Catching Up in Industrialized Countries: A Disaggregated Study*

by

Pär Hansson & Magnus Henrekson

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Abstract: In this study we test whether catching up, the hypothesis that there is technological spillover from leaders to followers, is still important among industrialized countries. Since the U.S. is no longer the technological leader in many industries and since catching up, if it still exists, may not operate uniformly across different industries, a disaggregated study is more appropriate. A testable model is developed and a number of tests for the existence of catching up are performed. A major improvement on previous tests is that the level of technology is measured in terms of total factor productivity. The two major conclusions, which are quite robust, are that after 1970 there is no catching up effect left in the tradables sector, while catching up is found for industries in the nontradables sector.

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Trade Union Institute for Economic Research, FIEF
Wallingatan 38
S-111 24 Stockholm
SWEDEN

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1. Introduction

Two different explanations why one should expect income and productivity growth to be faster in relatively poorer countries have been expounded. First, there is a long tradition among economic historians to predict a long-run tendency towards convergence of per capita income based on the premise that it is much easier for latecomers in terms of industrialization and economic development to imitate technologies already in existence, than it is for the technologically leading country(ies) to advance the technological frontier through innovation. This mechanism is often referred to as *catching up*. Second, in the neoclassical aggregate growth model developed by Solow (1956) and refined by Cass (1965) and Koopmans (1965), the rate of return on investment and the rate of growth of per capita output are expected to be decreasing functions of the level of the capital stock per capita. Hence, in the absence of shocks poor and rich countries would tend to converge in terms of levels of per capita income.

But how do these convergence hypotheses square with the facts? From the numerous tests of the convergence hypothesis two general findings stand out. There is a very strong tendency towards convergence among the OECD countries during the postwar period, but when the number of countries is expanded to include increasingly poor countries any obvious sign of convergence disappears. The tendency towards convergence is also weaker when the time period is extended backward. These findings point to the possibility that convergence may not be such a universal phenomenon after all. It is not unreasonable to hypothesize that the first quarter of a century following World War II was exceptionally conducive to convergence among the presently advanced countries, or to use the words of Abramovitz (1986, p. 395):

> The post-World War II decades then proved to be the period when—exceptionally—the three elements required for rapid growth by catching up came together. The elements were large technological gaps; enlarged social competence, reflecting higher levels of education and greater experience with large-scale production, distribution and finance; and conditions favoring rapid realization of potential.

The main purpose of this study is to test whether catching up is still important among industrialized countries. In the framework we develop catching up is attributed to technological spillover from leaders to followers. However, although it is uncontroversial to assert that the United States was the undisputed technological leader in almost every field at the beginning of the postwar period, such an assertion would be in considerable dispute today. Now technological leadership in different sectors is likely to be spread among different countries. To account for this possibility it is necessary to use disaggregated data.

Furthermore, one may reasonably hypothesize that there are sectoral differences in the rate of technological progress and diffusion of technology. In particular, international competition may promote technical change and growth in the tradables sector. For this reason, the potential for technological catching up in the tradables and nontradables sectors may not have been the same by 1970, which is the starting year for our investigation. Hence, we allow for different catching up effects in these two sectors.[1]

Our empirical study covers 14 OECD countries during the period 1970–85. The results indicate systematic differences between sectors in rates of

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[1]The potential for different catching up effects across sectors has previously been proposed by Dowrick and Gemmel (1991). They assume that the catching up effect operates differently in agriculture and nonagriculture. However, no rationale is given for making this assumption.

technological progress and technological diffusion. The rate of growth in total factor productivity is faster for tradables than for nontradables, and catching up only occurs for nontradables. Hence, the potential for catching up in the tradables sector seems to have been depleted before the beginning of the studied period.

In section 2 we briefly review the catching up literature, largely with the purpose of pinpointing why the methodologies used in previous tests are less suitable for testing whether catching up is still important among the richest countries. In section 3 we give a broad picture of the catching up process in different industries in 14 OECD countries during the 1970–85 period and perform two preliminary nonparametric tests for catching up on the industry level. In the following section we present our theoretical model and the results from our regression analysis. Section 5 serves as a conclusion.

2. A Brief Review of the Catching Up Literature

Although there are two different hypotheses that predict income and productivity growth to be faster in countries at lower levels of economic development, we mainly intend to test the catching up hypothesis. The idea of catching up can be traced back at least to Gerschenkron (1952), who argued that regarding the growth prospects of a country there may exist an advantage of "relative backwardness". The hypothesis, excellently summarized in Abramovitz (1986), says that when the productivity level is considerably higher in one or more countries compared to a number of other countries, the latter have the opportunity to embark on a catching up process by borrowing superior production techniques from the more advanced economies. Hence, we should expect technologically less advanced countries to grow faster than the technologically leading country(ies). But, it should be stressed that this is a potentiality that need not take place. Another necessary condition for catching up is a sufficient degree of "social capability", i.e., the laggard country must be sufficiently sophisticated to be able to adopt the superior technology. Therefore, one should expect catching up to be strongest in countries that are technologically backward, but socially advanced.

