Comparing Apples to Oranges: Productivity Convergence and Measurement Across Industries and Countries

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This paper examines the role of sectors in aggregate convergence for 14 OECD countries during 1970–1987. The major finding is that manufacturing shows little evidence of either labor productivity or multifactor productivity convergence, while other sectors, especially services, are driving the aggregate convergence result. To determine the robustness of the convergence results, the paper introduces a new measure of multifactor productivity which avoids many problems inherent to traditional measures of total factor productivity when comparing productivity levels. The lack of convergence in manufacturing is robust to the method of calculating multifactor productivity. (*JEL* O41, O47)

Comparisons of productivity performance across countries are central to many of the questions concerning long-run economic growth: are less productive nations catching up to the most productive countries, and if so, how quickly and by what means? Groups as disparate as economic growth theorists and business leaders express profound interest in the answer to the question of whether the United States can maintain its role as the world productivity leader (see e.g., Michael L. Dertouzos et al., 1989; William J. Baumol et al., 1989). The question itself is potentially misleading: should we be interested in the productivity of the entire private sector or that of individual industries? And whatever the level of analysis, are we concerned with labor productivity or a more general notion of technological advance? Using data for a group of 14 industrialized countries during 1970–1987, we ask whether trends in aggregate productivity are also reflected at the individual industry level, taking care to distinguish between productivity of labor and that of all factors taken together. In the process, we consider the complicated question of how to compare multifactor productivity levels across economies, and we provide a new measure of total technological productivity.

The results for individual industries are quite striking. While aggregate productivity was converging over the period, the sectors show disparate behavior. For all measures of productivity, the manufacturing sector shows no or little convergence, while other sectors, especially services, show strong evidence in favor of convergence. This finding for services, together with the declining share of manufacturing in all 14 countries, contributes to the convergence found at the aggregate level. The lack of convergence within manufacturing over this 17-year period indicates that convergence is not an automatic phenomenon. Most theories of economic growth predict that openness and spillovers from R&D investment would contribute to convergence across countries and thus are not easily reconciled with these findings. These results are especially pertinent to

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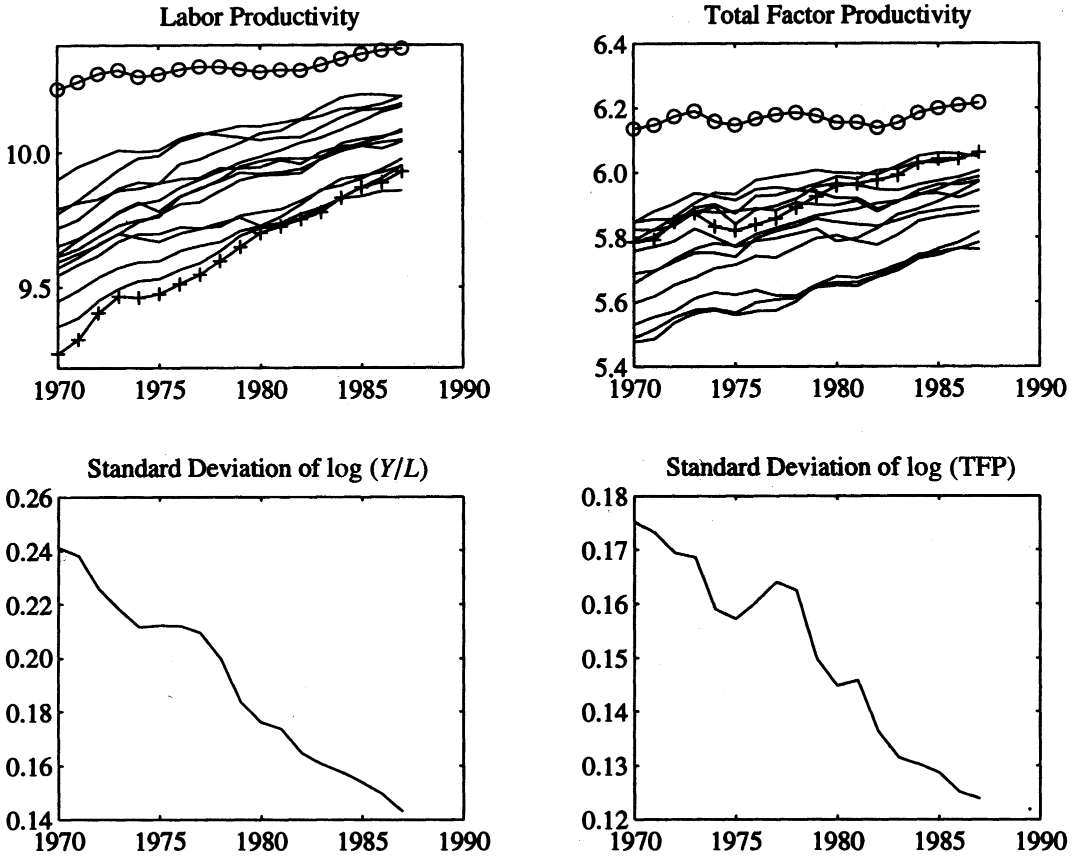

FIGURE 1. TOTAL INDUSTRY CONVERGENCE IN LABOR PRODUCTIVITY AND TOTAL FACTOR PRODUCTIVITY (NATURAL LOGS)

Note: Open circles denote the United States, and "plus" symbols denote Japan.

the study of convergence in countries at more heterogeneous levels of development. In a recent paper, Alwyn Young (1992) showed that, while Hong Kong and Singapore apparently followed similar growth paths, their productivity performances were quite dramatically different. Our results suggest further that convergence of aggregate productivity may mask substantial differences at the sectoral level.

Previous work on convergence across countries has concentrated almost exclusively on labor productivity, using GDP per capita as the measure. This is due largely to a lack of data on labor and capital inputs necessary to construct broader measures of productivity. Using cross-section regressions, William J. Baumol (1986), Robert J. Barro and Xavier Sala-i-Martin (1991, 1992) and N. Gregory Mankiw et al. (1992) argue that countries and regions are converging, or catching up, since initially poor areas grow faster than their richer counterparts. However, the cross-section evidence is not uniform. Barro (1991) and J. Bradford De Long (1988) show that the particular sample of countries determines whether catch-up holds. Time-series results on longer series for OECD countries also show evidence of common trends but no tendency for convergence in levels (see e.g., Bernard and Steven N.

Durlauf, 1995). Stephen N. Broadberry (1993) fails to find convergence in manufacturing productivity during 1870–1987 for Germany, the United Kingdom, and the United States and argues, as we do, that aggregate convergence for those countries must be driven by other sectors or compositional changes.

The use of labor productivity necessarily entails restrictions on the depth of analysis. By its very definition, a change in labor productivity confounds potential changes in technology and factor accumulation. Convergence in a neoclassical growth framework places heavy emphasis on the accumulation of capital as the driving force behind convergence, but analysis of labor productivity does not allow the identification of separate influences of technology and capital. To this end, we consider both multifactor productivity measures and labor productivity measures.

To conduct our analysis of convergence we require both growth rates of productivity and the productivity levels themselves. Most analyses of productivity concentrate on the changes, thus avoiding complicated issues concerning the measurement and comparison of productivity levels across industries and countries, which is particularly difficult for multifactor productivity. In Section III, we describe alternative measures of multifactor productivity and discuss the robustness of our convergence findings.

In this paper, multifactor productivity (MFP) refers to the broad concept of factor productivity. We consider two types of measures of multifactor productivity, which we label total factor productivity (TFP) and total technological productivity (TTP). TFP and TTP refer to specific measures of multifactor productivity, while MFP refers to the basic concept. The growth rates of all multifactor productivity measures are the same; the measures differ only according to the way in which the initial levels are pinned down. For this reason, we refer to the growth rates as multifactor productivity-growth rates.

The most consistent empirical regularity on cross-country growth in the OECD is that productivity and output per capita differences have narrowed over time. Log levels of labor productivity, Y/L, and total factor productivity, TFP, are shown for total industry, excluding government, for 14 OECD countries during 1970–1987 in Figure 1.[1] (The United States denoted by open circles and Japan by "plus" symbols in all figures.) Y/L has grown on average at a rate of 2.4 percent per year, but the gap between the most productive country (the United States) and the least productive country declined consistently from 1970 to 1987. The same qualitative results hold for TFP; there is substantial narrowing of the gap between the leader (again the United States) and the less productive countries. However, the degree of catch-up is less for TFP, suggesting that capital accumulation is playing a role in the convergence of labor productivity.

The reduction in cross-section dispersion can be seen again in the lower half of Figure 1, which plots the cross-section standard deviations of the logs of Y/L and TFP. Cross-section dispersion declines steadily throughout the period from 0.24 to 0.14 for labor productivity and from 0.17 to 0.12 for total factor productivity. Tests for catch-up, regressions of average growth rates on initial levels of the productivity measures for the 14 countries, confirm the visual evidence:[2]

$$(1) \quad \Delta \ln\left(\frac{Y}{L}\right)_i = \alpha + \beta \ln\left(\frac{Y}{L}\right)_i^{1970} + \varepsilon_i$$

($\alpha = 0.3109$ [SE = 0.0501]; $\beta = -0.0298$ [SE = 0.0052]; $\bar{R}^2 = 0.71$)

$$(2) \quad \Delta \ln(\text{TFP}_i) = \alpha + \beta \ln(\text{TFP}_i^{1970}) + \varepsilon_i$$

($\alpha = 0.1428$ [SE = 0.0322]; $\beta = -0.0226$ [SE = 0.0056]; $\bar{R}^2 = 0.54$).

