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MARKET STRUCTURE, TECHNOLOGY SPILLOVERS, AND PERSISTENCE IN PRODUCTIVITY DIFFERENTIALS

Yin-Wong Cheung
Antonio Garcia Pascual

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CESifo
Center for Economic Studies & Ifo Institute for Economic Research
Poschingerstr. 5, 81679 Munich, Germany
Phone: +49 (89) 9224-1410 - Fax: +49 (89) 9224-1409
e-mail: office@CESifo.de
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Abstract

Using data from 11 main manufacturing industries in 17 OECD countries, this paper empirically investigates the determinants of cross-country differences in the persistence of productivity differentials Specifically, we focus on the effects of product market structure and technology diffusion. It is found that the manufacturing industries display a wide range of convergence rates. Consistent with theories, the persistence of productivity differentials is found to be positively correlated with the price-cost margin and the intra-industry trade index - the proxies for market monopolistic behavior. The proxies for tecnology diffusion, however, do not exhibit consistently significant effect. Among the conditioning macro variables, productivity convergence appears to be enhanced by human capital but deterred by government spending.

JEL Classification: O40, F43.

Keywords: Total factor productivity, convergence, market structure, technology diffusion.

Yin-Wong Cheung
Economics Department
University of California
Santa Cruz, CA 95064
USA

Antonio Garcia Pascual
Economics Department
University of Munich
85039 Munich
Germany
Antonio.pascual@lrz.uni-muenchen.de

1 Introduction

The convergence of per capita real output across countries is an active research area. Several theoretical models and empirical studies are devoted to investigate the question of whether less productive economies are catching up with the most productive economies. One perspective asserts that technology diffusion and resource re-allocation will eliminate productivity differentials and, hence, eradicate national output disparities. In fact, in a world of fully integrated markets and absence of adjustment costs, one would expect rapid convergence of output per worker across countries.[1] Extant empirical studies, however, indicate that cross-country productivity differentials are surprisingly persistent and convergence in output is quite sluggish. If there is convergence across countries, the rate is likely to be small.

The empirical evidence on cross-country convergence depends on the sample of countries under investigation. Baumol (1986), for example, reports strong evidence of convergence among a group of OECD countries. The result is, however, not robust to the inclusion of other countries. Baumol *et al.* (1989) assert that convergence occurs within each income group and not across the groups. Overall, the existing empirical results suggest that convergence is likely to occur in a group of *homogenous* countries at a similar stage of economic development (Barro 1991; Mankiw *et al.*., 1992).[2] Using a large sample of countries, Hall and Jones (1999) find that cross-country differences in capital accumulation and productivity are related to differences in institutions and government policies. For instance, the countries that have efficient social infrastructures and government policies in favor

[1] Modifications of the basic neoclassical framework, such as the introduction of heterogenous agents, capital markets imperfections, externalities, or non-convexities, may lead to persistent differences in national output per capita (Galor, 1996). For example, Galor and Zeira (1993) suggest that initial cross-country differences in the distribution of income may result in differences in human capital accumulation and persistent inequality.

[2] Countries are homogenous in the sense that they share similar preferences, technologies, capital stocks (human and physical), population growth, government policies, institutions,..., etc.

of physical and human capital accumulation as well as diffusion of new technologies tend to display a similar level of investment and productivity.

The existing empirical results suggest that convergence is likely to occur in a group of homogenous countries at a similar stage of economic development. Yet, different economic sectors may experience uneven degrees of persistence in productivity differentials across similar countries. Bernard and Jones (1996a, 1996b) argue that studies of aggregate productivity convergence ignore the possible differential behavior at the sectoral level. Using data from OECD countries, the authors report dissimilar convergence patterns for different sectors. For example, the services sector yields support for convergence while the manufacturing sector reveals little evidence of it. The lack of convergence in the manufacturing sector, however, may be attributed to the problem of aggregation. Garcia Pascual and Westermann (2001) use data on disaggregated manufacturing industries in some OECD countries to examine the convergence behavior and report more supportive evidence of productivity convergence.

Which are the determinants of the persistence of productivity differentials across OECD countries? While there are empirical studies examining the convergence of output and productivity data, not much effort has been devoted to investigate the economic determinants of the persistence of cross-country productivity differentials. Jaffe *et al.* (1993), Jaffe and Trajtenberg (1996), and Eaton and Kortum (1999, 1996), for example, point to the locality of technology spillovers as a potential explanation for the slow convergence of some industries. If technology diffusion is local rather than global, then productivity differential can be very persistent. Thus, the migration of local to global technology transfer will foster convergence and reduce productivity-differential persistence (Keller, 2000).

Market structure is another factor that would affect the convergence behavior. Aghion *et al.* (1997a,b), for example, argue that the degree of product market competition influences the incentives to engage in R&D activities and to invest in leading-edge technologies. Thus, in the presence of a less competitive market structure, one expects a prolonged period of productivity gap. Because different manufacturing industries endure various degrees of market competitiveness, one expects to observe a diverse pattern of cross-industry convergence.

This paper examines the empirical relevance of market structure and technology diffusion to productivity convergence. Specifically, we use cross-country data on several manufacturing industries to investigate whether productivity-differential persistence is systematically related to proxies for market structure and technology diffusion. A group of 17 OECD countries, which are quite homogenous and have comparable national income, are studied. To ensure the market structure and technology diffusion effects are not spurious, a set of macro variables that are traditionally used in the empirical growth literature is included in the empirical analysis.

The remainder of the paper is organized as follows. Section 2 presents a selective review of the theoretical literature on the relationships between market structure, technology diffusion, and productivity convergence. It also briefly discusses the macro variables that are used as controls in the exercise. Section 3 describes the productivity data from 11 manufacturing industries in 17 OECD countries. The estimates of relative convergence rates (with the US as the benchmark) are reported in the same section. Section 4 introduces (a) the price-cost margin and intra-industry trade variables which are proxies for market structure, (b) the US patent applications and fees on royalties and licenses which are proxies for technology diffusion, and (c) conditioning macro variables. Estimation results based on seemingly unrelated and censored regression methods are presented in Section 5. Section 6 concludes.