Abramovitz (1986) and Baumol (1986) find a strongly significant negative correlation between the initial level of labor productivity and its rate of growth during the 1870–1979 period for the 16 developed countries studied by Maddison (1982).[2] At first glance, this seems to be strong evidence of catching up. But the evidence is weaker than it appears. First, the average productivity of the follower countries does not approach that of the U.S. — which is defined as the technological leader — when the whole period is considered. Catching up manifests itself mainly through a decrease in the variance of productivity levels between countries. There are signs that convergence has weakened or ceased after 1973, and there are considerable changes in the rank order of countries over time, something which is not predicted by the catching up hypothesis. Second, and more important, De Long (1988) points out that Maddison's 16 countries is an *ex post* selection of countries that have developed successfully. Thus, convergence is practically guaranteed in the statistical analysis. De Long shows that an *ex ante* sample of nations relatively rich in 1870 and well-integrated into the world economy in 1870 have not converged.[3] In addition, as documented by several scholars (Baumol and Wolff, 1988; Romer 1989; Barro, 1991) it is

[2]In an even more recent study Wolff (1991) finds strong support for the catching up hypothesis for the group of seven countries during the same period.
[3]The same point is made by Streissler (1979) for the postwar period when comparing a sample of *ex post* and *ex ante* industrialized countries.

clear that when the sample of countries is extended to include as many market economies as data availability permits, one cannot find that the growth rates vary systematically with initial income.

But if catching up is caused by technological spillover to follower countries, one should actually expect convergence in total factor productivity (TFP) rather than in GDP per capita. An observed convergence in labor productivity or GDP per capita can be the result of different rates of capital accumulation per capita. If that is the case, convergence is falsely attributed to technological catching up. Catching up in TFP is examined in a recent study by Dowrick and Nguyen (1989). They find TFP catching up for the period 1950–85 for all countries but the very poorest. When the data is split up in subperiods, there is still catching up during the last period, 1973–85. Although Dowrick and Nguyen test TFP catching up, they have no data on the (relative) levels of TFP to measure the potential for catching up. Instead catching up potential in this and other studies is proxied by GDP per head relative to the U.S. at the beginning of the studied period. Neither do they have a measure of the size of the capital stock, which forces them to implicitly assume that capital output ratios are constant across countries over time.

As previously noted by Dollar and Wolff (1988) it may be inappropriate to test for the existence of catching up at the most aggregate level. A regression analysis restricted to the GDP level may spuriously attribute income convergence to catching up, when the real explanation is something else. For instance, Dowrick and Nguyen (1987) and Dowrick (1989) have suggested that a lower marginal productivity in the production of services and a faster-growing service sector in richer countries would account at least for part of the observed convergence. Preference shifts towards activities of self-expression and enhancement of “quality of life” in richer economies have also been put forward as explanations (Gruen, 1986). The main reason, however, for using starting levels of sectoral productivity rather than aggregate productivity or GDP per capita in testing for technological catching up is that there may be systematic differences between sectors in technological catching up. Dowrick and Gemmel (1991) found that the productivity levels in agriculture tended to diverge across countries in 1960–85, whereas there was convergence in the nonagricultural sector. Moreover, a specification test showed that their sectoral model was superior to models using aggregate measures. Hence, we conclude that in order to discern whether technological catching up is still important among industrialized countries, it is advantageous to make a study of disaggregated data, measuring catching up potential within industries across countries, rather than just across countries at the most aggregate level.

Earlier studies have always used catching up variables that define the U.S. as the technological leader. Even if it is uncontroversial to claim that the U.S. was the technological leader in virtually all industries at the end of World War II, this has gradually changed. A preliminary analysis of our data indicates that the U.S. by no means had the highest TFP in the majority of industries by 1970.

Our test presented below tries to avoid the shortcomings of previous studies, which have made them less valuable for testing whether catching up is *still* an important factor among industrialized countries.

3. A Broad Picture of Catching Up on the Industry Level

Catching up is defined in terms of TFP levels in different industries. TFP_{ik} is a measure of the technological level in industry i in country k. The indices of TFP levels are implicitly based on a Cobb-Douglas function:[4]

$$\log TFP_{ik} = \log Y_{ik} - \alpha_i \log L_{ik} - (1 - \alpha_i)\log K_{ik} \qquad (1)$$

Y_{ik} is value added and K_{ik} is the capital stock in industry i in country k. To be able to compare TFP levels across countries, the local currencies have been converted to a common standard by using the OECD purchasing power parity estimates with 1980 as the base year (see Ward (1985)).[5] L_{ik} is total employment in industry i in country k.

