cross-country variance. Moreover, convergence patterns turned out to depend on the level of aggregation, with different sectors displaying varying behaviour: some show reduction in variation, some increasing variation and others neither a clear reduction nor increase over the whole period.

These results suggest that different mechanisms may be at work in the different sectors. For example, the observed patterns of divergence might be the result of increasing international specialisation while the tendency to converge might be caused by technology spill-overs from 'leaders' to 'followers', allowing lagging countries to catch-up. Moreover, our results suggest that determinants of energy-productivity growth and labour-productivity growth might differ from each other, since we found no clear-cut (and sometimes even an opposite) relationship between cross-country convergence patterns in terms of energy productivity and labour productivity. Finally, even in those sectors showing evidence of convergence there remains substantial cross-country productivity differences, in particular in terms of energy productivity. This suggests that convergence does not pertain to a uniform steady state for all countries. In order to further examine this issue, we continue in the next section with a search for empirical regularities in the productivity improvements over our cross-section of countries by testing for sectoral patterns of β-convergence. As part of that analysis we will also try to explain (differences in) energy- and labour-productivity growth.

4 β–Convergence

This section deals with the notion of convergence in terms of growth rates. In this case energy- and labour-productivity convergence implies that energy- and labour-productivity growth rates tend to decline if countries reach their steady states. Obviously, it is not an easy task – if possible at all – to judge whether a country is in its steady state or not. It is possible, however, to analyse the correlation between growth rates and levels, assuming that a negative correlation between these two provides an indication for convergence, because it suggests that being relatively backward in terms of initial level carries a potential for rapid growth. This way of testing for convergence has become known as β-convergence. It may be noted that by definition the notion of β-convergence establishes a link between an interpretation of convergence in terms of growth rates and in terms of levels, implying a close relationship between σ-convergence and β-convergence. In the remainder of this section we adopt a panel-data framework to regress average energy- and labour-productivity growth rates on initial productivity levels, generating an estimate of the coefficient β, for each sector. A negative estimated coefficient β indicates the existence of β-convergence, suggesting that countries with relatively low initial energy- and labour-productivity levels catch-up to more advanced countries. We refer to Appendix B for descriptive statistics of the data used in the subsequent regression analyses.

4.1 Unconditional β-convergence

We start our analysis by testing for unconditional convergence, assuming that energy- and labour productivity converge towards a unique steady-state for all countries included in the data set. We do so by regressing for each sector the growth rate (g) of, respectively, energy- and labour productivity (y), on its initial level (and a constant α), generating an estimate of β, according to:

$$g_{it} = \log(y)_{i,t} - \log(y)_{i,t-1} = \alpha + \beta \ln(y)_{i,t-1} + \varepsilon_{it} \qquad (4.1)$$

with i and t denoting, respectively, the cross-country and the time-series dimension, while ε_{it} is the standard error. Following Islam (1995) we use five-year time intervals in order to reduce the influence of business-cycle fluctuations and serial correlation on the error term. Hence, the growth rate (g) in equation (4.1) is an average over a five-year period (if t = 1975, for example, t–1 = 1970). The results are presented in Table 4.1.

Table 4.1 Unconditional β-convergence

	Energy			Labour		
	β_E	R^2	Implied λ	β_L	R^2	Implied λ
Total	- 0.0368	0.03	0.0075	- 0.1138***	0.30	0.0242
	(0.0246)			(0.0218)		
Agriculture	- 0.3227***	0.33	0.0779	- 0.0575*	0.03	0.0118
	(0.0598)			(0.0300)		
Services	- 0.1432***	0.26	0.0309	- 0.1445***	0.44	0.0312
	(0.0424)			(0.0300)		
Transport	- 0.0827**	0.12	0.0173	- 0.1046**	0.10	0.0221
	(0.0312)			(0.0465)		
Manufacturing	- 0.1524***	0.16	0.0331	- 0.0392	0.00	0.0080
	(0.0459)			(0.0324)		
Chemicals	- 0.0190	0.01	0.0038	- 0.1027***	0.12	0.0217
	(0.0436)			(0.0366)		
Food and Tobacco	- 0.0782**	0.07	0.0163	- 0.1058**	0.12	0.0224
	(0.0385)			(0.0401)		
Iron and Steel	- 0.0442	0.01	0.0090	- 0.1060*	0.05	0.0224
	(0.0557)			(0.0461)		
Machinery	- 0.1729***	0.17	0.0380	- 0.1263**	0.12	0.0270
	(0.0557)			(0.0461)		
Transport Equipment	- 0.3082***	0.21	0.0737	- 0.1480*	0.07	0.0320
	(0.0823)			(0.0834)		
Non-Ferrous Metals	- 0.0153	0.00	0.0031	- 0.0683	0.03	0.0141
	(0.0617)			(0.0494)		
Non-Metallic Minerals	- 0.3156***	0.24	0.0758	- 0.1459***	0.12	0.0315
	(0.0761)			(0.0536)		
Paper, Pulp and Printing	- 0.0435	0.03	0.0089	- 0.0755**	0.06	0.0157
	(0.0355)			(0.0376)		
Textiles and Leather	- 0.3497***	0.19	0.0861	- 0.1577***	0.18	0.0343
	(0.1020)			(0.0433)		
Wood and Wood Products	- 0.0236	0.01	0.0048	- 0.1925***	0.29	0.0428
	(0.0349)			(0.0381)		

Standard errors in parentheses. Asterisks denote levels of significance: *** (1%), ** (5%), * (10%).

From the table it can be seen that we obtain a statistically significant negative estimate of β for energy-productivity growth in most sectors, except for Total (i.e., the macroeconomic level), Chemicals, Iron and Steel, Non-Ferrous Metals, Paper and Wood. In terms of labour-productivity growth we found β to be statistically significant in all sectors, except for aggregate Manufacturing and Non-Ferrous Metals.[13]

