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Productivity Growth, Technological Convergence, R&D, Trade, and Labor Markets: Evidence from the French Manufacturing Sector

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Productivity Growth, Technological Convergence, R&D, Trade, and Labor Markets: Evidence from the French Manufacturing Sector

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Abstract

Total factor productivity (TFP) of 14 manufacturing sectors in France has kept up with that of the United States during 1980–2002 and remained well above that of the United Kingdom. Estimates using a dynamic panel equilibrium correction model indicate that sectors further behind the technological frontier experience faster productivity growth and that spending on research and development and trade with technologically advanced economies positively influences TFP growth, but not the speed of convergence. Conversely, TFP growth is negatively related to some key labor market variables, namely the replacement ratio and the ratio of the minimum wage to the median wage.

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I. Introduction

Over the last decade, strong policy concerns have emerged in Europe (and France in particular) about the threat to European standards of living from the slowdown in productivity growth. These concerns have been heightened by the sharp acceleration of U.S. income per capita and productivity growth and by the growing competition in the manufacturing sector from low-cost economies[2] (Van Ark, 2005). With questions being raised about whether advanced economies can ever compete on the basis of costs, innovation is being advocated as the way forward. This is evident in the Lisbon Strategy (2000) and its subsequent reviews, which have called for an increase in European research and development (R&D) expenditures to 3 percent of GDP to further European Union (EU) aspirations of becoming the "most competitive and dynamic knowledge-based economy" by 2010. Consequently, innovation has become a major pillar of French policy as reflected in the introduction of support for R&D in "*pôles de compétitivité*" (competitiveness clusters) announced in July 2005 and the "*Pacte Recherche*" announced in November 2005. Under the latter, annual state spending on research, which includes significant fiscal incentives to promote innovation and private sector R&D investment, has been set to increase by €1 billion from 2005 through 2007.

Pertinent to any discussion regarding the productivity gap between European countries and the United States is the role of labor market institutions and product market regulations. Recent studies (Van Ark, 2005; OECD, 2003) indicate that the institutional environment of Europe is inhibiting the reallocation of resources towards the most productive uses and is thus impeding its transition to a "new industrial structure."[3] According to Scarpetta and Tressel (2002), stringent product market regulation as well as strict employment legislation have had a negative effect on productivity at the industry, and consequently at the macroeconomic, level. Thus the key to productivity growth in Europe (including France, which is typically seen as having very rigid labor markets) would appear to lie not only in increasing R&D but also in easing these rigidities. This is supported by a recent study (Meister and Verspagen, 2004) that simulates the impact on catchup to U.S. total factor productivity (TFP) levels as a result of the implementation of the Barcelona R&D targets in France, Germany, Italy, and the United Kingdom. Results indicate that the effect, albeit

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[2] Labor productivity measured as output per hour is higher in France than in the United States. Its growth rate in France, however, has remained constant since the 1970s, while that in the United States has sharply accelerated, particularly after 1995. The gap in output per capita between France and the United States has also been steadily widening since the early 1980s. The discrepancy between per hour and per capita figures for France partly reflects the substantially lower number of working hours per employed worker as well as a lower ratio of employed workers to the working age population. For the purposes of this paper, however, I am concerned with total factor productivity, which is a measure of the technical efficiency with which all inputs are used.

[3] See Van Ark (2005, page 4).

positive, would be small, leading the authors to argue that increased R&D spending may only be part of the solution. If these countries wish to catch up with the United States, other institutional factors will need to be addressed.

This paper analyzes TFP growth in 14 manufacturing industries in France over the period 1980–2002. First, the evolution of TFP in these industries relative to their U.S. and U.K. counterparts is examined. This is followed by a formal econometric exercise that investigates the influence of R&D, trade, and labor market characteristics in stimulating two potential sources of TFP growth in France, namely innovation and technology transfer. Specifically, the study analyzes whether distance from the technological frontier (defined as the United States) is related to productivity growth in the French manufacturing sector. In addition, it investigates whether R&D intensity, trading patterns and labor market institutions have an effect on, first, the rate of innovation, and second, the speed at which the technology gap between France and the technological leader is closed. Following Bernard and Jones (1996a and 1996b), the difference in the TFP levels between France and the leader is used to measure the potential for technology transfer. The availability of panel data for the period under study allows us to control for unobserved sector-specific heterogeneities that influence productivity growth.

The author finds the following results: First, TFP levels in France lead U.K. TFP levels for the period under consideration, and relative TFP levels are higher in France in 2002 for all but one sector. This is consistent with evidence by O' Mahoney and de Boer (2002), in that there is a considerable lag between U.K. TFP levels and those of France, Germany, and the United States. Second, there does not appear to be a significant gap between French and U.S. TFP levels in total manufacturing. Furthermore, most sectors show signs of convergence toward U.S. levels.

The results from the econometric exercise indicate the following. First, technology transfer plays a role in TFP growth. Other things equal, the larger the size of the gap in technical efficiency in French manufacturing sectors relative to their U.S. counterparts, the higher is the rate of TFP growth. Second, TFP growth rates are also positively related to R&D intensity and to imports from the Germany, the United States, and the United Kingdom. There is no evidence, however, that these variables affect the speed of technology transfer. Finally, there is strong evidence that higher levels of replacement ratios and minimum wage-to-median income ratios have a negative impact on TFP growth rates. These results are consistent with a wider industry-level panel study for 18 Organization for Economic Cooperation and Development (OECD) countries by Scarpetta and Tressel (2002), who found a positive impact of R&D and a negative impact of employment protection legislation on TFP growth. Consequently, the results of this study are consistent with the argument that in addition to R&D spending, future increases in TFP growth in France may depend significantly on labor market reforms that reduce the costs of adjusting labor.

The paper is organized as follows: Section II briefly reviews the literature on the effect of R&D, trade and labor markets on productivity, while Section III sets up the theoretical model. Section IV outlines data sources and the construction of variables. It also compares TFP levels in French manufacturing industries with their U.S. and U.K. counterparts. Section V discusses the econometric methodology adopted and presents estimation results, while Section VI concludes.

II. Theoretical Literature and Empirical Evidence

Recent theoretical work by Acemoglu, Aghion, and Zilibotti (2003) and Aghion, Meghir, and Vandenbussche (2005) emphasizes that technological progress is a combination of both innovation and the adoption and imitation of existing technologies from technological leaders. Furthermore, proximity to the technological frontier determines the relative importance of these two factors. Imitation plays a crucial role in "catching up" when a country is far away from the frontier. However, the returns from imitation decline the closer it moves to the frontier, and pure innovation becomes more important for both closing the gap between the leader and the follower and eventually for overtaking the leader.

The effect of R&D on productivity growth through its effect on innovation has been discussed at length in the theoretical literature (see Jones, 1995, for a review). More recently, Griffith, Redding, and Van Reenen (2003) have argued that R&D not only boosts growth directly through innovation but also through an increased potential for imitation. In other words, R&D raises the "absorptive capacity" for technology transfer.[4] Investigating an industry panel of 12 OECD countries covering the period 1984–90, they find strong evidence in favor of this "second face" of R&D. However, their results show that only one-fifth of the social return to R&D in France can be attributed to this indirect effect. On the other hand, Scarpetta and Tressel (2002)[5] who undertake an industry level analysis of 18 countries over the period 1984–98 do not find evidence of an indirect channel by which R&D influences growth.

Nevertheless, both Scarpetta and Tressel (2002) and Griffith, Redding, and Van Reenen (2003) find that R&D is statistically important in stimulating innovation, and therefore productivity growth. This is also borne out in firm level studies. For example, one early paper by Hall and Mairesse (1995) for French manufacturing finds that a longer history of R&D expenditures helps in predicting productivity growth. More recently, using French firm survey data, Mairesse and Mohnen (2005) find that a 1 percent increase in R&D intensity

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[4] For the seminal paper on the effects of R&D on absorptive capacity, see Cohen and Levinthal (1989).

[5] The same study is also published in OECD (2003).

leads to an increase in the probability of innovating by 20 percentage points in high-tech sectors. The effect on low-tech sectors is even stronger.

Similarly, there exists a theoretical literature that argues that trade has a beneficial effect on productivity growth by making available products and services that embody foreign technology, by exposure to international best practice and by providing foreign technologies and other types of knowledge, which would otherwise be too costly to produce at home (Helpman, 1997). Furthermore, trade may have an indirect effect on productivity growth, analogous to the second face of R&D. In other words, it may also help to increase the rate at which technology transfer can occur (for example by reducing the costs of technology adoption, see Barro and Sala-i-Martin, 1995).

Investigating productivity growth in a panel of 14 U.K. manufacturing industries for the period 1979–92, Cameron, Proudman, and Redding (2005) find that openness to trade matters significantly for the speed of technology transfer from the United States while Cameron (2005) finds that Japanese industries that are more open catch up faster to their U.S. counterparts. However, evidence by Eaton and Kortum (1996) and Bernstein and Mohnen (1998) that R&D spillovers from the United States to Japan are more significant than the other way round, suggests that it is trade with the technological leader that matters. This is also consistent with other evidence by Xu and Chiang (2005) that productivity in advanced countries benefits from foreign technology embodied in imported capital goods. Such evidence suggests that, insofar as the diffusion of technology occurs through trade with technologically advanced countries and given that the French economy is already relatively open, it is not the degree of openness per se that is important but rather the trading partners that matter.

