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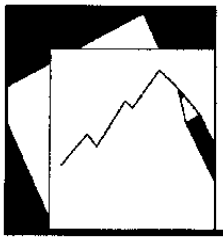

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Productivity in the OECD Countries: A Critical Appraisal of the Evidence

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Productivity in the OECD Countries: A Critical Appraisal of the Evidence

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Abstract

The failure of the neoclassical growth model to account for differences in output per worker across countries has suggested that these differences should be driven by cross-country differences in total factor productivity (TFP). This paper discusses various measures of productivity and its determinants for the OECD countries from different dimensions: (i) the measurement perspective; (ii) evidence on the evolution of productivity levels across OECD countries; and (iii) a critical review of the theoretical and empirical issues regarding the determinants of cross-country productivity differentials.

JEL Classification Numbers: O40, O47, O52

Keywords: Economic growth, total factor productivity (TFP), cross-country productivity differentials

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I. Introduction

Productivity is a notion widely used in economics to address short-run and long-run issues related to differences in growth performance. While the cyclical properties of productivity are important to evaluate policy effects in the context of business cycle models in the short run (Prescott, 1986), productivity is also key to understanding the post-war slowdown in economic activity and identifying the long-run sources of growth. The main focus of the present paper relies on the long-run aspects of productivity. In this spirit, the empirical evidence has largely shown that differences in natural resources or in capital per worker fail to explain systematic differences in output per worker (Prescott, 1998), thus implying that differences in output per worker might be driven by differences in total factor productivity (TFP). Therefore, our focus of research turns to explain TFP differences across countries.

Recent models of endogenous growth have reformulated the role played by technology in posting growth and have provided a theoretical framework to assess the impact of economic growth policy. Hence, TFP differentials across countries and over time might be driven by differences in technology across countries (Coe and Helpman, 1995) and differences in economy policy,e.g., trade policy (Edwards, 1997), government expenditure (Hansson and Henreksson, 1994), and institutional quality (Hall and Jones, 1999). Although theoretical advances and newly developed databases have generated an increasing amount of research on economic growth, the empirical work has been inconsistent and has not discriminated among competing theories of endogenous growth (Klenow and Rodriguez-Clare, 1997a). On the other hand, substantial evidence on measurement errors (van Ark, 1996a; Diewert and Fox, 1999) has cast doubt on the magnitude of productivity differential across countries.

The main goal of the present paper is to summarize the theoretical and empirical evidence on total factor productivity for the OECD economies in the following dimensions:[2]

- Present the current state of the literature on TFP measurement not only from the perspective of the appropriate measure of capital stocks, labor input, and output, but also from the perspective of internationally comparable measures of TFP.
- Outline the findings on the evolution of productivity growth across certain OECD countries relative to the United States.
- Present a critical review of the theoretical and empirical issues regarding the determinants of cross-country productivity differentials among the OECD countries.

The present paper consists of four sections. First, we summarize the current state of the literature on the measurement of productivity and its implications for international comparison. Second, we present an overview of the empirical evidence on relative

[2] Appendix I presents a description of each study.

productivity levels across the OECD economies at the aggregate level. Third, we survey the theoretical and empirical literature on the determinants of productivity differences. Finally, we conclude and propose some topics for further research.

II. Measurement Issues in Productivity

Despite the rapid technological advances during the post-1973 period (i.e., the information technology boom), productivity growth has significantly slowed down in the OECD countries. The literature has tried to address this paradox from both the theoretical and the empirical perspectives. Endogenous growth theory has reformulated the relationship between technology change and productivity growth,[3] allowing a wider range of explanatory factors to explain the slowdown. On the other hand, new measurement issues have been raised in an era of rapid investment-specific technological progress associated with the development of information technologies (Greenwood and Yorukoglu, 1997). Here, long-run productivity fluctuations might be driven by capital-embodied technological changes, thus capturing the increasing productivity in the production of new capital goods (Greenwood, Hercowitz, and Krusell, 1997).

A. Measurement Issues for Output and Inputs

Systematic measurement errors in inputs (capital and labor) and/or output, as well as inconsistent estimates of weighting procedures for index aggregation, have generated a significant bias in the calculation of total factor productivity (TFP) and in the magnitude of the differences in TFP across countries and over time.

- At the aggregate level, value added is the preferred proxy for *real output*, whereas gross output is the best approximation at the industry level (van Ark, 1996).[4]

- There is consensus on the need to adjust the *labor input* for working hours and quality changes, although significant cross-country methodological differences remain in the compilation of labor market statistics (e.g., the definition of workers, quality adjustment procedures, and labor participation rates).

Corrections for the quality of the labor input have generally relied on changes in the age-sex composition and the education of the labor force. However, types of schooling (general and vocational education) should also be distinguished because their impact on the development of human capital and on productivity growth is quite different.

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[3] Here, the Solow residual could be considered as the sum of technological change and a factor that could depend on *knowledge spillovers* (Romer, 1986); or *R&D spending* through an increase in the number of varieties for inputs (Romer, 1990) or their quality (Aghion and Howitt, 1992).

[4] However, there are still unsolved issues regarding measures of value added (gross vs. net, and national vs. domestic), and the coverage of the output sectors (including housing and/or government sector or not).

- The perpetual inventory method (PIM) used to construct (unadjusted) *capital stocks* has been criticized for its lack of international comparability. This is attributed to large variations in assumed asset lives across countries and different retirement models (O'Mahony, 1993).

In order to compute the aggregate capital stock, the literature suggests using asset prices as weights for unadjusted capital stocks and rental prices for individual capital inputs if service flows from the capital stock are measured (these prices already reflect quality changes). Asset-price weights are generally used in international comparisons because of the lack of availability of rental weights.