These results confirm the findings of Bernard and Jones (1996a) who also report lack of labour-productivity convergence in Manufacturing, weak evidence for convergence in Agriculture and strong evidence in Services. It is to be noted, however, that in most sectors that display evidence of convergence, estimates of β are rather small, indicating that lagging countries catch-up only very slowly. Using the estimated values of β, the rate at which the productivity level is converging to a uniform productivity level can be derived (e.g., Barro and Sala-i-Martin 1992, Mankiw et al. 1992, Islam 1995). Let y^* be the steady state productivity level and $y(t)$ its actual value at any time t. Approximating around the steady state, the speed of convergence is given by

$$\frac{d\log(y(t))}{dt} = \lambda\left[\log\left(y^*\right) - \log(y(t))\right] \tag{4.2}$$

which implies that:

$$\log(y(t)) = \left(1 - e^{-\lambda t}\right)\log\left(y^*\right) + e^{-\lambda t}\log(y(0)) \tag{4.3}$$

where $(y(0))$ is energy- or labour productivity level at some initial date. Subtracting log $(y(0))$ from both sides yields

$$\log(y(t)) - \log(y(0)) = \left(1 - e^{-\lambda t}\right)\left[\log\left(y^*\right) - \log(y(0))\right] \tag{4.4}$$

in which $-(1-e^{-\lambda t})=\beta$. Hence, the speed of convergence, λ, is given by $\lambda = -[1/T \log(\beta+1)]$ with T denoting the time interval under consideration.[14] The values of the implied λ are shown in Table 4.1. They confirm the finding of a slow rate of convergence: the time t needed for energy productivity to move halfway its initial level $(y(0))$ and the steady state y^* varies from 8 years (Textiles) to 225 years (Non-Ferrous metals); the half life for labour productivity lies in between 16 years (Wood) and 87 years (Manufacturing).[15]

[13] We also estimated equation (4.1) including a period-specific fixed effect η_t according to $g_{it} = \alpha + \beta \ln(y)_{i,t-1} + \eta_t + \varepsilon_{it}$. The regression results with these period dummies included do not substantially improve the estimates in most sectors, except for Non-Ferrous Metals and in terms of labour productivity also for Chemicals, Iron and Steel and Machinery. These findings suggest that in spite of a few exceptions, in general there is not much evidence for substantial differences in growth rates between the time periods included. We refer to Table A1 in Appendix A for the regression results.

[14] Since we use five-year time intervals, $T = 5$ in our analysis. Note that in Islam (1995) $\lambda = -[(1/T)\ln(\beta)]$ due to the fact that he takes $\ln(y)_{it}$ instead of $[\ln(y)_{it} - \ln(y)_{it-1}]$ as dependent variable, after rewriting equation (4.4).

[15] The half life (H) is derived from $e^{-\lambda H} = 0.5 \Leftrightarrow H = \ln(2) / \lambda$.

Comparing these results with the sectoral patterns of σ-convergence reveals that those sectors showing evidence of σ-convergence also display evidence of β-convergence. As noted before, this is obvious since there will be no σ-convergence without β-convergence: a decreasing cross-country variation of productivity levels implies by definition that countries with relatively low initial energy- and labour-productivity levels grow relatively fast. However, the opposite is not necessarily true: although β-convergence is a necessary condition for σ-convergence, it is not a sufficient one. This is illustrated for labour productivity by the sectors Machinery, Non-Metallic Minerals and Textiles in that they pass the test for β-convergence without showing evidence of σ-convergence (see Figure 3.3b).

Finally, it is to be noted that the ability of the simple regression equation (4.1) to explain cross-country productivity growth rates is rather small in most sectors. This is not surprising since the specification of equation (4.1) implicitly builds upon the assumption that energy- and labour-productivity levels converge towards a uniform steady state. However, economies differ and so do (most likely) their steady states. Contrary to a framework of single cross-country regressions, a panel data framework is capable of allowing for cross-country differences in steady state functions in the form of unobservable individual 'country-effects' (Islam 1995). These country-effects might include all sorts of country-specific tangible and intangible factors that affect productivity growth and which have not been included in equation (4.1) or, to state it differently, have been subsumed in its error term. Therefore, in the next section we test for β-convergence allowing for these 'country-effects'.

4.2 Conditional *β*-convergence

Including individual country-effects in equation (4.1) implies that we test for conditional β-convergence, assuming productivity levels converge to multiple steady-states that are conditional on country-specific characteristics. We do so by reformulating equation (4.1) into a panel data model with individual country effects, as follows:

$$g_{it} = \log(y)_{i,t} - \log(y)_{i,t-1} = \beta \ln(y)_{i,t-1} + \mu_i + \varepsilon_{it} \qquad (4.5)$$

with μ_i representing unspecified country-specific (fixed) effects. In Table 4.2 we present for each sector, the estimated coefficient β obtained from equation (4.5).

Table 4.2 Unconditional β-convergence

	Energy			Labour		
	β_E	R^2	Implied λ	β_L	R^2	Implied λ
Total	- 0.2214***	0.19	0.0501	- 0.1068***	0.58	0.0226
	(0.0691)			(0.0262)		
Agriculture	- 0.4797***	0.49	0.1307	- 0.0831*	0.22	0.0174
	(0.0888)			(0.0431)		
Services	- 0.2181**	0.44	0.0492	- 0.1783***	0.80	0.0393
	(0.1169)			(0.0422)		
Transport	- 0.6301***	0.42	0.1989	- 0.1040	0.16	0.0220
	(0.1593)			(0.1115)		
Manufacturing	- 0.6162***	0.67	0.1915	- 0.0553	0.16	0.0114
	(0.0680)			(0.0382)		
Chemicals	- 0.2620***	0.33	0.0608	- 0.0929*	0.29	0.0195
	(0.0836)			(0.0484)		
Food and Tobacco	- 0.5180***	0.36	0.1460	- 0.1879***	0.49	0.0416
	(0.1292)			(0.0542)		
Iron and Steel	- 0.3889***	0.32	0.0985	- 0.0642	0.11	0.0133
	(0.1113)			(0.1055)		
Machinery	- 0.2305*	0.31	0.0524	- 0.0549	0.45	0.0113
	(0.1365)			(0.0499)		
Transport Equipment	- 0.9504***	0.68	0.6008	- 0.3104**	0.23	0.0743
	(0.1127)			(0.1253)		
Non-Ferrous Metals	- 0.5924***	0.38	0.1795	- 0.0439	0.10	0.0090
	(0.1426)			(0.0932)		
Non-Metallic Minerals	- 0.5087***	0.55	0.1421	- 0.2089***	0.39	0.0469
	(0.0980)			(0.0635)		
Paper, Pulp and Printing	- 0.6513***	0.60	0.2107	- 0.1053	0.24	0.0223
	(0.1033)			(0.0783)		
Textiles and Leather	- 0.8612***	0.60	0.3949	- 0.2330***	0.33	0.0531
	(0.1285)			(0.0545)		
Wood and Wood Products	- 1.0637***	0.60	--	- 0.2298***	0.47	0.0522
	(0.1941			(0.0650)		

Standard errors in parentheses. Asterisks denote levels of significance: *** (1%), ** (5%), * (10%).