Finally, Bassanini and Ernst (2002) and Scarpetta and Tressel (2002 and 2004) provide strong evidence that innovation activity and productivity are affected by the institutional environment of countries including employment protection legislation. Stringent hiring and firing regulations, high minimum wage provisions and administrative extension of collective rules can prevent firms from reorganizing production processes and utilizing labor and capital inputs in the most optimal manner. They can also prevent firms from pursuing and/or implementing innovations with negative implications for TFP.[6] In addition, they may impose heavy burdens on small firms and raise the costs of entry into industries. In a panel study of 60 countries, Caballero, Cowan, Engel, and Micco (2004) find that job security regulations[7]

[6] For instance by increasing the cost of investing in R&D as well as implementing innovations. If they also lead to the appropriation of rents by strong insiders, then firms may lack an incentive to invest in productivity-enhancing innovation. See Scarpetta and Tressel (2004) for a comprehensive discussion of the impact of labor adjustment costs on innovation and productivity.

[7] They refer to legal protection against dismissals.

clearly hinder the process of creative destruction, especially in countries where these regulations are likely to be enforced, such as France (see OECD, 2005b). Their findings suggest that higher levels of job security[8] reduce the annual speed of adjustment to productivity shocks by a third while also reducing annual productivity growth by approximately 1 percent. A very interesting result is that France has the third lowest speed of adjustment to productivity shocks out of the 60 countries in their sample (just ahead of Kenya). Investigating 17 manufacturing industries in 18 OECD countries over the period 1984–98, Scarpetta and Tressel (2004) find that high labor adjustment costs can have a strong negative impact on productivity.

France, typically considered to have heavily regulated labor markets, has in recent years attempted to make its labor markets relatively more flexible. A recent example is the New Employment Contract (CNE), introduced in 2005, which allows small firms to fire long-term employees at will during their first two years of employment.[9] Furthermore, although well-publicized strikes by public sector French unions tend to give the impression of all-powerful unions, it is noteworthy that France has the lowest union density in the OECD (an average of 10 percent in 1996–98 compared to 14 percent and 35 percent for the United States and the United Kingdom, respectively; see Nickell, Nunziata, and Ochel (2005)). Union membership is also overwhelmingly dominated by public sector employees (private sector employees account for some 5 percent of union membership), and the unions are "highly fragmented and in a state of internal rivalry and ideological conflict" (see Kroos, 2005).[10] Collective agreements at the national and sectoral levels prominent in the 1970s and early 1980s were in decline until the 1990s, after which the state has actively intervened to negotiate solutions

[8] More specifically, moving from the 20th to the 80th percentile in job security in countries with a strong rule of law.

[9] After two years, legal justification is required.

[10] The French collective bargaining system is considerably complex, with consultation occurring at different levels. The highly fragmented and competing nature of French trade unions (and to some extent employer associations as well) makes consensus hard to establish, so that the state frequently intervenes. At the enterprise level, employee representation is conducted through trade unions as well as social councils (*comités d'entreprise*). While these councils are legally invested with only consultative powers, and collective bargaining is the legal prerogative of trade unions alone, there is a very fine line between consultation and bargaining, and the councils can and do act as virtual competitors to trade unions. Thus, the source of union power in France is not the outcome of membership or of legislation that makes annual collective bargaining compulsory at the firm level (legislation has contributed to the decentralization of wage bargaining and to an increase in enterprise level negotiations at the cost of industry or sector level agreements). Rather, it stems from the unions' formal role in the welfare system, namely the *mutuelles,* which are organizations responsible for delivering health and unemployment insurance (*Economist*, June 5, 2003). For a comprehensive discussion of these issues, see Kroos, 2005.

when negotiations between employers and unions broke down and also to extend successful agreements to other sectors and areas.[11]

Nevertheless, overall employment protection has been increasing over the last two decades in France and is particularly stringent for long-term employees, with substantial administrative and legal costs associated with firing workers. Although fixed-duration contracts (CDDs) were introduced as early as 1979, they can be used only to fill temporary/short-term vacancies. (See Blanchard and Landier (2001) and Zhou (2006) for a discussion.) Furthermore, since 1970, French law has required the minimum wage or "*salaire minimum de croissance*" (SMIC) to provide "workers with the lowest remuneration a purchasing power guarantee and a participation in the economic development of the country."[12] The SMIC has steadily increased in line with median wages since the early 1980s so that the ratio of the minimum wage to average labor costs stood at approximately 55 percent in 2002—roughly 10 and 20 percentage points higher than the OECD and U.S. averages, respectively.[13] Such high minimum labor costs and strong employment protection legislation make employers reluctant to hire labor, particularly young and low-skilled workers. Finally, there is evidence that the income tax and benefit-support system in France significantly distorts incentives to return to work to the extent that approximately 57 percent of "voluntary unemployment" in France can be attributed to the tax-benefit system (Laroque and Salanie, 2000; Estevão and Nargis, 2005). These features of French labor markets are deemed to be partly responsible for both high rates of unemployment and severe recruitment difficulties for employers. (See OECD, 2005a.) To the extent that high minimum labor costs and high costs of workforce adjustment induce a suboptimal utilization of inputs and reduce incentives to innovate, there may be negative effects on TFP growth. (See Scarpetta and Tressel, 2004, for a discussion.)

III. Theoretical Model

Consider country $i \in \{0, F\}$ producing output in sector j at time t. Production is characterized by a standard neoclassical framework using a constant returns to scale Cobb-Douglas production function.

$$Y_{i,j,t}=A_{i,j,t}f(K_{i,j,t},L_{i,j,t}) \tag{1}$$

[11] So that union coverage is high.

[12] Cited from DiPrete, Maurin, Goux, and Quesnell-Vallee, 2005.

[13] See OECD, 2005b.

There are diminishing marginal returns to capital (K) and labor (L). $Y_{i,j,t}$ represents value-added, and $A_{i,j,t}$ is an index of technical efficiency or total factor productivity and varies across countries, sectors, and time.

Henceforth, the country at the technological frontier is indexed by F while i denotes the country that lies behind the frontier. In the empirical analysis, the United States and France are denoted as the frontier and nonfrontier economies, respectively. As Figure 1 shows, TFP levels in most French manufacturing sectors have tended to be relatively lower than those in the United States for the period under study.

Following Bernard and Jones (1996a), $A_{i,j,t}$ evolves as a result of either domestic innovation or technology transfer from the frontier economy:

$$\Delta lnA_{i,j,t}=\gamma_{i,j}+\lambda_{i,j}\ ln\left(\frac{A_{F,j,t-1}}{A_{i,j,t-1}}\right) \tag{2}$$

where $\gamma_{i,j}$ is the rate of growth as a result of sector-specific innovation while $\left(\frac{A_{F,j,t-1}}{A_{i,j,t-1}}\right)$ is the sector-specific TFP gap between the frontier economy and the nonfrontier economy. The term is used as an indicator of the potential for technology transfer from F to i with λ denoting the speed of convergence.

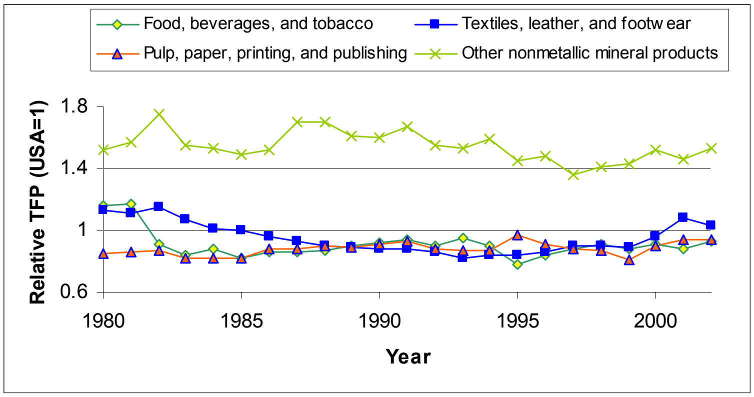
Equation (2) therefore neatly summarizes the notion that productivity growth in sector j of country i is the outcome of the rate of sector specific innovation ($\gamma_{i,j}$) or the outcome of technology transfer from the frontier economy to the nonfrontier economy ($\lambda_{i,j}$). The larger the sector-specific technology gap as denoted by $\left(\frac{A_{F,j,t-1}}{A_{i,j,t-1}}\right)$ is, the greater the potential for productivity growth through technology transfer. Note that productivity growth in the frontier economy is driven solely by innovation so that

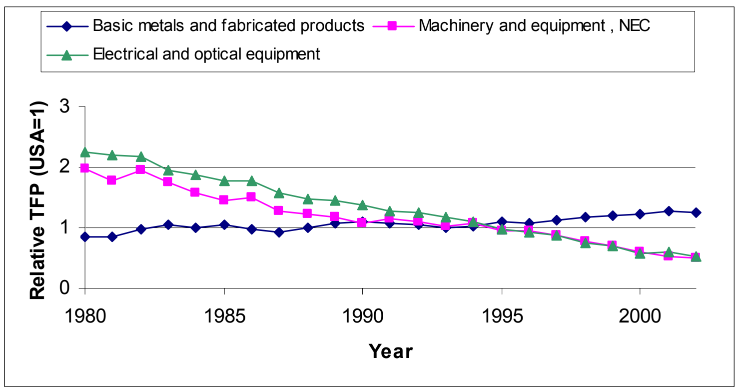
$$\Delta lnA_{F,j,t}=\gamma_{F,j}. \tag{3}$$