The coefficients on the initial levels are negative and strongly significant for both measures. Both labor and TFP measures for aggregate output indicate that less productive countries are

[1] Y/L is constructed as output per worker, and TFP is a standard measure of total factor productivity (see Section II for details). We consider alternative multifactor productivity measures in Section III.

[2] Average growth rates here and throughout the paper are constructed as the trend coefficient from a regression of the log level on a constant and a linear trend. This minimizes problems with measurement error and business cycles.

catching up to the most productive countries. Based on the simple model presented in the next section, these estimates imply that labor productivity is converging at a rate of 3.85 percent per year, faster than the 2.87 percent for TFP.[3] The results from Equations (1) and (2) suggest that convergence is continuing for these economies throughout the 1970's and 1980's.

To understand what is driving this strong evidence of convergence for total industry productivity, we now turn to the evidence from the sectoral data. First, we outline a simple testable framework for analyzing relative productivity growth. We then construct six broadly defined sectors for each economy and test for convergence in labor productivity and TFP within each sector across countries. Finally we discuss the robustness of the results, considering alternative measures of multifactor productivity.

I. A Basic Model of Productivity Convergence

We construct a simple model of productivity catch-up and derive testable implications for cross sections of productivity levels and growth rates. Abstracting from issues of multifactor productivity measurement, we assume that productivity for a given sector in country i, $P_{i,t}$, evolves according to

$$\ln P_{i,t} = \gamma_i + \lambda \ln D_{i,t} + \ln P_{i,t-1} + \ln \epsilon_{i,t} \tag{3}$$

with γ_i being the asymptotic rate of productivity growth of country-sector i, λ parameterizing the speed of catch-up denoted by $D_{i,t}$, and $\epsilon_{i,t}$ representing an industry and country-specific productivity shock.[4] We allow $D_{i,t}$, the catch-up variable, to be a function of the productivity in country-sector i relative to that in country 1, the most productive country,

$$\ln D_{i,t} = -\ln \hat{P}_{i,t-1} \tag{4}$$

where a hat indicates a ratio of a variable in country i to the same variable in country 1; that is,

$$\hat{P}_{i,t} = \frac{P_{i,t}}{P_{1,t}}. \tag{5}$$

This formulation of productivity catch-up implies that productivity gaps between countries are functions of the lagged gap in the same productivity measure. For example, if TFP is the measure of productivity, then lagged gaps in TFP determine the degree of catch-up. This simple diffusion process is subject to criticism. Steve Dowrick and Duc-Tho Nguyen (1989) allow the catch-up in TFP to be determined by labor-productivity differentials; however, it seems appropriate to suppose that technological catch-up may be occurring independent of capital deepening.

This formulation of output leads to a natural path for productivity:

$$\ln \hat{P}_{i,t} = (\gamma_i - \gamma_1) + (1-\lambda)\ln \hat{P}_{i,t-1} + \ln \hat{\epsilon}_{i,t}. \tag{6}$$

In this framework, values of $\lambda > 0$ provide an impetus for "catch-up": productivity differentials between two countries increase the relative growth rate of the country with lower productivity. However, only if $\lambda > 0$ and if $\gamma_i = \gamma_1$ (i.e., only when the asymptotic growth rates of productivity are the same) will countries exhibit a tendency to converge. Alternatively, if $\lambda = 0$, productivity levels will grow at different rates permanently and will show no tendency to converge asymptotically.[5] Considering the relationship between long-run growth rates across countries, we can rewrite the difference equation in equation (3) to yield

$$\bar{p}_i = -\frac{1-(1-\lambda)^T}{T}\ln \hat{P}_{i,0} + \frac{1}{T}\sum_{s=0}^{T}(1-\lambda)^{T-s}(\gamma_i - \gamma_1 + \ln \hat{\epsilon}_{i,s}) \tag{7}$$

[3] In contrast, Barro and Sala-i-Martin (1992) have found 2-percent convergence for aggregate output per capita for a range of regions.

[4] To conserve notation and because we examine sectors separately, we omit sector subscripts throughout.

[5] Of course, if the country with the lower initial level has a higher γ_i, the countries may appear to be converging in small samples. This case is extremely difficult to rule out in practice.

where $\bar{p}_i$ denotes the average growth rate relative to country 1 between time 0 and time T.[6] This is the familiar regression of long-run average growth rates on the initial level, where catch-up is denoted by a negative coefficient on the level.[7] This simple setup for analyzing productivity movements across countries is convenient, because the regression specification is not dependent on the form of the production function. We use this framework to test for convergence in both labor productivity and multifactor productivity.

II. Convergence in Industry Productivity

In this section we present cross-section convergence results for labor productivity and TFP for six sectors and for 14 countries. We describe the data set before looking at the changing composition of output across countries. Results for β-convergence and σ-convergence follow. Finally, we review previous empirical work on industry productivity and convergence.

A. *Data*

The empirical work for this paper employs data for six sectors and total industry for (a maximum of) 14 OECD countries over the period 1970–1987. The 14 countries are Australia, Belgium, Canada, Denmark, Finland, France, Italy, Japan, the Netherlands, Norway, Sweden, the United Kingdom, the United States, and West Germany. The six sectors are agriculture, mining, manufacturing, electricity/gas/water (EGW), construction, and services. The basic data source is an updated version of the OECD Intersectoral Database (ISDB), constructed by F. J. M. Meyer-zu-Schlochtern (1988).[8]

The ISDB database contains data on GDP, total employment, number of employees, capital stock, and the wage bill. All of the currency-denominated variables are in 1980 dollars, having been converted by the OECD using 1980 purchasing-power parities (PPP's). We construct our labor-productivity and multifactor productivity measures using these variables.[9]

We measure labor productivity as value-added per worker. The construction of multifactor productivity is more complicated, primarily because we require level comparisons, not simply growth rate comparisons. We begin by following Robert M. Solow (1957) in constructing the Divisia-Tornquist multifactor productivity growth rates:

$$(8) \quad \Delta \ln(\text{MFP}_{i,t}) = \Delta \ln Y_{i,t} - \bar{\alpha}_{i,t} \Delta \ln L_{i,t} - (1 - \bar{\alpha}_{i,t}) \Delta \ln K_{i,t}$$

where $\bar{\alpha}_{i,t} \equiv 0.5(\alpha_{i,t} + \alpha_{i,t-1})$ and $\alpha_{i,t}$ is the labor share of value-added in country-sector i. Implicit in this calculation are assumptions of perfect competition and constant returns to scale.

In this paper, we consider several different measures of multifactor productivity levels. The measures differ by the assumptions employed to pin down the levels of productivity across countries in the base year, 1970. For all measures considered in this paper, subsequent levels are constructed by cumulating the multifactor productivity growth rates calculated in the equation above.

Our first method for calculating multifactor productivity levels, which we will refer to as the "standard" TFP measure, assumes that the production function takes a Cobb-Douglas

[6] An alternative testing approach, employed in Bernard and Jones (1996), is to estimate equation (6) directly. If $\lambda > 0$, then the difference between the technology levels in the two countries will be stationary. If there is no catch-up ($\lambda = 0$), then the difference between TFP in country i and that in country 1 will contain a unit root. The drift term $\gamma_i - \gamma_1$ will typically be small but nonzero if the countries' technologies are driven by different processes (i.e., under the hypothesis of no convergence). Under the hypothesis of convergence, $\gamma_i = \gamma_1$ is plausible.

[7] For potential problems with this type of regression, see Bernard and Durlauf (1996).

[8] With the exception of the services aggregate, all the other sectors are taken directly from the ISDB. The services aggregate is constructed by summing Retail Trade, Transportation/Communication, F.I.R.E., and Other Services. Government services are excluded. Our measure of aggregate output also excludes the government sector.

[9] We discuss robustness of the results to different PPP measures in Subsection III-E.

form with factor exponents that are constant across countries. Therefore,

$$\ln A_{i,0} \equiv \ln(\text{TFP}_{i,0}) = \alpha \ln\left(\frac{Y_{i,0}}{L_{i,0}}\right) + (1-\alpha)\ln\left(\frac{Y_{i,0}}{K_{i,0}}\right) \tag{9}$$

where time 0 corresponds to the base year, 1970. For our standard TFP measure, we will compute α as the average labor share across all years and across all countries for the given sector. In section III we discuss a number of alternative ways to calculate multifactor productivity levels. As will be seen, the results are robust to the exact form of multifactor productivity employed.

To summarize the data, Table 1 reports average annual labor productivity and multifactor productivity growth rates by country and sector for the period 1970–1987.[10] Similarly, Figures 2 and 3 plot the logs of labor productivity and TFP levels, respectively, by sector for each country. The table shows substantial heterogeneity in growth rates both across industries and across countries. Average sectoral growth rates of labor productivity vary from 4.0 percent per year in mining to 0.9 percent in construction. The MFP growth rates show similar variation, with agriculture experiencing the fastest multifactor productivity growth, 3.0 percent per year, and with mining and construction actually showing negative growth over the period. Within sectors, there are also substantially different growth experiences. Manufacturing growth in labor productivity varies from a high of 5.9 percent in Japan to a low of 1.7 percent in Norway. MFP growth in manufacturing was highest in Belgium, 3.5 percent per year, and lowest again in Norway, 0.7 percent per year. Labor productivity in services, the largest sector in these economies, grew at a 2.8-percent rate in Japan and at a rate of only 0.6 percent in Italy.