The table shows that allowing for individual country-effects substantially improves the explanatory power of the regression equations for both energy- and labour productivity. Moreover, in terms of energy productivity, equation (4.5) yields significantly negative estimates of β in all sectors, including now also Total (i.e., the macroeconomic level), Chemicals, Iron and Steel, Non-Ferrous Metals and Machinery. Also in terms of labour productivity the estimates of β are higher in several sectors such as, for example, Services and Food. The evidence on conditional labour-productivity convergence is, however, less clear-cut than it is for energy-productivity convergence: in some sectors such as, for example, Iron and Steel and Machinery, allowing for individual country-effects in explaining labour-productivity growth yields statistically less significant or even insignificant estimates of β.

This suggests that in terms of labour productivity the variation in explanatory variables over time is relatively small as compared to cross-country differences, since correcting for the latter by means of including country-specific intercepts results in weaker evidence of a negative relationship between the initial labour productivity level and its growth over time. Nevertheless, the regression results suggest that both energy- and labour-productivity convergence depend to a large extent on individual country-effects, indicating energy- and labour productivity to be conditional rather than absolute in virtually all sectors. This is illustrated by the fact that the speed of conditional convergence is substantially higher than of unconditional convergence: for energy productivity the half life that follows from the implied λ now lies between 1 year (Transport Equipment) and 14 years (Total) and for labour productivity it has been reduced to a period in between 47 years (Transport Equipment) and 77 years (Non-Ferrous Metals).

Of course, this brings back the question as to which are the country-specific variables driving energy- and labour-productivity growth and, hence, determining the country-specific steady states? Recall from the introduction that several mechanisms may be at work, causing 'followers' to grow faster than 'leaders': advanced economies may suffer from diminishing returns, lagging countries may benefit from knowledge spill-overs, production processes may convergence due to increasing competition, etcetera.

In order to explain (persistent) differences in cross-country energy- and labour-productivity growth we replace in equation (4.5) the unspecified country-effects μ_i by a number of country-specific explanatory variables x_i^j , according to:

$$g_{it} = \log(y)_{i,t} - \log(y)_{i,t-1} = \alpha + \beta \ln(y)_{i,t-1} + \sum_{j=1}^{5} \gamma_j x_{it}^j + \varepsilon_{it} \qquad (4.6)$$

The specified explanatory variables are defined at the sectoral level and include:

Energy prices: $x_{it}^{1a} = \frac{(p_{E,t} + p_{E,t-1} + p_{E,t-2})}{3}$

Wages: $x_{it}^{1b} = \frac{(w_t + w_{t-1} + w_{t-2})}{3}$

Investment share: $x_{it}^{2} = \frac{I}{Y}$

Openness: $x_{it}^{3} = \frac{XGS + MGS}{Y}$

Balassa index: $x_{it}^{4} = \frac{XGS_i \Big/ \sum_{i=1}^{14} XGS_i}{\sum_{s=1}^{10} XGS_{i,s} \Big/ \sum_{i=1}^{14}\sum_{s=1}^{10} XGS_{i,s}}$

Economies of scale: $x_{it}^{5} = \frac{Y}{\sum_{s=1}^{13} Y}$

where sectoral indices are omitted for reasons of expositional clarity and with energy prices (x_{it}^{1a}) or wages (x_{it}^{1b}) included, respectively, in case of explaining energy-productivity growth or labour-productivity growth. We expect energy prices and wages to be positively correlated with, respectively, energy- and labour-productivity growth. We took a three-year moving average for the energy price and wages to avoid capturing the effect of short-term price fluctuations, assuming that investments in energy- and labour-augmenting technologies do respond to a structural trend in energy price/wage developments rather than to short term fluctuations. By including the investment share as an explanatory variable we test for the so-called embodiment hypothesis or vintage effect, assuming that higher investment will contribute to increasing energy- and labour-productivity growth via technological change embodied in new capital goods (see, for example, Howarth et al. 1991 and Mulder et al. 2003). We expect Openness to have a positive impact on productivity growth, since an open sector faces relatively strong competition as well as exchange of knowledge, which we both assume to have a stimulating effect on productivity growth. The Balassa index is an indictor measuring relative specialisation patterns. We expect that if a country specialises in a particular sector, that sector will be technologically relatively advanced, and hence we expect a positive effect on productivity. Finally, including an indicator for the relative size of a sector within a country captures the potential effect of economies of scale on productivity growth, assuming that a large sector is able to invest relatively much in R&D and in new capital goods and, hence, might be a technological leader displaying relatively high productivity growth rates.

The results of regressing average energy productivity growth rates on initial energy productivity levels and these additional explanatory variables are presented in Table 4.3.[16]

[16] We also controlled for different specifications of energy prices (current prices, 5-year moving average, and log 3-year and log 5-year moving average), investment share ($(I/Y)_{t-1}$, (I/K), $(I/K)_{t-1}$ and $\ln(I/K)_{t-1}$), as well as an interaction term of investment share and log initial energy productivity ($\ln(Y/E)_0 * (I/Y)$). All these specifications did not substantially alter the estimates. Details are available upon request.

Table 4.3 Conditional *β*-convergence energy productivity, specified

	β	Energy Price	Investment share	Open	Balassa	Value added share	R^2	*F*-stat	Implied *λ*
Agriculture	- 0.1995*	0.0394	- 1.0158			- 2.2995	0.15	1.10	0.0445
	(0.1136)	(0.7225)	(0.8969)			(2.1086)			
Services	- 0.2296	- 0.0147	0.0714			0.3858	0.45	2.25	0.0522
	(0.1791)	(0.5612)	(0.918)			(0.9388)			
Transport	- 0.2350***	0.1168	0.7991**			4.1693**	0.46	3.87	0.0536
	(0.0655)	(0.1439)	(0.3266)			(1.6905)			
Chemicals	- 0.0820	1.3526**	0.9093	- 0.0427	0.1631	- 4.8405	0.28	1.39	0.0171
	(0.0819)	(0.5008)	(1.2271)	(0.0335)	(0.1661)	(8.5819)			
Food	- 0.1211	0.2130	- 0.5277	- 0.0432	0.0113	5.5691	0.35	1.79	0.0258
	(0.0745)	(0.4951)	(0.9092)	(0.0363)	(0.0308)	(3.829)			
Iron and Steel	- 0.3377**	1.9263**	- 0.8636	- 0.0251	0.0068	- 9.5859	0.44	2.79	0.0824
	(0.1252)	(0.7689)	(0.7094)	(0.0184)	(0.1095)	(10.7085)			
Machinery	- 0.2042***	0.4170	0.7337	0.0131	- 0.1112	2.3311	0.43	2.48	0.0457
	(0.0684)	(0.4823)	(1.7063)	(0.0345)	(0.1997)	(1.6439)			
Transport Equipment	- 0.2855	- 0.1642	0.4689	0.0011	0.2225	- 8.1921	0.25	0.79	0.0672
	(0.1888)	(0.729)	(1.6648)	(0.0472)	(0.2079)	(13.7238)			
Non-Ferrous Metals	- 0.0844	0.3943	0.0573	- 0.0307	- 0.0943	- 0.4460	0.20	0.75	0.0176
	(0.2229)	(0.5285)	(0.2724)	(0.0208)	(0.1549)	(36.3853)			
Non-Metallic Minerals	- 0.4561***	1.8238	0.0505	- 0.0336	0.2064	- 36.2293*	0.32	1.63	0.1218
	(0.1611)	(1.0916)	(1.1821)	(0.1062)	(0.2016)	(20.1039)			
Paper	- 0.1118*	0.6632**	- 0.8569	- 0.0740	- 0.0643	7.5805	0.47	2.76	0.0237
	(0.0613)	(0.3052)	(0.8666)	(0.0527)	(0.0723)	(6.1778)			
Textiles	- 0.3656*	- 0.4195	0.3092	- 0.0497	0.2136	- 11.7071	0.29	1.29	0.0910
	(0.2053)	(0.783)	(3.1265)	(0.0368)	(0.2621)	(19.7875)			
Wood	- 0.4686	- 0.8418	- 2.7443	- 0.1293*	0.0229	- 53.1902	0.51	1.23	0.1264
	(0.3351)	(0.5508)	(2.2403)	(0.0699)	(0.0667)	(34.2262)			