The factor shares α_i are computed under the assumptions that the technology is the same in each industry across countries. This implies that factor shares should be equal across countries, and we can use the international (arithmetic) average factor shares in different industries as measures of α_i. The share of labor in value added in sector i in country k is calculated as

$$\alpha_{ik} = \frac{W_{ik}\left(\frac{L_{ik}}{E_{ik}}\right)}{Y^{*}_{ik}} \qquad (2)$$

where W_{ik} denotes compensation to employees; Y^{*}_{ik}, value added in current prices; L_{ik}, total employment including self-employed; and E_{ik}, total number of employees. The self-employed are included in the weighting scheme by

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[4]The same measure is used, *inter alia*, by Wolff (1991).
[5]Current exchange rates are inappropriate for the conversion because of the strong volatility of exchange rates after the demise of the Bretton Woods system. The use of PPP exchange rates follows the standard used by other researchers, e.g., Dowrick and Nguyen (1989), Dowrick (1989) and Dowrick and Gemmel (1991).

assuming that they receive the same average rate of compensation, and total compensation is rescaled in accordance.

We perform two tests to determine whether there has been any international catching up at the industry level. First, we compare the means of the quotients between the followers' and the leader's TFP level in 1970 and 1985 in different industries, $\left(\frac{\bar{\tau}}{\tau^*}\right)_i^{\text{year}}$; $\bar{\tau}$ is the mean of the TFP levels among the followers and τ^* is the TFP level in the leading country. An increased quotient, $\left(\frac{\bar{\tau}}{\tau^*}\right)_i^{1985} > \left(\frac{\bar{\tau}}{\tau^*}\right)_i^{1970}$, indicates convergence of productivity levels and international technology spillover. Second, we compare the coefficients of variation in TFP levels in 1970 and 1985, $\text{CV}(\tau)_i^{\text{year}}$. A decrease in the coefficient of variation over the period reflects that countries that started out at a relatively low level of TFP have progressed relatively faster.

Our data comes from the International Sectoral Data Bank (ISDB) compiled by the OECD. It contains 14 countries and covers the period 1970–85. The countries and industries contained in the ISDB are described in *Appendix*.

The results are reported in *Table 1*. We find that the quotients $\left(\frac{\bar{\tau}}{\tau^*}\right)_i^{\text{year}}$ have increased in all industries outside manufacturing, except electricity. The coefficients of variation, $\text{CV}(\tau)_i^{\text{year}}$ have decreased in all industries except the food, paper and non-metalic industries. Thus, even though the pattern in manufacturing is ambiguous, these preliminary tests indicate that a catching up effect may exist. But in order to establish whether catching up has been statistically significant, a regression analysis is called for.

Table 1 about here

4. A Growth Model of Intersectoral Disequilibrium and Catching Up

Our model, which integrates and adapts features from Dowrick (1989) and Dowrick and Gemmel (1991), takes its point of departure in a production function (sector and country indices are suppressed):

$$Y_t = A_t \, \mathrm{f}\,(K_t, L_t) \tag{3}$$

Output Y in a given industry i and country k at time t is a function of capital K and labor L. A_t measures the level of total factor productivity (TFP), i.e., how efficiently capital and labor are used jointly in the production process.[6]

Differentiation with respect to time and some rewriting gives us an expression of the relative growth of output:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \mathrm{f}_K\left[\frac{\dot{K}}{K}\frac{K}{Y}\right] + \mathrm{f}_L\left[\frac{\dot{L}}{L}\frac{L}{Y}\right] \tag{4}$$

$\frac{\dot{A}}{A}$, $\frac{\dot{K}}{K}$ and $\frac{\dot{L}}{L}$ denote, respectively, the relative growth rate in TFP, capital and labor. f_K and f_L are the marginal productivity of capital and labor. K/Y and L/Y are the inverses of the average productivity of capital and labor.

Lower marginal productivities of labor and capital in nontradables than in tradables in combination with a faster growing nontradables sector has, as we pointed out in section 2, been proposed as a (partial) explanation of convergence. Different marginal products could be caused by factor immobility between sectors. Another reason might be measurement problems; failure to capture improvements in the quality of output in services leads to an underestimation of true productivity. To examine whether

[6]The production function (3) implies disembodied Hicks-neutral technical change.

there are sectoral differences between the tradables and nontradables sectors we estimate the following model:

$$\left[\frac{\dot{Y}}{Y}\right]_{ik} = \beta_0 + \beta_{11} Z\left[\frac{\dot{K}}{K}\frac{K}{Y}\right]_{ik} + \beta_{12}(1-Z)\left[\frac{\dot{K}}{K}\frac{K}{Y}\right]_{ik} + \\ + \beta_{21} Z\left[\frac{\dot{L}}{L}\frac{L}{Y}\right]_{ik} + \beta_{22}(1-Z)\left[\frac{\dot{L}}{L}\frac{L}{Y}\right]_{ik} + \varepsilon_{ik} \tag{5}$$

Z is a dummy variable that equals 1 if industry i belongs to the tradables sector and 0 if it belongs to the nontradables sector. An implicit assumption underlying this specification is that free mobility of factors within a country will equalize the marginal products across industries. Even in the absence of international factor mobility, free trade will, under certain conditions, equalize the marginal products in the tradables sector across countries, and indirectly also in the nontradables sector. On the other hand, we do not assume anything about the functional form of the production function.