2 A Selective Review

2.1 Market Structure

Does market competition foster or deter productivity convergence? At first glance, the basic endogenous growth mechanism may suggest a negative relationship between growth and product market competition. The "New Growth Theory" endogenizes the firm's decision on investment in the development of new products and ideas (Romer, 1990). The decision to innovate is justified by the expected flow of net profits from the invention. As monopoly rents constitute a stimulus for firms to innovate, a higher level of market competition reduces firms' monopoly rents and, consequently, lowers the incentive to innovate.[3]

Aghion *et al.* (1997a) offer some qualifications for a negative correlation between competition and growth. Using a principal-agent framework, they derive a positive effect of competition on productivity. In their model, the manager faces private costs of adopting new technologies (including training, reorganization costs, ..., etc.) and benefits from being in control of the company. Hence, the manager will delay the adoption of new vintage technologies as long as the firm stays in business. A higher level of competition leads to lower profits and, thus, forces the manager to adopt new technologies to remain in business. Competition provides a disciplinary device to ensure the adoption of advanced technologies and enhances productivity.[4]

A similar positive effect of competition on productivity growth is demonstrated by Aghion *et al.* (1997b). Assuming a step-by-step innovation procedure, the technological laggards cannot leapfrog the technological leaders. Instead, the laggards need to catch up before they can become leaders themselves. Under these

[3] Grossman and Helpman (1991a), however, point out that there are two opposing effects of competition on productivity.

[4] The relationship between competition and managerial efforts is also investigated by Meyer and Vickers (1995). Similarly, competition has a positive impact on workers' efforts if they claim a share of market rents (Smirlock and Marshall, 1983).

circumstances, easier imitation induces laggards to catch up with the technology leaders. The process leads to further competition among participants and provides the appropriate incentives for innovation and productivity improvement.

2.2 Technology Diffusion

The international transmission of technological know-how is an important channel through which the technologically underdeveloped economies acquire the necessary knowledge to enhance productivity and growth. Both locally generated and foreign innovations benefit growth (Rivera-Batiz and Romer, 1991). The technological know-how can be acquired via various venues. For instance, through imitation, a technologically underdeveloped economy enhances its technology and production efficiency. Besides aiding technologically underdeveloped economies, Grossman and Helpman (1991a), for example, show that imitation can also promote innovation. In a model of expanding varieties, Barro and Sala-i-Martin (1997) investigate the role of technology diffusion as a contributing factor to conditional convergence. It is shown that technology diffusion leads to convergence. Technologically underdeveloped economies initially grow faster than the leader and the speed of convergence falls as the technology gap narrows.

For practical purposes, patent applications in a foreign country are commonly used to capture trade in ideas, which improves transmission of know-how and promotes technology diffusion (Jaffe and Trajtenberg, 1996; Eaton and Kortum, 1996, 1999; Branstetter, 2000). Patent registration is conceived as a means to protect intellectual property rights. With property right protection, technology transfers that benefit productivity are more likely to occur.

An alternative channel of technology diffusion is foreign direct investment (FDI). Existing empirical evidence on the relationship between FDI and technology spillovers is mixed. For example, Lichtenberg and van Pottelsberghe de la Potterie (1996) find that FDI inflows did not enhance productivity spillovers among the OECD countries during the period 1970-1990. For the same sample period, however, Hejazi and Safarian (1996) find significant R&D spillovers as a result of FDI from the US to the OECD countries. The conflicting results may be partially explained by the difficulty of measuring FDI data. One strategy to ameliorate the data-quality problem is to use the payment for royalties and licenses as a proxy for technology diffusion (Xu, 2000). Ideally, the ratio of royalties and license payments to FDI is large when FDI contains a large component of technology transfers.

2.3 Control Variables

The convergence result – as in the neoclassical growth models – is conditional on a set of country-specific characteristics that may encourage or hinder productivity growth. For instance, the education level and government policy can have both direct and indirect effects on productivity convergence. To ensure our analysis of market structure and technology diffusion effects is robust to these economic factors, we include the variables that are commonly considered in the (empirical) growth literature.

Human Capital. As pointed out by Nelson and Phelps (1966) human capital augments a country's ability to innovate. Therefore, constraints on human capital can be impediments to productivity convergence across countries (Barro *et al.*, 1995). Intuitively, for a technologically underdeveloped economy, it is easier to absorb and adopt advanced technologies if the population is better educated, *ceteris paribus* (Lucas, 1993). Therefore we expect a negative relationship between the level of human capital and the persistence of productivity differences.

R&D Intensity. In a standard endogenous growth model, R&D intensity exerts a direct positive effect on productivity growth (Romer, 1990; Grossman and Helpman, 1991a,b; Aghion and Howitt, 1992). Similarly, the rate of productivity convergence is also directly related to the R&D intensity (Howitt, 2000). A high level of R&D intensity in a technologically underdeveloped economy provides a favorable environment to narrow the technology gap and catch up with advanced economies.

Government Spending. The effect of government spending depends on its implications for (private sector) productivity. Unproductive spending that crowds out private investment obstructs growth while spending (e.g., on infrastructure and education) that augments productivity promotes growth. In a model with government spending in the production function and distortionary taxation, Barro (1990) and Barro and Sala-i-Martin (1995) show that there is a U-shaped relationship between government expenditure and growth. *A priori*, government spending has an ambiguous effect on convergence.

Sunk Costs. The presence of high sunk costs, which cannot be recovered upon exit, will deter firms from entering the market (Dixit, 1989). For instance, in an oligopolistic industry, the over-investment strategy can be used to stave off potential competition. High sunk costs also discourage foreign direct investment, which is a channel for technology diffusion. Therefore, sunk costs are likely to have a positive implication for productivity-differential persistence.

Openness. The openness of an economy helps advance productivity growth as it allows the economy to gain access to foreign technology and the global financial market. Openness also facilitates the flow of knowledge toward technologically underdeveloped economies and, hence, is perceived as a positive factor for convergence (Grossman and Helpman, 1991a). Some studies report a positive link between international trade and growth (Levine and Renelt, 1992), and between trade and per capita income convergence (Ben-David, 1993, 1996; Sachs and Warner, 1995). However, more recent studies tend to find the effects of openness on growth and convergence ambiguous or insignificant (Rodriguez and Rodrik, 1999; Slaughter, 2000).