- The *quality adjustment of capital stocks* is performed using the resource cost and the user value approaches. According to the former, price indexes account only for quality changes reflected in increasing input costs, while the latter approach considers the full spectrum of quality change as perceived from a utility perspective. Empirical evidence suggests the use of resource cost for output goods and user value for inputs (Triplett, 1983).

- *Non-human intangible capital* (i.e., knowledge not embodied in labor) is imperfectly approximated either by input measures (e.g. R&D expenditures) or by output measures (e.g., patents[5]).

- The national accounts and the regression approaches present serious disadvantages in the *estimation of factor shares for TFP calculation*.[6] Given these disadvantages, Sarel (1999) proposes a three-step procedure to consistently estimate factor shares. First, we collect data to construct the intrinsic technological factor shares for each major type of economic activity.[7] Second, we estimate the relative intensity of each major economic activity (i.e., the shares in GDP at factor cost). And, third, we estimate the aggregate capital share in each country (i.e., the weighted average of the capital shares for each major economic activity using the relative intensities of these activities as weights).

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[5] Different patenting practices over time and across countries hinder the analysis of their economic content.

[6] The *national accounts approach* ignores the possibility of increasing returns to scale in production and does not take account of the impact of government policies and regulation. The *regression approach* might generate biased ordinary least squares (OLS) estimates of the factor shares because of the significant correlation between the growth rate of inputs and TFP growth and measurement errors in factors of production.

[7] Sarel computes compensation for the use of capital inputs as the difference between the gross surplus (i.e., the sum of capital consumption and the net operating surplus from the national accounts) and the compensation of labor (i.e., compensation of employer and own-account workers and compensation of unpaid family workers).

- Many studies have *computed cyclically adjusted measures of productivity to limit the effects of* volatility and procyclical fluctuations. Methods used in the literature include (i) adjustment for strong cyclical movements in capacity utilization (Harrigan, 1999); (ii) piece-wise linear spline (Gordon, 1993); and (iii) the leading indicators approach (Thomas, 1999a,b).

B. Issues on the International Comparison of Productivity Measures

According to the literature, the international comparison of productivity measures faces several challenges, inter alia, (1) the use of appropriate conversion factors that may account for cross-country differences in relative price levels so that we can express each country's output in a common currency; and (2) the choice of an appropriate weighting scheme for aggregation.

Currency Conversion Factors

- *Optimal currency conversion factors are sensitive to the chosen method of output aggregation.* For instance, purchasing power parities (PPPs) and GDP PPPs are recommended if the expenditure approach is used, whereas unit value ratios (UVRs) are recommended for comparisons at the industry level.[8]

- Value-added-productivity comparisons have used *"single-deflation"* procedures, although using different deflators for output and intermediate goods (*"double-deflation"* procedures) would be more appropriate. However, the latter method is sensitive to measurement errors in the quantity and prices of the intermediate inputs and the weighting scheme used.

The Weighting Procedure

Growth rates of TFP are useful for intertemporal comparisons for a given country at different points in time, but are not useful for comparing the relative productivity levels of different countries.

In this respect, the literature distinguishes between the use of two different types of weighting schemes: the bilateral and the multilateral indices. Among the former, the Fisher index has been widely used for industry comparisons of productivity because of its good

[8] However, the limited sample and coverage (20-25 percent of GDP in OECD countries), as well as the lack of adjustment for cross-country differences in product quality, discourage their use (van Ark, 1996a).

performance (Diewert, 1981). However, bilateral indexes demonstrate a lack of transitivity,[9] lack of base country invariance,[10] and lack of additivity (or matrix inconsistency).[11] Among multilateral indices, the Geary-Khamis method and the generalized Theil-Tornqvist index have been widely used for international productivity comparisons.[12] Although these indices satisfy some properties (i.e., transitivity and base country invariance), the Geary-Khamis index is biased toward the weight of the largest country in terms of output, and the generalized Theil-Tornqvist index lacks additivity.

Caves, Christensen, and Diewert (1982) have suggested adopting the Malquist index to compare relative productivity levels.[13] However, their most appealing result was that the Theil-Tornqvist and Malquist approaches yielded the same result if technology had translog form. The Malquist indexes have been used in productivity measurement mainly in the context of non-parametric Frontier analysis (Fare et al., 1994).

III. Aggregate Productivity Across OECD Economies: Trends and Issues

Productivity differences across OECD countries are significantly affected by the use of alternative definitions of productivity (i.e., labor productivity or total factor productivity) and different indicators for its construction (Englander and Gurney, 1994; Griffith and Simpson, 1998; Jorgenson and Yip, 1999; O'Mahony, 1999). [See figure 1]

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[9]The PPP index between two countries does not equal the ratio of PPPs between each of these two countries with a third one. Hence, binary indices cannot provide a unique ranking of countries according to their productivity level.

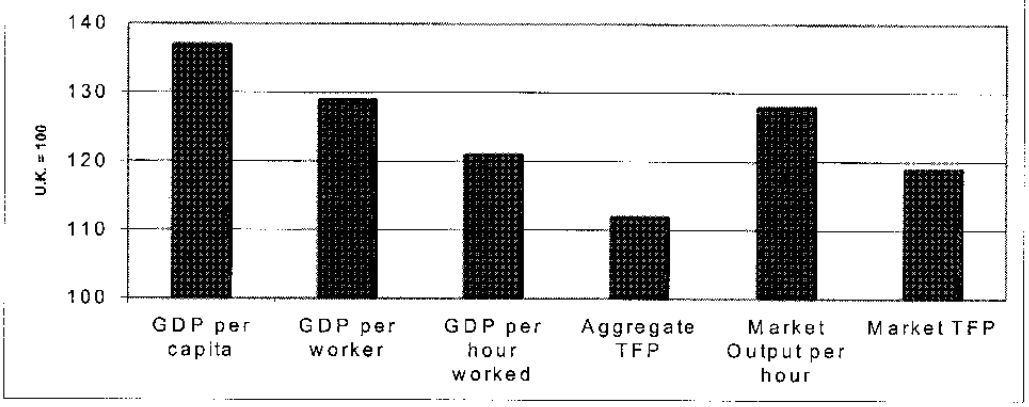
[10] Base country invariance is achieved if the weights represent an average of all countries in the sample.