Standard errors in parentheses. Asterisks denote levels of significance: *** (1%), ** (5%), * (10%).

It can be seen that the regression analysis generates significantly negative estimates of β in Agriculture, Transport, Iron and Steel, Machinery, Non-Metallic Minerals, Paper and Textiles. Compared to Table 4.2 this means that in 6 sectors the estimate of β is no longer statistically significant once we include the above-mentioned specified explanatory variables. The effect of investment share, openness, specialisation, and economies of scale on energy productivity growth is mixed and their impact is statistically insignificant in virtually all sectors. An exception is the energy-price effect, which has in all sectors the expected (positive) sign, while the positive impact of energy prices on energy-productivity growth is statistically significant in Chemicals, Iron and Steel and Paper – which makes sense since these are energy intensive sectors. Finally, the speed of convergence has slowed down with the half life increased to a minimum of 5 years (Wood) and a maximum of 41 years (Chemicals).

In Table 4.4 we present the results of regressing average labour-productivity growth rates on initial labour-productivity levels and the five additional explanatory variables, according to equation (4.6).

Table 4.4	Conditional *β*-convergence labour productivity, specified								
	β	Wage	Investment share	Open	Balassa	Value added share	R^2	*F*-stat	Implied *λ*
Agriculture	- 0.1050**	0.0315	- 0.6869**			0.2704	0.24	2.48	0.0222
	(0.0456)	(0.4028)	(0.3014)			(0.8205)			
Services	0.0450	0.0032	0.1665			- 0.6100***	0.70	8.07	- 0.0088
	(0.0616)	(0.0028)	(0.1467)			(0.2173)			
Transport	- 0.1778	0.0805	0.1422			0.9614	0.19	1.26	0.0392
	(0.1123)	(0.1180)	(0.3348)			(1.8576)			
Chemicals	- 0.1037	0.1050	- 0.1674	- 0.0111	0.0978	- 2.8729	0.20	1.21	0.0219
	(0.076)	(0.2568)	(0.3365)	(0.0196)	(0.0951)	(4.5006)			
Food	- 0.2054**	0.2028	- 0.3856	0.0167	- 0.0003	- 0.8228	0.33	2.22	0.0460
	(0.0822)	(0.1436)	(0.5348)	(0.0258)	(0.0212)	(2.5040)			
Iron and Steel	- 0.1224	- 0.2134	- 0.6313**	0.0074	0.0554	- 4.4848	0.34	2.44	0.0261
	(0.0748)	(0.5454)	(0.2447)	(0.0113)	(0.1089)	(7.5135)			
Machinery	- 0.0360	0.0227	- 2.9856	0.0183	- 0.1914	- 0.3505	- 0.14	0.53	0.0073
	(0.1253)	(0.1023)	(1.8858)	(0.0328)	(0.2035)	(1.2179)			
Transport Equipment	0.3188	- 0.8364	- 1.3317*	- 0.0106	0.5252	- 8.1424	0.51	1.20	- 0.0553
	(0.3182)	(0.6482)	(0.7010)	(0.0188)	(0.3654)	(6.8885)			
Non-Ferrous Metals	- 0.0531	- 0.5926	- 0.0312	0.0085	- 0.0279	21.6064	0.10	0.52	0.0109
	(0.0672)	(1.2052)	(0.1540)	(0.0114)	(0.0575)	(25.3957)			
Non-Metallic Minerals	- 0.1192	0.0392	- 0.6816	0.0169	- 0.0028	5.3651	0.12	0.61	0.0254
	(0.1140)	(0.5893)	(0.5820)	(0.0629)	(0.0968)	(10.2905)			
Paper	- 0.0946	0.0711	- 0.7480	0.0504	0.0047	3.1122	0.37	2.63	0.0199
	(0.1009)	(0.1254)	(0.4340)	(0.0378)	(0.0208)	(2.9214)			
Textiles	- 0.2539***	0.0173	0.3843	- 0.0194	- 0.0088	- 4.8024	0.46	3.88	0.0586
	(0.0755)	(0.2092)	(1.1500)	(0.0158)	(0.078)	(6.2200)			
Wood	- 0.1102	- 0.2230	- 0.8868**	- 0.0175	- 0.0030	8.9504	0.30	1.65	0.0234
	(0.1214)	(0.7199)	(0.4077)	(0.0321)	(0.0155)	(6.0659)			

Standard errors in parentheses. Asterisks denote levels of significance: *** (1%), ** (5%), * (10%).

Table 4.4 shows statistically significantly negative estimates of β for Agriculture, Food and Textiles only. Similar to energy-productivity growth, the effect of the investment share, openness, specialisation, and economies of scale on labour-productivity growth is mixed while their impact is statistically insignificant in virtually all sectors (or it is statistically significant with an unexpected sign such as, for example, in case of the 'vintage effect' in Agriculture, Iron and Steel, Transport Equipment and Wood, and economies of scale in Services). Finally, the speed of convergence has slowed down with the half life increasing to in between 12 years (Textiles) and 95 years (Machinery), while for Services the estimate yields a positive β, implying divergence.