A further hypothesis we will test is whether there are systematic differences in the rates of technological progress and technological diffusion between sectors. We hypothesize that the relative rate of growth in TFP, $\dot{A}/A$ in (4), is larger in tradables than in nontradables industries. In order to model this we assume that the relative growth in TFP is determined by a sector specific factor as well as by a catching up factor. Catching up potential is measured by the initial technological gap in terms of TFP levels between a country k and the leading country in that industry. The catching up factor is allowed to vary between the tradables and nontradables sectors. The relative rate of growth in TFP in industry i in country k is then given by:

$$\left[\frac{\dot{A}}{A}\right]_{ik} = \lambda_j + \kappa_j \log\left[\frac{\tau_{ik}}{\tau_{il}}\right], \quad j = 1, 2 \tag{6}$$

λ_j is the sector-specific factor, and we hypothesize that $\lambda_1 > \lambda_2$. τ_{ik}/τ_{il} is the catching up factor. τ_{il} is the TFP level in the country with the highest productivity in industry i in 1970 and τ_{ik} is the TFP level in industry i in country k.

By combining (5) and (6) we get our basic model:

$$\left[\frac{\dot{Y}}{Y}\right]_{ik} = \alpha_0 + \alpha_1 Z + \beta_{11} Z\left[\frac{\dot{K}}{K}\frac{K}{Y}\right]_{ik} + \beta_{12}(1-Z)\left[\frac{\dot{K}}{K}\frac{K}{Y}\right]_{ik} + \beta_{21} Z\left[\frac{\dot{L}}{L}\frac{L}{Y}\right]_{ik} + \\ + \beta_{22}(1-Z)\left[\frac{\dot{L}}{L}\frac{L}{Y}\right]_{ik} + \beta_{31} Z\log\left[\frac{\tau_{ik}}{\tau_{il}}\right] + \beta_{32}(1-Z)\log\left[\frac{\tau_{ik}}{\tau_{il}}\right] + \varepsilon_{ik} \quad (7)$$

where $\alpha_0 = (\beta_0 + \lambda_2)$, $\alpha_1 = (\lambda_1 - \lambda_2)$, $\beta_{31} = \kappa_1$ and $\beta_{32} = \kappa_2$.

We use the same data as in section 3. The average annual relative growth rate of a variable X during the period 1970–85 is given by:

$$\frac{\dot{X}}{X} = \frac{1}{15}\left(\log X_{ik}^{85} - \log X_{ik}^{70}\right) \quad (8)$$

The means and standard deviations of the variables in (7) are presented in *Table 2*. The growth rate has been higher in the nontradables sector. The average productivity gap between the leader and the other countries has decreased somewhat in the nontradables sector, whereas it has increased slightly in the tradables sector. This is consistent with the results presented in the previous section. In *Table 3* we present regression results from the estimation of equation (7).

Table 2 about here

In specification (i) we find that the marginal productivity of capital is equal in the two sectors.[7] The marginal productivity of labor is larger in the

[7] $\beta_{12} - \beta_{11} = 0.001$ (0.02); t-value in parentheses.

nontradables sector.[8] In specification (ii) we assume that the marginal productivity of capital is equal in the tradables and nontradables sectors (β_1). The marginal productivity of labor is significantly larger in the nontradables sector, $\beta_{22} > \beta_{21}$.[9] Contrary to what is commonly believed, a faster growing nontradables sector cannot explain the productivity slowdown in the OECD in the 1970s and 80s, since the marginal productivities of labor and capital are not lower in that sector.[10]

Table 3 about here

In specification (ii) there is no catching up effect in the tradables sector, in contrast to the nontradables sector where a statistically significant catching up effect is found.[11] In Dowrick and Gemmel (1991) the catching up potential is measured by the quotient of labor productivities. Although our measure of catching up is theoretically more satisfactory since it also takes into account capital productivity, we use the quotient of labor productivities as an alternative measure of catching up potential in specification (iii). In (iii) there is no significant catching up effect in either sector. In specification (iv) we assume that the catching up factor is identical in both sectors. In this case no catching up is found.

