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Productivity convergence at the disaggregate levels

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Abstract

Using recently developed industry-specific purchasing power parities (PPPs), we test for β-convergence and σ-convergence of labor productivity at one-digit and two-digit industrial levels for 17 OECD countries. We confirm that the principal finding of Bernard and Jones (1996)—that total manufacturing shows little evidence of productivity convergence among OECD countries—is in fact supported by the data, even though their approach is flawed by the use of aggregate rather than industry-specific PPPs. However, we find that many two-digit manufacturing industries do converge. All one-digit sectors except manufacturing exhibit strong convergence trends. Convergence also occurs in all services industries except post and telecommunications. Respective contributions of industrial productivity growth and across-industry labor shifts to trends at the next aggregate level are also analyzed.

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1 Introduction

Since the seminal work of Bernard and Jones (1996, hereafter BJ), increasing attention has been drawn to productivity convergence at the disaggregate levels (see Carree *et al.* 2000, Margaritis *et al.* 2007, among others). BJ point out that international transfer and diffusion of technology are likely to vary in nature and intensity across sectors, and thus provide a compelling argument for examining productivity convergence at the sectoral level as well as at the economy-wide level. They examine β-convergence and σ-convergence for six one-digit sectors among 14 OECD countries over the period 1970–1987.[1] Their main conclusion is that there is no evidence of convergence in manufacturing and hence that the convergence trend at the aggregate level is driven by non-manufacturing sectors, especially services.

This widely cited finding of BJ, however, is challenged by Sorensen (2001), who shows that the use of economy-wide purchasing power parities (PPPs) to convert sector-specific output quantities to a common currency seriously undermines the BJ international comparisons. Sorensen (2001) argues that, for international comparisons at the sectoral level, producer prices on domestic production related to specific sectors should be used, while aggregate expenditure PPPs are calculated from the expenditure prices of a bundle of consumption goods from all sectors. In particular, he shows that the BJ results are sensitive to the choice of the PPP base year, indicating that the aggregate expenditure PPPs are inappropriate conversion factors for sector-specific productivity levels.

In their response to Sorensen (2001), Bernard and Jones (2001) write that "... future research is needed to construct conversion factors appropriate to each sector, and that research relying on international comparisons of sector-specific productivity and income should proceed with caution until these conversion factors are available". As part of the EU KLEMS project, Timmer *et al.* (2007) construct a set of industry-specific PPPs and provide a new database of growth accounts. In this paper, we establish the empirics on productivity convergence at the disaggregate levels using the appropriate industry-specific PPPs.[2]

Focusing only on one-digit sectors can still be misleading. In 2004, for a group of 17 OECD countries included in this study, manufacturing and services accounted for, on average, almost 90% of total output, with services alone accounting for around 70%. As these two sectors comprise very heterogeneous industries, analysis purely on one-digit sectors fails to account for within-sector disparities, essentially resembling the "comparing apples to orange" problem identified by BJ. Carree *et al.* (2000) test convergence in 28 manufacturing industries among 18 OECD countries and Margaritis *et al.* (2007) test convergence in low-tech manufacturing, high-tech manufacturing and several services industries among 19 OECD countries.[3] But again, lacking appropriate industry-specific

[1] The six one-digit sectors are agriculture, mining, manufacturing, EGW (electricity, gas and water), construction and services.

[2] Due to very limited data on capital stock, we focus on labor productivity.

[3] We report in this paper the results from the absolute β-convergence test, which directly examines whether different economies are getting closer to one another. But we also tested conditional β-convergence hypotheses, following Margaritis *et al.* (2007) in choosing controlling variables. Conditional β-convergence test examines whether economies that are farther from their steady states grow faster than those that are nearer to their steady states. Results are available upon request.

PPPs, these papers use aggregate PPPs, raising, most probably in a severer way, the issue pointed out by Sorenson (2001).

Using appropriate industry-specific PPPs, this paper studies productivity convergence among 17 OECD countries for six one-digit sectors as well as two-digit industries in manufacturing and services for the time period 1975-2004. The notions of β-convergence and σ-convergence are tested. A counterfactual analysis is performed to assess the respective contributions of productivity growth within individual industries and labor shifts across industries to trends at the next aggregate level.