In sum, while there is strong evidence of conditional convergence in terms of both energy- and labour-productivity growth (see Table 4.2), we found energy prices and in particular wages, investment share, openness, specialisation and economies of scale to play only a limited role in explaining energy- and labour-productivity growth and, hence, in determining cross-country productivity differentials. The results shown in Tables 4.3 and 4.4 might suffer from an omitted variable bias if the included explanatory variables are correlated with the unspecified country-effects μ_i, which are excluded from equation (4.6). Hence, to correct for this potential bias, we add the unspecified individual country-effects to equation (4.6), according to

$$g_{it} = \log(y)_{i,t} - \log(y)_{i,t-1} = \beta \ln(y)_{i,t-1} + \sum_{j=1}^{5} \gamma_j x_{it}^{j} + \mu_i + \varepsilon_{it} \tag{4.7}$$

The results for energy-productivity growth are presented in Table 4.5. It can be seen that adding the unspecified country effects affects the estimates substantially. The estimation results in Table 4.5 show that except for Food, Non-Ferrous Metals and Wood all sectors yield a statistically significant estimate of β, with regression equation (4.7) displaying a much better goodness of fit in most sectors than equation (4.6) (see Table 4.3). Except for Food and Non-Ferrous Metals, the speed of convergence has increased considerably as compared to Table 4.3 with the half-life between 1 and 5 years in all other sectors. The statistically significant energy-price effect is robust in Iron and Steel and Paper, while in Chemicals the null hypothesis of no effect is only just rejected at the 10% level. In addition, energy prices also seem to have a statistically significant positive effect on energy-productivity growth in Services and Textiles. The impact of the other explanatory variables on energy-productivity growth remains mixed, with economies of scale having the largest statically significant effect on energy productivity growth, being positive in Services, Chemicals and Transport Equipment, while negative in Textiles. We found the vintage effect and openness to have a statistically significant positive effect in Transport Equipment only, while for specialisation this is only the case in Iron and Steel.

Table 4.5 Conditional *β*-convergence energy productivity, specified, fixed effects

	β	Energy Price	Investment share	Open	Balassa	Value added share	R^2	*F*-stat	Implied *λ*
Agriculture	- 0.8615***	1.3546	0.2182			12.3662	0.64	9.54	0.3954
	(0.1965)	(1.1801)	(1.1274)			(7.6932)			
Services	- 0.8039***	1.1183*	- 0.5308			7.1791**	0.81	9.88	0.3258
	(0.238)	(0.6375	(0.7828)			(3.2129)			
Transport	- 0.5122*	0.0540	- 0.0171			16.8394	0.80	15.84	0.1436
	(0.2604)	(0.1633)	(0.3651)			(4.3809)			
Chemicals	- 0.7638***	0.7270	1.7622	0.0023	- 0.4818	76.7954***	0.88	19.29	0.2886
	(0.1475)	(0.4416)	(1.0992)	(0.0323)	(0.3812)	(13.9899)			
Food	- 0.0403	1.0346	- 0.5494	- 0.2596**	- 0.5764	- 0.7585	0.63	4.13	0.0082
	(0.3799)	(0.7692)	(1.0185)	(0.1147)	(0.394)	(10.9498)			
Iron and Steel	- 0.8670***	3.8639***	- 1.3162**	0.0052	0.9330***	- 5.4317	0.85	14.58	0.4035
	(0.1679)	(1.2861)	(0.6329)	(0.031)	(0.2287)	(18.3749)			
Machinery	- 0.5964**	- 0.3718	3.8541	0.1009	0.6565	3.7735	0.66	4.62	0.1815
	(0.2732)	(1.1718)	(3.208)	(0.0971)	(0.8200)	(5.8699)			
Transport Equipment	- 1.1444***	-1.6712***	3.4196**	0.2016***	0.2657	57.3976**	0.84	8.30	---
	(0.2930)	(0.5916)	(1.4195)	(0.0718)	(0.5175)	(26.7348)			
Non-Ferrous Metals	- 0.0262	0.5837	0.0350	- 0.0494	0.0833	132.9891	0.56	2.76	0.0053
	(0.2872)	(1.1114)	(0.429)	(0.0552)	(0.2178)	(80.1969)			
Non-Metallic Minerals	- 0.9527***	0.2167	1.3573	0.0321	- 0.1779	- 17.6544	0.80	10.53	0.6102
	(0.1758)	(1.593)	(1.2800)	(0.1503)	(0.2079)	(32.8798)			
Paper	- 0.4712**	1.0724*	- 0.9484	- 0.0681	- 0.0111	- 5.335	0.73	5.91	0.1274
	(0.2015)	(0.567)	(1.0232)	(0.1107)	(0.0879)	(19.1876)			
Textiles	- 0.7502***	2.4389*	3.1294	- 0.1738***	0.3466	- 49.3355**	0.79	8.35	0.2774
	(0.2705)	(1.284)	(2.6318)	(0.0544)	(0.2923)	(21.5613)			
Wood	- 0.5676	- 0.9473	- 0.1751	- 0.1839	0.0299	68.6120	0.82	1.76	0.1677
	(1.8578)	(1.054)	(6.9099)	(0.4739)	(0.1620)	(333.4143)			

Standard errors in parentheses. Asterisks denote levels of significance: *** (1%), ** (5%), * (10%).

In Table 4.6 we present the regression results of equation (4.7) for labour productivity. It can be seen that in most sectors labour-productivity growth is also better explained if we account for country-specific fixed effects. Moreover, the speed of convergence increased in most sectors as compared to Table 4.4, with the half-life between 4 years (Transport) and 36 years (Agriculture), and with Machinery as the most important exception (with its half life increasing to 367 years). Table 4.6 shows that wages have a statistically significant positive effect on labour-productivity growth in Agriculture and Textiles, while this is negative in Transport Equipment. Moreover, similar to energy-productivity growth, the impact of the other explanatory variables on labour-productivity growth remains mixed, with economies of scale having again the largest statistically significant effect, being positive in Transport, Non-Ferrous Metals and Paper, while it is again negative in Textiles. We found openness to have a statistically significant positive effect in Paper only, while for specialisation this is again only the case in Iron and Steel. Finally, the results do not give any support to the vintage effect, with the only statistically significant estimates displaying a negative sign.