Our interpretation of the results is that the diffusion of technology had already narrowed some of the technology gaps in the tradables sector at the

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[8] $\beta_{22} - \beta_{21} = 8509$ (2.31)**; *t*-value in parentheses.

[9] Hours worked would have been a better measure of labor (L). Unfortunately, data on average hours worked per week are only available for manufacturing. If we assume that the change in hours worked in a country is equal to the change in manufacturing in all sectors, we obtain a rough estimate of hours worked. We have reestimated the specifications in *Table 3* and *4* using this measure of L. The results remain virtually unchanged.

[10] Dowrick (1989) reached the same conclusion for the service sector. However, he found a significantly lower marginal productivity of labor in agriculture, which implies that a reallocation of labor from agriculture to the rest of the economy leads to an increase in productivity.

[11] $\beta_{32} - \beta_{31} = -0.012$ (–1.72)*. β_{31} and β_{32} are significantly different from each other at the 10% level.

beginning of the studied period (1970) and with that the potential for catching up was also decreased. Increased international competition, caused by trade liberalization in the 1950s and 60s, and increased co-operation internationally among researchers and engineers are factors pointing in that direction. Technological diffusion in the 1970s and 80s has probably been more complex than a one-sided transfer from an undisputable leader to the followers, a pattern that may have been valid in the 1950s and 60s. Our results differ in interesting ways from Dollar and Wolff (1988), who, in their disaggregated study of convergence in 28 manufacturing industries in 13 countries between 1963–82, find convergence in labor productivity. There are at least two plausible reasons for this difference. First, they study convergence in labor productivity and not in TFP. Second, and more important, they include most of the 1960s in their study, and in 1963 the U.S. is still the technological leader in virtually every industry. This is contrary to what we find for our starting year 1970.

In specification (ii) the rate of growth of TFP is larger in the tradables sector, $\alpha_1 > 0$, which indicates that international competition promotes technical progress and a faster diffusion of technology. We know, for instance, that investment in R&D is considerably larger in the tradables sector, which could be a result of greater competitive pressure.[12] There may also be other explanations. Besides openness to international competition, the tradables and nontradables sectors differ to a large extent in character.

The large standard deviation of β_{22} indicates that the assumption of equal marginal productivity of labor in all industries across countries in the nontradables sector may be questioned.[13] As an alternative specification we

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[12]See Englander, Evenson and Hanazaki (1988).

[13]Despite the fact that the estimate of β_{22} in *Table 3* is larger than β_{21}, the t-value of the β_{22} estimate is smaller, which means that the standard deviation of β_{22} is larger.

assume that the production function in nontradables industries is (quasi Cobb-Douglas):

$$Y_t = A_t \, \mathrm{f}\,(K_t) L_t^{\gamma} \tag{9}$$

In other words, we assume that the output elasticities of labor (γ) are equal in the same industry across countries, but may vary between industries in the nontradables sector. This means that in specification (v) we exchange $\beta_{22}(1 - Z)\left[\frac{\dot{L}}{L}\frac{L}{Y}\right]_{ik}$ for $\sum_{i=1}^{5} \gamma_i I_i \left[\frac{\dot{L}}{L}\right]_{ik}$, where I_i are dummy variables for the industries in the nontradables sector, i = 1 (electricity), 2 (construction), 3 (trade), 4 (transport), 5 (finance).[14]

Table 4 and 5 about here

The results, presented in *Table 4*, in specification (v) are in accordance with the results in specification (ii). To determine our preferred specification we evaluate the two models in *Table 5*, using the Davidson-MacKinnon (1981) J-test. In this test the maintained model is augmented by inclusion of the predictions of the alternative model as an additional regressor. Based on the test we judge that specification (v) is our preferred model. The estimation results for the catching up parameters, β_{31} and β_{32}, and for α_1, which measures the difference in the rate of technological progress in the tradables and nontradables sector, lead to the same conclusion as before. If anything, our findings become even more pronounced.

[14]An alternative specification would be the substitution of $\left[\frac{\dot{L}}{L}\frac{L}{Y}\right]_{ik}$ for $\left[\frac{\dot{L}}{L}\right]_{ik}$, i.e., to assume equality of marginal productivities in the same industry across countries in the nontradables sector. Due to the absence of foreign trade and the likely existence of more pronounced distortions in nontradables, we judge that equal output elasticities of labor in the same industry across countries is a more reasonable restriction to impose on the model.

5. Conclusions

In this study we have tested whether catching up still operates among industrialized countries. We have argued that if one wants to answer that question a disaggregated study is called for. First, it is unlikely that one country can be identified as the undisputed technological leader, rather it is more likely that technological leadership in different industries is domiciled in different countries. Second, it is possible that the potential for catching up was depleted by the late 1960s in the tradables sector, while it was still possible in the sector sheltered from foreign competition.