Section 2 discusses convergence notions and testable implications. Section 3 explains the data source. Section 4 presents convergence test results. Section 5 provides results from the counterfactual analysis. Section 6 proposes possible future directions.

2 Convergence Notions and Testable Implications

The β-convergence hypothesis proposes that economies with relatively lower initial incomes per capita tend to growth faster than those with higher incomes. β-convergence can be tested by running the following simple regression:

$$\bar{g}_i = \alpha + \beta \ln P_{i0} + \epsilon_i \tag{1}$$

where $\bar{g}_i$ denotes the mean growth rate of country i over the sample period and P_{i0} represents country i's initial productivity level.[4] A significantly negative estimate of β confirms β-convergence.

The notion of σ-convergence hypothesizes that income dispersion across economies decreases over time, *i.e.*, $\sigma_T < \sigma_0$, where σ_0 and σ_T are the respective cross-country standard deviations of incomes in the first and last period. Carree and Klomp (1997) develop the following adjusted likelihood ratio statistic to test whether σ_T is significantly below σ_0:

$$S = \sqrt{N} \frac{\hat{\sigma}_0^2/\hat{\sigma}_T^2 - 1}{2\sqrt{1-(\hat{\beta}T+1)}} \tag{2}$$

where N is the number of countries and $\hat{\beta}$is the estimate of β from the β-convergence regression. This S statistic has a standard normal distribution under $H_0 : \sigma_T - \sigma_0 = 0$.

As summarized in Sala-i-Martin (1996), β-convergence is a necessary but not sufficient condition for σ-convergence. Strong β-convergence and a violation of σ-convergence can coexist under two possible scenarios. The first scenario is overshooting, where the initially poorer countries grow so fast that they not only catch up with the richer ones but overreach them. This is not very common for aggregate economies but more likely to happen at the disaggregate levels. The second possible scenario is the case of regression to the mean (the Galton's Fallacy). As critiqued by Friedman (1992) and Quah (1993), when there is regression to the mean, a significantly negative β can be obtained even though the economies are not converging at all and across-country dispersion is enlarging.

[4]Following BJ, average growth rate is constructed as the trend coefficient from a regression of the log level on a constant and a linear trend.

3 Data

Data are drawn from the EU KLEMS Database, March 2007 release (see Timmer *et al.* 2007). The 17 OECD countries are the EU-15, Japan and the USA. Labor productivity is measured as value added per hour worked in 1997 industry-specific PPP German Euros.

4 Convergence Test Results

4.1 Results for One-Digit Sector

A gestalt impression of convergence by sector is provided by Figure 1. A convergence trend is fairly evident in several sectors (especially agriculture and EGW), but there appears to be no evidence of convergence in manufacturing. Table 1 provides the convergence test results: the OLS estimates of the β coefficients (along with relevant statistics), the standard deviation of the natural log of labor productivity in both 1975 and 2004, and the S statistic. Except for manufacturing, all the estimated β coefficients are significantly negative at 1% level. The overall picture, for total industry (the sum of all six one-digit sectors), is that of strongly significant β-convergence.

σ-convergence is significant in agriculture, mining, EGW, services and total industry. The standard deviation of productivity levels in construction did fall, but the decrease is not statistically significant. Manufacturing again constitutes an outlier as the only sector for which σ increased during the sample period. However, despite the fact that the σ in manufacturing has increased, its absolute value in 2004 is still lower than that in agriculture, mining and EGW, all of which exhibit strong σ-convergence. It might well be the case that technological catch-up had already occurred largely in manufacturing. Dispersion of labor productivity in mining is the greatest and this might reasonably be attributable to the differences in the sizes of the mining sector in individual countries, which, in turn, is likely due to differences in natural resources and mineral reserves.

Our results at the sectoral level thus strongly support the BJ conclusion that convergence does not exist in total manufacturing, despite the fact that their results are potentially misleading because of the use of inappropriate PPPs. On the other hand, we find, in contrast to BJ, that all sectors other than manufacturing—including agriculture and mining (in which BJ find no convergence)—are converging.

4.2 Results for Manufacturing Industries

As discussed earlier, total manufacturing is composed of production in rather heterogeneous goods. It is necessary to examine more disaggregate industries to have a better understanding of the diverging trend in total manufacturing.