Table 4.6 Conditional β-convergence labour productivity, specified, fixed effects

	β	Energy Price	Investment share	Open	Balassa	Value added share	R^2	F-stat	Implied λ
Agriculture	- 0.0915	1.3847*	- 0.7385*			- 0.2200	0.57	10.11	0.0192
	(0.0595)	(0.8037)	(0.3722)			(2.8331)			
Services	- 0.1663	- 0.0038	- 0.0671			0.0866	0.83	16.20	0.0364
	(0.1190)	(0.0077)	(0.1744)			(0.8378)			
Transport	- 0.5373***	0.4192	- 0.4716			21.6825***	0.74	14.90	0.1541
	(0.1551)	(0.3580)	(0.3011)			(4.0113)			
Chemicals	- 0.6136***	0.5821	- 0.2272	0.0169	0.0073	58.5063	0.65	7.97	0.1902
	(0.1461)	(0.5868)	(0.3363)	(0.0278)	(0.2747)	(15.9523)			
Food	- 0.1863	0.2232	- 0.6493	- 0.0319	- 0.1722	- 2.4415	0.42	2.72	0.0412
	(0.1945)	(1.3284)	(0.8939)	(0.0831)	(0.3118)	(6.809)			
Iron and Steel	- 0.4745***	- 2.3347	- 0.8303***	0.0411	0.3912**	- 8.8493	0.64	7.40	0.1287
	(0.1462)	(1.7504)	(0.2629)	(0.0325)	(0.1807)	(14.9038)			
Machinery	- 0.0094	0.1354	- 0.9026	- 0.0432	0.0462	4.8580	0.90	5.50	- 0.0663
	(0.1600)	(0.1573)	(1.3723)	(0.0379)	(0.4437)	(3.6685)			
Transport Equipment	0.3931	- 2.9548**	- 0.9192	0.0180	0.8165	5.9757	0.90	5.50	- 0.0663
	(0.2863)	(1.3232)	(0.6803)	(0.0262)	(0.6111)	(12.0548)			
Non-Ferrous Metals	- 0.1292	0.4453	- 0.0765	0.0192	- 0.0522	99.8361*	0.28	1.65	0.0277
	(0.1562)	(9.2387)	(0.2227)	(0.0231)	(0.1578)	(59.341)			
Non-Metallic Minerals	- 0.4089*	0.9708	- 0.7470	0.1170	- 0.3337	5.4763	0.36	2.15	0.1052
	(0.2234)	(5.8474)	(0.7213)	(0.1174)	(0.3058)	(21.5337)			
Paper	- 0.3015*	0.2964	0.2624	0.0966**	0.0173	30.0144***	0.77	12.57	0.0718
	(0.1693)	(0.6340)	(0.4128)	(0.0450)	(0.0381)	(5.6951)			
Textiles	- 0.5183***	2.8072*	1.1598	- 0.0426**	- 0.1660	- 23.1631**	0.69	8.41	0.1461
	(0.1459)	(1.5751)	(1.2021)	(0.0204)	(0.1246)	(10.8028)			
Wood	- 0.1014	- 0.4483	- 1.3205**	0.0001	- 0.0080	26.0902	0.78	11.51	0.0214
	(0.1266)	(1.6638)	(0.3985)	(0.0348)	(0.0210)	(17.3229)			

Standard errors in parentheses. Asterisks denote levels of significance: *** (1%), ** (5%), * (10%).

In sum, most sectors display evidence of energy-productivity convergence, while several sectors show also evidence of labour-productivity convergence. Moreover, the speed of energy-productivity convergence is in general higher than the speed of labour-productivity convergence, in particular if we account for unspecified country-effects. These findings support the hypothesis that lagging countries tend to catch up with technological leaders, in particular in terms of energy productivity.

5 Conclusions

The introduction of new or endogenous growth theories generated renewed interest in the question of whether income- and/or productivity levels across countries tend to converge, for example, due to capital accumulation or technology transfers. In this paper we added to the existing empirical analyses of convergence patterns a systematic comparison of energy- and labour-productivity convergence at a detailed sectoral level for 14 OECD countries, covering the period 1970-1997. We found cross-country differences in energy-productivity levels to be substantially larger than cross-country differences in labour-productivity levels at all levels of sectoral aggregation. A σ-convergence analysis revealed that the development of the cross-country variation in productivity performance depends on the level of aggregation, with different patterns of productivity convergence and divergence across sectors. At the macroeconomic level we found evidence of energy-productivity divergence, driven by aggregate Manufacturing, as well as labour-productivity convergence, mainly driven by Services. It is the Iron and Steel and Non-Ferrous Metals sectors that drive energy-productivity divergence in aggregate Manufacturing. Moreover, despite a lack of evidence of labour-productivity convergence at the aggregate Manufacturing level, there is evidence of labour-productivity convergence in several Manufacturing sub-sectors, with Machinery as the most important exception in that it shows a clear pattern of divergence (in particular after 1985).

Using a panel-data approach, we found energy productivity in most sectors to grow relatively fast in countries with relatively low initial productivity levels, while in several sectors this is also true for labour productivity. This evidence of β-convergence supports the hypothesis that being relatively backward in productivity carries a potential for rapid advance, in particular in terms of energy productivity. Furthermore, the results have shown convergence to be conditional on cross-country differences in steady-state characteristics, rather than to be unconditional with productivity levels converging to a uniform steady state for all countries. In our search for the fundamentals determining these country-specific steady states, we found energy prices to stimulate energy-productivity growth in the energy–intensive sectors while we did not find much evidence of a positive relationship between wages and labour-productivity growth. Moreover, we found economies of scale to contribute to energy- and labour-productivity growth in several sectors, while investment share, openness and specialisation play only a very limited role in explaining (cross-country) differences in energy- and labour-productivity growth.

Combined with the observed important role of unspecified country-effects, these findings suggest a need for additional variables, such as for example Research & Development and human capital, in order to further explain sectoral trends in energy- and labour-productivity growth across countries. The need for further exploration of sectoral trends is also supported by the fact that in spite of the evidence that lagging countries tend to catch up with technological leaders, there remains substantial cross-country productivity differentials, in particular in terms of energy productivity. Finally, since productivity growth is primarily driven by technological change, our results suggest that patterns of international technology flows do exist, while at the same time they seem to be limited and at least to some extent sector-specific.