[11] Here, the matrix of real quantities cannot be consistently added up across the columns (representing the countries) and the rows (representing the products or industries).

[12] The Geary-Khamis method derives an international price for commodities simultaneously with the purchasing power parity, and it is essentially an average of the prices of all countries. On the other hand, the generalized Theil-Tornqvist index (i.e., a multilateral version of the binary Theil-Tornqvist index) is a geometric average of binary (Fisher) UVRs weighted at average value shares of two countries.

[13] As Hulten (2000) states, the Malquist productivity index is the Geometric Mean of the answers to these two questions: (i) how much output could country A produce if it used country B's technology with its own inputs? and (ii) how much output could country B produce if it used country A's technology with its inputs?

Figure 1. Alternative Measures of U.S./U.K. Productivity



A proper measure of productivity is achieved by adjusting GDP for differences in all the inputs used, i.e., the *so-called* total factor productivity (TFP). Whereas the United States currently enjoys levels of *GDP per capita* about 37 percent higher than in the United Kingdom (1996 data), the U.S. lead over the United Kingdom in TFP is only 12 percent in the aggregate economy and 19 percent in the market economy. In addition, if we consider cross-country differences in labor force skills, the U.S./U.K. productivity gap (as measured by the ratio of market economy TFP) decreases from 19 percent to 16 percent in 1995 (O'Mahony, 1999).[14] Moreover, in a recent paper, Jorgenson and Yip (1999) found that the United States led the United Kingdom in output per capita by 60 percent in 1995, but once they computed a quality-adjusted measure of total factor productivity (TFP), the productivity gap was reduced to 14 percent.

The following section bases its presentation of productivity growth rates and levels on the work of Jorgenson and Yip because it takes account of differences in quality in adjusting factor inputs. First, they impute output for the services of consumer durables, land, buildings, and equipment owned by non-profit institutions in deriving their TFP measure in order to preserve comparability in the treatment of income from different types of capital. Second, the index of capital input uses different types of capital classified by asset type and tax treatment and values them using rental rates based on property income figures from national accounting data. The labor input index combines different categories of labor input weighted by wage rates. Labor input is classified by sex, educational attainment, and employment status and the weights are computed using labor compensation for type of labor input from labor force surveys.[15]

[14] O'Mahony divides the workforce skills into three categories: those with higher levels of qualification (degree or above), intermediate qualifications (vocational qualifications above high school but below degree), and those with low or no skills.

[15] For a complete discussion on constant quality indices, see Jorgenson, Gollop and Fraumeni (1987)

A. Growth Performance

As shown in the table below, Japan was the leader in *output per capita growth* and TFP growth over the 1960-95 period, although, during the weak productivity growth period since 1973, France had a slightly higher rate (Table 2). The United States, Canada, and the United Kingdom registered the weakest productivity growth performance throughout the period, averaging between 0.6 and 0.8 percent per annum, respectively.

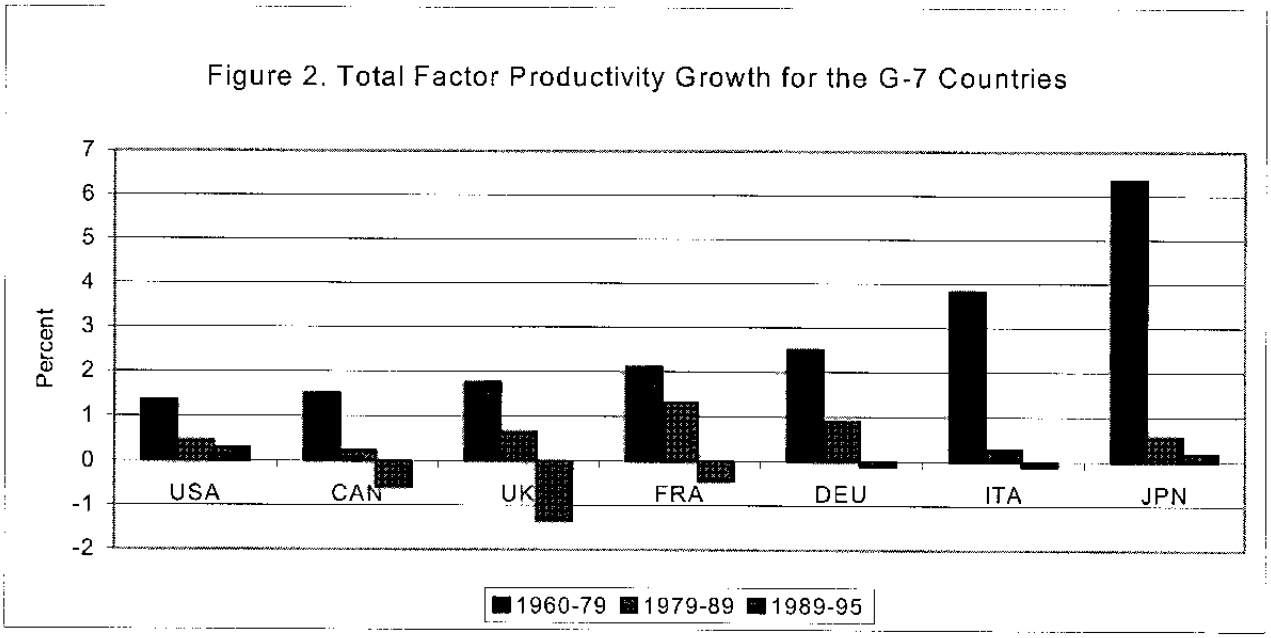
Table 1. Comparisons in Per-Capita Growth Rates
Between the G-7 Countries, 1960-95