For every sector, average labor productivity growth was faster than MFP growth, suggesting a continuing role for capital accumulation in changes in labor productivity, even for these developed economies over the 1970's and 1980's. The difference was most dramatic in mining, which had the fastest labor productivity growth but the lowest, even negative, multifactor productivity growth. The differences between labor productivity and multifactor productivity was smallest in services.

As a check on the validity of these numbers, we can compare the growth rates for productivity in the United States to productivity growth rates calculated by the Bureau of Labor Statistics (1991), as shown in Table 2.[11]

The growth rates for the manufacturing sector agree nicely, while those for total industry are somewhat different. Because the key findings in this paper focus on the manufacturing sector, the slightly anomalous results for the total-industry measure is less disconcerting.

Looking at the labor productivity and TFP levels by sector in Figures 2 and 3, we can see several immediate differences from the aggregate movements shown earlier. Sectors do not show the same patterns in either trend or dispersion over time. Neither labor productivity nor TFP shows much change in dispersion for manufacturing, while in services, both measures display a narrowing of the gap between the highest-productivity country and the lowest. The figures also bear out the substantial heterogeneity of productivity performances across sectors.

One perhaps puzzling feature of the figures concerns Japanese productivity in the services sector. According to the labor-productivity measure, Japanese productivity in the service sector in 1970 was at the bottom of the sample, while the TFP measure places Japan right at the top. One interpretation of this observation is that Japanese labor productivity is low in services because of the relatively large number of workers employed. For example, anecdotes suggest a much higher ratio of employees to customers in department stores in Japan compared to the United States. This may be reflected in labor productivity, but there is no

[10] For a few sectors, 1986 is taken as the endpoint because of data availability.

[11] The Bureau of Labor Statistics (BLS) data on labor hours, as opposed to the total employment measure used by the ISDB.

TABLE 1—PRODUCTIVITY GROWTH RATES, 1970–1987

Country	Agriculture	Mining	Manufacturing	Services	EGW	Construction	Total industry
Labor Productivity:							
United States	0.021	−0.034	0.026	0.002	0.012	−0.020	0.006
Canada	0.017	−0.038	0.018	0.011	0.035	0.022	0.013
Japan	0.022	0.052	0.059	0.028	0.027	−0.007	0.038
W. Germany	0.055	−0.012	0.024	0.021	0.028	0.010	0.025
France	0.054	0.023	0.030	0.021	0.048	0.019	0.031
Italy	0.036	NA	0.045	0.006	0.003	0.004	0.024
United Kingdom	0.042	0.064	0.026	0.011	0.022	−0.001	0.020
Australia	0.023	0.017	0.025	0.007	0.024	0.019	0.014
Netherlands	0.057	0.041	0.038	NA	0.008	0.005	0.025
Belgium	0.047	−0.001	0.051	0.012	0.056	0.020	0.028
Denmark	0.056	0.217	0.029	0.016	0.044	−0.004	0.024
Norway	0.035	0.169	0.017	0.012	0.016	0.018	0.029
Sweden	0.032	−0.007	0.022	0.016	0.041	0.026	0.022
Finland	0.034	0.032	0.037	0.027	0.026	0.020	0.033
Average:	0.038	0.040	0.032	0.015	0.028	0.009	0.024
Multifactor Productivity, Divisia:							
United States	0.007	−0.038	0.018	0.002	0.006	−0.019	0.002
Canada	0.004	−0.066	0.008	0.006	0.003	0.016	0.004
Japan	0.077	0.016	0.033	0.006	−0.013	−0.026	0.017
W. Germany	0.062	−0.018	0.015	0.004	0.004	0.006	0.012
France	0.037	−0.003	0.018	0.011	0.028	0.010	0.018
Italy	0.026	NA	0.029	0.007	−0.020	−0.036	0.010
United Kingdom	0.030	−0.008	0.017	0.006	0.010	−0.006	0.010
Australia	0.014	−0.014	0.014	NA	0.019	0.008	0.005
Netherlands	0.043	−0.005	0.024	NA	−0.012	−0.008	0.014
Belgium	0.028	NA	0.035	NA	0.039	0.007	0.015
Denmark	0.039	0.109	0.023	0.010	0.033	−0.009	0.015
Norway	0.004	0.016	0.007	0.008	0.003	0.009	0.016
Sweden	0.021	−0.026	0.014	0.010	0.018	0.022	0.013
Finland	0.031	0.024	0.025	0.013	0.014	0.015	0.019
Average:	0.030	−0.001	0.020	0.008	0.009	−0.001	0.012

Notes: Growth rates are computed as the coefficient on a time trend in the regression of the log(productivity) on a constant and the trend. EGW = electricity/gas/water; NA indicates that the growth rate could not be computed.
Source: OECD Intersectoral Database.

reason for this difference to carry over into multifactor productivity. Another possibility, however, is measurement error. Martin N. Baily (1993) cites numbers from the McKinsey Global Institute which suggest that total factor productivity in Japanese general merchandise retailing was only 55 percent of that of the United States as of 1987, which suggests that measurement error may plague the service-sector data. Once again, however, as long as the manufacturing data are accurate, the key results of this paper hold up.

Before reporting the sectoral convergence results, we consider the changing share of sectors in overall GDP. Even if there is convergence within sectors, aggregate convergence may not occur. For example, if output shares of industries vary across countries, then once all sectors have converged to their sector-specific long-run productivity levels there will still be differences in aggregate productivity levels across countries. Convergence in output shares together with sector-specific convergence is sufficient for aggregate convergence. Both the level and change in shares differ dramatically over time. Within manufacturing, services, construction, and agriculture, most countries show similar trends over time.

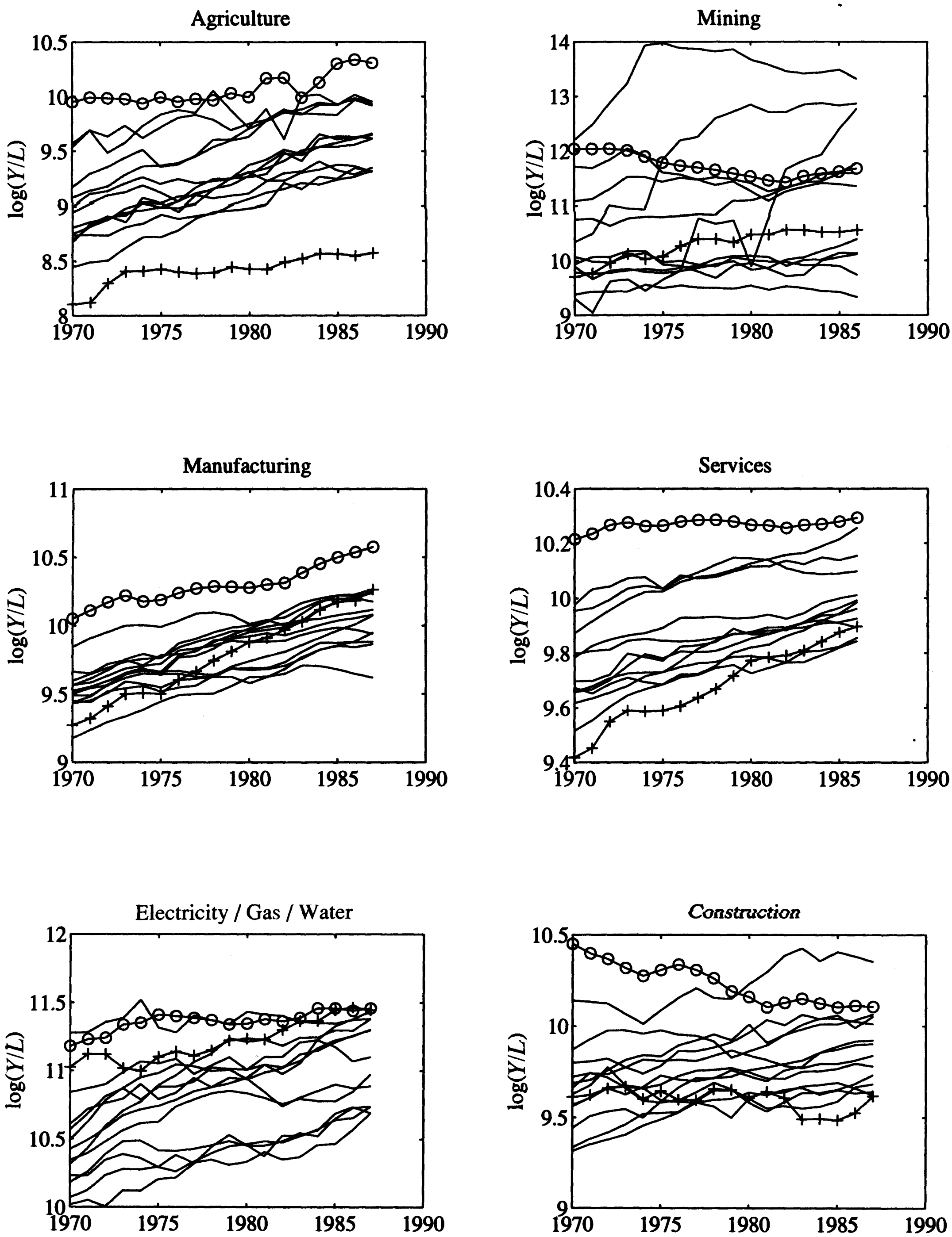

FIGURE 2. LABOR PRODUCTIVITY BY SECTOR (NATURAL LOGS)

Note: Open circles denote the United States, and "plus" symbols denote Japan.