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Appendix A

Table A1 Unconditional β-convergence, with inclusion of period dummies

	Energy			Labour		
	β_E	R^2	Implied λ	β_L	R^2	Implied λ
Total	- 0.0193	0.26	0.0039	- 0.1127***	0.28	0.0239
	(0.0223)			(0.0233)		
Agriculture	- 0.3109***	0.38	0.0745	- 0.0636*	0.07	0.0131
	(0.0585)			(0.0372)		
Services	- 0.1427***	0.35	0.0308	- 0.1209***	0.53	0.0258
	(0.0445)			(0.0331)		
Transport	- 0.0832***	0.25	0.0174	- 0.1665***	0.39	0.0364
	(0.0301)			(0.0462)		
Manufacturing	- 0.1500***	0.12	0.0325	- 0.0311	0.01	0.0063
	(0.0474)			(0.0350)		
Chemicals	- 0.0172	0.10	0.0035	- 0.1678***	0.33	0.0367
	(0.0452)			(0.0484)		
Food and Tobacco	- 0.0804**	0.18	0.0168	- 0.0755	0.18	0.0157
	(0.0377)			(0.0486)		
Iron and Steel	- 0.0489	0.08	0.0100	- 0.1965***	0.40	0.0438
	(0.0520)			(0.0540)		
Machinery	- 0.1969***	0.31	0.0439	- 0.2172***	0.25	0.0490
	(0.0544)			(0.0623)		
Transport Equipment	- 0.2833***	0.31	0.0666	- 0.1534	0.26	0.0333
	(0.0808)			(0.0951)		
Non-Ferrous Metals	- 0.0243	0.30	0.0049	- 0.1369**	0.25	0.0294
	(0.0551)			(0.0517)		
Non-Metallic Minerals	- 0.3002***	0.33	0.0714	- 0.1639**	0.15	0.0358
	(0.0764)			(0.0777)		
Paper, Pulp and Printing	- 0.0417	0.21	0.0085	- 0.0796*	0.22	0.0166
	(0.0336)			(0.0401)		
Textiles and Leather	- 0.3204***	0.33	0.0773	- 0.1351**	0.24	0.0290
	(0.0998)			(0.0731)		
Wood and Wood Products	- 0.0180	0.19	0.0036	- 0.2028***	0.32	0.0453
	(0.0343)			(0.0461)		

Standard errors in parentheses. Asterisks denote levels of significance: *** (1%), ** (5%), * (10%).

Appendix B

Table B1 **Total**

	ln (Y/E)	ln (Y/L)	ln (Y)
Mean	1.50	10.39	26.22
Median	1.55	10.39	26.29
Maximum	2.14	10.91	29.31
Minimum	0.66	9.65	23.96
Std. Dev.	0.34	0.26	1.39
Skewness	- 0.22	- 0.28	0.18
Kurtosis	2.37	2.66	2.10
Observations	300	339	355

Table B2 **Manufacturing**

	ln (Y/E)	ln (Y/L)	ln (Y)
Mean	0.99	10.35	24.97
Median	0.94	10.33	24.70
Maximum	1.89	11.24	27.98
Minimum	- 0.85	9.70	22.78
Std. Dev.	0.52	0.31	1.41
Skewness	- 0.30	0.11	0.20
Kurtosis	2.72	2.41	1.89
Observations	328	385	386

Table B3 **Agriculture**

	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Y_i/Y
Mean	15.66	9.70	23.04	0.04	0.23	0.25	0.04
Median	15.68	9.73	23.05	0.02	0.22	0.24	0.04
Maximum	18.45	10.74	25.58	0.39	0.45	0.51	0.14
Minimum	14.20	8.44	21.24	0.00	0.08	0.08	0.02
Std. Dev.	0.52	0.46	1.14	0.06	0.08	0.07	0.02
Skewness	0.43	- 0.22	0.29	2.82	0.38	0.66	1.66
Kurtosis	6.12	2.73	1.97	13.11	2.69	3.56	5.85
Observations	344	370	382	366	279	349	217

Table B4	**Services**						
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Y_i/Y
Mean	16.80	10.54	25.71	2.34	0.47	0.29	0.52
Median	16.79	10.52	25.93	0.60	0.39	0.28	0.52
Maximum	18.06	10.91	28.93	18.65	1.22	0.52	0.68
Minimum	15.51	9.88	23.08	0.05	0.19	0.14	0.36
Std. Dev.	0.60	0.22	1.46	4.49	0.23	0.08	0.08
Skewness	0.14	- 0.43	0.23	2.28	1.21	0.48	- 0.01
Kurtosis	2.27	3.03	2.48	6,86	3.60	2.85	2.33
Observations	214	184	245	179	279	155	217

Table B5	**Transport**						
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Y_i/Y
Mean	13.54	10.41	23.47	0.20	0.22	0.29	0.06
Median	13.66	10.42	23.56	0.08	0.20	0.29	0.05
Maximum	14.41	11.13	26.13	1.48	0.92	0.54	0.11
Minimum	12.56	9,39	21.52	0.01	0.00	0.13	0.04
Std. Dev.	0.43	0.32	1.14	0.31	0.11	0.08	0.02
Skewness	- 0.65	- 0.36	0.28	2.54	2.99	0.17	0.74
Kurtosis	2.44	3.18	2.48	8.58	17.37	2.41	3.03
Observations	297	262	300	257	281	239	217

Table B6	**Chemicals**								
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Open	Balassa	Y_i/Y
Mean	13.65	10.73	22.52	0.08	0.28	0.24	2.45	0.94	0.02
Median	13.71	10.75	22.53	0.03	0.29	0.20	2.02	0.94	0.02
Maximum	15.68	11.75	25.60	0.57	0.56	0.94	9.58	1.91	0.13
Minimum	12.26	9.17	19.57	0.00	0.00	0.11	0.10	0.29	0.01
Std. Dev.	0.65	0.45	1.55	0.12	0.10	0.12	1.82	0.37	0.01
Skewness	0.39	- 0.41	- 0.01	2.47	- 0.26	2.40	0.93	0.43	5.72
Kurtosis	3.54	3.43	1.96	9.00	3.87	10.48	3.45	2.55	59.28
Observations	347	343	364	344	287	298	345	351	218

Table B7	**Food**								
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Open	Balassa	Y_i/Y
Mean	15.66	10.53	23.04	0.11	0.37	0.15	1.15	1.28	0.04
Median	15.72	10.56	23.16	0.06	0.34	0.15	0.71	0.97	0.04
Maximum	16.69	11.20	25.54	0.59	0.99	0.30	5.48	5.10	0.14
Minimum	14.55	9.56	20.99	0.01	0.20	0.08	0.04	0.06	0.02
Std. Dev.	0.50	0.30	1.34	0.14	0.13	0.05	1.16	1.14	0.01
Skewness	0.09	- 0.27	0.08	2.08	2.27	0.77	1.79	1.64	4.43
Kurtosis	2.09	3.11	1.76	6.69	9.20	3.27	5.65	5.18	45.47
Observations	328	337	364	332	270	310	351	351	218