Geographic Distance. One perspective is that geographical distance limits the extent of technology spillovers. Countries far away from the R&D centers benefit less than neighboring countries since technology spillovers tend to be local rather than global (Keller, 2000). The distance variable is also commonly used in the studies that examine, for example, price convergence and relative trade activity (Engel and Rogers, 1996; McCallum, 1995). However, given the advance in information technology, geographic distance may not constitute a determining factor of knowledge flows.

3 Persistence of Productivity Differentials

Industry-level data from 17 OECD countries are considered: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, Norway, Portugal, Sweden, United Kingdom, and United States. The sample covers 11 industries that span the manufacturing sector. Table 1 lists these industries and their ISIC codes. The annual data from 1970 to 1995 were retrieved from the STAN database (OECD, 1999a).

For the i-th industry of country j, the productivity at time t is measured by

$$\begin{aligned}
\ln TFP_{i,j,t} &= (\ln VA_{i,j,t} - \ln VA_{i,.,t}) - \gamma_{i,j,t} (\ln L_{i,j,t} - \ln L_{i,.,t}) \\
&\quad - \left(1 - \gamma_{i,j,t}\right) (\ln K_{i,j,t} - \ln K_{i,.,t}) \qquad (1) \\
i &= 1, ..., 11 \ ; \ j = 1, ..., 17 \ ; \ t = 1970, ..., 1995,
\end{aligned}$$

where $\gamma_{i,j,t}$ is

$$\gamma_{i,j,t} = \frac{\alpha_{i,j,t} + \alpha_{i,.,t}}{2} \ , \qquad (2)$$

VA is value added, L is total employment, K is the capital stock, and α is the labor compensation share of the value added. $Z_{i,.,t}$ is the average of $Z_{i,j,t}$ across j. Equation (1) is the multilateral total factor productivity (TFP) index proposed by Caves, Christensen, and Diewert (1982a, b). This TFP index has some desirable properties including superlativeness and transitiveness, which make it possible to compare national productivity levels. See Hulten (2000), for example, for further discussion on the index.

The values of the average TFP index for each country and each industry are given in Table 2. Data on the average productivity of a country are given in the last column. There are considerable variations in the productivity data across both industries and countries. In most industries, the US is the most productive economy. When all the 11 industries are considered, ten countries have a negative average productivity index while seven have a positive one. The US has the highest average productivity index (0.42) and Portugal is the least productive economy. Because of its productivity leadership, the US is used as a benchmark in constructing the productivity-differential data (Bernard and Jones, 1996a, b). From a theoretical viewpoint, the productivity laggards catch up to the leaders, for example, by adopting the leader's technology (Barro and Sala-i-Martin, 1997; Howitt, 2000). Therefore, it is desirable to use the US, the productivity leader, as the benchmark country in assessing the degree of productivity-differential persistence.

Following the common practice, we use a time series specification to characterize data persistence. Let $X_{i,j,t} = lnTFP_{i,j,t}$ be the logarithm of the industry i's productivity in country j at time t, and $X_{i,*,t}$ is the productivity variable of the benchmark country. The productivity differential is given by $x_{i,j,t} = X_{i,j,t} - X_{i,*,t}$. Assuming that the productivity-differential series can be approximated by a finite-order autoregressive process,

$$x_{i,j,t} = a_{i,j} + b_{i,j,0}x_{i,j,t-1} + \sum_{k=1}^{p_{i,j}-1} b_{i,j,k}\Delta x_{i,j,t-k} + \varepsilon_{i,j,t} \qquad t = 1, ..., T \qquad (3)$$

For industry i of country j, the mean reversion coefficient ($MRC_{i,j} = b_{i,j,0}$) is used to measure the degree of persistence.[5] Specifically, a large MRC implies a high level of persistence and a long time period to narrow a productivity gap. To gain

[5] The mean reversion coefficient is commonly used to gauge the persistence of a time series. A similar measure is employed by, for example, Campa and Wolf (1997) to measure the speed of convergence.
In the estimation of equation (3), we also allowed for a time trend. As it turned out to be statistically insignificant, the time trend was dropped to gain efficiency.

efficiency, we pooled data across countries to estimate the coefficients. The Akaike information criterion is used to determine the lag length parameter $p_{i,j}$. Table 3 contains some descriptive statistics for the estimated MRC. Across industries, the average MRC estimates are between 0.83 (TAL) and 0.34 (NFM). Among the countries in the sample, Denmark, Italy, and Japan have the largest average MRC estimates, and Norway has the smallest average persistence measure. The standard deviations and range measures (maximum and minimum) confirm that there is a wide variety of convergence behavior across industries and countries (Garcia Pascual and Westermann, 2001).[6]

4 Potential Determinants

4.1 Market Structure and Technology Diffusion

Two measures of competitiveness are used as proxies for market structure. The first variable is the price-cost margin (PCM), which is commonly used to gauge the degree of monopolistic behavior or market competitiveness (Domowitz *et al.*, 1986; Campa and Goldberg, 1995; Cheung *et al.*, 2001). For industry i of country j at time t, the PCM is defined as

$$PCM_{i,j,t} = \frac{VA_{i,j,t} - W_{i,j,t}}{F_{i,j,t}} \tag{4}$$

where W is the labor compensation and F is the value of total production. A high value of PCM reflects a low degree of competition in the industry. Table 4 presents some descriptive statistics for the time averages of PCM estimates. The industry and country averages are, respectively, given in the upper and lower panels.

[6] Unit root tests are routinely applied to productivity-differential series to infer convergence. Given the notoriously low power of unit root tests, it is very difficult for the relatively short annual data series under examination to reject the unit root hypothesis. However, the consensus and existing literature suggest that manufacturing industries in these OCDE countries are converging. Hence, convergence is assumed in the subsequent analysis. As a robustness check, we also report the specification that accommodates different convergence behavior in Section 5.2.

According to the PCM measure, the non-metallic mineral (NMM) industry is the least competitive industry and the iron and steel (IST) industry is the most competitive one. The most and least competitive countries are, respectively, Sweden and Greece. As reflected by standard deviations and ranges, there is considerable variation of PCM in the data though it is not as variable as MRC.