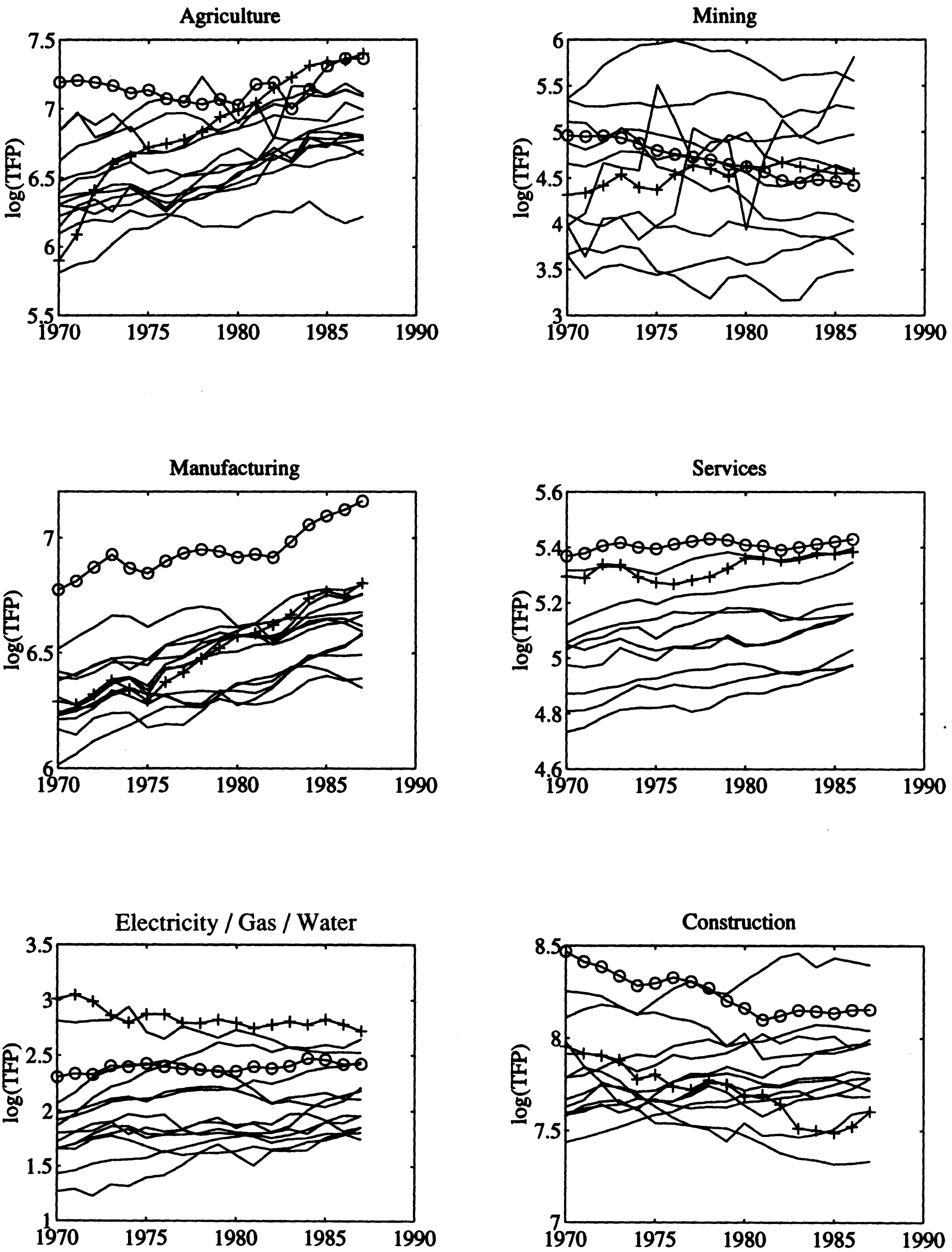

FIGURE 3. TOTAL FACTOR PRODUCTIVITY BY SECTOR (NATURAL LOGS)

Note: Open circles denote the United States, and "plus" symbols denote Japan.

TABLE 2—COMPARISONS OF PRODUCTIVITY FROM ALTERNATIVE SOURCES

Source	Y/L growth (percent)		MFP growth (percent)	
	Total industry	Manufacturing	Total industry	Manufacturing
BLS	1.5	2.8	0.8	2.2
ISDB	0.6	2.6	0.2	1.8

Generally, the share of manufacturing is declining (Japan is a notable exception to this trend), as are the shares of construction and agriculture. Services is the only sector to show substantial share growth for most countries, accounting for at least 49 percent and as much as 64 percent of total industry output in 1987. Manufacturing and services make up at least two-thirds of total output in every country throughout the period.[12] As a result, in testing for convergence at the industry level, we will concentrate on the results for these two sectors.

B. *Cross-Country Convergence*

Distinct definitions of convergence have emerged in recent empirical work. Cross-section analyses focus on the tendency of countries with relatively high initial levels of output per worker to grow relatively slowly (β-convergence) or on the reduction in cross-sectional variance of output per worker (σ-convergence), as in Barro and Sala-i-Martin (1991, 1992). This idea of convergence as catching-up is linked to the predicted output paths from a neoclassical growth model with different initial levels of capital. Once countries attain their steady-state levels of capital, there is no further expected reduction in cross-section output variance. Time-series studies define convergence as identical long-run trends, either deterministic or stochastic. This definition assumes that initial conditions do not matter within samples, and it tests for convergence using the framework of cointegration.[13]

The model of catch-up in Section I implies that both types of convergence should hold given a long enough sample. If the 14 OECD countries are on their long-run steady-state growth paths as of 1970, then the appropriate framework for testing industry-level convergence is that of cointegration. However, if technology catch-up is still taking place as of 1970 then the cross-section tests are more informative. In this paper, we will focus on the cross-section analysis of convergence, examining β-convergence and σ-convergence. Elsewhere (Bernard and Jones, 1996) we have tested for convergence using the sectoral data in a time-series framework, with similar results.

Table 3 presents the results on β-convergence for labor productivity. For each sector, the growth rate of productivity is regressed on its initial level (and a constant), generating an estimate of β. The implied speed of converge, λ, is then calculated using the formula from equation (7). In this framework, the speed of

[12] To test whether these countries are becoming more similar in output composition, broadly defined, we tested for convergence in the sectoral output shares. Only agriculture and construction showed a narrowing of the differences of output shares across countries during the sample. Mining shares diverge, while shares of manufacturing, services, and EGW do not show much change in the cross-country dispersion. The cross-section growth-rate regressions confirm these results. Agriculture and construction show convergence in shares with negative and significant coefficients on initial levels, the coefficient for services is negative and significant at the 10-percent level, and the other sectors have negative but insignificant coefficients. These results on sectoral output shares suggest that, while services is growing as a share of output and manufacturing is declining in most countries, there remain substantial differences in sectoral shares across countries. In particular, there is little tendency for shares to become more similar, as measured by standard convergence criteria.

[13] For a discussion of the theoretical and empirical inconsistencies associated with these two measures of convergence, see Bernard and Durlauf (1996).

TABLE 3—CONVERGENCE REGRESSIONS: SECTORAL LABOR PRODUCTIVITY

Sector	β	SE	t	λ	R^2
Agriculture	−0.0122	0.0078	−1.57	0.0134	0.10
Mining	−0.0290	0.0210	−1.38	0.0364	0.07
Manufacturing	−0.0262	0.0147	−1.78	0.0326	0.14
Services	−0.0244	0.0086	−2.85	0.0283	0.56
Electricity/gas/water	−0.0208	0.0095	−2.20	0.0246	0.23
Construction	−0.0227	0.0112	−2.03	0.0274	0.19
Total industry	−0.0298	0.0052	−5.73	0.0385	0.71

Notes: Coefficients are estimated from the following equation:

$$\Delta \ln\left(\frac{Y}{L}\right)_i = \alpha + \beta \ln\left(\frac{Y}{L}\right)_i^{1970} + \varepsilon_i$$

with the speed of convergence, λ, calculated from

$$\beta = -\frac{1-(1-\lambda)^T}{T}.$$

convergence can be interpreted as the rate at which the productivity level is converging to some worldwide productivity level, which may itself be growing over time.

For labor productivity, the basic convergence result for total industry shown in equation (3) appears to hold for some sectors but not for others. For services, construction, and EGW, we obtain a significant negative estimate of β, implying that there has been catch-up in labor productivity during this period. The convergence rates for these industries vary from 2.46 percent per year in EGW to 2.83 percent per year in services. However, even within these converging sectors, the simple regression formulation differs widely in its ability to explain cross-country growth rates. In services, the regression accounts for 56 percent of the variation in total cross-country growth rate, while $\bar{R}^2$ is only 0.19 in the construction sector.

Surprisingly, there is no evidence for convergence in manufacturing, as the null hypothesis of no convergence is not rejected even at the 10-percent level. The $\bar{R}^2$ is correspondingly low. Similar results hold for mining and agriculture as well.

Table 4 shows comparable results for the standard TFP measure of multifactor productivity. Looking at TFP, we find even less evidence for convergence within manufacturing, as the coefficient, although still negative, is smaller and the t statistic is lower. The $\bar{R}^2$ for the manufacturing regression is also smaller at 0.02. Services once again shows convergence, albeit at a slower rate of 1.34 percent per year, and the simple regression explains 56 percent of the cross-country variation. Agriculture now shows strong evidence of convergence, suggesting that capital accumulation may even be offsetting technological convergence. Mining, construction, and EGW all show broadly similar patterns for TFP and labor productivity.