We carry out β-convergence and σ-convergence tests for all the two-digit industries in manufacturing.[5] Tests results are presented in Table 3.[6] Despite the fact that the overall manufacturing sector does not converge among the OECD countries under examination,

[5]Due to data unavailability, for some industries, the country group includes less countries or the time period starts from 1977 instead of 1975. Detailed information is available upon request.

[6]The industry classification is based on ISIC *Rev.3*.

many manufacturing industries do. A significantly negative β estimate is obtained for all manufacturing industries except textile and textile products (ISIC 17 to 18) and rubber and plastics (ISIC 25).

Significant σ-convergence is not found in several industries (*i.e.*, ISIC 15 to 16, 17 to 18, 20, 22, 24 and 25). More specifically, the cross-country dispersion increased three industries—textile and textile products (ISIC 17 to 18), chemical and chemical products (ISIC 24) and rubber and plastic (ISIC 25)—two of which (ISIC 17 to 18 and 25) are exactly those with no evidence for β-convergence evidence. For chemical and chemical products (ISIC 24), β-convergence is not statistically rejected while there is a significant increase in σ. This is the overshooting case discussed earlier. Ireland, with relatively low productivity in producing chemical products back in 1975, achieved tremendous productivity increase over the sample period and was well above all other countries in 2004. The pattern is similar for food, beverages and tobacco (ISIC 15 to 16) and printing, publishing and reproduction (ISIC 22), where β-convergence is statistically significant while the standard deviation of the distribution remains roughly the same. Again, Ireland enjoyed very fast growth from a relatively low position.

Combining both β-convergence and σ-convergence tests, we conclude that most manufacturing industries do converge. The non-convergence trend in total manufacturing is mainly attributable to divergence in a few industries (mainly ISIC 17 to 18 and 25).

4.3 Results for Service Industries

As the services sector is the largest one-digit sector in the economies, trend in services can have a substantial effect on that at the economy-wide level. Total services contain many heterogeneous industries. Some services, such as financial services, are fairly tradable, while others, such as community, social and personal services, are local and less likely to be traded. It would be interesting to see whether and how industries in services might differ regarding convergence.

Almost all industries in services are converging, according to results presented in Table 4. The only exception is post and telecommunication (ISIC 64), which does not exhibit statistically significant β-convergence. Estimates of β in all others are strongly significant. The σ-convergence tests fail to reject the no convergence null for a few industries (ISIC I, 64 and L), but the standard deviation in all industries, including post and telecommunication (ISIC 64), has decreased. Strong convergence trends in service industries might be attributable to the easy transferability of services technologies.

5 A Counterfactual Analysis

To better understand the mechanism behind the strong convergence evidence at the aggregate level, it is also important to pay attention to changes in industrial labor shares. When labor shifts occur among industries featuring different producibility levels, productivity performance at the aggregate level can be affected non-trivially. For the OECD countries included, the largest sector—total services—is the only sector which expanded in terms of labor share, accounting for, on average, 55% of total working hours in 1975 and more than 70% by 2004. The average share of total manufacturing, the second largest sector, shrank from around 30% in 1975 to 18% in 2004. Other sectors generally accounted for many fewer working hours, holding, altogether, only around 10% of total industry in 2004. There is also considerable heterogeneity in the growth rates of labor productivity across sectors. On average, labor productivity in manufacturing, mining, and EGW grow the fastest while growth in services and construction is relatively slow. To assess the separate contributions of within-sector productivity growth and across-sector labor shifts to the aggregate level convergence, we propose two counterfactuals of labor productivity for total industry in the last period.