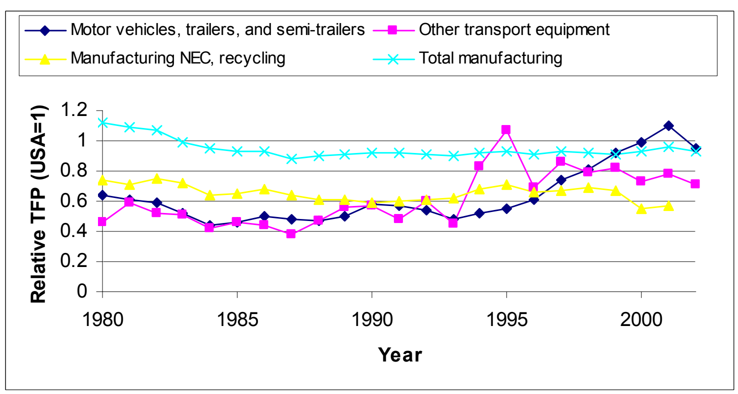
Combining Equations (2) and (3) yields the following:

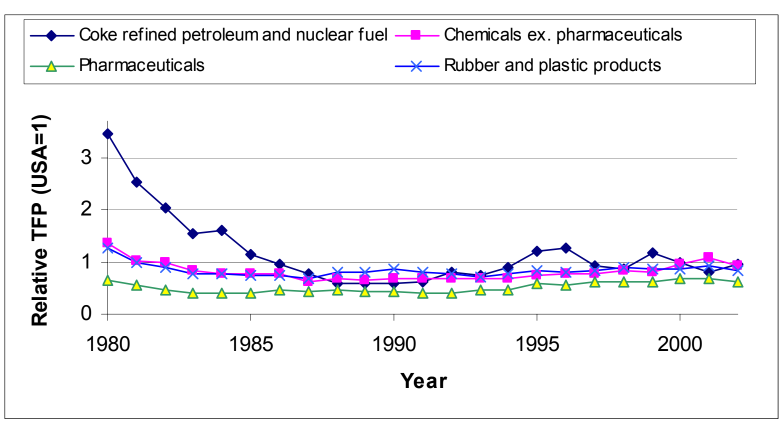
$$\Delta ln\left(\frac{\mathrm{A}_{\mathrm{i,j,t}}}{\mathrm{A}_{\mathrm{F,j,t}}}\right) = (\gamma_{i,j} - \gamma_{F,j})\ \text{-}\ \lambda_{i,j}\ ln\left(\frac{\mathrm{A}_{\mathrm{i,j,t-1}}}{\mathrm{A}_{\mathrm{F,j,t-1}}}\right) \tag{4}$$

Figure 1. Relative French/U.S. Total Factor Productivity
(Adjusted for capacity utilization and using industry-specific PPPs.
Depreciation rates: 7.5 percent for all countries.)









Equation (4) can also be thought of as an equilibrium correction model with a long-run steady state level of relative TFP. Assuming that in the long run, $\Delta ln\left(\frac{A_{i,j,t}}{A_{F,j,t}}\right)=0$, the steady-state equilibrium is given by

$$ln\left(\frac{A^*_{i,j}}{A^*_{F,j}}\right)=\frac{\gamma_{i,j}-\gamma_{F,j}}{\lambda_{i,j}}. \tag{5}$$

Country i will remain behind country F in steady state as long as the rate of innovation in the frontier economy is greater than the rate of innovation in the nonfrontier economy $(\gamma_{F,j} > \gamma_{i,j})$. Note that steady-state equilibrium depends on all three parameters $\gamma_{i,j}$,$\gamma_{F,j}$, and $\lambda_{i,j}$, indicating that for an equilibrium distance to be maintained between F and i, the combined growth rate from innovation and technology transfer in country i must equal the growth rate from innovation alone in the frontier economy F.

Innovation ($\gamma_{i,j}$) is specified as a function of R&D and trade variables (denoted by matrix of variables Z) and of labor market variables (L). Note that trade and R&D variables vary across both industry sectors and time, time-varying labor market variables on the other hand are available only at the aggregate and not at the sectoral level.

$$\gamma_{i,j}= \eta_{i,j}+\delta Z_{i,j,t-1} +\rho L_{i, t-1} \tag{6}$$

Following Griffith, Redding, and Van Reenen (2003) and Cameron, Proudman, and Redding (2005), the author allows for an indirect effect of R&D and trade on productivity growth via the impact on the speed of technology transfer ($\lambda_{i,j}$).

$$\lambda_{i,j}= \theta+\mu Z_{i,j,t-1} \tag{7}$$

Equation (2) can now be rewritten as

$$\Delta lnA_{i,j,t}= \eta_{i,j} + \theta\, ln\left(\frac{A_{F,j,t-1}}{A_{i,j,t-1}}\right) + \delta Z_{i,j,t-1} + \rho L_{i, t-1} +\mu Z_{i,j,t-1}\, ln\left(\frac{A_{F,j,t-1}}{A_{i,j,t-1}}\right)+ e_{i,j,t} \tag{8}$$

Equation (8) is a fixed-effects model, in which $\eta_{i,j}$ captures unobserved sector-specific and time-invariant heterogeneities. δ captures the effect of trade and R&D variables, while ρ captures the effect of labor market variables on the rate of innovation and thereby TFP growth. On the other hand, μ is the coefficient on the interaction term $Z_{i,j,t-1}\, ln\left(\frac{A_{F,j,t-1}}{A_{i,j,t-1}}\right)$ and denotes the effect of trade and R&D on the speed at which the technology gap between French and U.S. sectors j is closed. Thus, the specification of $\lambda_{i,j}$ as a function of R&D in Equation (7) explicitly allows for a test of the hypothesis that R&D has an indirect effect on productivity growth by raising the absorptive capacity of an economy. Similarly, the specification of $\lambda_{i,j}$ as a function of trade variables such as import or export intensity allows a test of whether these variables matter for the speed of convergence with the frontier economy (if at all). Finally, a statistically significant and positive coefficient on the technology gap term (θ) indicates that the larger the technology gap between French and U.S. industries, the higher is the rate of TFP growth.

Note that in the model itself, productivity convergence is conditional upon the economic determinants of $\gamma_{i,j}$,$\gamma_{F,j}$, and $\lambda_{i,j}$. It is therefore not necessary that productivity convergence be observed, since a fall in the rate of innovation in France ($\gamma_{i,j}$) relative to innovation rates in the United States ($\gamma_{F,j}$) will lead to productivity divergence. This concept of convergence differs from the traditional β convergence that one generally encounters in the growth literature: β convergence concerns the relationship between a country's growth rate and its own initial income, while the concept of convergence discussed in this study concerns the relationship between growth rates and *a country's distance from the technological frontier in the previous period* (see Cameron, Proudman, and Redding, 2005, for a more detailed explanation).

IV. Data Sources and Variable Construction

The main source of data for this exercise is OECD STAN, which provides internationally comparable industry level data on value added, physical capital and investment, and employment for a variety of OECD countries. It also provides sector level data on R&D investments and bilateral trade. This information is matched with information on total hours worked obtained from the Groningen Growth Development Centre. Appendix I provides an overview of the data and data sources that are used in the construction of TFP estimates. Annual time series data on labor market variables were obtained from the Labor Markets Institutions Database set up by Nickell and Nunziata (2001) and from the OECD (see Nicoletti, Scarpetta, and Boylaud, 1999, for a discussion of labor market variables).

Overall, our analysis broadly covers 14 sectors for the period 1980–02. Details of Sector ISIC classification are presented in Table 1. A number of sectors were excluded because of a lack of data on both gross fixed capital formation and capital stocks—information on at least one of these variables is necessary for the construction of TFP estimates.

Table 1. Sector Coverage

ISIC Rev. 3	Sector Name
15–16	Food, beverages, and tobacco
17–19	Textiles, leather, and footwear
21–22	Pulp, paper, printing, and publishing
23	Coke refined petroleum and nuclear fuel
2401	Chemicals excluding pharmaceuticals
2423	Pharmaceuticals
25	Rubber and plastic products
26	Other nonmetallic mineral products
27–28	Basic metals and fabricated products
29	Machinery and equipment, NEC
30–33	Electrical and optical equipment
34	Motor vehicles, trailers, and semi-trailers
35	Other transport equipment
36–37	Manufacturing NEC and recycling

A. Measuring Total Factor Productivity

The OECD Manual (2001) discusses several measures of productivity and recommends a value-added measure of total factor productivity[14] calculated using the Tornqvist index number approach of Caves, Christensen, and Diewert (1982a and 1982b). This index has the advantage that it implies (or is "exact" for) a flexible homogenous translog production function. It is also superlative in that the translog production function nests the Cobb-Douglas production function. According to the OECD Manual, it provides a "reasonable approximation" to an independent measure of technical change even when the underlying production function is not strictly the same as in Equation (1). Finally, the index number approach allows bilateral productivity growth and level comparisons. For a nontechnical summary of the Tornqvist index approach, see Van Biesebroeck (2003).

TFP growth in each country is measured as

$$ln\left(\frac{A_{i,j,t}}{A_{i,j,t-1}}\right)=\ln\left(\frac{Y_{i,j,t}}{Y_{i,j,t-1}}\right)-\alpha\ln\left(\frac{L_{i,j,t}}{L_{i,j,t-1}}\right)-(1-\alpha)\ln\left(\frac{K_{i,j,t}}{K_{i,j,t-1}}\right) \quad (9)$$

[14] TFP is preferred over labor productivity. The latter is a partial productivity measure and reflects the combined effects of changes in capital and intermediate inputs as well as technological change. TFP on the other hand disentangles the contributions of labor and capital inputs from those of technological change.

where Y denotes real value added in common currency units, L is a measure of total labor input (total annual hours of work), K is the measure of capital stock/services, and $\alpha = (\alpha_{i,j,t} + \alpha_{i,j,t-1})/2$ is the average share of labor in value-added in sector j of economy i. $A_{i,j,t}$ is an index of technical efficiency or total factor productivity. Sector-specific deflators for value added and investment were also obtained from OECD STAN. In cases where these were not available for specific sectors, deflators for the aggregate sector were used as a proxy in order to convert current price data into constant prices (base year 1995).