The index of intra-industry trade (IIT) is our second proxy for market structure. It uses the degree of product differentiation to characterize the nature of competition in a market. For industry i of country j at time t, the IIT index is (Grubel and Lloyd, 1975)

$$IIT_{i,j,t} = 1 - \frac{|EX_{i,j,t} - IM_{i,j,t}|}{EX_{i,j,t} + IM_{i,j,t}} \tag{5}$$

where EX and IM represent exports and imports, respectively. The intra-industry trade increases as the index increases from 0 to 1. A high level of intra-industry trade is symbolic of a high degree of product differentiation (Helpman and Krugman, 1985), which is associated with a strong presence of monopolistic competition in the industry (Dixit and Stiglitz, 1977).[7]

Some descriptive statistics for industry and county averages of IIT estimates are given in Table 5. According to the industry averages, the chemical products industry (CHP) has the most intensive intra-industry trade. The same industry also has a relatively narrow range of IIT estimates, which are all larger than 0.5 and indicative of a high level of intra-industry trade across the sample countries. The wood products and furniture (WOD) industry has the lowest average IIT estimate, but the estimates display a wide range (between 0.1194 and 0.8088) across countries. On country averages, the core European Union countries have the largest IIT estimates (Belgium, France, Netherlands, and Germany) while Australia has the smallest.

The two proxies, PCM and IIT, for market structure are constructed differ-

[7] The IIT index is used to measure the degree of competitiveness by, for example, Cheung *et al.* (2001).

ently. The former one focuses on the price and cost structure and the latter on product heterogeneity. They represent two different approaches to describe the market structure of an industry. It is likely that these two measures capture different aspects of monopolistic behavior. In fact, the sample correlation between PCM and IIT is quite small, -0.02, and is not significantly different from zero. Thus, the use of both PCM and IIT offers a better chance to reveal the market structure effect.

Two different proxy variables, the number of patent applications and payment for royalties and licenses, are used to quantify technology diffusion. The data were retrieved from the Basic Science and Technology Statistics (OECD, 1999*b*) and US Department of Commerce (2001). The data on these two proxy variables are available at the country level but not the industry level. The use of country-level data may lead to imprecise estimation of the effect of technology diffusion on productivity-differential persistence.

Since the US is the benchmark country, the patent application variable is defined as the ratio of the number of US patent applications to the total number of patent applications in the manufacturing industry of country j (Jaffe and Trajtenberg, 1986; Eaton and Kortum, 1996, 1999; Branstetter, 2000). The variable is denoted as $PAT\_US_{j,t}$. By the same token, the royalties and licenses variable is defined as the amount of royalties and license fees paid by the US affiliates normalized by the US foreign direct investment position in a given country (Xu, 2000) and is denoted as $FDI\_ROY_{j,t}$.

Table 6 presents the estimates of these two proxy variables and some descriptive statistics. It is interesting to note that Canada has a large $PAT\_US_{j,t}$ estimate but a relatively small $FDI\_ROY_{j,t}$ number. In the case of Japan, the $PAT\_US_{j,t}$ estimate is small but $FDI\_ROY_{j,t}$ is among the largest. Apparently, $PAT\_US_{j,t}$ and $FDI\_ROY_{j,t}$ are two alternative ways to capture technology diffusion. In fact, the sample correlation between $PAT\_US_{j,t}$ and $FDI\_ROY_{j,t}$ is -0.562; indicating that these two proxies are two complementary measures.

4.2 Control Variables

Following Benhabib and Spiegel (1994), the average year of schooling is used as the proxy for the country's stock of human capital and is denoted as $HC_{j,t}$ (Penn World Tables 5.6). R&D intensity ($R\&D_{i,j,t}$) is measured as the ratio of the R&D expenditure to the total production in industry i of country j at time t.[8] Similar measures have been used to investigate the effect of domestic and foreign R&D expenditures on productivity and growth (Coe and Helpman, 1995; Coe *et al.*, 1996). The physical investment normalized by total production in industry i of country j at time t, which measures the physical investment intensity, is used as the proxy for sunk costs ($SUNK_{i,j,t}$).[9] Data on both $R\&D_{i,j,t}$ and $SUNK_{i,j,t}$ are from the Main Industrial Indicators, OECD (1999*c*).

The government spending ($GOV_{j,t}$) variable for country j at time t is defined by the government consumption as a share of GDP (International Financial Statistics, CD-ROM, 2001). The variable is commonly used in the empirical growth literature to explain cross-country differences in per capita income (Barro and Sala-i-Martin, 1995). The degree of openness ($OPEN_{i,j,t}$) in each industry is measured by imports over total production in industry i of country j at time t (Romer, 1993). The required data were drawn from OECD (1999*a*). Finally, the distance variable ($DIST_j$) is defined by the geographical distance between the state capital of country j and that of the US (Barro and Lee, 1993).

5 Estimation Results

Using the empirical variables discussed in the previous sections, we examine the determinants of productivity-differential persistence. We consider the following

[8] For some industries in Portugal and Greece, the data are not available. In these cases, the R&D intensity variables in the corresponding Spanish industries are used.

[9] Campa (1993), for example, uses the ratio of the expenditures on information and advertising to sales as a measure of sunk costs for the industries with a relatively small physical investment.

three specifications:

$$\begin{aligned} MRC_{i,j} &= \alpha + \delta_i + \beta_1 PCM_{i,j} + \beta_2 IIT_{i,j} \\ &+\beta_5 SUNK_{i,j} + \beta_6 GOV_j + \beta_7 OPEN_{i,j} \\ &+\beta_8 HC_j + \beta_9 R\&D_{i,j} + \beta_{10} DIST_j + \varepsilon_{i,j} \end{aligned} \quad (6)$$

$$\begin{aligned} MRC_{i,j} &= \alpha + \delta_i + \beta_3 PAT\_US_j + \beta_4 FDI\_ROY_j \\ &+\beta_5 SUNK_{i,j} + \beta_6 GOV_j + \beta_7 OPEN_{i,j} \\ &+\beta_8 HC_j + \beta_9 R\&D_{i,j} + \beta_{10} DIST_j + \varepsilon_{i,j} \end{aligned} \quad (7)$$