Table B8	**Iron and Steel**								
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Open	Balassa	Y_i/Y
Mean	13.49	10.39	21.65	0.05	0.29	0.24	3.01	0.98	0.01
Median	13.59	10.48	21.59	0.02	0.27	0.20	1.83	0.89	0.01
Maximum	14.79	11.46	24.51	0.34	0.75	1.54	16.71	3.02	0.03
Minimum	11.99	9.18	17.96	0.00	0.12	0.00	0.09	0.14	0.00
Std. Dev.	0.56	0.49	1.77	0.07	0.12	0.17	3.34	0.58	0.01
Skewness	- 0.61	- 0.30	- 0.19	1.90	1.23	3.28	2.04	1.01	1.29
Kurtosis	2.90	2.41	2.05	6.09	4.46	20.60	7.19	3.76	5.00
Observations	353	343	364	344	279	322	351	351	218

Table B9	**Machinery**								
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Open	Balassa	Y_i/Y
Mean	13.49	10.39	21.65	0.05	0.29	0.24	3.01	0.98	0.01
Median	13.59	10.48	21.59	0.02	0.27	0.20	1.83	0.89	0.01
Maximum	14.79	11.46	24.51	0.34	0.75	1.54	16.71	3.02	0.03
Minimum	11.99	9.18	17.96	0.00	0.12	0.00	0.09	0.14	0.00
Std. Dev.	0.56	0.49	1.77	0.07	0.12	0.17	3.34	0.58	0.01
Skewness	- 0.61	- 0.30	- 0.19	1.90	1.23	3.28	2.04	1.01	1.29
Kurtosis	2.90	2.41	2.05	6.09	4.46	20.60	7.19	3.76	5.00
Observations	353	343	364	344	279	322	351	351	218

Table B10	**Transport Equipment**								
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Open	Balassa	Y_i/Y
Mean	16.72	10.44	22.63	0.17	0.47	0.15	3.19	0.87	0.03
Median	16.71	10.43	22.84	0.08	0.38	0.15	2.25	0.89	0.03
Maximum	17.89	11.05	25.57	0.98	1.88	0.40	16.27	1.85	0.12
Minimum	15.72	9.78	19.90	0.00	0.09	0.05	0.19	0.22	0.01
Std. Dev.	0.48	0.27	1.58	0.24	0.33	0.05	2.85	0.38	0.01
Skewness	0.20	0.18	0.02	2.05	2.11	0.83	1.59	0.41	1.56
Kurtosis	2.26	2.24	1.78	6.26	7.21	4.93	5.63	2.62	13.03
Observations	338	240	364	229	270	222	351	351	218

Table B11	**Non-Ferrous Metals**								
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Open	Balassa	Y_i/Y
Mean	14.03	10.52	20.82	0.02	0.50	0.22	4.04	1.36	0.00
Median	14.11	10.54	21.03	0.01	0.47	0.17	3.02	0.85	0.00
Maximum	15.17	11.58	23.66	0.13	1.08	1.04	20.18	8.68	0.01
Minimum	12.50	8.93	16.87	0.00	0.13	0.06	0.16	0.11	0.00
Std. Dev.	0.61	0.53	1.65	0.03	0.19	0.14	3.83	1.55	0.00
Skewness	- 0.70	- 0.46	- 0.34	2.47	0.62	1.88	1.98	2.60	0.15
Kurtosis	3.00	2.77	2.69	8.29	3.09	8.08	7.21	10.05	2.97
Observations	321	343	364	344	272	322	351	351	218

Table B12	Non-Metallic Metals								
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Open	Balassa	Y_i/Y
Mean	14.23	10.43	21.86	0.05	0.22	0.18	0.74	0.91	0.01
Median	14.24	10.44	21.63	0.02	0.21	0.18	0.50	0.71	0.01
Maximum	15.25	11.11	24.11	0.20	0.42	0.37	3.18	4.04	0.03
Minimum	13.18	9.74	19.40	0.00	0.08	0.07	0.03	0.18	0.00
Std. Dev.	0.34	0.28	1.39	0.05	0.07	0.06	0.65	0.66	0.00
Skewness	- 0.29	- 0.03	- 0.02	1.36	0.53	0.61	1.38	2.04	0.73
Kurtosis	3.08	2.40	1.56	4.08	3.11	3.31	4.41	8.18	4.40
Observations	340	315	364	332	279	282	351	351	218

Table B13	Paper								
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Open	Balassa	Y_i/Y
Mean	15.11	10.52	22.73	0.11	0.44	0.17	0.89	1.67	0.04
Median	15.44	10.46	22.96	0.05	0.41	0.15	0.66	0.72	0.03
Maximum	16.51	11.73	25.53	0.80	1.15	0.49	4.18	8.59	0.11
Minimum	13.35	9.82	20.98	0.01	0.22	0.07	0.02	0.11	0.02
Std. Dev.	0.89	0.38	1.26	0.19	0.16	0.07	0.78	1.97	0.01
Skewness	- 0.79	1.07	0.41	2.90	1.35	1.37	1.32	1.97	1.22
Kurtosis	2.12	4.24	2.40	10.00	5.49	5.07	4.68	6.30	5.32
Observations	314	337	363	332	279	285	351	351	218

Table B14	Textiles								
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Open	Balassa	Y_i/Y
Mean	15.99	9.86	22.14	0.08	0.37	0.10	2.88	0.98	0.02
Median	15.99	9.88	22.13	0.03	0.35	0.09	1.67	0.91	0.02
Maximum	16.83	10.46	24.78	0.43	0.72	0.23	14.05	3.71	0.05
Minimum	15.29	9.089	18.98	0.00	0.16	0.00	0.12	0.14	0.00
Std. Dev.	0.33	0.31	1.66	0.10	0.10	0.03	3.15	0.73	0.01
Skewness	0.14	- 0.29	- 0.14	1.85	0.95	0.99	1.71	1.69	1.01
Kurtosis	2.64	2.57	1.68	6.12	3.85	4.40	5.24	6.18	5.04
Observations	319	337	364	332	279	310	351	351	218

Table B15	Wood								
	ln (Y/E)	ln (Y/L)	ln (Y)	Wage	P_{energy}	I/Y	Open	Balassa	Y_i/Y
Mean	15.71	10.01	21.30	0.03	0.44	0.15	1.49	1.62	0.01
Median	15.60	10.06	21.44	0.01	0.40	0.14	0.99	0.58	0.01
Maximum	17.51	10.65	24.25	0.20	1.18	0.60	9.37	10.51	0.03
Minimum	14.11	8.30	18.37	0.00	0.08	0.04	0.05	0.01	0.00
Std. Dev.	0.87	0.38	1.30	0.04	0.20	0.07	1.62	2.25	0.01
Skewness	0.12	- 1.24	0.11	2.63	0.95	1.76	2.44	1.92	1.09
Kurtosis	1.96	5.47	2.52	9.05	4.27	11.06	9.71	5.93	2.80
Observations	254	346	364	323	260	283	351	351	218