Denote labor productivity for country i's total industry in the last period as p_{iT}. Also denote sector j's initial labor productivity and hour share as p_{ij0} and s_{ij0}, and those in the last period as p_{ijT} and s_{ijT}, respectively. It is straightforward that $p_{iT} = \sum_j s_{ijT} \cdot p_{ijT}$. We construct two counterfactuals for p_{iT} as $\hat{p}_{iT} = \sum_j s_{ij0} \cdot p_{ijT}$ and $\tilde{p}_{iT} = \sum_j s_{ijT} \cdot p_{ij0}$, where $\hat{p}_{iT}$ is the counterfactual for p_{iT} if there had been no labor shifts across sectors, while $\tilde{p}_{iT}$ is the counterfactual if there had been no productivity growth in any individual sectors. We then calculate the corresponding counterfactual growth rates for total industry under the construction and run the convergence tests. The results show that labor shifts across sectors do not have a significant effect on convergence in total industry. As a matter of fact, if there had only been growth in individual sectors but no labor shifts across sectors, the counterfactual ($\hat{p}_{iT}$) would be very close to the actual value. Correspondingly, the convergence test results based on the counterfactual reveal the same pattern, *i.e.*, there would be both strong β-convergence and strong σ-convergence in total industry. However, if there had been only labor shifts but no growth, labor producibility in total industry would not have converged among the countries. Evidently, productivity growth in individual sectors explains the convergence of aggregate productivity among the OECD economies.

We can apply the same exercise to total manufacturing and total services to explore how growth in two-digit industries and changes in labor share composition affect the the convergence/nonconvergence trends in the corresponding one-digit sectors. Results shows that neither productivity growth in two-digit manufacturing industries nor labor shifts within total manufacturing has contributed to convergence—both cause cross-economy dispersion (σ) in total manufacturing to increase. Particularly, if there had been no productivity growth in any manufacturing industry, we would obtain a significantly positive β estimate, *i.e.*, change in labor share composition within total manufacturing forces the OECD countries to diverge. Convergence in services is mainly driven by productivity growth within two-digit services industries.

6 Future Directions

Using newly constructed industry-specific PPPs, we establish the empirics regarding productivity convergence at the disaggregate levels. For a group of 17 OECD countries over the period 1975-2004, our results provide evidence for convergence in all one-digit sectors except total manufacturing. However, we find that many manufacturing industries do converge. Within the services sector, almost all industries show strong convergence trends. A simple counterfactual analysis that separates the contributions of productivity growth and labor shifts reveals that convergence at the aggregate level is mainly driven by productivity growth.

Data unavailability imposes serious restrictions on research regarding productivity convergence at the disaggregate levels. Lacking internationally comparable capital data, we can only assess labor productivity. When such data become available, the more economically interesting multi-factor productivity should be analyzed. Another interesting direction to pursue, with capital data, is the growth accounting exercise based on data envelopment analysis (DEA) as in Kumar and Russell (2002). Such analysis would help identify the underlying driving forces of industrial growth and convergence, and their respective contributions to aggregate cross-country trends.

Future research may also address questions such as how international trade can affect productivity convergence at the disaggregate levels (especially for manufacturing industries). The fact that convergence does not occur in total manufacturing seems to falsify the conventional wisdom that spillovers from international trade and R&D investment would speed up technical transfer and facilitate convergence. Then could international trade impede productivity convergence among trade partners because it creates specialization in producing different traded goods that might be associated with different production technologies?

The OECD countries in our sample are fairly homogeneous in nature. A natural question to ask is: if more heterogeneous countries (such as those with low productivity levels) are included, will the convergence pattern remain the same for all industries? Will there be "twin clubs" for individual industries that are found by Quah (1996, 1997) for aggregate economies? Data covering more heterogeneous economies will also help the understanding of convergence at the disaggregate levels.

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Table 1: Convergence Test Results for One-Digit Sectors, 1975-2004

Sector	β	$s.e.$	t	R^2	SD in 1975	SD in 2004	S
Agriculture	-0.021***	0.004	-5.99	0.64	0.85	0.50	4.25***
Mining	-0.029***	0.010	-2.95	0.57	1.57	1.08	2.33**
Manufacturing	-0.016	0.015	-1.09	0.16	0.37	0.44	-0.73
EGW	-0.019***	0.004	-4.35	0.57	0.64	0.45	2.42**
Construction	-0.024***	0.007	-3.51	0.53	0.35	0.30	0.73
Services	-0.019***	0.004	-5.08	0.51	0.32	0.23	2.28**
Total Industry	-0.016***	0.004	-4.43	0.49	0.31	0.23	1.96**

* significant at 10% level; ** significant at 5% level; *** significant at 1% level.
This applies to all following tables.