(Levels: US=100 in 1985; Growth rates: In %)

Country	1960-73	1973-89	1973-95	1989-95	1960-95
A. Output					
U.S.	2.9	1.9	1.7	1.0	**2.1**
Canada	3.2	2.5	1.7	-0.4	**2.2**
United Kingdom	2.7	1.8	1.4	0.4	**1.9**
Germany	3.7	2.2	2.0	1.7	**2.7**
France	4.3	2.0	1.7	0.9	**2.7**
Italy	4.6	2.7	2.3	1.4	**3.2**
Japan	8.8	2.7	2.5	1.8	**4.8**
B. Productivity					
United States	1.4	0.5	0.4	0.3	**0.8**
Canada	1.5	0.2	0.0	-0.6	**0.6**
United Kingdom	1.8	0.7	0.0	-1.4	**0.7**
Germany	2.5	0.9	0.6	-0.1	**1.3**
France	2.1	1.3	0.8	-0.5	**1.3**
Italy	3.8	0.3	0.2	-0.1	**1.5**
Japan	6.4	0.6	0.5	0.2	**2.7**

Source: Jorgenson and Yip (1999)

For the OECD countries as a whole, there is a significant slowdown in productivity growth after 1973 with no pronounced rebound of either labor productivity or total factor productivity during the 1980s and 1990s (Englander and Gurney, 1994b, Jorgenson and Yip, 1999, O'Mahony, 1999). Indeed, all the G-7 countries, excluding Japan and the United States, experience a negative growth rate in total factor productivity over the 1989-95 period (see Figure 2).



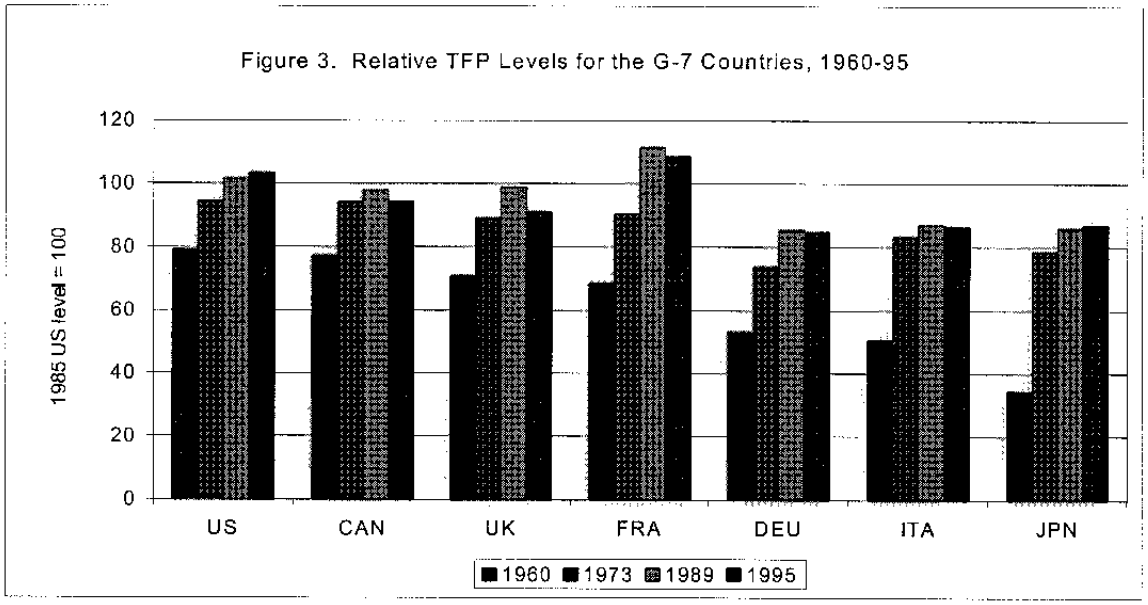
One of the major factors in explaining the different growth profiles of OECD countries over the past 40 years is technological catch up. Countries with initial low levels of TFP have grown faster than countries with initial higher levels ceteris paribus. This is clearly evident in the TFP estimates computed by Jorgenson and Yip who find that the countries with the lowest initial levels of TFP (Japan, Italy, and France) have grown much faster than the technological leaders in 1960 (the United States and Canada).

Table 2. Comparisons in Per-Capita Levels Between the G-7 Countries, 1960-95
(US=100 in 1985)

Country	1960	1973	1989	1995
A. Output				
U.S.	55.6	80.9	109.7	116.3
Canada	43.1	65.4	96.7	94.6
U.K.	37.5	53.6	70.8	72.6
Germany	32.9	53.6	75.6	83.5
France	29.2	50.9	70.6	74.6
Italy	22.7	41.4	63.7	69.2
Japan	17.3	54.0	83.3	92.8
B. Productivity				
U.S.	79.2	94.5	101.6	103.4
Canada	77.5	94.3	97.9	94.5
U.K.	70.9	89.1	98.8	91.1
Germany	53.4	73.9	85.4	84.8
France	68.8	90.5	111.5	108.6
Italy	50.7	83.3	87.0	86.5
Japan	34.5	78.7	86.1	87.0

Source: Jorgenson and Yip (1999)

In 1960, the productivity level in the United States was over twice that of Japan (the G-7 country with the lowest initial level) but over the past 35 years, the productivity levels have converged substantially so that in 1995 the spread between the lowest and the highest productivity levels was only about 20 percent. Englander and Gurney 1994b have documented a similar result, although they do not account for the heterogeneity of labor and capital inputs within and across countries in the manner of Jorgenson and Yip (1999).