We test for the existence of catching up in 14 OECD countries during the period 1970–85. There are nine industries in the tradables sector and five industries in the nontradables sector. The marginal productivity of capital and labor as well as the catching up effect is allowed to vary between sectors. In our preferred specification we also allow for differing marginal productivity of labor in the various industries in the nontradables sector. In contrast to all previous studies, catching up potential is measured in terms of relative levels of total factor productivity, which is the appropriate measure of technological gaps, superior to relative labor productivities or GDP per capita, which were used by previous researchers.

Tests of catching up at the most aggregate level, e.g., Dowrick and Nguyen (1989) and Dowrick (1989), find strong empirical evidence of catching up. We have argued that the test procedure in these studies is too crude, and that disaggregated studies would give more dependable results. Dowrick and Gemmel (1991) found catching up in the nonagricultural sector but not for agriculture. In light of their and our results, we would like to again emphasize the importance of allowing for sectoral differences in catching up.

There are also sectoral differences in technological progress and diffusion of technology. A faster growth of TFP in the tradables sector indicates that international competition promotes technical change and growth. However, in Dowrick (1989) and Dowrick and Gemmel (1991), which use other sectoral divisions, the differences in TFP growth between sectors is in-significant.

Furthermore, it is worth noting that the marginal productivity of labor and capital are not lower in nontradables. The marginal productivity of labor is even higher in the nontradables sector. Dowrick (1989) reaches a similar conclusion. This is evidence against the hypothesis that a faster-growing nontradables sector would be an explanation of the productivity slowdown in the OECD area in the 1970s and 80s.

In no instance do we find catching up in the tradables sector, and if we assume a uniform catching up effect in both sectors, no significant catching up is found. This is the case irrespective of whether the catching up potential is measured by the ratio of labor productivity or TFP relative to the leading country. In the nontradables sector, on the other hand, catching up is still operative. These results conform with our preliminary tests of convergence.

Our results point to the conclusion that technological catching up in the tradables sector, although it was probably important in the 1950s and 60s, has no longer been important after 1970. This view is further supported by a comparison with Dollar and Wolff (1988) who still find convergence in labor productivity across manufacturing industries when most of the 1960s is included. According to our interpretation this indicates that in the part of the economy facing direct competition from foreign rivals, the potential for fast TFP growth based on catching up was depleted by the early 1970s. This is all the more likely considering that technology is today often carried across national boundaries while remaining within the same firm.

On the other hand, catching up still operates in the nontradables sector, which is not very surprising. Since industries in that sector are not exposed to foreign competition, they have not been forced to adopt superior technology from abroad in order to survive. Neither have multinational companies, which have probably played a large role in the diffusion of new production technologies in the tradables sector, been important in sheltered industries. Hence, technology has spread more slowly across national boundaries in the nontradables sector, and by 1970 a potential for catching up still remained to be exploited.

References

Abramovitz, M. (1986) “Catching Up, Forging Ahead, and Falling Behind”. *Journal of Economic History* **66**, 385–406.

Barro, R.J. (1991) “Economic Growth in a Cross Section of Countries”. *Quarterly Journal of Economics* **106**, 407–43.

Baumol, W.J. (1986) “Productivity Growth, Convergence, and Welfare”. *American Economic Review* **76**, 1072–85.

Baumol, W.J. and Wolff, E.N. (1988) “Productivity Growth Convergence, and Welfare: Reply”. *American Economic Review* **78**, 1155–9.

Cass, D. (1965), “Optimum Growth in an Aggregative Model of Capital Accumulation”. *Review of Economic Studies* **32**, 233–40.

Davidson, R. and MacKinnon, J.G. (1981) “Several Tests for Model Specification in the Presence of Alternative Hypotheses”. *Econometrica* **49**, 781–94.

De Long, J.B. (1988) “Productivity Growth, Convergence, and Welfare: Comment”. *American Economic Review* **78**, 1138–54.

Dollar, D. and Wolff, E.N. (1988) “Convergence of Industry Labor Productivity among Advanced Economies, 1963–1982”. *Review of Economics and Statistics* **70**, 549–58.

Dowrick, S. (1989) “Sectoral Change, Catching Up and Slowing Down. OECD Post-war Economic Growth Revisited”. *Economics Letters* **31**, 331–5.

Dowrick, S. and Gemmel, N. (1991) “Industrialisation, Catching Up and Economic Growth: A Comparative Study across the World’s Capitalist Economies”. *Economic Journal* **101**, 263–75.

Dowrick, S. and Nguyen, D.-T. (1987) “Australia’s Post-War Economic Growth: Measurement and International Comparison”. Working Paper No. 160, Centre for Economic Policy Research, Australian National University, Canberra.

Dowrick, S. and Nguyen, D.-T. (1989) “OECD Comparative Economic Growth 1950–85: Catching up and Convergence”. *American Economic Review* **79**, 1010–30.