The relative level of TFP in sector j across countries is similarly estimated using the Tornqvist index approach and is given by

$$ln\left(\frac{A_{i,j,t}}{A_{F,j,t-1}}\right) = \ln\left(\frac{Y_{i,j,t}}{Y_{F,j,t-1}}\right) - \alpha \ln\left(\frac{L_{i,j,t}}{L_{F,j,t-1}}\right) - (1-\alpha)\ln\left(\frac{K_{i,j,t}}{K_{F,j,t-1}}\right) \quad (10)$$

where $\alpha = (\alpha_{i,j,t} + \alpha_{F,j,t})/2$

B. Conversion of Industry Value Added

The estimation of Equation (8) requires that real value added and capital input be measured in the same currency, namely dollars. While this issue does not arise with the labor input, which is measured in terms of total hours of work, real value added and physical capital for France and the United Kingdom are converted using industry-specific estimates of purchasing power parity (PPP)—also known as unit value ratios (UVRs)—obtained from the GGDC International Comparison of Productivity Programme (ICOP).[15] These are derived from producer output data and indicate the relative producer price of matched industry sectors in two countries (one of which is the United States) for the benchmark year (1997).[16] As O' Mahoney (1996) shows, relative levels of TFP can vary substantially according to the conversion factor used.[17] However, UVRs have the advantage over alternative final expenditure PPPs for a number of reasons. Firstly, expenditure PPPs rely on output comparisons of final retail sales[18] and need to be adjusted for differences in distribution

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[15] See van Ark and Timmer, 2001.

[16] Benchmark estimates are extrapolated to other years using data on national price indices. In certain cases, UVRs are available for only subsectors rather than the aggregate sectors that I am interested in for the purposes of my analysis. Aggregate sector UVRs were estimated by taking the average of each subsector UVR where each subsector is weighted by its contribution to the aggregate sectors value added in 1997.

[17] Note, however, that the time path of relative TFP are unaffected as are any conclusions about productivity convergence. See Cameron and others, 2005.

[18] This is conceptually hard to justify for the manufacturing sector where the output can consist of products that are not for sale to final consumers.

margins, sales, and VAT, whereas UVRs are calculated using producer prices. Secondly, they are available at an aggregate national level and need to be "mapped" to industries (as in e.g., Scarpetta and Tressel, 2002), unlike UVRs that are available at a more disaggregated industry/sector level.[19] Appendix II compares whole economy PPPs in 1997 with industry-specific UVRs for France and the United Kingdom. The latter vary considerably across sectors: UVRs that are greater (less) than the whole economy PPP indicate that goods produced by those sectors are actually more (less) expensive than what would be implied by the whole economy PPP.

C. Measuring Inputs

Data on hours of work are obtained from the GGDC 60 Industry Database.[20] Following Pilat and Schreyer (2004), the labor share of value added is defined as $\alpha_{\mathrm{i,j,t}} = \frac{\mathrm{LABR}_{\mathrm{i,j,t}}}{\mathrm{VALU}_{\mathrm{i,j,t}}}$ where remuneration for labor input (LABR) is the average remuneration per employee (COMP/EE) multiplied by the total number of persons employed (E) (See Appendix I for a description of all relevant variables). Thus it is assumed that total wage per self-employed person is the same as the wage of employed persons. Note that VALU is the value added in current terms.

$$LABR_{i,j,t} = \left(\frac{COMP}{EE}\right)_{i,j,t} E_{i,j,t}$$

The share of labor in value added can typically be quite volatile. Furthermore, it can frequently exceed 1, which is observed for labor shares for all three countries in the dataset. Consequently, this study employs simple time-averaged sector-specific factor shares as measures of output elasticities (See Appendix III for information on sector-specific elasticities) rather than using actual labor shares or more sophisticated time-varying factor shares (e.g., Harrigan (1997a and b) recommends that output elasticities be estimated econometrically). With regard to the latter, Bassanini, Pilat, Scarpetta, and Schreyer (2000) show that the use of econometrically estimated output elasticities does not make a significant difference to TFP estimates.

Regarding the construction of measures of capital stock, it is important to note that the OECD STAN database provides estimates of gross capital stock based on the ISIC REV3

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[19] See O' Mahoney, 1996, "Conversion factors in relative productivity calculations: theory and practice." Overall GDP PPPs are also inappropriate when converting industry outputs into internationally comparable units. An implicit assumption is that relative prices are the same for different countries, and if this is not the case, then output comparisons will be distorted.

[20] For two sectors (chemicals and pharmaceuticals) for which on total hours of work is not available, data on total employment is adjusted to reflect total hours of work.

industry classification only for France (and that, too, not for all industry sectors). However, data is available for gross fixed capital formation in current prices for the United States, the United Kingdom, and France. The capital stock data are constructed using the perpetual inventory method. First, the investment flows are converted into constant 1995 prices using industry-specific investment goods deflators available from OECD STAN. Suppressing country subscripts, industry and time-specific capital stocks are given by:

$$k_{j,t} = (1-\delta)k_{j,t-1} + inv_{j,t-1}$$

Following Young (1995) and Keller (2000), it is assumed that the growth rate of the national accounts investment series is representative of the growth rate prior to the start of the series. Thus capital stock at time *t=0* is given by

$$k_{j,0} = \sum_{t=0}^{\infty} inv_{j,-t-1}(1-\delta)^t = \sum_{t=0}^{\infty} inv_{j,0}(1-g_i)^{-t-1} = \frac{inv_{j,0}}{g_i^{inv} + \delta}$$

Where *inv* is GFCF in constant prices; g^{inv} is the average annual growth rate of investment over the period under study, and δ is the country specific rate of capital depreciation. In the case of France, data on the gross capital stock in constant prices (where available) is used as the initial value. Depreciation rates are assumed to be the same for all countries and industries, namely 7.5 percent.

Capital stock measures are also adjusted for capacity utilization. Generally, the literature assumes that capital services are proportional to the capital stock. If the factor of proportionality stays constant over time, then the growth rate of capital services will exactly equal the growth rate of capital stock, which is clearly unrealistic when one takes into account the effect of the business cycle on capital stock utilization. Measured TFP will consequently exhibit strong procyclical movements: in periods of high (low) capital utilization, the flow of services from capital is likely to be under-(over)estimated and TFP over-(under)estimated.

Capital stock estimates for France are adjusted using data on aggregate capacity utilization for the manufacturing sector.[21] Assuming that capacity utilization is the same for all industry sectors,[22] estimates of capital services can be derived by multiplying unadjusted estimates of capital stock for each industry with the capacity utilization data. A similar technique is used for the United States and the United Kingdom: estimates of real capital stocks are adjusted

[21] Cameron and others (2005) control for capacity utilization by including a proxy for it (they do not have data on capital hours per week) in Equation (6).

[22] Not necessarily a reasonable assumption since utilization rates will vary across industry sectors depending on industry capital-labor ratios and technology, etc.

using data from the Federal Reserve Board on aggregate manufacturing capacity utilization (measured as an output index divided by a capacity index) for the U.S. and the Confederation of British Industry's (CBI) Industrial Trends Survey data. Consequently, there are two measures of capital stock used in this study: unadjusted and adjusted. However, the preferred measure of capital stock is the one adjusted for capacity utilization.

Table 2 presents the time-averaged TFP growth rates for different sectors for the United States, the United Kingdom, and France using both the adjusted and the unadjusted capital stock series. Adjusted average TFP growth rates are higher than unadjusted rates for the United States whereas no significant difference can be discerned for France and the U.K.[23]

Sectors with the highest average TFP growth in France for the period under study are pharmaceuticals and "other transport equipment." The latter comprises the shipbuilding, aerospace, and railway industries, of which shipbuilding accounts for roughly three quarters of total value added.[24] The motor vehicles, trailers, and semi-trailers sector also exhibits strong TFP growth. In contrast, average TFP growth rates in the food, drink, and tobacco sector and the coke, refined petroleum products, and nuclear fuel sector are negative.

Figure 1 compares TFP in France relative to the United States (USA=1) for the period 1980-02. The only sector to have maintained technological "leadership" in France is "other nonmetallic mineral products." Several sectors have higher TFP levels than their U.S. counterparts in 1980 but lose competitiveness in the early 1980s. These are food, textiles, electrical and optical equipment, rubber and plastic, chemical excluding pharmaceuticals, machinery and equipment NEC, and coke, refined petroleum, and nuclear fuel. However, there is evidence of convergence back towards U.S. levels in the textiles, chemicals, rubber and plastic, and the coke, petroleum, and nuclear fuel sectors. The surge in the competitiveness of the French automotive and "other transport equipment" industries is evident in panel (c) of Figure 1. For instance, TFP in the French car industry rises from 57 percent of American levels in 1990 to 98 percent in 2000, after which French TFP levels in this sector lead U.S. levels due in large part to increased competition and the adoption of better management practices in these sectors over the last decade. TFP levels in the "other transport equipment" sector increased from 57 percent of U.S. levels in 1990 to 77 percent

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[23] Note that while our TFP growth rates for manufacturing appear to be somewhat on the high side for example, as compared to Bassanini, Pilat, Scarpetta, and Schreyer (2000), it should be noted that different methods of estimation, variables, deflators and data sets can give rise to different estimates. For instance, this study does not correct TFP for differences across countries in human capital. Second, Bassanini and others find that the annual average TFP growth rate in manufacturing in the United States for the period 1990–98 is 1.1 percent whereas O' Mahoney and de Boer (2002) report estimates of 2.47 percent for the same period using a different dataset.