$$\begin{aligned} MRC_{i,j} &= \alpha + \delta_i + \beta_1 PCM_{i,j} + \beta_2 IIT_{i,j} + \beta_3 PAT\_US_j + \beta_4 FDI\_ROY_j \\ &+\beta_5 SUNK_{i,j} + \beta_6 GOV_j + \beta_7 OPEN_{i,j} \\ &+\beta_8 HC_j + \beta_9 R\&D_{i,j} + \beta_{10} DIST_j + \varepsilon_{i,j} \end{aligned} \quad (8)$$

where i (= 1,...,11) is the industrial index, j (=1,...,16) is the country index, α is a constant term, δ_i is a industry-specific dummy variable, and ε is the residual term. All the right-hand-side variables are the sample averages over the 1970-1995 period and are expressed in natural logarithms, a common practice in the literature.[10] With the control variables in all the three specifications, equation (6) studies the market structure effect, (7) focuses on the technology diffusion effect, and (8) examines the combined effects.

5.1 Multiple-Equation Regression

In this subsection, we estimate the three specifications using all the available data. Two different estimation procedures are considered: seemingly unrelated regression (SUR) and full information maximum likelihood estimation. The results from these two estimation methods turn out to be quite similar. For brevity, we only reported the SUR results in Table 7.

[10] Indeed, the use of the data themselves yields qualitatively similar results, which are available from the authors.

The estimates from the first model specification are given under (S1). The (S1') column reports the case in which the insignificant control variables are excluded. The estimation results indicate a strong market structure effect on the level of productivity-differential persistence. For instance, in the presence of all the conditioning variables, both PCM and IIT (the proxies for market monopolistic behavior) have a significant positive effect on the persistence of productivity differentials. This finding is related to those of Nickell (1996) and Blundell *et al.* (1995), who find a positive relationship between product market competition and productivity growth and lend support to the prediction of Aghion *et al.* (1997a, b).

The coefficients of most conditioning variables have the expected sign. However, only government spending (GOV) and human capital (HC) are likely to have a statistically significance effect on productivity-differential persistence. In fact, when the other insignificant control variables are excluded, the government spending variable is marginally significant and the human capital variable is significant at the conventional level. A higher level of government spending is associated with a higher degree of productivity-differential persistence, a result that is comparable to the one in Barro and Sala-i-Martin (1995). On the human capital effect, the negative effect is consistent with the finding that human capital is a source of labor productivity differences across countries (Hall and Jones, 1999).

The effect of technology diffusion on the persistence of productivity differences, as given in equation (7), is reported under (S2) and (S2') in Table 7. Even though the two proxies for technology diffusion have a negative coefficient, both variables are statistically insignificant. The coefficients of control variables have the expected sign, but all of them are insignificant. When the insignificant control variables are excluded, the patent variable is marginally significant.

In an empirical study, Keller (2000) finds weak evidence in favor of international technology spillovers in the OECD countries for a similar sample period. His empirical study lends more support to the geographical locality of technological spillovers. Yet, he also points out that the globalization of spillovers seem to have increased over time. The weak evidence revealed in (S2) and (S2') may be related to data quality. Unlike the market structure proxy variables, the technology diffusion proxies are country-level but not industry-specific data. This may make it difficult to estimate the technology diffusion effect precisely.

What are the effects of market structure and technology diffusion on the persistence of productivity differentials when both types of proxies are simultaneously included in the regression? The estimates reported under (S3) and (S3') in Table 7 indicate that the market structure proxy variables remain positive and significant in the combined model. Apparently, the presence of technology diffusion variables has no obvious impact on the estimated effects of both PCM and IIT. The coefficient estimates of PCM and IIT are very similar to those under specifications (S1) and (S1') in terms of magnitude and level of significance. The significance of the technology diffusion proxy variables depends on the control variables. The exclusion of the highly insignificant control variables enhances the level of significance of the patent variable (PAT_US). It seems the PAT_US is the technology diffusion variable that has a consistent impact on productivity-differential persistence across specifications. Again, the coefficients of the control variables have the expected sign but only the GOV and HC variables are (marginally) significant.

Overall, there is strong evidence on the effect of market structure on the productivity-differential persistence. A higher degree of monopolistic competition implies a higher level of persistence and a longer time to achieve output convergence across countries. The technology diffusion effect is, however, not unambiguous. While the patent variable may be significant, the royalties and license fees variable does not appear to effect productivity-differential persistence. For the control variables, they tend to have the expected effect. However, it is likely that only two of the six control variables, government spending and human capital, have a statistically significant impact on productivity-differential persistence.

5.2 Qualitative Response Analysis

In this subsection, we consider a modified mean reversion coefficient $(MRC^*_{i,j})$ which accounts for different types of convergence behavior. The modified mean reversion coefficient is defined as

$$MRC^*_{i,j} = \begin{cases} 0 & \text{if } MRC_{i,j} \leq 0 \\ MRC_{i,j} & \text{if } 0 < MRC_{i,j} < 1 \\ 1 & \text{if } MRC_{i,j} \geq 1 \end{cases} \tag{9}$$

A priori, we anticipate the productivity-differential persistence is affected by market structure and technology diffusion when national output data are converging; i.e. when $0 < MRC_{i,j} < 1$. When $MRC_{i,j} \geq 1$, the relationship may experience a change or is no longer defined. On the other hand, when $MRC_{i,j} \leq 0$, the productivity-differential series may display oscillating behavior, which implies alternation of technology leadership between countries. Under such circumstances, it may be a change in the nature of the market structure and technology diffusion effects. The use of the modified mean reversion coefficient explicitly allows for the qualitative changes associated with the regressand.[11]

The qualitative response analysis is used to study the model with $MRC^*_{i,j}$ as the regressand. Specifically, the censored-regression model is used and its log likelihood function is (Amemiya, 1985)

$$\begin{aligned} \log L(\gamma, \sigma) &= \sum_{k \in MRC^*_{i,j}=0} \log\left(F\left[\left(-w'_{i,j}\gamma\right)/\sigma\right]\right) \\ &+ \sum_{k \in 0 < MRC^*_{i,j} < 1} \log\left(f\left[\left(MRC^*_{i,j} - w'_{i,j}\gamma\right)/\sigma\right]\right) \\ &+ \sum_{k \in MRC^*_{i,j}=1} \log\left(1 - F\left[\left(1 - w'_{i,j}\gamma\right)/\sigma\right]\right) \end{aligned} \tag{10}$$

where the residual term ε follows a normal distribution $N(0, \sigma^2)$, $f[.]$ and $F[.]$ are the normal density and cumulative distribution functions, $w_{i,j}$ contains the rele-

[11] For a total of 173 observations, there are 10 cases in which $MRC_{i,j} \leq 0$ and 7 cases $MRC_{i,j} \geq 1$.

vant explanatory variables, and γ is the associated vector of parameters. The use of logit distribution, another commonly used specification in qualitative response models, gives very similar estimation results.[12]

The censored-regression results for the three specifications are reported in Table 8. Again, for each specification, we first include all the six control variables and then exclude the insignificant ones. The results can be summarized as follows.