Table 2: Convergence Test Results for Manufacturing Industries, 1975-2004

Industry	β	$s.e.$	t	R^2	SD in 1975	SD in 2004	S
D	-0.016	0.015	-1.09	0.16	0.37	0.44	-0.73
15t16	-0.020*	0.011	-1.83	0.29	0.47	0.47	0.03
17t18	-0.023	0.017	-1.35	0.12	0.34	0.49	-1.14
19	-0.026***	0.008	-3.29	0.47	0.61	0.48	5.44***
20	-0.028***	0.007	-3.97	0.50	0.61	0.52	0.82
21	-0.026***	0.008	-3.38	0.44	0.45	0.40	2.17**
22	-0.020***	0.005	-3.70	0.30	0.45	0.47	0.07
23	-0.033***	0.010	-3.18	0.61	1.27	1.15	1.78*
24	-0.016***	0.005	-3.10	0.20	0.51	0.61	-0.62
25	-0.025	0.016	-1.58	0.14	0.42	0.55	-0.90
26	-0.026***	0.004	-6.04	0.65	0.44	0.26	4.32***
27	-0.033***	0.002	-14.08	0.88	0.87	0.36	39.51***
28	-0.032***	0.006	-5.46	0.80	0.76	0.32	38.40***
29	-0.022***	0.006	-3.61	0.59	0.63	0.41	3.17***
30	-0.048***	0.003	-17.12	0.91	2.00	1.15	17.32***
31	-0.035***	0.004	-9.32	0.85	1.12	0.47	9.47***
32	-0.049***	0.003	-15.37	0.85	0.95	0.66	9.38***
33	-0.033***	0.007	-4.88	0.69	0.75	0.41	4.84***
34	-0.019***	0.005	-3.85	0.53	0.86	0.60	10.37***
35	-0.018***	0.003	-5.45	0.59	0.76	0.52	2.61***
36t37	-0.021***	0.006	-3.64	0.61	0.75	0.53	2.19**

Table 3: Convergence Test Results for Services Industries, 1975-2004

Industry	β	*s.e.*	t	R^2	SD in 1975	SD in 2004	S
G	-0.021***	0.0042	-5.01	0.69	0.54	0.34	3.56***
50	-0.027***	0.0052	-5.14	0.52	0.46	0.30	10.52***
51	-0.021***	0.0055	-3.75	0.48	0.63	0.47	6.91***
52	-0.022***	0.0023	-9.80	0.86	0.60	0.32	21.19***
H	-0.015***	0.0024	-6.27	0.74	0.71	0.46	3.51***
I	-0.016***	0.0053	-3.03	0.29	0.39	0.33	0.96
60	-0.028***	0.0067	-4.15	0.55	0.52	0.36	8.84***
61	-0.030***	0.0073	-4.13	0.62	0.75	0.49	10.04***
62	-0.041***	0.0041	-9.79	0.89	1.52	0.62	40.62***
63	-0.020***	0.0032	-6.27	0.53	0.66	0.42	12.49***
64	-0.009	0.0095	-0.95	0.14	0.61	0.58	1.08
J	-0.034***	0.0061	-5.55	0.65	0.46	0.27	4.09***
K	-0.017***	0.0030	-5.69	0.67	0.51	0.34	3.23***
70	-0.008***	0.0018	-4.32	0.28	1.28	1.10	4.55***
71	-0.025***	0.0039	-6.33	0.70	1.63	0.79	26.86***
72	-0.031***	0.0062	-5.02	0.74	0.71	0.33	31.31***
73	-0.020***	0.0045	-4.51	0.66	1.10	0.66	16.58***
74	-0.021***	0.0047	-4.53	0.57	0.47	0.36	6.76***
L	-0.027**	0.0098	-2.80	0.41	0.22	0.20	0.49
M	-0.023***	0.0065	-3.45	0.53	0.32	0.21	2.88***
N	-0.027***	0.0059	-4.63	0.58	0.42	0.26	3.24***
O	-0.029***	0.0035	-8.40	0.71	0.49	0.26	5.34***
P	-0.007**	0.0026	-2.64	0.22	1.27	1.13	3.41***

Figure 1: Growth Paths of Labor Productivity (Natural Log) for One-Digit Sectors and Total Industry, 1975-2004