[24] According to 1997 current price data.

in 2001. The only two sectors where relative TFP levels show a persistent decline are the electrical and optical equipment and the machinery and equipment sectors (panel (d), Figure 1).

Table 2. Time-Averaged Total Factor Productivity Growth Rates in France and the United States, 1980–2002

(In percent)

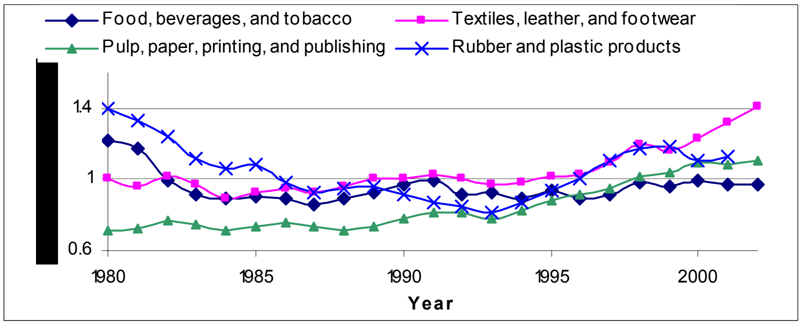
Sector name	ISIC Rev. 3	France Unadj.	France Adj.	United States Unadj.	United States Adj.	United Kingdom Unadj.	United Kingdom Adj.
Food, beverages, and tobacco	15-16	-0.57	-0.58	-0.09	0.06	1.27	1.23
Textiles, leather, and footwear	17-19	2.51	2.50	2.61	2.68	1.85	1.82
Pulp, paper, printing, and publishing	21-22	2.23	2.23	1.34	1.45	1.49	1.47
Coke refined petroleum and Nuclear fuel	23	-4.40	-4.41	0.81	0.99	0.59	0.54
Chemicals and chemical products	24	2.14	2.13	3.26	3.41	4.17	4.13
Chemicals excluding pharmaceuticals	2401	1.50	1.49	2.72	2.87	0.00	0.00
Pharmaceuticals	2423	3.64	3.63	2.95	3.12	0.00	0.00
Rubber and plastic products	25	-0.01	-0.02	1.49	1.60	1.98	1.95
Other nonmetallic mineral products	26	2.33	2.32	1.98	2.08	2.13	2.09
Basic metals and fabricated products	27-28	3.04	3.03	1.08	1.17	2.27	2.24
Machinery and equipment, NEC	29	0.41	0.40	6.38	6.46	1.68	1.65
Electrical and optical equipment	30-33	0.97	0.96	7.39	7.46	4.60	4.57
Motor vehicles, trailers, and semi-trailers	34	2.78	2.77	1.49	1.54	3.47	3.44
Other transport equipment	35	3.62	3.62	0.20	0.27	3.81	3.79
Manufacturing NEC and recycling	36-37	2.04	2.03	2.79	2.87	-1.22	-1.26
Total manufacturing	15-37	2.11	2.10	2.66	2.76	2.71	2.68

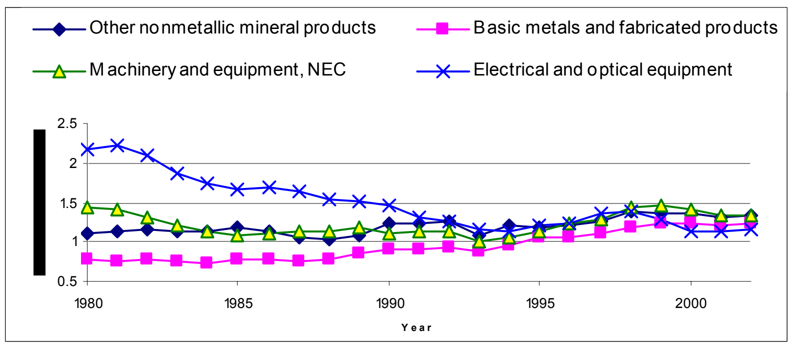
Notes: TFP growth rates are measured as given by Equation (9). They are averaged over the period 1980-2002. The capital stock series used in the measurement of TFP was constructed using the perpetual inventory method, namely $k_{j,t} = (1-\delta)k_{j,t-1} + inv_{j,t-1}$. Initial capital stocks were constructed as: $k_{j,0} = inv_{j,0} / (g_i^{inv} + \delta)$. “unadj” refers to TFP estimates calculated using capital stock measures that were not adjusted for capital utilization. “adj” refers to adjusted series constructed using data on aggregate capacity utilization. Depreciation rates are assumed to be 7.5 percent for all three countries.

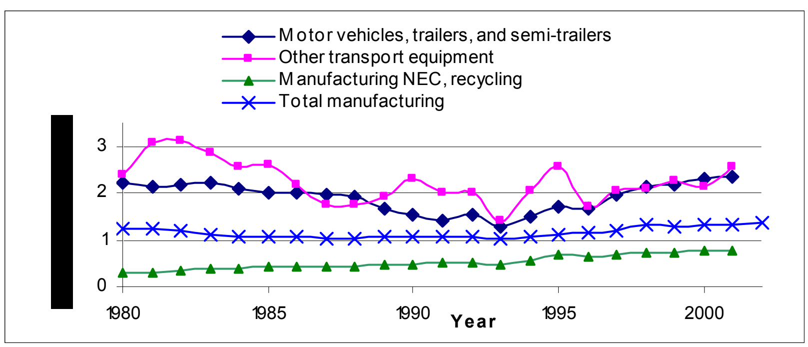
Figure 2 shows that TFP in the French manufacturing sector is higher than in the United Kingdom. In 1980, there were only three French sectors with TFP levels lower than their U.K. counterparts: pulp, paper, and printing and publishing; base metals and fabricated products; and manufacturing NEC and recycling. All three converge with the United Kingdom, and in the case of the first two, actually overtake their U.K. counterparts by the mid-1990s. A deterioration in French-U.K. relative TFP levels is visible in other sectors (for example, see panel (a), Figure 2) but in most sectors, relative TFP levels pick up from 1994 onwards, and France continues to lead the United Kingdom. That French TFP levels are higher than those of the United Kingdom is consistent with other studies investigating the relative productivity performance of the United Kingdom, for example O' Mahoney and de Boer (2002).

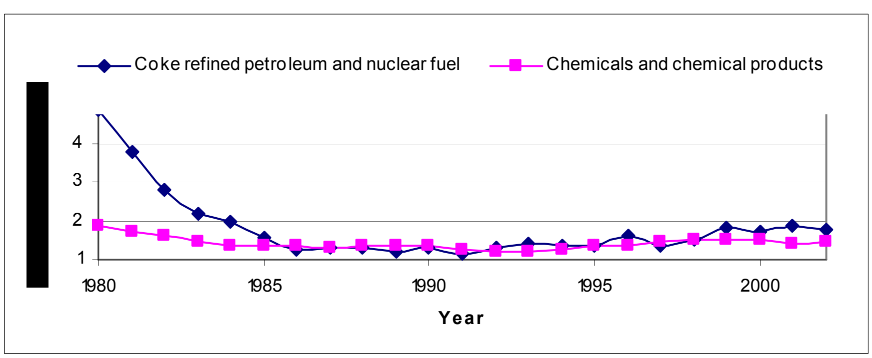
Figure 2. Relative French/U.K. Total Factor Productivity

(Adjusted for capacity utilization and estimated using industry-specific PPPs.
Depreciation rates: 7.5 percent for all countries.)









V. Estimation Methodology and Results

The model outlined in Section II can be expressed as a dynamic panel equilibrium correction model with a long run cointegrating relationship between TFP levels in a frontier and a nonfrontier economy. If TFP growth in the nonfrontier economy is written as an auto-regressive ADL(1,1) model, such that:

$$\ln A_{i,t} = \beta_o + \beta_1 \ln A_{i,t-1} + \beta_2 \ln A_{F,t} + \beta_3 \ln A_{F,t-1} + \varepsilon_{i,t}$$

then under the assumption of long-run homogeneity ($1- \beta_1 = \beta_2 + \beta_3$) it is possible to rearrange the above as:

$$\Delta \ln A_{i,t} = \beta_o + \beta_2 \Delta \ln A_{F,t} + (1-\beta_1) \ln\left(\frac{A_{F,t-1}}{A_{i,t-1}}\right) + \varepsilon_{i,t}$$

As explained in Section III, the rate of innovation is specified as function of trade and R&D variables (denoted by the matrix of variables Z) and labor market variables (L). In addition, I allow for the possibility that R&D and trade may have an impact on the speed at which technology transfer takes place. This yields an equation identical to Equation (8) except for an additional term for the rate of TFP growth in the frontier economy, namely

$$\Delta lnA_{i,j,t} = \eta_{i,j} + \alpha \Delta lnA_{F,j,t} + \delta Z_{i,j,t-1} + \rho L_{i,t-1} + \theta \ln\left(\frac{A_{F,j,t-1}}{A_{i,j,t-1}}\right) + \mu Z_{i,j,t-1} \ln\left(\frac{A_{F,j,t-1}}{A_{i,j,t-1}}\right) + e_{i,j,t} \tag{11}$$

α captures the effect of TFP growth in the frontier economy on the nonfrontier economy, while θ indicates the pace of technology transfer. Z comprises sector-specific and time-varying information on R&D expenditures and trade. I allow for both a direct (captured by δ) and an indirect effect (captured by μ) of these variables on TFP growth. When Z is interacted with the technology gap variable, it is normalized with respect to the manufacturing average, namely log $(Z_{i,j,t-1})$- log (Zm) where Zm is the manufacturing average. This has the advantage that it allows us to test whether sectors with R&D and trade intensities greater than the manufacturing average have different speeds of catchup relative to sectors characterized by relatively lower R&D and trade intensities. L allows us to investigate if labor market rigidities have a direct impact on innovation and thereby TFP growth. Two key variables of interest are the ratio of the minimum wage to median wages and the replacement ratio (a measure of the amount of income replaced by benefits in the first year that an employee is made redundant). The minimum wage to median wage ratio serves as a "proxy" for high labor costs in France, which influences the demand for labor, while the replacement ratio, which influences the reservation wage of workers, serves as indicator of distortions in the labor market on the supply side. No sector-specific information is available for labor market variables. Furthermore, time-varying information for minimum wage to median wage and the replacement ratio is available only up to 2000 and 1999, respectively. Consequently, the econometric analysis utilizes the level of these variables dated *t-2* and *t-3*, respectively.