First, both proxies for market structure, PCM and IIT, have a significant and positive effect on productivity-differential persistence. The result is similar to the SUR one. The estimates clearly show that both measures of competitiveness are highly significant and competition reduces the persistence of productivity differentials.

Second, the two technology diffusion proxies, PAT_US and FDI_ROY, behave differently. On the one hand, the patent variable PAT_US displays a significantly negative effect on productivity-differential persistence; an evidence that is consistent with the notion of cross-country technology diffusion encourages productivity catch-up. On the other hand, the FDI variable, FDI_ROY, has a negative but insignificant coefficient.

Third, in most cases, the coefficients of the six control variables have the expected sign. With the exceptions of GOV and HC, however, these coefficients are not statistically significant. The government spending variable, GOV, shows a marginally significant effect in the presence of proxies for both market structure and technology diffusion.

In sum, the market structure and technology diffusion effects are quite robust to variations in model specification and estimation method.

[12] Results based on the Logit distribution are available from the authors upon request.

6 Concluding Remarks

We empirically investigate the determinants of cross-country differences in the persistence of productivity differentials. Specifically, we focus on the market structure and technology diffusion, two factors that have received limited attention in the empirical growth literature. Data from 11 main manufacturing industries of 17 OECD countries are examined. Using the US as the benchmark, we find significant variations in the convergence behavior across industries among these countries. The convergence rate ranges from a very low to a very high level.

Our empirical analysis reveals a significant market structure effect but a weak technology diffusion influence. It is found that the two proxies for market imperfection (the price-cost margin and intra-industry trade index) have a negative effect on productivity-differential persistence. A monopolistic market structure tends to hinder convergence and prolong the presence of productivity gap. The market structure effect appears robust to various model specifications and estimation methods.

For the two technology diffusion proxy variables, only the US patent applications variable is weakly significant in some specifications. The other proxy variable, the amount of royalties and license fees, displays no discernible effect on the persistence of productivity differentials. Among the six control variables, only government spending and human capital are likely to have a significant effect. Specifically, it is found that productivity convergence is enhanced by improvement in human capital but deterred by government spending.

While the current study presents some significant results, a large proportion of variation in cross-country and cross-industry productivity differentials remains unexplained. Further research, for example, employing better data on technology diffusion and other industry-level factors is warranted to gain further insights on the determinants of the persistence of productivity differentials.

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Table 1: Manufacturing industries

ISIC code	Manufacturing industries	Abbreviation
31	Food, Beverages and Tobacco	FOD
32	Textiles, Apparel and Leather	TAL
33	Wood Products and Furniture	WOD
34 (341+342)	Paper, Printing and Publishing	
341	Paper and Paper Products	PAP
342	Printing and Publishing	PUB
35	Chemical Products	CHP
36	Non Metallic Mineral Products	NMM
37 (371+372)	Basic Metal Industries	
371	Iron and Steel	IST
372	Non Ferrous Metals	NFM
38	Fabricated Metal Products	FMP
39	Other Manufacturing	OMA

Note: The manufacturing industries, together with their ISIC codes and abbreviations, are listed.

Table 2 : The Average TFP Indexes

	CHP	FMP	FOD	IST	NFM	NMM	OMA	PAP	PUB	TAL	WOD	Avg.	Min	Max
Australia	0.13	-0.02	-0.01	-0.17	0.16	0.11	-0.51	-0.09	-0.03	0.06	0.04	-0.03	-0.51	0.16
Austria	0.17	0.12	-0.06	-0.06	-0.26	0.13	NA	-0.04	-0.20	0.01	-0.04	-0.02	-0.26	0.17
Belgium	0.03	0.14	0.24	-0.20	0.26	-0.16	0.08	-0.11	-0.18	-0.11	-0.69	-0.06	-0.69	0.26
Canada	-0.10	0.23	0.23	0.17	0.02	0.30	0.09	0.17	0.39	0.19	0.09	0.16	-0.10	0.39
Denmark	-0.16	-0.14	-0.31	-0.21	-0.76	-0.12	0.12	0.07	-0.01	-0.03	-0.08	-0.15	-0.76	0.12
Finland	-0.21	-0.13	-0.30	-0.13	-0.16	-0.05	-0.26	-0.15	-0.09	-0.17	-0.09	-0.16	-0.30	-0.05
France	0.38	0.24	0.17	0.06	0.21	0.37	NA	0.29	0.30	0.32	0.18	0.25	0.06	0.38
Germany	0.36	0.22	0.21	0.16	-0.04	0.26	0.22	0.20	-0.03	0.16	0.20	0.17	-0.04	0.36
Italy	-0.21	-0.12	-0.17	0.14	0.20	0.01	1.19	-0.04	0.25	0.19	0.43	0.17	-0.21	1.19
Grece	-0.18	0.05	0.20	-0.13	0.05	0.08	-0.08	-0.11	0.24	0.17	-0.01	0.03	-0.18	0.24
Japan	-0.19	-0.23	0.03	0.23	0.05	-0.23	0.89	-0.21	-0.05	-0.40	-0.47	-0.05	-0.47	0.89
Netherlands	0.26	0.12	-0.05	0.20	0.39	0.16	-0.25	0.20	0.13	0.19	0.40	0.16	-0.25	0.40
Norway	-0.24	-0.03	-0.18	-0.28	0.27	-0.17	-0.25	-0.44	-0.28	-0.21	0.08	-0.16	-0.44	0.27
Portugal	-0.32	-0.59	-0.23	0.10	-0.66	-0.61	-0.64	-0.06	-0.95	-0.55	-0.67	-0.47	-0.95	0.10
Sweden	-0.07	-0.15	-0.26	-0.43	-0.24	-0.16	-1.65	-0.18	-0.13	-0.05	0.16	-0.29	-1.65	0.16
UK	-0.13	-0.22	-0.10	-0.30	-0.54	-0.22	-0.09	-0.14	0.11	-0.02	-0.06	-0.16	-0.54	0.11
US	0.40	0.43	0.56	0.52	0.46	0.27	0.41	0.51	0.50	0.23	0.44	0.43	0.23	0.56

Note: The country-and-industry-specific average TFP indexes, as defined by equation (1), are reported.