To understand more clearly the movements and convergence of productivity, we now turn to a measure of σ-convergence, the cross-section standard deviation of log productivity over time.[14] In the graphs, σ-convergence is indicated by a declining standard deviation, reflecting the fact that countries' productivity levels are getting closer together over time. The different sectoral contributions to aggregate labor productivity can be seen more clearly in Figure 4 which plots the cross-country sectoral standard deviations of log labor productivity over time. Services and EGW display substantial evidence of catch-up, as σ_t

[14] Combining the β- and σ-convergence results allows us to avoid potential problems associated with Galton's fallacy. Danny Quah (1993) shows that negative coefficients on β are consistent with a constant cross-section distribution.

TABLE 4—CONVERGENCE REGRESSIONS, SECTORAL TFP

Sector	β	SE	t	λ	R^2
Agriculture	−0.0390	0.0113	−3.45	0.0650	0.46
Mining	−0.0267	0.0198	−1.35	0.0350	0.07
Manufacturing	−0.0146	0.0132	−1.11	0.0168	0.02
Services	−0.0120	0.0033	−3.69	0.0134	0.56
Electricity/gas/water	−0.0253	0.0072	−3.49	0.0331	0.46
Construction	−0.0281	0.0148	−1.90	0.0384	0.17
Total industry	−0.0226	0.0056	−4.03	0.0287	0.54

Notes: Coefficients are estimated from the following equation:

$$\Delta \ln(\mathrm{TFP}_i) = \alpha + \beta \ln(\mathrm{TFP}_i^{1970}) + \varepsilon_i$$

with the speed of convergence, λ, calculated from

$$\beta = -\frac{1 - (1 - \lambda)^T}{T}.$$

is declining throughout the period. The results for manufacturing are particularly interesting: during the 1970's there is gradual convergence as the standard deviation of productivity falls from 0.22 to 0.18; however, after 1982 the standard deviation rises sharply for the remainder of the 1980's, reaching more than 0.23 by 1987. Evidence on the other sectors is less clear-cut: construction and agriculture fall initially and then become relatively steady, while mining rises dramatically and then falls back somewhat. These results do not change if the United States is removed from the sample. In fact, the increase in manufacturing dispersion is augmented.

Figure 5 plots the cross-country standard deviation in the log of TFP for the six major sectors. The results are similar to those for labor productivity and the β-convergence regressions. Services, agriculture, and EGW all exhibit substantial convergence, confirming the regression results. In contrast, productivity in the manufacturing sector shows no convergence in the 1970's, and it diverges during the 1980's.

One possible explanation for the lack of convergence in manufacturing is that these countries have already reached steady-state productivity levels in that sector, and we are observing a steady-state dispersion of productivity levels during our sample period. However, a quick calculation reveals that, even at the end of the period, labor productivity in manufacturing was $39,153 per worker in the United States and substantially less than half that in Denmark, the poorest performer at $15,048. This proportional gap of 2.6 in 1987 compares to a gap of 2.4 in 1970. The median country had labor productivity of $24,329 per worker, while the standard deviation of the level was $5,842, suggesting that substantial potential for catch-up and convergence remains in this sector. Similarly, for multifactor productivity, the level of manufacturing TFP in the United States was more than 2.2 times higher than that in the least productive country. These numbers are actually more dispersed than the comparable productivity levels in the service sector or in the private sector as a whole.[15]

The results on convergence in this section are in stark contrast to the picture given in previous work at the aggregate level. Convergence, defined as catch-up by low-productivity countries to high-productivity countries, is occurring at the aggregate level and within some

[15] The gaps in labor productivity between the most and least productive countries in 1970 were $17,479, $15,003 and $13,524 for total industry, services, and manufacturing, respectively. For 1987, the same differences were $13,329, $10,883, and $24,106. A complete set of productivity levels is given in Bernard and Jones (1995).