Equation (11) above is a fixed effects specification: the term $\eta_{i,j}$ allows for unobserved industry-specific time-invariant heterogeneity in the means of $\Delta lnA_{i,j,t}$ across industry sectors. It is likely that $\eta_{i,j}$ is correlated with the explanatory variables and thus leads to inconsistent and biased OLS estimates. Instead, the Within-Groups estimator, which transforms Equation (9) such that the original observations are expressed as deviations from sector means thus eliminating $\eta_{i,j}$ is our preferred method of estimation. The consistency of the estimator depends on a large T[25] and Monte Carlo studies (Judson and Owen, 1999; Bruno, 2005) show that when N is small relative to T, the within estimator outperforms IV-GMM estimators in terms of bias and root mean square error. This is partly because the asymptotic properties of IV-GMM type estimators rely on large N when T is fixed so that the use of these estimators can yield highly biased and imprecise point estimates in small samples. Beck and Katz (2004, p. 9) comment, "the researcher needs to understand the cost of correcting the biases (arising from the use of the Within estimator). We might be trading a small reduction in bias for a large decrease in efficiency."

Table 3 presents preliminary regression results. The estimator used is Within-Groups with standard errors corrected for group-wise heteroskedasticity ($var(e^2_{j,t})=\sigma_j^2$) and for cross-sectional correlation ($E(e_{i,t}\, e_{j,t}) =\sigma_{ij}$.).[26] In other words, I assume that the variance of the disturbance term in Equation (9) differs across the industry cross-section and that it is also contemporaneously correlated *across* the industry panel. The latter is particularly likely to be true, given that macroeconomic factors that affect one of the 14 industries in the panel are also likely to affect the other industries as well.

In column (1), TFP growth in France is regressed upon the distance from the frontier economy ($TFPgap_{t-1} = ln(A_{US,j,t-1} / A_{France,j,t-1}))$, TFP growth in the frontier economy (Δ *U.S.* TFP_t) and on R&D intensity[27] lagged one period and its interaction with the technology gap variable ($R\&D*Gap_{t-1}$). The statistically significant and positive technological gap variable indicates that the further an industry is from the frontier, the higher its rate of growth of TFP. The positive and statistically significant coefficient on the level of R&D implies that R&D has a direct effect on innovation and therefore productivity growth but the lack of significance of the coefficient on the R&D interaction term implies

[25] The order of the bias is (1/T).

[26] The study makes use of the Panel Corrected Standard Error (PCSE) estimator developed by Beck and Katz (1995). PCSE is preferred to the feasible generalized least squares (FGLS) estimator on account of the implausibly small and nonconservative FGLS standard errors (see Beck and Katz, 1995).

[27] Measured as the log of the ratio of R&D spending to value added.

that there are no "absorptive capacity" effects of R&D. This is consistent with the finding by Griffith, Redding, and van Reenen (2003) that the indirect effects of R&D on TFP growth in France are quite small.

Table 3. Within-Groups Estimation: Preliminary Results

	Within-Groups						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$TFPgap_{t-1}$	0.063 *(0.019)****	0.060 *(0.024)***	0.058 *(0.024)***	0.064 *(0.019)* ***	0.058 *(0.022)****	0.056 *(0.024)**	0.054 *(0.018)****
Δ US TFP_t	-0.062 *(0.060)*	-0.061 *(0.060)*	-0.067 *(0.059)*	-0.059 *(0.057)*	-0.062 *(0.056)*	-0.064 *(0.056)*	-0.063 *(0.057)*
$R\&D_{t-1}$	0.027 *(0.013)***						0.021 *(0.012)**
$(M/Y)_{t-1}$		0.041 *(0.025)**			0.023 *(0.025)*		
$(X/Y)_{t-1}$			0.048 *(0.027)**			0.029 *(0.030)*	
$(IM\text{-}USA, Germany, UK)_{t-1}$				0.054 *(0.015)* ***	0.045 *(0.017)****	0.044 *(0.016)****	0.052 *(0.015)****
Interaction terms							
R&D*Gap	-0.013 *(0.022)*						0.005 *(0.023)*
M/Y*Gap		-0.014 *(0.047)*			-0.007 *(0.077)*		
X/Y*Gap			-0.028 *(0.053)*			-0.002 *(0.063)*	
IM-USA, Germany, UK* Gap				-0.025 *(0.029)*	-0.027 *(0.047)*	-0.027 *(0.033)*	-0.033 *(0.029)*
Diagnostics							
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Sq	0.17	0.18	0.18	0.20	0.21	0.21	0.21
Observations	307	307	307	307	307	307	307
No. of sectors	14	14	14	14	14	14	14

Notes: I estimate equation (11) where the dependent variable is the rate of growth of TFP in France (Δ France TFP_t). Explanatory variables are the log U.S. TFP relative to France (TFPgap); the log of the ratio of R&D to value added (R&D) and its interaction with the technology gap variable (R&D* Gap); the log of the ratio of imports (M/Y) and exports (X/Y) to value added and their respective interaction terms (M/Y)*Gap and (X/Y)*Gap; and finally the log of the ratio of the sum of imports from the United States, Germany, and the United Kingdom, to value added (IM-USA, Germany, UK) and its interaction term (IM-USA, Germany, UK)* Gap. The estimator is the Within-Groups estimator that controls for unobserved sector specific heterogeneity. Following Beck and Katz (1995), standard errors (reported in parentheses) are corrected for contemporaneous cross-section correlation and group wise heteroskedasticity. *** represents significance at the 1 percent level, ** at the 5 percent level and * at the 10 percent level.

Columns (2)–(4) examine the influence of trade openness as measured by import and export intensity ($(M/Y)_{t-1}$ and $(X/Y)_{t-1}$, respectively). Column (5) analyzes whether the identity of the trading partner matters for TFP growth: the variable of interest is the sum of imports from the United States, Germany, and the United Kingdom to value added (*IM-USA,Germ,UK*).[28] Export and import intensity are marginally significant at the 10 percent level on their own, while the sum of imports to the United States, the United Kingdom, and Germany is statistically significant and positively signed at the 1 percent level. Overall, there appears to be a beneficial impact of trade on innovation and thereby on TFP growth. Note that the interaction terms of each of these variables are insignificant, indicating that trade openness or the identity of trading partners does not have an effect on the speed of convergence. The regressions in Columns (5)–(6) indicate that the most informative trade variable is trade with the United States, Germany, and the United Kingdom rather than total imports or exports.[29]

Since the sum of imports from the United States, Germany, and the United Kingdom is statistically informative as is R&D in column (7), this is the preferred specification in this study. The most robust results obtained so far are that there is evidence of autonomous technology transfer (albeit small) and that R&D and the sum of imports from the United States, the United Kingdom, and Germany have a positive effect on innovation and therefore TFP growth. However, while the latter variable is statistically significant at the 1 percent level, R&D is only marginally significant at the 10 percent level.

Column (1) and (2) of Table 4 investigate whether the labor market has any effect on innovation and therefore TFP growth. Column (1) is identical to the specification in column (7) of Table 3 but includes the ratio of the minimum wage to median wages while the labor market variable of interest in column (3) is the replacement ratio. Both variables have a statistically significant and unambiguously negative effect.[30] As discussed earlier in Section II, these variables represent the costs of adjusting labor: the minimum wage to median income ratio measures minimum labor costs while the replacement ratio represents skewed incentives in the benefit system which can affect the costs of adjusting labor. Note that R&D is statistically insignificant in column (1) and is very weakly significant (p-value=11.1) in column (2).

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[28] Imports and exports to G-7 countries or to the United States alone were also considered but were found to be statistically uninformative as was the sum of exports to the United States, the United Kingdom, and Germany.

[29] Regressions (not shown), which include R&D with import or export intensity in the same specification, yield statistically insignificant results for these variables. Appendix VI shows that R&D and trade variables are highly correlated. Note that Bassanini and Ernst (2002) find that R&D activity tends to increase with trade openness. They explain this as firstly evidence of positive knowledge spillovers and secondly, the possibility that by increasing product variety, trade openness may induce greater R&D spending when domestic producers try to imitate the new products.

[30] When the ratio of minimum to median wages and the replacement ratio are included in the same regression, both variables lose statistical significance.