Table 3 : Descriptive statistics for $MRC_{i,j}$

		Mean	S.D.	Min	Max
INDUSTRY:	CHP	0.6043	0.2682	0.2188	1.2565
	FMP	0.5546	0.3608	-0.1515	0.9362
	FOD	0.7259	0.3326	-0.3220	1.0067
	IST	0.4775	0.2586	-0.1186	0.7838
	NFM	0.3453	0.5220	-0.8109	0.9057
	NMM	0.6219	0.3032	-0.3798	1.0649
	OMA	0.5424	0.1815	0.2411	0.8244
	PAP	0.6869	0.2272	0.2574	1.0212
	PUB	0.4278	0.3799	-0.4058	0.9015
	TAL	0.8314	0.2836	0.1025	1.2792
	WOD	0.5698	0.1913	0.1500	0.8538
COUNTRY:	Australia	0.6251	0.2946	0.2021	1.2792
	Austria	0.6315	0.3259	-0.2366	0.9256
	Belgium	0.5192	0.5061	-0.8109	0.9400
	Canada	0.6036	0.2869	0.0052	0.9328
	Denmark	0.6868	0.1658	0.3974	0.9041
	Finland	0.5029	0.2785	0.0390	1.0067
	France	0.6546	0.2750	0.0554	0.8859
	Germany	0.5391	0.5494	-0.5841	1.0212
	Greece	0.4819	0.3251	-0.1186	1.0521
	Italy	0.6861	0.2090	0.2672	0.9593
	Japan	0.6844	0.1762	0.3651	1.0154
	Netherlands	0.6107	0.3927	-0.3220	1.0649
	Norway	0.4253	0.3183	-0.0898	0.9964
	Portugal	0.4802	0.4101	-0.2722	1.2565
	Sweden	0.6153	0.2488	0.1792	0.9299
	UK	0.5594	0.4191	-0.3798	0.9977

Note: The cross-industry and cross-country descriptive statistics of the mean reversion coefficient, $MRC_{i,j}$, estimates are reported. See Table 1 for the industry abbreviations.

Table 4 : Descriptive statistics for $PCM_{i,j}$

		Mean	S.D.	Min	Max
INDUSTRY:	CHP	0.1502	0.0440	0.0951	0.2468
	FMP	0.1312	0.0457	0.0682	0.2136
	FOD	0.1041	0.0325	0.0459	0.1694
	IST	0.0960	0.0611	-0.0041	0.2827
	NFM	0.1025	0.0607	-0.0213	0.2052
	NMM	0.1590	0.0460	0.0774	0.2412
	OMA	0.1328	0.1765	-0.4778	0.3837
	PAP	0.1332	0.0464	0.0780	0.2706
	PUB	0.1276	0.0454	0.0689	0.2600
	TAL	0.1077	0.0349	0.0759	0.2118
	WOD	0.1265	0.0435	0.0637	0.2442
COUNTRY:	Australia	0.1479	0.0273	0.1011	0.1876
	Austria	0.1139	0.0375	0.0588	0.1821
	Belgium	0.0856	0.0630	-0.0213	0.2123
	Canada	0.1126	0.0307	0.0719	0.1688
	Denmark	0.1044	0.0466	0.0325	0.2105
	Finland	0.1297	0.0386	0.0580	0.1937
	France	0.1380	0.0353	0.0820	0.2029
	Germany	0.1318	0.0441	0.0813	0.2071
	Greece	0.2110	0.0727	0.1204	0.3837
	Italy	0.1524	0.0236	0.1196	0.2038
	Japan	0.1614	0.0441	0.0869	0.2290
	Netherlands	0.1166	0.0306	0.0682	0.1693
	Norway	0.0975	0.0228	0.0618	0.1343
	Portugal	0.1856	0.0631	0.1020	0.2827
	Sweden	0.0398	0.1742	-0.4778	0.1472
	UK	0.0755	0.0301	0.0279	0.1178
	US	0.1134	0.0306	0.0743	0.1612

Note: The cross-industry and cross-country descriptive statistics of the average price-cost margin, $PCM_{i,j}$, estimates are reported. See Table 1 for the industry abbreviations.

Table 5: Descriptive statistics for $IIT_{i,j}$

		Mean	S.D.	Min	Max
INDUSTRY:	CHP	0.7829	0.1383	0.5380	0.9617
	FMP	0.7098	0.2599	0.1336	0.9443
	FOD	0.7021	0.1966	0.2642	0.9284
	IST	0.6980	0.2222	0.2332	0.9447
	NFM	0.6515	0.2443	0.1530	0.9620
	NMM	0.7054	0.1874	0.2465	0.9542
	OMA	0.6873	0.2133	0.3407	0.9646
	PAP	0.5132	0.2712	0.0662	0.8295
	PUB	0.6771	0.2273	0.2516	0.9422
	TAL	0.6674	0.2052	0.2582	0.9441
	WOD	0.4370	0.2291	0.1194	0.8088
COUNTRY:	Australia	0.3956	0.2038	0.1530	0.8161
	Austria	0.7345	0.1371	0.4641	0.9022
	Belgium	0.8628	0.1381	0.4983	0.9646
	Canada	0.5605	0.2706	0.1945	0.9024
	Denmark	0.6913	0.1814	0.4319	0.9280
	Finland	0.6696	0.2915	0.0662	0.8718
	France	0.8604	0.0860	0.7177	0.9617
	Germany	0.7650	0.1167	0.5818	0.9267
	Greece	0.5468	0.2521	0.1336	0.8289
	Italy	0.6199	0.1666	0.4273	0.8747
	Japan	0.5467	0.2841	0.1998	0.9243
	Netherlands	0.7837	0.1568	0.3945	0.9447
	Norway	0.5818	0.2229	0.2516	0.9345
	Portugal	0.5102	0.2182	0.1401	0.8414
	Sweden	0.6298	0.2380	0.1493	0.8656
	UK	0.7301	0.2502	0.1194	0.9224
	US	0.6876	0.1759	0.4506	0.9372

Note: The cross-industry and cross-country descriptive statistics of the average intra-industry trade index, $IIT_{i,j}$, estimates are reported. See Table 1 for the industry abbreviations.