Evidence of convergence in productivity levels for OECD economies has been documented in a number of studies (Abramovitz, 1986; Baumol, 1986; Dowrick and Nguyen, 1989; Englander and Gurney, 1994a,b; Islam, 1995; Jorgenson and Yip, 1999). Using a simple regression analysis, Baumol (1986) found evidence of *"β-convergence"* of GDP per hour worked across OECD economies. However, De Long (1988) cast doubt on the results because of a sample-selection bias. Later, Mankiw, Romer and Weil (1992) found evidence of convergence that was conditional on the ratio of investment to GDP and the rate of population growth. Taking advantage of panel data techniques, Islam (1995) found that the rate of convergence of output per capita among countries supported the Solow model, although Dowrick and Nguyen (1989) found that the convergence of income levels in the rich industrialized economies appeared to have slowed down or even reversed after 1973. However, the TFP catching-up process appears to have operated throughout the post-war period at a steady underlying rate. [16] Finally, Jorgenson and Yip have shown evidence of σ-*convergence* (i.e., a declining standard deviation of per capita income) for the G-7 countries.

[16] TFP catch-up implies a tendency for convergence in income levels. However, such a tendency may be biased if factor intensity growth varies systematically with income (Dowrick and Nguyen, 1989).

IV. Explaining Cross-Country Differences of Productivity

Empirical surveys (Fagerberg, 1994; Mankiw, 1995; Barro, 1996; Temple, 1999) have broadly classified the determinants of labor (and/or total factor) productivity growth into three groups: (1) the *catching-up term* (i.e., initial value of GDP per capita -or per hour worked- or initial TFP value), which is used as a proxy for the productivity and/or technology gap; (2) proxies for efforts to close the productivity gap, such as investment in physical and human capital, and resources devoted to output from innovation activities (e.g., R&D, patents, scientists and engineers); and (3) policy-related variables and institutional factors (e.g., fiscal policy, trade policy, institutional quality, demographics). This section attempts to explain the factors driving productivity differences across the OECD countries with emphasis on the problems faced by the empirical growth literature from theoretical and practical perspectives.

A. Explaining Cross-Country Productivity Differentials: A Critical Review of the Evidence

An Overview of Some Analytical Issues

What factors drive differences in labor productivity across countries? The neoclassical growth model states that differences in output per capita across countries should be driven by differences in capital per worker. However, in practice, the accumulation of capital per worker has failed to explain differences in output per worker so that differences in TFP (treated as a residual) have been brought to the fore as an explanation. A number of researchers have argued that this approach fails to provide a convincing explanation of the productivity slowdown since it indicated little productivity growth at times when a technological revolution was underway, challenging the credibility of the procedure (Greenwood and Yorokoglu, 1997; Hulten, 2000). Evidence shows that there has been significant technological change in the production of new equipment, and that these improvements have made equipment less expensive, thus triggering a more rapid accumulation of equipment both in the short and long run (Greenwood, Hercowitz, and Krusell, 1997). These facts have highlighted the role of investment-specific technological change as a source of economic growth and economic fluctuations, and supported the relevance of vintage capital models as an appropriate way to model productivity (Hulten, 1992, Greenwood and Yorukoglu, 1997; Greenwood, Hercowitz and Krusell, 1997).

The weakness of the traditional approach has motivated the claim that differences in the estimated TFP growth across countries might be accounted for by changes in the speed of human capital accumulation or deviations from perfect competition, elements that the neoclassical model is unable to identify (Prescott, 1998; Klenow and Rodriguez-Clare, 1997a,b; Hulten, 2000). Indeed, New Growth Theory has redefined the residual from the

neoclassical growth model as a process in sustaining growth rather than a nonparametric method for estimating a fixed parameter of the production function. [17]

Table 3. Reinterpreting the Solow residual: An endogenous growth perspective

Model	Assumptions	Interpretation of the Solow Residual
Increasing Returns (Romer, 1986)	World with non-rival ideas. Productivity of each firm depends on aggregate learning (proxied by aggregate capital stock).	Investment-based knowledge spillovers incorporate in the Solow residual not only the exogenous technological change but also the growth effect from spillovers and increasing returns.
Varieties Model (Romer, 1990)	Technological progress perceived as the increase of the number of varieties of inputs over time through increasing R&D.	The Solow residual is the sum of the contribution from exogenous technological change and the endogenous expansion of the number of varieties, where the latter is proportional to the amount of output devoted to R&D
Quality-Ladders Model (Aghion and Howitt, 1992)	Technological progress = Improvements in the quality of intermediate inputs. Grades of intermediate inputs with different quality modeled as perfect substitutes.	The Solow residual incorporates exogenous technological change and the growth rate of overall quality, where changes in quality are proportional to aggregate R&D spending.
Investment-Specific Technological Change (Greenwood *et al.*, 1997)	Growth Accounting: Vintage capital framework. Each type of physical and human capital is specific to the technology it embodies.	Technological progress occurs in capital-goods sector and it passes onto final output producers in the form of *"pecuniary external effect"* transmitted by the falling relative price of capital.

Recent growth models have identified a number of factors that can sustain per capita growth. These factors include human capital (Lucas, 1988); knowledge either obtained through learning by doing (Romer, 1986; Young, 1991) or through R&D (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992); and capital embodied in other factors whose accumulation implies non-diminishing returns to scale. Given that these models have different positive and normative implications and predictions, it is important to distinguish between them empirically.[18] However, at present there is a lack of uniformity in testing their implications.

In addition to differences in types of capital, differences in the speed at which countries adapt their policies and structures to match those of leader countries play an important role in explaining country growth differences. A number of researchers have identified the diffusion of technology—through some combination of trade, foreign direct investment, and migration—as a key determinant of productivity growth (OECD, 1996a; Klenow and

[17] A summary of the interpretations of the Solow residual according to different endogenous growth models is presented in Table 6.