Table 4. Within-Groups and IV Estimation

	(1) **Within-Groups**	(2) **Within-Groups**	(3) **IV-FE**	(4) **IV-FE**	(5) **Within-Groups**	(6) **Within-Groups**
$TFPgap_{t-1}$	0.065	0.064	0.068	0.067		
	*(0.018)******	*(0.018)******	*(0.021)******	*(0.021)******		
Δ U.S. TFP_t	-0.068	-0.072	-0.064	-0.070		
	(0.055)	*(0.056)*	*(0.053)*	*(0.053)*		
R&D $_{t-1}$	0.015	0.018	0.016	0.023	0.012	0.016
	(0.012)	*(0.012)*[a]	*(0.015)*	*(0.014)*[b]	*(0.012)*	*(0.012)*
(IM-USA, Germ,UK) $_{t-1}$	0.057	0.057	0.060	0.061	0.067	0.066
	*(0.015)******	*(0.015)******	*(0.019)******	*(0.019)******	*(0.015)******	*(0.015)******
(Min. Wage/Med. Wage) $_{t-2}$	-0.007		-0.007		-0.007	
	*(0.003)****		*(0.003)****		*(0.004)**	
Rep. Ratio $_{t-3}$		-0.486		-0.464		-0.434
		*(0.218)****		*(0.177)******		*(0.234)**
Interaction Terms						
R&D	0.007	0.006	0.003	0.000	0.011	0.008
	(0.023)	*(0.023)*	*(0.019)*	*(0.018)*	*(0.024)*	*(0.025)*
IM-USA, Germany, UK	-0.042	-0.042	-0.038	-0.038	-0.037	-0.036
	(0.030)	*(0.029)*	*(0.028)*	*(0.028)*	*(0.031)*	*(0.031)*
$TFPgap_{t-2}$					0.058	0.059
					*(0.020)******	*(0.021)******
Δ U.S. TFP_{t-1}					-0.032	-0.026
					(0.054)	*(0.054)*
Diagnostics						
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-Sq	0.23	0.23	0.16	0.16	0.22	0.22
Observations	307	307	293	293	294	294
Number of sectors	14	14	14	14	14	14
Sargan			0.48	0.35		
Serial Correlation: Critical F (p-value)			37.12 (0.00)	34.9 (0.00)		

Notes: I estimate Equation (9) where the dependent variable is the rate of growth of TFP in France (Δ France TFP_t). Explanatory variables are the log U.S. TFP relative to France (TFPgap); the log of the ratio of R&D to value added (R&D) and its interaction with the technology gap variable (R&D * Gap); the log of the ratio of the sum of imports from the United States, Germany, and the United Kingdom, to value added (IM-USA, Germany, UK) and its interaction term (IM-USA, Germany, UK)* Gap. Labor market variables include the ratio of the minimum wage to median wages (Min Wage/Med. Wage) and the replacement ratio (Rep. Ratio). The estimator is the Within-Groups estimator that controls for unobserved sector specific heterogeneity. Following Beck and Katz (1995), standard errors (reported in parentheses) are corrected for contemporaneous cross-section correlation and group wise heteroskedasticity. IV-FE is a two stage least squares estimator in which the fixed effects have been swept out by removing panel level means from each variable. At the same time, the potential endogeneity of all explanatory variables excluding labor market variables is controlled through the use of lagged level instruments dated t-2. Imports from the US, Germany and the United Kingdom was instrumented by overall imports from OECD countries. ***represents significance at the 1 percent level, ** at the 5 percent level and * at the 10 percent level. Serial correlation is the Wooldridge (2002) panel data test for first order serial correlation in the residuals under the null of no autocorrelation. Sargan is the Sargan test of overidentifying restrictions. “a” indicates that the p-value=11.1, while “b” indicates that the p-value=11.3.

Columns (3)–(4) check the robustness of these results using the Instrumental Variable (IV) estimator with fixed effects where the potential endogeneity of the technology gap variable, R&D and import variables[31] is controlled for by using their lagged values dated *t-2* and using total imports from OECD countries as instruments. The IV coefficient estimates lie very close to the Within-Groups estimates so that the key findings remain unchanged. The coefficient estimate on the technology gap term is slightly higher. The small absolute value of the coefficient (6.5 percent in column (1)) implies that autonomous technology transfer takes ten years to close half the gap in technical efficiency between France and the United States. This is quite a small effect, suggesting that dynamic adjustment towards long-run steady-state equilibrium relationship between French and U.S. TFP levels is somewhat slow.[32]

The Sargan test of overidentifying restrictions and associated *p*-values are also reported in columns (3)–(4). The test statistics show that it is not possible to reject the null that the instrument set is valid, that the instruments are not correlated with TFP growth residuals and that the model is correctly specified. A further test that the instruments are uncorrelated with TFP growth residual requires that the latter be serially uncorrelated. Consequently, the results from the Wooldridge (2002) panel data test for first-order serial correlation are also reported. They indicate that there does not seem to be any evidence of serial correlation in the TFP growth residuals.

As a further robustness test, columns (5) and (6) present Within-Groups estimates where the TFP gap between France and the United States and TFP growth in the United States are dated *t-2* rather then *t-1* as in earlier regressions. The coefficient on the technology transfer term ($TFPGap_{t-2}$) remains statistically significant although it is slightly smaller. The estimated coefficients on the remaining variables also remain the same.

Overall, the estimation results indicate a statistically significant but small effect of autonomous technology transfer on TFP growth in France. However, there does not appear to be any significant effect of R&D or trade variables on the rate at which technology transfer occurs. A positive but marginally significant effect of R&D on the rate of innovation, and thereby productivity growth, can also be detected.

There is, nevertheless, a particularly strong positive relationship between the sum of imports from the United States, the United Kingdom, and Germany and TFP growth. This raises the question of why imports from such countries would have such a positive effect. A closer

[31] Shocks to French TFP will have an effect on future TFP growth, as well as on the initial distance from the technological frontier.

[32] Appendix V reports test statistics of the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS, 1992) test for each individual sector under the null that the TFP gap series is stationary. Test statistics show that it is possible to accept the null hypothesis of stationarity for most of the industry sectors under study at the 1 percent level.

examination of the composition of French imports reveals that a very large proportion of imports from these countries consists of capital goods. For instance, rough estimates[33] obtained from the OECD International Trade by Commodity Statistics indicate that the share of capital goods imports in total imports from the United States was roughly 66 (69) percent in 1996 (2000), while the corresponding figure for capital goods imports from Germany was 51 (53) percent. The estimation results therefore suggest that there may be significant positive technology and R&D spillovers embedded in capital goods imports.[34] The study by Xu and Chiang (2005) is also relevant. They found evidence consistent with the hypothesis that productivity in advanced countries benefits from foreign technology embodied in imported capital goods. Given that they use exports of capital goods from the United Kingdom, the United States, Germany, Japan, and France to construct their measure of imported capital goods, it would appear that their results point towards the benefits from trade in capital goods with other technologically advanced economies. The highly significant coefficient estimate on the sum of imports from the United States, the United Kingdom, and Germany would be consistent with such evidence.

Finally, the study finds a negative relationship between TFP growth and key labor market variables, which reflect labor adjustment costs. As discussed in Section II, mass underemployment and chronic hiring difficulties faced by French firms are symptomatic of skewed incentives in the unemployment benefit system and inflexible labor markets where costs of adjusting labor are high. To the extent that replacement ratios and the ratio of the minimum wage to median wages are "proxies" for these deeper underlying rigidities, the results in this study suggest that they are hampering innovation and consequently productivity growth. Furthermore, they suggest that if France wishes to successfully reap any benefits from increasing expenditure on R&D (France is currently the world's fifth largest spender on R&D[35]), it may need to comprehensively reform its labor markets.

VI. Conclusions

This paper investigates TFP growth and sector-specific convergence between France and the United Kingdom and the United States for the period 1980–2002. Results indicate that although both France and the United Kingdom lag behind the United States in terms of relative TFP levels, French TFP levels are higher than those in the United Kingdom.

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[33] Author's own estimates.

[34] A related issue is why aggregate manufacturing TFP in France seems to be doing rather well when it utilizes the inputs of capital goods sectors (machinery and equipment and electrical and optical equipment, see Figure 1, panel (b)) whose relative TFP performance has been quite poor over the last two decades. A possible answer is that these capital good inputs must be coming from abroad, and this, indeed, appears to be the case when looking at the OECD ITCS figures.

[35] OECD (2005) Briefing Note for France.

Technology transfer and R&D spending are both found to have a positive impact on French TFP growth. R&D is only marginally significant, however. Furthermore, the effects of technology transfer on TFP growth are quite small, with results suggesting that autonomous technology transfer takes ten years to close half the gap in technical efficiency between French and U.S. manufacturing sectors. Nevertheless, there is strong evidence that imports from technologically advanced countries, as measured by the sum of imports from the United States, the United Kingdom, and Germany, have a positive effect on innovation, and consequently TFP growth, while the converse is true for the minimum wage to median wage and labor replacement ratios. There is no evidence that any of these variables affect the rate of technology transfer from U.S. industries to their French counterparts.

These results suggest that, consistent with Acemoglu, Aghion, and Zilibotti (2003) and Aghion, Meghir, and Vandenbussche (2005), innovation is the primary source of TFP growth in countries that are already very close to the technological frontier, such as France. Moreover, the positive impact on TFP growth from trade with the United States, the United Kingdom, and Germany suggests that there may be substantial knowledge and R&D spillovers from imports from these countries and is consistent with evidence by MacGarvie (2006) that innovation in French firms that import is strongly influenced by foreign technology. Finally, the negative relationship between French labor market institutions and TFP growth appears to lend support to Meister and Verspagen's (2004) argument that "a policy solely aimed at increasing R&D expenditures, without paying attention to the broad institutional context in which innovation and technological development take place, is not likely to succeed."[36]

[36] Meister and Verspagen (2004, pg. 17).