Table 6 : Descriptive statistics for PAT_US_j and FDI_ROY_j

Country	PAT_US_j	FDI_ROY_j
Australia	0.350	0.022
Austria	0.322	0.021
Belgium	0.354	0.037
Canada	0.505	0.022
Denmark	0.397	0.029
Finland	0.338	0.054
France	0.277	0.084
Germany	0.219	0.066
Greece	0.412	0.031
Italy	0.284	0.073
Japan	0.058	0.116
Netherlands	0.346	0.080
Norway	0.387	0.033
Portugal	0.435	0.061
Sweden	0.329	0.120
UK	0.253	0.048
Avg	0.329	0.056
Min	0.058	0.021
Max	0.505	0.120
S.D.	0.225	0.050

Note: The country-level US patent application (PAT_US_j) and royalties and licenses (FDI_ROY_j) estimates and their descriptive statistics are reported.

Table 7 : SUR estimates

	(S1)	(S1')	(S2)	(S2')	(S3)	(S3')
$PCM_{i,j}$	0.4227	0.4268			0.4431	0.4539
	(0.0006)	(0.0003)			(0.0003)	(0.0002)
$IIT_{i,j}$	0.1117	0.1059			0.1027	0.0997
	(0.0252)	(0.0304)			(0.0454)	(0.0420)
PAT_US_j			-0.1365	-0.1278	-0.1488	-0.1447
			(0.1785)	(0.1050)	(0.1331)	(0.0553)
FDI_ROY_j			-0.0228	-0.0194	-0.0467	-0.0413
			(0.6611)	(0.7036)	(0.3522)	(0.4017)
GOV_j	0.1922	0.1879	0.1951	0.1458	0.3439	0.3086
	(0.1464)	(0.1247)	(0.2397)	(0.3085)	(0.0399)	(0.0348)
HC_j	-0.1323	-0.1501	-0.0461		-0.1090	-0.0853
	(0.0794)	(0.0282)	(0.5612)		(0.1615)	(0.1274)
$R\&D_{i,j}$	0.0122		-0.0218		-0.0086	
	(0.7116)		(0.5574)		(0.8099)	
$DIST_j$	0.0558	0.0641	0.0091		0.0270	
	(0.3221)	(0.2353)	(0.8869)		(0.6609)	
$OPEN_{i,j}$	-0.0152		-0.0037		-0.0003	
	(0.5950)		(0.9051)		(0.9920)	
$SUNK_{i,j}$	0.0038		0.0806	0.0761	0.0363	
	(0.9563)		(0.2770)	(0.2947)	(0.6143)	
R-sqr	0.2364	0.2342	0.1766	0.1736	0.2466	0.2445
Adjusted R-sqr	0.1472	0.1611	0.0803	0.1004	0.1475	0.1670

Note: The table presents SUR estimates –S1, S2 and S3 – of equations (6), (7), and (8). Columns S1', S2', and S3' exclude the control varibles with p-values above 50%. The p-values are given in parentheses.

Table 8: Estimates for the qualiative response specifications

	(S1)	(S1')	(S2)	(S2')	(S3)	(S3')
$\text{PCM}_{i,j}$	0.2794	0.2805			0.3271	0.3108
	(0.0167)	(0.0097)			(0.0057)	(0.0044)
$\text{IIT}_{i,j}$	0.1140	0.1132			0.1062	0.1074
	(0.0103)	(0.0108)			(0.0179)	(0.0155)
PAT_US_j			-0.1473	-0.1169	-0.1822	-0.1445
			(0.1176)	(0.0866)	(0.0530)	(0.0356)
FDI_ROY_j			-0.0169	-0.0102	-0.0426	-0.0353
			(0.7169)	(0.8218)	(0.3532)	(0.4306)
GOV_j	0.0910	0.0982	0.1731	0.1082	0.2628	0.2362
	(0.4646)	(0.3789)	(0.2460)	(0.3802)	(0.0836)	(0.0758)
HC_j	-0.0913	-0.1108	-0.0150		-0.0626	-0.0556
	(0.1856)	(0.0742)	(0.8337)		(0.3745)	(0.2724)
$\text{R\&D}_{i,j}$	0.0166		-0.0159		-0.0081	
	(0.5824)		(0.6326)		(0.8036)	
DIST_j	0.0401	0.0504	-0.0105		0.0035	
	(0.4371)	(0.3046)	(0.8539)		(0.9493)	
$\text{OPEN}_{i,j}$	-0.0102		-0.0059		0.0269	
	(0.7923)		(0.8861)		(0.5331)	
$\text{SUNK}_{i,j}$	-0.0001		0.0574		0.0216	
	(0.9987)		(0.3877)		(0.7454)	
log likelihood	-34.0901	-34.3005	-38.0161	-38.5292	-32.2397	-32.5590
L.R.	43.9630	43.5421	36.1111	35.0849	47.6638	47.0251
	(0.0006)	(0.0001)	(0.0068)	(0.0008)	(0.0005)	(0.0001)

Note: Estimates for the censored regression model with $MRC^*_{i,j}$ (equation 9) as the LHS variable. S1, S2 and S3 are given by equations (6), (7), and (8). Columns S1', S2', and S3' exclude the control variables with p-values above 50%. The row "L.R." reports the LR statistics for the hypothesis that all the RHS variables are jointly insignificant. The p-values are given in parentheses.