Englander, A.S., Evenson, R. and Hanazaki, M. (1988) “R&D, Innovation and the Total Factor Productivity Slowdown”. *OECD Economic Studies* **11**, 7–42.

Gerschenkron, A. (1952) “Economic Backwardness in Historical Perspective”. In Hoselitz, B.F. (ed.), *The Progress of Underdeveloped Areas*. Chicago: University of Chicago Press.

Gruen, F.H. (1986) “How Bad is Australia’s Economic Performance and Why?”. *Economic Record* **62**, 180–93.

Koopmans, T.C. (1965) “On the Concept of Optimal Economic Growth”. In *The Econometric Approach to Optimal Planning*. Amsterdam: North-Holland.

Maddison, A. (1982) *Phases of Capitalist Development*. Oxford: Oxford University Press.

Meyer-zu-Schlochtern, F.J.M. (1988) “An International Sectoral Data Base for Thirteen OECD Countries”. Working Paper No. 57, OECD Econometric Unit, Paris.

Romer, P. (1989) “Capital Accumulation in the Theory of Long-Run Growth”. In Barro, R.J. (ed.), *Modern Business Cycle Theory*. Oxford: Basil Blackwell.

Solow, R.M. (1956) “A Contribution to the Theory of Economic Growth”. *Quarterly Journal of Economics* **70**, 65–94.

Streissler, E. (1979) “Growth Models as Diffusion Processes: II. Empirical Illustrations”. *Kyklos* **32**, 571–86.

Ward, M. (1985) *Purchasing Power Parities and Real Expenditure in the OECD*. Paris: OECD.

White, H. (1980) “A Heteroscedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroscedasticity”. *Econometrica* **48**, 817–38.

Wolff, E.N. (1991), “Capital Formation and Productivity Convergence over the Longer Term”. *American Economic Review* **81**, 565–79.

Appendix Sector Classification and Countries in ISDB

Sector 1: Tradables	*Sector 2: Nontradables*
Food, beverages, tobacco	Electricity, gas, water
Textiles	Construction
Wood, wood products	Wholesale, retail trade, restaurants, hotels
Paper, printing, publishing	Transport, storage, communication
Other manufactured products	Finance, insurance, real estate
Chemicals	
Nonmetallic mineral products	
Basic metal products	
Machinery, equipment	

Countries

Australia	France	Sweden
Belgium	Italy	U.K.
Canada	Japan	U.S.A.
Denmark	The Netherlands	West Germany
Finland	Norway	

Note: Agriculture, Mining, and The public sector (Community, social, personal services and Producers of government services) have been excluded. Due to lack of data on the more disaggregated levels, we were forced to aggregate Wholesale, retail trade, restaurants, hotels as well as Finance, insurance, real estate. See Meyer-zu-Schlochtern (1988) for further details.

Table 1 Two Preliminary Tests of Convergence

Industry	$\left(\frac{\bar{\tau}}{\tau^*}\right)_i^{1970}$	$\left(\frac{\bar{\tau}}{\tau^*}\right)_i^{1985}$	$CV(\tau)_i^{1970}$	$CV(\tau)_i^{1985}$
Agriculture*	0.658	0.668	0.315	0.301
Mining*	0.304	0.329	0.908	0.806
Food	0.763	0.700	0.252	0.304
Textile*	0.783	0.813	0.216	0.159
Wood*	0.769	0.837	0.227	0.181
Paper	0.746	0.682	0.186	0.202
Chemical	0.658	0.613	0.309	0.276
Non-metalic	0.743	0.717	0.157	0.178
Basic metal	0.512	0.512	0.398	0.370
Machinery	0.685	0.677	0.258	0.217
Other	0.549	0.498	0.456	0.448
Manufacturing	0.726	0.738	0.159	0.153
Electricity	0.351	0.330	0.697	0.641
Construction*	0.636	0.656	0.258	0.234
Trade*	0.760	0.849	0.199	0.148
Transportation*	0.685	0.749	0.262	0.171
Finance*	0.689	0.776	0.235	0.195

Note: A * denotes industries where both tests indicate catching up.

Table 2 Means and Standard Deviations of Variables in the Model

Variable	*All industries*	*Tradables*	*Non-tradables*
Annual average growth rate of value added (%)	2.20	1.75	2.82
	(2.16)	(2.20)	(1.96)
Annual average growth rate of capital (%)	3.57	3.30	3.93
	(2.00)	(2.20)	(1.66)
Annual average growth rate of employment (%)	0.00	–0.01	0.01
	(2.13)	(1.96)	(1.76)
τ_{ik}/τ_{il} (1970)	0.660	0.687	0.622
	(0.214)	(0.199)	(0.230)
τ_{ik}/τ_{il} (1985)	0.668	0.667	0.669
	(0.213)	(0.193)	(0.240)
Number of observations	162	94	68

Note: Standard deviations are in parentheses.