APPENDIXES

I. Data Sources

Description	Variable
OECD STAN INDUSTRY	
Production (Gross output; at current prices)	PROD
Production (Gross output; in volumes; quantity index)	PRODK
Intermediate inputs at current prices	INTI
Intermediate inputs volumes (quantity index)	INTIK
Value added at current prices	VALU
Value added volumes (quantity index)	VALUK
Labor costs (compensation of employees)	LABR
Wages and salaries	WAGE
Number engaged (total employment)	EMPN
Number of employees	EMPE
Number engaged (full-time equivalent jobs)	EMPN_FTE
Employees (full-time equivalent jobs)	EMPE_FTE
Gross fixed capital formation at current prices	GFCF
Gross fixed capital formation, volumes (quantity index)	GFCFK
Gross capital stock, volumes	CAPK
Net capital stock, volumes	NCAPK
Exports of goods at current prices	EXPO
Imports of goods at current prices	IMPO
Current price value added at basic prices (or factor costs)	VALU_B
Current price value added at producer's prices (or market prices)	VALU_P
Consumption of fixed capital	CFC
Net operating surplus	OPS

- Current price data (PROD, VALU, GFCF, LABR, EXPO, etc.) and capital stock: millions of national currency, i.e., euro for France, pound sterling for the United Kingdom, and U.S. dollar for the United States.
- Volumes (PRODK, VALUK, and GFCFK): index number with the reference year (usually 1995) = 100;
- Employment data: thousands.

Description	Variable
Groningen Growth and Development Centre, 60-Industry Database	
Value added in current prices (in millions of national currency)	*Valueadded_ggdc*
Persons engaged (in thousands of persons)	*Personsengaged_ggdc*
Employees (in thousands of persons)	*Employeed_ggdc*
Annual hours worked per employee	*Hoursperworker_ggdc*
Total annual hours worked	*Hours_ggdc*
Labor compensation per employees (in pounds sterling)	*Compensation_ggdc*
OECD: Economic Outlook, France, United Kindgom, United States	
GDP deflator (2000=100); rescaled to 1995	
Implied PPP exchange rate, national currency per U.S. dollar	
Gross fixed capital formation _def rescaled to 1995	
OECD Bilateral Trade Statistics: France	
Exports: Total. Measured in thousands of US$, current prices	Etotal
Imports: Total. Measured in thousands of US$, current prices	Mtotal

Trading partners: the sum of exports (X) or imports (M) from:	
United States, United Kingdom, and Germany	E/M US, UK & Germ
G-7	E/M g7
OECD	E/M oecd
non-OECD	E/M nonoecd
Other non-OECD/rest of the world	E/M row
OECD STAN ANBERD (Analytical Business Enterprise Research and Development) Database: France	
Total expenditure on R&D activity (measured in millions of euros)	R_D
Labor Market Institutions Database (Nickell and Nunziata, 2001) and OECD (Nicoletti, Scarpetta and Boylaud, 1999)	
Minimum wage/ median wage	
Labor replacement ratio: average first year unemployment benefits as a percentage of average earnings before tax	

II. Unit Value Ratios

(In national currency per US$)

Sector	France	United Kingdom
1516	0.926	0.678
1537	0.946	0.696
1719	1.414	0.890
2122	0.890	0.552
2300	0.946	0.696
2325	0.890	0.623
2400	0.897	0.665
2401	0.897	0.665
2423	0.897	0.665
2500	0.839	0.522
2600	0.700	0.489
2728	0.696	0.524
2900	0.887	0.649
2933	0.907	0.795
3033	0.919	0.892
3400	1.555	1.555
3435	1.381	1.403
3500	0.9999	1.275
3637	1.067	0.471
Whole economy PPP	0.992	0.643

III. France, United States, and the United Kingdom: Sector Shares of Labor in Value Added

Sector name	*ISIC Rev.3*	France	United States	United Kingdom
Food, beverages, and tobacco	15-16	0.61	0.49	0.68
Textiles, leather, and footwear	17-19	0.77	0.75	0.78
Pulp, paper, printing, and publishing	21-22	0.71	0.65	0.80
Coke refined petroleum and nuclear fuel	23	0.47	0.41	0.62
Chemicals, excluding pharmaceuticals	2401	0.56	0.51	0.63
Pharmaceuticals	2423	0.60	0.46	0.60
Rubber and plastic products	25	0.65	0.63	0.79
Other nonmetallic mineral products	26	0.72	0.68	0.71
Basic metals and fabricated products	27-28	0.73	0.73	0.82
Machinery and equipment, NEC	29	0.70	0.74	0.77
Electrical and optical equipment	30-33	0.71	0.77	0.76
Motor vehicles, trailers, and semi trailers	34	0.72	0.83	0.83
Other transport equipment	35	0.97	0.78	0.89
Manufacturing NEC, recycling	36-37	0.67	0.69	0.77
Total manufacturing	15-37	0.68	0.68	0.76

IV. Industry Characteristics Relative to Manufacturing Average

	Exports			Imports				
	Total	OECD	United States, United Kingdom, and Germany	Total	OECD	United States, United Kingdom, and Germany	R &D	K/L
Total manufacturing	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Food, beverages, and tobacco	0.81	0.83	0.79	0.66	0.61	0.47	0.13	1.34
Textiles, leather, and footwear	1.04	1.08	0.89	1.49	1.12	0.53	0.11	0.44
Pulp, paper, printing, and publishing	0.37	0.40	0.39	0.57	0.62	0.46	0.04	0.96
Coke refined peteroleum and nuclear fuel	0.65	0.71	0.64	1.03	0.71	0.96	0.62	7.96
Chemicals, excluding pharmaceuticals	1.87	1.99	1.94	1.72	1.83	2.09	1.30	1.88
Pharmaceuticals	0.93	0.79	0.71	0.66	0.74	1.11	3.56	1.88
Rubber and plastic products	0.66	0.73	0.77	0.65	0.69	0.58	0.63	1.25
Other nonmetallic mineral products	0.45	0.46	0.49	0.42	0.46	0.29	0.28	1.24
Basic metals and fabricated products	0.77	0.78	0.79	0.76	0.78	0.59	0.24	0.93
Machinery and equipment, NEC	1.13	1.00	1.04	1.19	1.32	1.29	0.60	0.58
Electrical and optical equipment	1.23	1.15	1.21	1.41	1.39	1.96	2.70	0.91
Motor vehicles, trailers, and semi-trailers	1.96	2.10	1.99	1.53	1.71	1.36	1.94	1.42
Other transport equipment	2.19	1.78	2.63	1.33	1.46	3.06	6.40	0.71
Manufacturing NEC, Recycling	0.52	0.56	0.45	0.76	0.67	0.38	0.14	0.97

Notes: All variables reported in the table above are normalized with respect to the manufacturing average, namely log ($Z_{i,j,t-1}$)- log (Zm) where Zm is the manufacturing average. The table shows which sectors are relatively import-, export-, R&D-, and capital stock-intensive relative to the manufacturing average.

V. Unit Root Tests

	A	B
Industry	Trend (test statistic)	Level (test statistic)
Food, beverages, and tobacco	0.105	0.219
Textiles, leather, and footwear	**0.231**	0.408
Pulp, paper, printing, and publishing	0.074	0.398
Coke refined petroleum and nuclear fuel	0.209	0.375
Chemicals, excluding pharmaceuticals	**0.234**	0.241
Pharmaceuticals	0.194	0.488
Rubber and plastic products	0.167	0.166
Other nonmetallic mineral products	0.104	0.443
Basic metals and fabricated products	0.076	**0.778**
Machinery and equipment, NEC	0.134	**0.921**
Electrical and optical equipment	**0.224**	**0.941**
Motor vehicles, trailers, and semi trailers	0.206	0.584
Other transport equipment	0.11	0.703
Manufacturing NEC, recycling	0.12	0.321

Notes:
Column A: Null hypothesis: TFPgap is (trend) stationary. Critical values: 2.5 percent: 0.176; 1 percent: 0.216
Column B: Null hypothesis: TFPgap is (level) stationary Critical values: 2.5 percent: 0.574; 1 percent: 0.739.

The table above reports the Kwiatkowski, Phillips, Schmidt, Shin (KPSS, 1992) test for stationarity of the TFP gap series. The null hypothesis is that the series is stationary and I report test statistics for both trend stationarity or level stationarity. The KPSS test is often used to investigate the possibility that a series is fractionally integrated (that is, neither I(1) nor I(0)): see Lee and Schmidt (1996). The test's denominator--an estimate of the long-run variance of the time series, computed from the empirical autocorrelation function—is calculated using the Quadratic Spectral kernel. Andrews (1991) and Newey and West (1994) "indicate that (this) yields more accurate estimates of sigma-squared than other kernels in finite samples" (Hobijn and others, 1998, page 6).

The maximum lag order (bandwidth) for the test is derived from an automatic bandwidth selection routine, rendering it unnecessary to evaluate a range of test statistics for various lags. Hobijn and others (1998) found that the combination of the automatic bandwidth selection option and the Quadratic Spectral kernel yielded the best small sample test performance in Monte Carlo simulations. In the table above the bandwidth was found to be 2 for all industry sectors.

Approximate critical values for the KPSS test are taken from KPSS, 1992. The sectors for which I fail to accept the null of stationarity (trend or level) at the 1 percent significance level are highlighted in bold.

VI. Correlation Matrix for Variables

	$(M/Y)_{t-1}$	$(X/Y)_{t-1}$	(IM-U.S., Germany, and U.K.) $_{t-1}$	$R\&D_{t-1}$	Rep. Ratio $_{t-3}$	(Min Wage/ Med Wage) $_{t-2}$
$(M/Y)_{t-1}$	1					
$(X/Y)_{t-1}$	0.8435***	1				
(IM-U.S., Germany, and U.K.) $_{t-1}$	0.6938***	0.7925***	1			
$R\&D_{t-1}$	0.4346***	0.6962***	0.7529***	1		
Rep. Ratio $_{t-3}$	0.0711	0.0311	0.0105	0.0217	1	
(Min Wage/Med Wage) $_{t-2}$	0.0591	0.0137	0.0101	0.0164	0.8369***	1

*** Indicates significance at the 1 percent level.

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