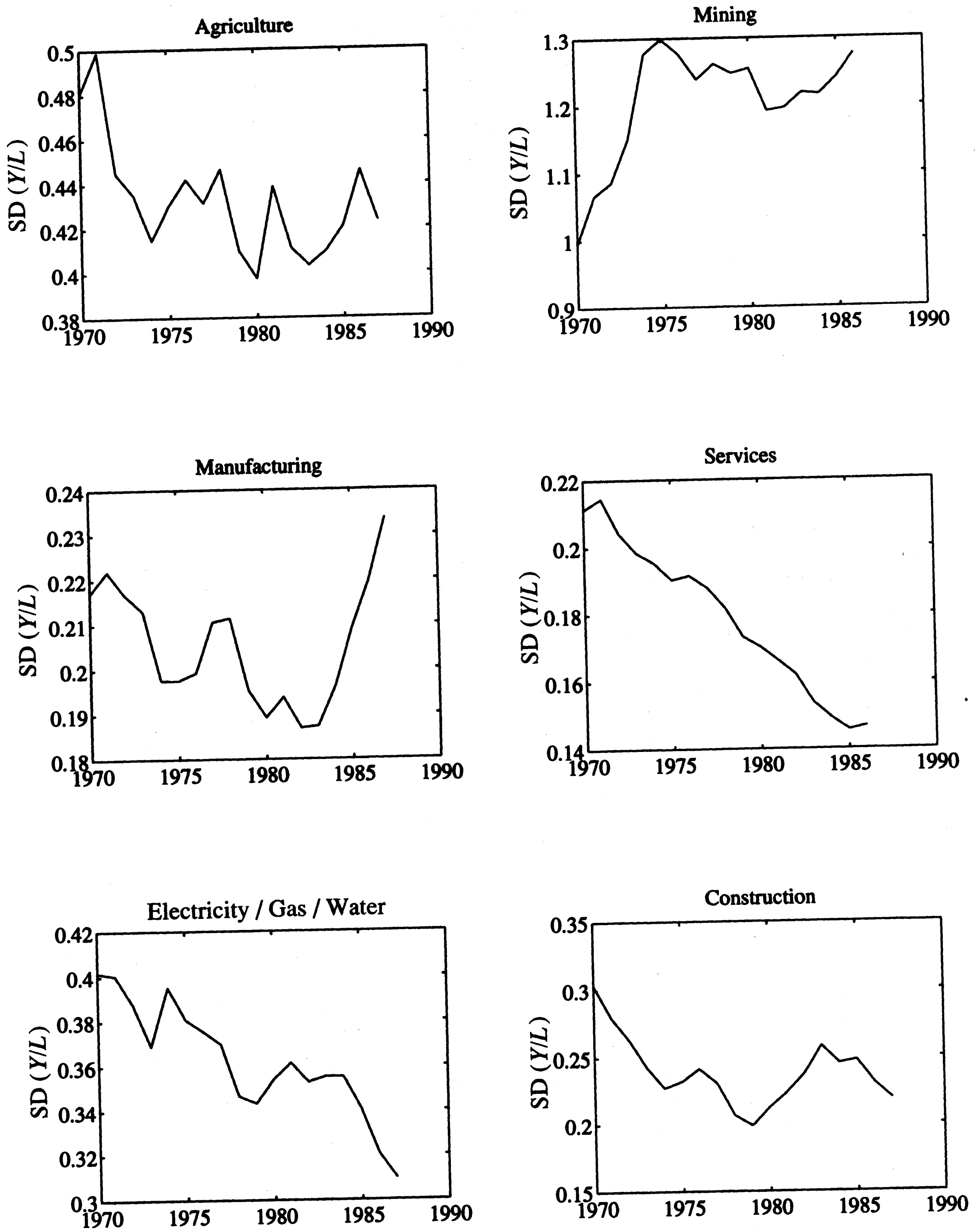

FIGURE 4. STANDARD DEVIATIONS OF (LOG) LABOR PRODUCTIVITY, BY SECTOR

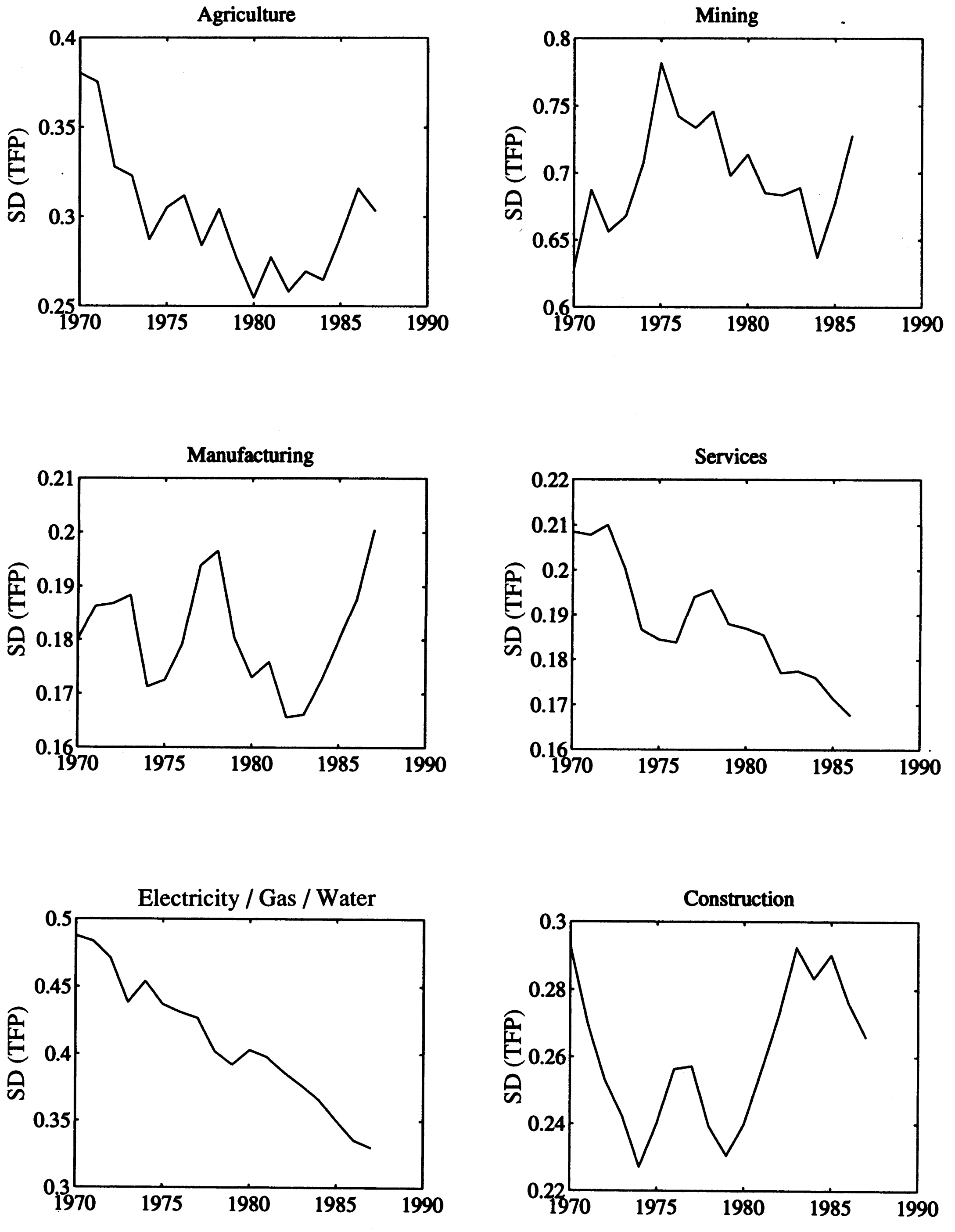

FIGURE 5. STANDARD DEVIATIONS OF (LOG) TOTAL FACTOR PRODUCTIVITY, BY SECTOR

sectors, such as services, for both labor productivity and multifactor productivity. However, surprisingly, manufacturing shows little or no evidence of convergence for either measure and, in particular, shows divergence during the 1980's. These results suggest that international flows, associated mostly with manufacturing, may not be contributing substantially to convergence either through capital accumulation or technological transfer.

C. *Previous Empirical Work on Sectors*

Most previous work on convergence has concentrated on aggregate data, looking in particular at output per capita or labor productivity (output per worker). An exception is work by David Dollar and Edward N. Wolff (1988, 1993) and Wolff (1991). Dollar and Wolff (1993) consider many of the issues addressed in this paper, such as convergence within sectors and the differences between labor productivity and TFP. They conclude that there has been substantial convergence in most sectors, and in particular within manufacturing during the period 1963–1985. In contrast, we find substantial evidence of convergence in most sectors after 1970, with the important and notable exception being manufacturing.

Several important differences in data and methodology exist between Dollar and Wolff (1993) and the present analysis. Dollar and Wolff use an early version of the OECD data set which ends in 1985. A symptom of likely problems with their data is that they find Norway to be the most productive country after 1982, a result not confirmed by any outside source. In addition, they use a problematic measure of multifactor productivity, as will be discussed in the next section. Their primary measure of multifactor productivity is not robust to a simple choice of units.

III. Robustness of the Convergence Results

The results of the previous section emphasize the variety of convergence outcomes across sectors, especially the lack of convergence in manufacturing. In this section, we determine whether those results are robust to problems in constructing multifactor productivity levels. We consider theoretical difficulties with the standard TFP measure employed in the previous section, propose an alternative which is robust to these problems, and report additional convergence results with the new measures. We also consider the robustness of the results to measuring the labor input in hours instead of workers and to using alternative purchasing-power-parity (PPP) conversions.

A. *Measuring Factor Productivity*

Assuming a Cobb-Douglas production function, $Y = AK^{1-\alpha}L^{\alpha}$, the Hicks-neutral measure of TFP is given by A, as in equation (9), which is a weighted average of capital and labor productivity. The problem with this measure is that if the parameter α differs across countries, comparisons of this measure of TFP can be misleading. Suppose that two countries have exactly the same inputs (i.e., the same capital and the same labor) as well as the same level of A, but they have different α's. Clearly, these two countries will produce different quantities of output. The problem with A as a measure of technology in this case is that it is incomplete: the technology of production varies with the α parameter as well as with the A's, and the simple Hicks-neutral measure of TFP does not take this into account.[16]

If factor shares vary substantially across countries, comparisons of productivity levels using the standard measure of TFP are incomplete. The first question we must ask, therefore, is whether or not this variation in factor shares is a problem empirically. Figure 6 illustrates that it is: for total industry in our data, the labor share varies substantially both across countries and over time.[17] With this motivation, we turn now to a new method for comparing productivity levels.

The joint productivity of capital and labor varies with both the "A term" in front of the

[16] There is another more serious problem with the Hicks-neutral measure; arbitrarily small differences in the α parameters across countries imply that changes in the units of measurement for an input can change the ranking of productivity levels. However, this problem can be resolved by using a Harrod-neutral rather than a Hicks-neutral productivity measure.

[17] Labor share varies over time and across countries for other sectors as well, especially manufacturing and services.

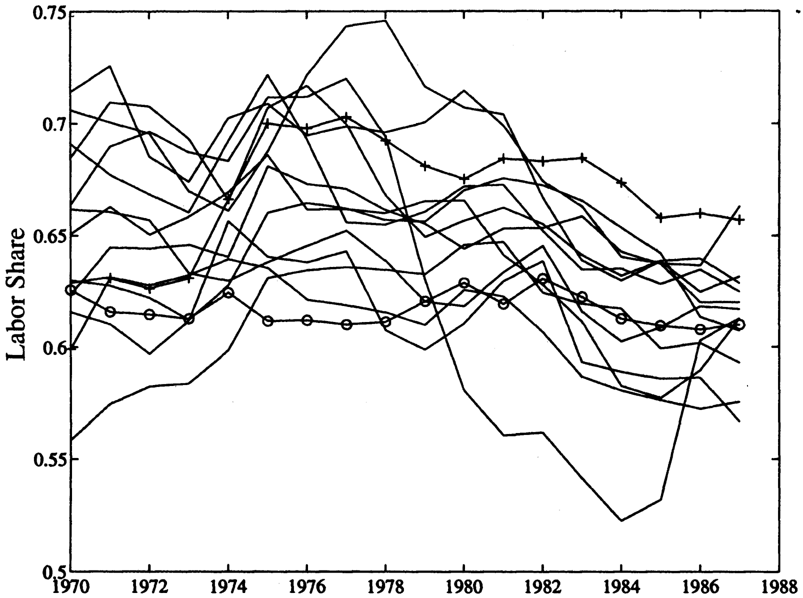

FIGURE 6. LABOR SHARE IN TOTAL OUTPUT, TOTAL INDUSTRY

production function and with the factor exponents. To capture both of these contributions to productivity, we define a new measure that will be referred to as total technological productivity (TTP). At any point in time for country-sector i, TTP is defined as

$$\text{(10)} \qquad \text{TTP}_{i,t} = F(K_0, L_0, i, t).$$

TTP has a very intuitive interpretation: it shows which country would produce more output if all countries employed exactly the same quantities of capital and labor. Since K_0 and L_0 are constant across time and country sector, comparisons using this measure incorporate only variation in the production function itself, not variation in the quantities of the inputs. In this sense, this definition of multifactor productivity is closely related to the definition of MFP growth given by Solow (1957). In practice, we will assume that the function $F(\cdot)$ is Cobb-Douglas so that

$$\text{(11)} \quad \ln(\text{TTP})_{i,t} = \ln A_{i,t} + (1 - \alpha_{i,t})\ln K_0 + \alpha_{i,t} \ln L_0$$

where $\ln A_{it}$ is defined as

$$\text{(12)} \qquad \ln A_{i,t} = (1 - \alpha_{i,t})\ln\left(\frac{Y_{i,t}}{K_{i,t}}\right) + \alpha_{i,t}\ln\left(\frac{Y_{i,t}}{L_{i,t}}\right).$$

Here, the labor share is allowed to vary across countries, sectors, and time to allow for the possibility that different industries in different countries have access to different technologies. Finally, because we are assuming constant returns to scale, we can normalize TTP by L_0 to get a measure of productivity in the familiar units of dollars per worker.[18]

The TTP measure is not without problems. Most importantly, comparisons of TTP may be sensitive to the capital–labor ratio K_0/L_0, as is obvious from equation (11). If two countries have different capital–labor ratios, the TTP measure may change rank depending on which capital–labor ratio is chosen.

[18] That is, we evaluate equation (11) at $K = K_0/L_0$ and $L = 1$.