Table 3 The Effect on the Rate of Growth in Output of Growth in Factors of Production, Technical Progress, and Catching Up

Variable	*Parameter*	(i)	(ii)	(iii)	(iv)
Country dummies					
Constant	α_0	–0.002	–0.002	–0.000	0.000
		(–0.30)	(–0.30)	(–0.04)	(0.17)
			[0.31]		
Z	α_1	0.010	0.010	0.013	0.004
		(2.10)**	(2.25)**	(2.71)***	(1.44)
			[2.84]***		
$\left[\frac{\dot{K}}{K}\frac{K}{Y}\right]_{ik}$	β_1		0.045	0.054	0.052
			(3.37)***	(4.45)***	(4.10)***
			[3.64]***		
$Z\left[\frac{\dot{K}}{K}\frac{K}{Y}\right]_{ik}$	β_{11}	0.044			
		(1.51)			
$(1-Z)\left[\frac{\dot{K}}{K}\frac{K}{Y}\right]_{ik}$	β_{12}	0.045			
		(3.06)***			
$Z\left[\frac{\dot{L}}{L}\frac{L}{Y}\right]_{ik}$	β_{21}	6464	6462	6805	6218
		(5.72)***	(5.78)***	(6.04)***	(5.57)***
			[3.51]***		
$(1-Z)\left[\frac{\dot{L}}{L}\frac{L}{Y}\right]_{ik}$	β_{22}	14973	14988	14490	13112
		(4.18)***	(4.36)***	(4.22)***	(3.99)***
			[4.33]***		
$\log\left[\frac{\tau_{ik}}{\tau_{il}}\right]$	β_3				–0.006
					(–1.47)
$Z\log\left[\frac{\tau_{ik}}{\tau_{il}}\right]$	β_{31}	0.000	0.000	0.006	
		(0.06)	(0.07)	(1.70)*	
			[0.06]		
$(1-Z)\log\left[\frac{\tau_{ik}}{\tau_{il}}\right]$	β_{32}	–0.012	–0.012	–0.007	
		(–2.17)**	(–2.25)**	(–1.48)	
			[–2.67]***		
$\overline{R}^2$		0.507	0.511	0.512	0.504
n		162	162	162	162

Note: Parentheses ( ) give *t*-statistics, brackets [ ] give White's (1980) heteroscedasticity consistent *t*-statistics. This correction is only presented for our preferred specification. *, ** and *** denote significance at the 10, 5 and 1% percent levels, respectively.

Table 4 Results when Output Elasticities in the Nontradables Sector Are Allowed to Vary Across Industries

Variable	*Parameter*	(v)
Country dummies		
Constant	α_0	–0.005
		(–0.86)
		[–0.84]
Z	α_1	0.015
		(2.72)***
		[2.96]***
$\left[\frac{\dot{K}}{K}\frac{K}{Y}\right]_{ik}$	β_1	0.032
		(1.73)*
		[1.74]*
$Z\left[\frac{\dot{L}}{L}\frac{L}{Y}\right]_{ik}$	β_{21}	6577
		(5.82)***
		[3.43]***
$I_1\left[\frac{\dot{L}}{L}\right]_{1k}$	γ_1	0.200
		(0.61)
		[1.08]
$I_2\left[\frac{\dot{L}}{L}\right]_{2k}$	γ_2	0.826
		(3.25)***
		[2.58]***
$I_3\left[\frac{\dot{L}}{L}\right]_{3k}$	γ_3	0.974
		(2.87)***
		[4.23]***
$I_4\left[\frac{\dot{L}}{L}\right]_{4k}$	γ_4	1.349
		(2.42)**
		[3.02]***
$I_5\left[\frac{\dot{L}}{L}\right]_{5k}$	γ_5	0.523
		(2.49)**
		[2.86]***
$Z\log\left[\frac{\tau_{ik}}{\tau_{il}}\right]$	β_{31}	0.000
		(0.000)
		[0.000]
$(1-Z)\log\left[\frac{\tau_{ik}}{\tau_{il}}\right]$	β_{32}	–0.018
		(–2.76)***
		[–3.22]***
$\overline{R}^2$		0.507
n		162

Note: Parentheses ( ) give *t*-statistics, brackets [ ] give White's (1980) heteroscedasticity consistent *t*-statistics. *, ** and *** denote significance at the 10, 5 and 1% percent levels, respectively.

Table 5 Econometric Evaluation of Specifications (ii) and (v)

Davidson-MacKinnon J-test		
	Alternative model (H_1)	
Maintained model (H_0)	(ii)	(v)
(ii)	——	t = 1.84*
(v)	t = 0.49	——

Note: * denotes significance at the 10% level.