[18] For instance, the decentralized equilibrium in Rebelo (1991) is Pareto-optimal, so no-intervention is the best policy. Other models feature positive externalities to human capital or ideas, leading to low growth in the absence of government subsidies. The activity deserving subsidy differs across the models, with some pointing to human capital investment and others to R&D. Moreover, as Romer (1993) emphasizes, the positive and normative implications of openness (e.g., to trade, foreign direct investment, and the flow of ideas) differ drastically across models. Some models imply that greater openness can slow down growth (Young, 1991), while others imply that openness can speed up growth (Romer, 1990)

Rodriguez-Clare, 1997a; Prescott, 1998). For example, Parente (1994) finds that even though all countries grow at the same rate in the long run, countries are located at different points of the growth spectrum because of policies and institutions that affect how fully they can benefit from the world frontier technology. According to their framework, faster than average growth could be attributed to the adoption of better policies and an improvement of institutions that allow countries to benefit more from the frontier technology.

Hall and Jones (1999) have also argued that differences in capital accumulation and productivity are fundamentally related to *differences in social infrastructure* across countries, i.e., differences in the institutions and government policies that determine the economic environment within which individuals accumulate skills, and firms accumulate capital and output. Prescott (1998) argues that differences in productivity across countries are driven by the resistance to the adoption of new technologies and to the efficient use of currently operating technologies, with the resistance dependent on the policy arrangement a society employs. He argues that in order to understand differences in cross-country productivity growth, a theory of how institutions affect total factor productivity and why a society chooses those institutions needs to be developed.

Determinants of Cross-Country Productivity Differences

There is a vast empirical literature on the determinants of cross-country productivity differences which has been recently triggered by the development of endogenous growth models and newly available cross-country data sets. In this section we summarize the main findings.

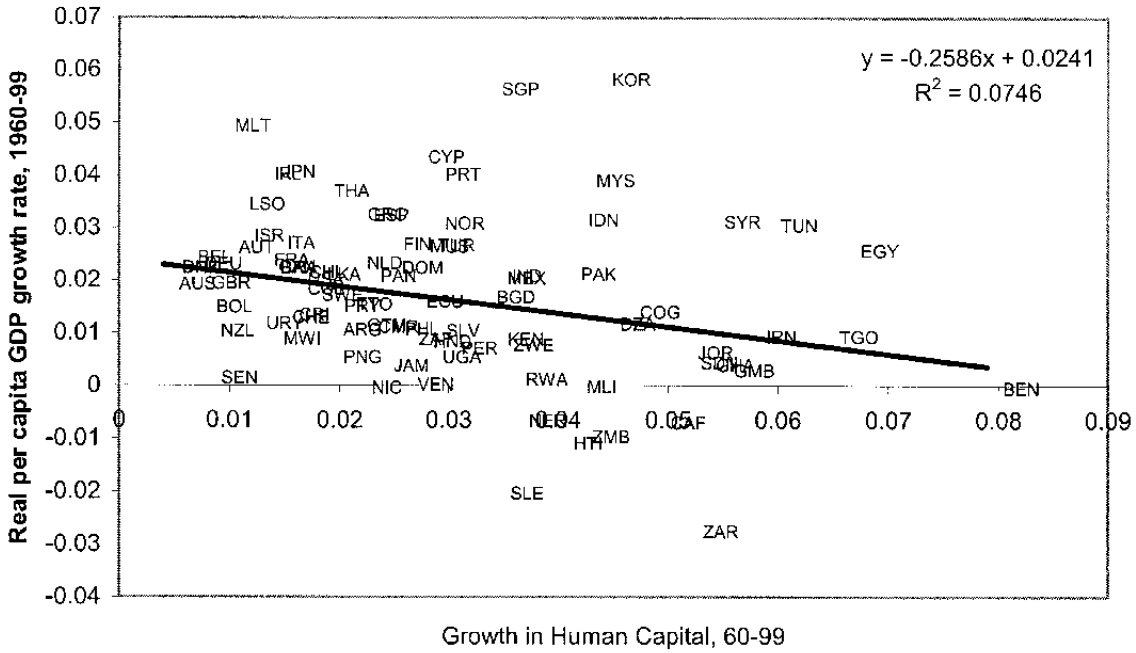
Wolff (1996) argues that convergence in capital-labor ratios explains convergence in labor productivity levels among G-7 countries over the 1870-1979 period, whereas Hulten (1992) finds that "embodiment effects," as captured by the *vintage effect,*[19] explains 40 percent of the post-1973 labor productivity slowdown among OECD countries, and 50 percent for the United States. It appears therefore that the aging of the capital stock in the post-1973 period may have created a drag on labor productivity growth.

The mediocre rate of (physical and human) capital accumulation has motivated the debate on whether labor productivity growth differences stem from accumulation of capital or technology catch-up. Evidence shows that differences in TFP growth explain about 90 percent of the variation in growth rates of output per worker across 98 countries over the 1960-85 period (Klenow and Rodriguez-Clare, 1997b). This evidence is consistent with *technology catch-up having a dominant role*.

[19] The vintage effect states that new capital is more productive than old capital per (constant) dollar of expenditure. If the capital stock is not adjusted for vintage effects, we could expect a negative correlation between change in the average age of capital and productivity growth.

As mentioned above, recent endogenous growth models (Lucas, 1988) have stressed the role of *human capital accumulation* as a source of long-run growth.[20] However, the evidence for a long-run relationship between educational levels and labor productivity is not robust. Several studies have failed to find a significant growth/education relationship using either growth on growth or level on level regressions.[21] Recent growth studies with panel datasets (Islam, 1995; Caselli et al., 1998) find negative signs for schooling variables.

Figure 4: Human Capital vs. Growth



Constructing measures of changes in human capital stock as Pritchett (1999), we observe in Figure 4 that the relationship between changes in human capital and the growth rate in real per capita GDP is negligible. It is quite surprising that while education expanded significantly during the 1960-95 period, economic growth fell to historic lows in some parts

[20] The accumulation of human capital enhances the ability of the labor force to adapt more easily to new processes and new industries, thus increasing productivity. Furthermore, positive externalities to human capital could generate greater productivity gains.