This aspect of the TTP measure is unfortunate. Ideally, we would like a single answer to the question, "In the aggregate, which country is more productive, the United States or Japan?" However, the answer may depend on whether we use the U.S. capital–labor ratio or the Japanese capital–labor ratio. This is analogous to the classic index-number problem. Suppose we wish to compare the total output of two economies that produce different quantities of apples and oranges. Depending on the relative price used to weight apples and oranges, either country may appear to be more productive than the other.[19]

It should be noted that the standard TFP measure (using the same α for all countries) also shares a similar problem. In comparing TFP levels between the United States and Japan, the rank comparison may depend on whether one uses the Japanese factor share or the U.S. factor share to construct the TFP measure. In addition, the TFP measure suffers another drawback relative to the TTP measure: by ignoring differences in factor exponents, the TFP measure ignores a potentially important dimension along which technology may vary across countries.

B. *Other Production Functions and Productivity Measures*

Two alternative generalizations of the Cobb-Douglas production function are the CES (constant elasticity of substitution) and the translog production functions, which have been used elsewhere in the literature on productivity comparisons. While extending our analysis to these more general functional forms might be useful, we discuss below the limitations of such an exercise.

The CES specification, recommended by John W. Kendrick and Ryuzo Sato (1963), allows factor shares to vary monotonically with the capital–labor ratio. In our data, however, it appears that factor shares do not vary monotonically with the capital–labor ratio, nor do the factor shares behave similarly across countries. Within a country, for example, the relationship is typically not monotonic, and across countries, factor shares differ substantially. Thus, to examine productivity differences using the CES production function, we would have to allow the elasticity of substitution between factors to vary across countries and perhaps even over time.

Another alternative is the definition of productivity proposed by Douglas W. Caves et al. (1982). Their definition is based on the translog production function first considered by Laurits Christensen et al. (1971). As with the CES production function, factor shares corresponding to the translog production function depend on the level of capital and the level of labor. Specifically, Caves et al. show that

$$(13) \qquad s_{i,t} = \beta_L^i + \beta_{KL} \ln K_{i,t} + \beta_{LL} \ln L_{i,t}$$

where $s_{i,t}$ represents factor payments to labor as a share of output. The intercept in this equation is allowed to vary by country, but the other coefficients are equal across countries and over time. Empirical estimates of this equation using our data reveal that the null hypothesis of equal coefficients on ln K and ln L across countries is rejected at the 1-percent level.[20]

Using either the CES or translog production setup does not address the fundamental problem that the parameters of the production function may vary across countries. For this reason and with an appeal to simplicity, we maintain the assumption of Cobb-Douglas functional form and allow the factor shares to vary across time, country, and sector.

Dollar and Wolff (1993) also focus on productivity convergence using industry data and employ the following measure of productivity:

$$(14) \qquad \text{TFP}_{i,t}^{\text{DW}} = \frac{Y_{i,t}}{\alpha L_{i,t} + (1 - \alpha) K_{i,t}}$$

where α is the labor share of total compensation, assumed to be constant across units of observation.

It is easy to show that this measure of productivity is not robust to a change of units. For

[19] We thank John Taylor for this analogy.

[20] The F statistics are 9.35 (d.f. = 26, 233) and 7.54 (d.f. = 26, 262) for total industry and manufacturing, respectively.

TABLE 5—CONVERGENCE RESULTS, ALTERNATIVE MULTIFACTOR PRODUCTIVITY MEASURES

MFP Measures	β	SE	t	λ	R^2
Total Industry:					
TTP (Median *K/L*)	−0.0215	0.0059	−3.66	0.0268	0.49
TTP (Max *K/L*)	−0.0193	0.0058	−3.33	0.0234	0.44
TTP (Min *K/L*)	−0.0292	0.0057	−5.12	0.0405	0.66
TFP (Max α)	−0.0232	0.0052	−4.47	0.0296	0.59
TFP (Min α)	−0.0216	0.0060	−3.59	0.0270	0.48
Manufacturing:					
TTP (Median *K/L*)	−0.0080	0.0129	−0.62	0.0086	−0.05
TTP (Max *K/L*)	−0.0042	0.0126	−0.34	0.0044	−0.07
TTP (Min *K/L*)	−0.0193	0.0119	−1.62	0.0235	0.11
TFP (Max α)	−0.0171	0.0124	−1.39	0.0203	0.07
TFP (Min α)	−0.0084	0.0140	−0.60	0.0090	−0.05
Services:					
TTP (Median *K/L*)	−0.0109	0.0033	−3.32	0.0120	0.50
TTP (Max *K/L*)	−0.0102	0.0034	−3.00	0.0111	0.44
TTP (Min *K/L*)	−0.0124	0.0029	−4.31	0.0139	0.64
TFP (Max α)	−0.0132	0.0034	−3.84	0.0149	0.58
TFP (Min α)	−0.0109	0.0031	−3.47	0.0120	0.53

Notes: Coefficients are estimated from the following equation:

$$\Delta \ln(\text{MFP}_i) = \alpha + \beta \ln(\text{MFP}_i^{1970}) + \varepsilon_i$$

with the speed of convergence, λ, calculated from

$$\beta = -\frac{1-(1-\lambda)^T}{T}.$$

example, by choosing the units for capital and labor, one can make the relative contributions of K and L to this measure arbitrarily small so that comparisons will look exactly like comparisons of capital productivity or labor productivity. If the rankings of capital productivity and labor productivity differ for two countries, then either country can be shown to be the more productive by choosing the appropriate units at which to measure the inputs. Our data suggest that such problems are not simply theoretical oddities: for all three key aggregates (total industry, manufacturing, and services) in 1970, Japan has a higher capital productivity level than the United States, while the United States has higher labor productivity.[21]

C. *Convergence with Alternative Measures*

As discussed above, the TFP measure of multifactor productivity we employ in Section II may give incorrect results if labor shares vary across countries. In Table 5, we present results on sectoral convergence of multifactor productivity for total industry, manufacturing, and services using alternative measures of multifactor productivity levels, several versions of both TTP and TFP.[22]

Construction of TTP requires a measure of total factor productivity, factor shares, and

[21] It is easy to show that our TTP measure does not suffer from this problem: it is robust to a change in units. The intuition is that any change in units of K or L will change A in such a way as to leave comparisons of TTP unaffected. For example, measuring K and Y in thousands of dollars instead of dollars will simply change TTP so that it is measured in thousands of dollars also.

[22] In all cases, the growth rates continue to be calculated using the Divisia formulation.

capital and labor data. To construct TTP levels in practice for 1970–1987, we apply equation (11) to calculate the level in 1970 and generate levels for the subsequent years by cumulating the Divisia multifactor productivity growth rates. The 1970 level is used as an initial value. We pick three different capital–labor ratios for each sector, the median (our preferred value), the highest in 1970, and the lowest in 1970. Likewise we examine the robustness of our TFP convergence results to variation in labor shares, again picking the highest and lowest values for 1970 for each sector.

The top row of each section of Table 5 reports our preferred estimates of β-convergence in multifactor productivity using TTP. We see results on convergence roughly similar to those from the labor and TFP productivity measures used earlier. However, manufacturing now shows even less convergence: both the level and significance of the coefficient are reduced, and the $\bar{R}^2$ value is now negative. Total industry TTP is catching up at a rate of 2.68 percent per year. This compares to a point estimate for the manufacturing sector of only 0.86 percent per year, which is insignificantly different from zero. The services sector shows strong evidence of convergence, with a negative and significant estimate of β and a high $\bar{R}^2$ value.

Looking at the other MFP measures, we find little to change our conclusions about sectoral convergence. Total industry productivity is converging for all measures, with estimated convergence rates ranging from 2.34 percent to 4.05 percent per year. Similarly, services shows convergence in every case. For both total industry and services, the explanatory power of the simple regressions is substantial with $\bar{R}^2$ values as high as 0.66. The manufacturing results again show no or little evidence for convergence. While the estimated coefficients are negative, in no case are they significant. Extreme values of the capital–labor ratio or labor share that increase the relative importance of labor productivity yield lower estimates of β. Again, the explanatory power of the specification is weak, with the $\bar{R}^2$ value above 0.10 in only one case.

These results using a variety of multifactor productivity measures highlight the robustness of the key conclusions of this paper: the aggregate convergence in technological productivity within the OECD economies over the last two decades is driven by the nonmanufacturing sectors; within manufacturing, there is virtually no evidence of convergence, and even weak evidence of divergence.

D. *Hours versus Workers*

One possible source of the surprising result of no convergence in manufacturing productivity could be the use of workers as the measure of labor rather than hours worked.[23] If hours are falling faster in countries with lower initial productivity levels, then we might be understating the degree of productivity catch-up. To determine whether the nonconvergence results are robust to measuring labor with hours rather than workers, we obtained data on average hours worked in manufacturing for 12 of the countries in our sample.[24] Since hours are not available for other sectors, we calculate productivity measures for all sectors within a country using the manufacturing hours per worker in conjunction with sector-specific output per worker.

Using the new labor input data, we construct our measures of labor productivity, TFP (mean α), and TTP (median K/L) and plot the evidence on σ-convergence in Figure 7. With the new measures, total industry and services continue to show convergence throughout the sample. However, for manufacturing there is now a substantial drop in the cross-country standard deviation in the first few years of the sample, followed by flat or rising dispersion after 1975.

The hours-based evidence is consistent with a view in which the manufacturing sector

[23] We thank a referee for this point. It should be noted that, to our knowledge, no prior work on convergence has used information on hours in constructing sectoral measures of productivity. As a consequence, results derived with productivity measures using workers provide the relevant benchmark with regard to previous research.

[24] We are grateful to Arthur Neef at the Bureau of Labor Statistics for providing the hours data. These data are contained in the supplementary appendix (Bernard and Jones, 1995) which is available from the authors upon request.