[21] See Pritchett (1999) for an analytical insight on this issue.

of the world.[22] In this case, despite the boom in education across countries since the late 1960s, the average education levels in the United States are still 1-2 years above those of the other OECD countries.

While standard growth models have interpreted the catch-up term as the speed at which a country adopts technological advances, new growth theories have elaborated different types of technological advances and diffusion mechanisms and have proposed different ways to test their implications. For example, the impact of R&D efforts on productivity is identified using a reduced form approach (Coe and Helpman, 1995; Lichtenberg et al., 1996; Coe, Helpman, and Hoffmaister, 1997). The evidence shows that countries with higher R&D per employee will also have higher TFP levels, and that surges in productivity over time might be attributed to an increase in *R&D investment per worker*. Furthermore, in a world with international trade of goods and services, foreign direct investment, international exchange of information and dissemination of knowledge, a country's productivity depends on both domestic and foreign R&D efforts

Coe and Helpman (1995) found that both domestic and foreign R&D capital stocks have important effects on TFP, with the impact of foreign R&D stocks on domestic productivity being a direct function of the share of domestic imports in GDP.[23] Extensions to the Coe-Helpman's study involved: (i) the inclusion of human capital as an additional regressor (Engelbrecht, 1997), and (ii) the introduction of foreign direct investment as an additional channel of technological diffusion across countries (Lichtenberg et al., 1996). Although these studies confirmed the Coe and Helpman results, they also found that human capital and R&D play different roles in both domestic innovation and in the absorption of international knowledge spillovers, and that technological sourcing associated with multinational enterprises plays a role in the process of technological transfer.

Another strand of this literature has built nonlinear simultaneous equation models from theories of innovation and international technology diffusion (Eaton and Kortum, 1996). Using data on research scientists and engineers and international patents, Eaton and Kortum found that the flow of ideas originating abroad explains more than 50 percent of the productivity growth in OECD countries (except for the United States). Also, they found that ideas from the five leading research economies (United States, Japan, Germany, France, and the UK) have contributed more than 90 percent of the productivity growth of the rest of the OECD countries.

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[22] If we restrict to our sample of OECD countries, the correlation between growth in human capital and growth in real per capita GDP is 0.13.

[23] Coe and Helpman found that foreign R&D capital stocks might be at least as important as domestic R&D capital stocks in the smaller countries, whereas in the larger countries (e.g., G-7 countries) the domestic R&D capital stocks might be more important.

Recent models of technology diffusion and knowledge spillovers have rediscovered the *role of openness and trade policy* in influencing productivity growth. In these models countries that are more open have a greater ability to absorb technological advances and to capture new ideas from the rest of the world (Grossman and Helpman, 1991). However, the literature is still inconclusive on the connection between trade policy and productivity growth (Romer, 1993; Klenow and Rodriguez-Clare, 1997; Rodriguez and Rodrik, 1999). From a theoretical perspective, the positive and normative implications of openness to trade, foreign direct investment, and the flow of ideas differ across models (Romer, 1993). Some models (Lucas, 1988; Romer, 1990) support the notion that openness enhances growth, while others claim that greater openness may slowdown growth (Young, 1991; Stokey, 1991).

On the empirical level, Edwards (1997) has found a positive and robust relationship between openness and productivity growth using a comparative data set on consistent measures of trade policy for 93 countries over the 1960-90 period.[24] Although he suggests that more open countries will tend to experience faster productivity growth than more protectionist countries, his evidence is considered tenuous and doubtful by other researchers (Krugman, 1994; Rodriguez and Rodrik, 1999).

Analogous to the case of trade policy, endogenous growth models have reassessed the *role of fiscal policy* on output and productivity growth. However, while the empirical evidence indicates a strong positive effect, the theoretical implications are more equivocal. Hansson and Henreksson (1994) empirically evaluate the impact of fiscal policy on TFP growth for the private sector in a sample of 14 industries and 14 OECD countries during the 1970-87 period. They find that the level of government consumption, transfers, and total spending (expressed as a share of GDP) have strong negative effects on TFP growth in the private sector, whereas education spending has a positive effect, and government investment has no impact. Finally, Cassou and Lansing (1999) show that declining public capital ratios and increasing tax profiles can account for the post-1973 growth experience across OECD countries.

From a theoretical perspective, some models perceive fiscal policy as a growth-enhancing tool. For instance, *"productive"* government spending—i.e., type of expenditure used to correct distortions by the existence of collective goods, externalities, and natural monopolies—generates productivity gains (Barro, 1990). However, fiscal policy can also play a detrimental role in growth. For example, taxes might create a wedge between gross and net return on savings, thus leading to a lower rate of capital accumulation and a slower growth rate (King and Rebelo, 1990).

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[24] These indices are: (1) Sachs and Warner Openness Index, (3) World Development Report Outward Orientation Index, (3) Leamer's Openness index, (4) Average Black Market Premium; (5) Average Import Tariff on Manufacturing; (6) Average Coverage of Non-Tariff Barriers; (7) Heritage Foundation Index of Distortions in International Trade; (8) Collected Trade Taxes Ratio; (9) Wolf's Index of Import Distortions.

V. Conclusion and Recommendations for Further Research

The main goal of the present paper has been to present an analytical overview of the theoretical and empirical issues regarding the measurement and evolution of productivity across OECD countries relative to the United States as well as a survey of the factors driving productivity differences across countries at the aggregate level. From this analysis, we have found the following stylized facts.

First, productivity rankings for the OECD countries and the magnitude of cross-country productivity differences could be sensitive to: (a) changes in the definition of output; (b) changes in the proxies for labor and capital input; (c) different methods of adjustment for quality in the measurement of inputs, and (d) different procedures to adjust productivity for cyclical fluctuations.

Second, taking into account the caveats suggested by the measurement problems, the literature presents strong evidence of β- and σ-convergence in income and productivity levels across OECD countries during the post-war period. Moreover, there is evidence of a significant productivity slowdown for these OECD countries after 1973. Both labor productivity and total factor productivity declined between the 1960-73 and the 1973-89 period, and have decreased even further in the 1989-95 period.

In general, technology catch-up is one of the main factors explaining cross-country productivity differences. Although average years of education does not seem to be a robust factor, R&D spending and technology innovation and diffusion play an important role. Consistent with Easterly and Levine (2000), national policies do influence long-run economic growth rates. Thus, there is evidence of a significant link between productivity and fiscal policy and trade policy.

The present review of the literature has also revealed some issues that could be addressed in future research:

Measurement Issues: The literature highlights the need to foster international coordination in the construction of better measures of intermediate goods, services, and quality adjustments through the application of hedonic techniques. In addition, the suggestion has been made to create harmonized industrial statistics across countries through increased use of input-output tables to facilitate international comparisons (van Ark, 1996a).

Empirical Testing of Growth Models: Despite numerous cross-country regression studies identifying which variables are correlated with growth rates, there is a lack of consistent empirical work testing and discriminating between theories of endogenous growth (Klenow and Rodriguez-Clare, 1997a).

New Roads in the Empirical Literature: Recent theoretical models and new comprehensive databases have shifted the study of productivity at the aggregate and industry level to the firm and plant level (Hulten, 2000). Recent studies have reassessed the impact on

productivity at the firm/plant level of R&D spending (David, Hall and Toole, 1999), exporting activities (Bernard and Jensen, 1999), technology flows and trade patterns (Keller, 1999) as well as geographical factors behind technological diffusion (Keller, 2000).

In summary, we find that given the strong interdependence among countries, differences in total factor productivity across countries appear to be driven by the speed of technological diffusion (through trade, foreign direct investment, or migration). These factors are likely affected by policy arrangements or institutions in a country.

APPENDIX I

Summary of the Empirical Literature on Productivity Differences Across OECD Countries

Author	Sample/Period	Dep. Variable: Growth Rate of	Finding
A. Evidence at the Aggregate Level			
Baumol (1986)	16 IC / 1870-1979	GDP per hour worked	Absolute Convergence for Growth Rates. However, problem of sample selection bias is detected (De Long, 1988)
Dowrick and Nguyen (1989)	24 OECD / 1950-85	GDP and TFP	TFP catch-up even if we control for cyclical differences, different measures of PPP, potential errors in projection of income levels, and sample selection bias.
Wolff (1991)	6 IC / 1880-1979 Pooled Data	TFP	Catch-up driven by growth in capital-labor ratios (capital formation).
Mankiw, Romer and Weil (1992)	98 Countries / 60-85	GDP per worker	Conditional Convergence. Investment in human and physical capital as engines of growth.
Englander and Gurney (1994a,b)	19 OECD Countries / 1960-90 Pooled	Labor Productivity (LP) and TFP	Limited evidence for education, positive externalities of investment, infrastructure, and R&D spillovers on explaining TFP fluctuations. Robust evidence for the impact of trade and competition, and rent seeking
Coe and Helpman (1995)	21 OECD + Israel 1971-90 Pooled	TFP	TFP depends on domestic and foreign R&D capital stock. Return on both R&D stocks is very high (120% in G-7 and an additional 30% accrued to the other countries in the sample).
Coe, Helpman and Hoffmaister (1997)	77 DC / 1971-90 Pooled	TFP	A 1% increase in R&D capital in IC raises output in DC by 0.06%. US R&D capital stock accounts for largest share in foreign capital stock.
Engelbrecht (1997)	21 OECD + Israel 1971-90 Pooled	TFP	Distinct roles for human capital and R&D capital in both domestic innovation and in the absorption of international knowledge spillovers.
Eaton and Kortum (1996)	19 OECD / 1986-88	GDP per worker	Countries rely on innovations from US, Germany and Japan for over 50% of their total growth. Innovation is inferred from data on patenting.
B. Evidence at the Industry Level			
Bernard and Jones (1996a,b)	14 IC, 6 Sectors / 1970-87 Pooled	Value Added per worker	Aggregate Convergence for all Countries. Convergence in Services and Divergence in Manufacturing.
Thomas (1999b)	G-7 excl. Japan / 1970-90 Pooled	TFP	No convergence found for services and non-durable manufacturing. Strong convergence in durable manufacturing goods.
Dollar and Wolff (1988)	13 IC, 28 Manufact. Industries / 1963-82	Value Added per Work Hour	Productivity Convergence at the Industry Level. Convergence in K/L ratios and technologies across industries.
Hulten (1992) Wolff (1996)	US Manufacturing Industries / 1949-83	TFP	Embodied Technical Change as a source of economic growth. Role of the "Vintage Effect"
Hansson and Henrekson (1994)	14 OECD, 14 Industries / 1970-87	TFP	Total outlays, consumption and transfers have a negative impact on TFP growth rate. Education expenditure has a positive influence.
Harrigan (1999)	10 OECD, Manufacturing / 1980-89 Pooled	Value Added per Worker a/	Industry-level economies of scale are probably not large, and cannot account for the large size of cross-country TFP differences.
Gouyette and Perelman (1997)	13 OECD ; Manuf., Services / 1970-87	TFP (Frontier Analysis)	Evidence of Convergence in service activities. Weak evidence on capital intensity as determinant of productivity in services.
van Ark, Monnikhof, and Mulder (1999)	5 OECD; Services	Value Added per hour worked	Weak evidence for capital intensity, scale and scope and innovation. Deregulation has been an important determinant of cross-country productivity differences

Notes: a/ Measure adjusted for capacity utilization. IC = Industrial Countries, DC = Developing Countries

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