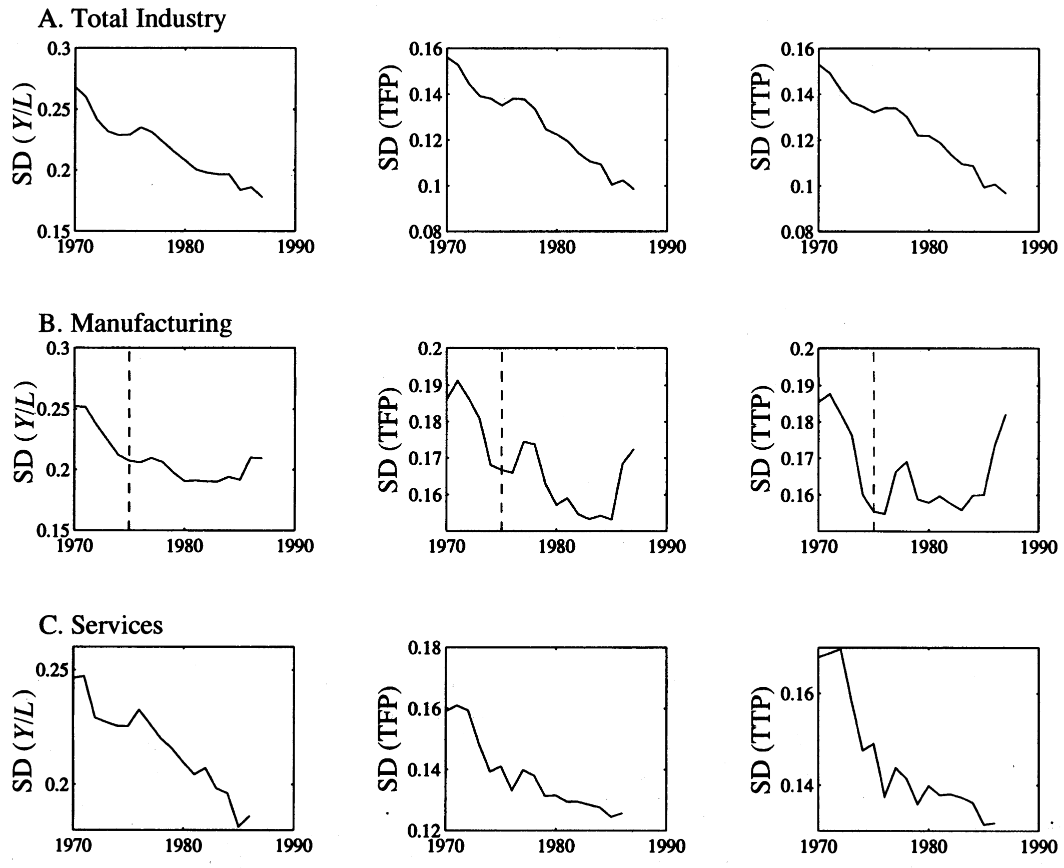

FIGURE 7. STANDARD DEVIATION OF (LOG) HOURS-BASED PRODUCTIVITY

shows little or no convergence after 1975. Is this because productivity levels have "already converged" by 1975, or do substantial differences remain? In fact, substantial differences seem to remain. The ratio between productivity in the most productive and least productive countries was at least 1.96 in 1987 for all three measures. Also, the ratio was at least as high in 1987 as it was in 1975 for all three measures. The range of productivity levels is quite striking. Labor productivity in the United States was \$12.12/hour in 1970 rising to \$20.29/hour in 1987. The least productive country was Japan in 1970 (\$4.68/hour) and Denmark in 1987 (\$9.32/hour). For TTP, the U.S. levels were \$11.50 and \$16.81 in 1970 and 1987, respectively, while the Danish levels were \$5.44 and \$8.39.

The β-convergence regressions for the manufacturing sector, given in Table 6, broadly support this interpretation. For the period 1970–1987, only the measure of labor productivity shows a negative and significant coefficient, although the $\bar{R}^2$'s are somewhat high for all measures. The second panel of Table 6 confirms the intuition provided by Figure 7 showing that after 1975 there is little or no evidence for convergence in manufacturing: the $\bar{R}^2$'s fall considerably and are very close to zero for both TFP and TTP.[25]

[25] The regression results for total industry and services continue to show convergence in all cases using the hours measure. These results, as well as those for other measures

TABLE 6—CONVERGENCE RESULTS FOR MANUFACTURING USING HOURS-BASED MEASURE OF LABOR

Productivity measure	β	SE	t	λ	R^2
1970–1987:					
Y/L	−0.0322	0.0132	−2.44	0.0470	0.31
TFP (Mean α)	−0.0236	0.0132	−1.79	0.0302	0.17
TTP (Median K/L)	−0.0194	0.0139	−1.40	0.0236	0.08
1975–1987:					
Y/L	−0.0275	0.0177	−1.55	0.0334	0.11
TFP (Mean α)	−0.0195	0.0178	−1.09	0.0222	0.02
TTP (Median K/L)	−0.0163	0.0181	−0.90	0.0181	−0.02

Notes: Coefficients are estimated from the following equation:

$$\Delta \ln(\text{MFP}_i) = \alpha + \beta \ln(\text{MFP}_i^{t0}) + \varepsilon_i$$

with the speed of convergence, λ, calculated from

$$\beta = -\frac{1-(1-\lambda)^T}{T}.$$

E. *Purchasing Power Parity*

Another possible explanation for our finding of little or no convergence in the manufacturing sector is the PPP conversion employed in the ISDB data. This conversion is based on 1980 PPP's. In results not reported here (but available from the authors upon request), we examined the evidence on sectoral convergence using 1970, 1975, and 1985 PPP conversions taken from Angus Maddison (1995). The theoretically correct PPP exchange rate to use in comparing 1970 productivity levels, as is required in the cross-section regressions, is the 1970 rate. When we use this rate, our results are strongly confirmed.[26] The $\bar{R}^2$'s from the regressions are all negative, the estimated speeds of convergence are small, and the standard deviations of log productivity are rising over time. Using 1975 PPP's produces similar confirming evidence. These results are even stronger than the results in the paper based on 1980 deflators.

The only evidence for convergence in manufacturing comes from using 1985 PPP exchange rates. The results using the 1985 PPP conversion show convergence in manufacturing prior to 1982 but divergence thereafter. Several noteworthy points lead us to favor the results found with 1970, 1975, and 1980 deflators. First, as mentioned above, the 1970 rates are the theoretically correct ones for converting 1970 levels. Second, 1985 was a year of substantial overvaluation for the U.S. dollar. While PPP rates are supposed to correct for such temporary movements, it is possible that the PPP's from that year may not be fully adjusted. Finally, the period for which the 1985 rates would give the best conversion is the 1980's. In those years, we still find divergence for manufacturing productivity. Overall, calculations with different PPP conversions support our conclusions of little or no convergence, and even divergence, in manufacturing productivity.

IV. Interpretations and Conclusion

This paper has asked whether the trends observed in aggregate productivity are represen-

of productivity, are contained in Bernard and Jones (1995), available from the authors upon request.

[26] The results are available in Bernard and Jones (1995). Unfortunately, we have 1970 and 1975 PPP exchange rates for fewer countries, leading us to report the 1980 results throughout the paper.

tative of movements at the industry level. Many sectors, such as services, show evidence of convergence at least as strong as that found in the aggregate. In contrast, we find that manufacturing does not display the pattern of convergence in labor and technological productivity found in other sectors.

To measure productivity for all factors we constructed a new measure of total technological productivity which is robust to several problems inherent in traditional formulations of total factor productivity. We show that whatever the measure of total productivity chosen, there remain inherent assumptions to be faced by the researcher, and we suggest that constant-factor-share TFP and the TTP based on median K/L be used to confirm the robustness of any level-based results.

Any explanation of the findings in this paper must reconcile the catch-up/convergence of technological productivity in some one-digit sectors together with the lack of convergence, and even divergence, of technological productivity in other one-digit sectors. One possible explanation centers on the distinction between tradable and nontradable goods in a world with specialization and spillovers, similar to the model in Paul Krugman (1987). The nontradable-goods sectors will behave very much like an aggregate growth model, and technological productivity levels will converge in these sectors as the technology for producing similar goods diffuses over time. For example, if you walk into a supermarket in Boston, Frankfurt, or Tokyo a laser scanner will record the price of each item you purchase, and you can stop by an automated teller machine (ATM) on your way home to replenish your liquidity: the technologies used to offer the same service across advanced countries are potentially similar.[27] On the other hand, in the tradable-goods sectors, comparative advantage leads to specialization, and to the extent that countries are producing different goods, there is no a priori reason to expect the technologies of production to be the same or to converge over time. Thus, computer-related products and aircraft are produced in the United States, rotary printing presses and production machinery are produced in Germany, and a myriad of consumer electronics are produced in Japan. There is no reason for the multifactor productivity for these different commodities to be the same. Of course, this effect may be mitigated somewhat by technological spillovers across goods.

The results from this paper raise many questions about productivity-performance comparisons over time and across countries at an aggregate level. Work on industry productivity for less developed countries will potentially reveal much about the underlying processes of convergence and industrial growth. More needs to be done on separating the role of capital accumulation and technological change. Also, our results hint that the 1970's and 1980's may have been very different times for productivity performance across countries and sectors. Longer time series on productivity at the industry level will help us understand the nature of longer trends in productivity.

[27] Of course, the word "potentially" is extremely relevant here, as illustrated by Baily's (1993) comparison of multifactor productivity in general merchandise retailing.

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