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Technology Spillover through Trade and TFP Convergence: 120 Years of Evidence for the OECD Countries

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Technology Spillover through Trade and TFP Convergence: 120 Years of Evidence for the OECD Countries[1]

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Abstract. Using a new dataset on imports of technology and total factor productivity (TFP) over more than a century for the OECD countries, this paper tests for international technological transmission through trade. The empirical estimates suggest that imports of knowledge have been responsible for an almost 200% increase in TFP over the past century, but that the spillover effect has been highly unevenly distributed across countries, but has contributed to TFP convergence among the OECD countries.

JEL classification: E13, E22, E23, O11, O3, O47.
Key words: Technology spillovers, Imports, TFP convergence.

1 Introduction

Since the seminal paper of Coe and Helpman (1995), henceforth C&H, several studies have documented that R&D cross-country spillovers, through the channel of trade flows, have been an important engine of TFP growth in the industrialised countries (del Barrio-Castro *et al*., 2002, Coe *et al*., 1997, Crespo *et al*., 2004, Engelbrecht, 1997, Frantzen, 2000, Guellec and Van Pottelsberghe de la Potterie, 2001, 2004, Lichtenberg and Van Pottelsberghe de la Potterie, 1998, and Lumenga-Neso *et al*., 2001). Other studies have found the spillover channel through imports to be less significant. Using the same model as C&H, Keller (1988) finds that randomly generated bilateral trade shares in some instances gave better results than those of C&H and Kao *et al*. (1999) find that the estimated coefficient of imports of knowledge is insignificant once the bias from their OLS panel estimates is corrected for.

Common for all these empirical studies is that the stock of ideas is generated from R&D expenditures. Although R&D stock is an excellent measure of knowledge, it has the limitation that R&D data have only increasingly become available across OECD countries over the last couple of decades. R&D data for the OECD countries are first scantly available from the late 1960s and, generally, were first consistently collected on a fixed-term basis from the beginning of the 1980s, and first consistently collected on an annual

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basis from 1995.[3] This data limitation has rendered it difficult to assess the effects of spillover on TFP growth with confidence, particularly because the R&D stock and total factor productivity (TFP) have both been increasing over the periods covered by the R&D based studies in almost all countries; thus lowering the identifying variations in the data.

This paper seeks to overcome the data problem by using a new data set to assess the effects of knowledge spillover through trade on TFP growth in 13 major OECD countries over more than a century, using bilateral trade flow weights for 21 OECD countries.[4] Patent data have been consistently collected on an annual basis in almost all OECD countries since the Paris Convention was signed in 1883. While it is not claimed that patent counts are superior to R&D data as a measure of the innovative activity, they are nevertheless a valuable complement to the R&D based studies; particularly because imports of patent-based knowledge stock have fluctuated markedly over the past 120 years. Knowledge imports to the OECD countries have, in fact, fluctuated markedly over the past century; thus putting the C&H hypothesis to the real test. Similarly, TFP has fluctuated over most of the past century and first stated to increase consistently for all the 13 OECD countries considered since the beginning of the 1960, which again challenges the spillover framework to explain both ups and downs. Furthermore, the industrialised countries are first now as open as they were in 1913.[5] The Great Depression, for instance, reduced openness, measured ad the import-GDP ratio, to almost a half in 1929 and, therefore, lowered substantially the potential for technological spillovers through imports.

The TFP data set is constructed for the OECD countries extending more than one century back in time using average factor shares for each individual country. Payments to the self employed have been imputed into factor shares. Furthermore, the TFP has been based on hours worked as opposed to number of employed, which is crucial since annual hours worked per worker have almost halved over the past 130 years. The import weighting scheme follows the suggestions of Coe *et al*. (1997) and Xu and Wang (1999). Since technological spillover through the channel of imports is most likely to take place through technologically sophisticated product imports, the bilateral import weights are based on products that are classified by the OECD as high technological such as machinery, equipment and chemical products.

The paper, furthermore, assesses whether technological spillovers through trade have been a contributing factor to the TFP convergence of OECD countries as documented by Dowrick and Nguyen (1989) and Wolff (1991) using a much more limited data sample than the one used here. Overall, this paper finds that

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[3] Only the US has consistent R&D data available on an annual basis from 1953.
[4] The following 13 OECD countries are considered: Canada, the US, Japan, Australia, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Sweden and the UK.
[5] The import-GDP ratio is on average the same today as in 1913 for the 13 countries in the sample. The following six countries have experienced a decline in the import-GDP ratio since 1913: Japan, Denmark, Germany, Italy, the Netherlands, Norway, and the UK.

international technology spillovers through trade have been a significant contributor to the TFP growth in the OECD countries over the past century and have contributed to TFP convergence, particularly before WWI.

2 Empirical framework

To estimate the effects on TFP of imports of technology the following error-correction and cointegration models are estimated using pooled cross section and time-series analysis:

$$\ln TFP_{it} = \alpha_0 + \alpha^d \ln(S_{it}^d / pop_{it}) + \alpha^f \ln S_{it}^f + TD + CD + \varepsilon_{1it} \quad (1)$$

$$\Delta \ln TFP_{it} = \beta_0 + \beta^d \Delta \ln(S_{it}^d / pop_{it}) + \beta^f \Delta \ln S_{it}^f + \beta^r \hat{\varepsilon}_{2i,t-1} + TD + \varepsilon_{2it} \quad (2)$$

where S^d is the stock of domestic patents, S^f is the stock of imports of technology, CD is fixed effect country dummies, TD is time-dummies, pop is size of population, $\hat{\varepsilon}_{2i,t-1}$ is the error-correction term, which is the lagged residual from estimates of (1), ε is a disturbance term, and the subscripts *t* and *i* signify time and country. One-period lags of the explanatory variables are included in the estimates of (2). Estimated coefficients of further lags and lags of the dependent variable were insignificant.

Time-dummies are included in the estimates to allow for the influence on TFP of excluded variables that are common across countries. As shown in the empirical section, the inclusion of time-dummies is of major importance in the cointegration estimates when data for more than a century is considered. This is because factors other than the stock of patents are likely to have influenced TFP, but have not been accounted for in the model, such as human capital, organisational capital, and shifts from low to high productivity sectors.

Models (1) and (2) deviate from most other empirical estimates in the following four respects. First, $\ln S_{it}^f$ is usually multiplied by the openness of the economy based on the premise that the economy's capacity to tap into the world knowledge depends on the openness of the economy. However, the measure of S^f used here incorporates import volume and, therefore, implicitly incorporates the openness of the economy. The empirical estimates below show that much better results are obtained when S^f is *not* multiplied by openness. Second, the coefficient of S^d is not allowed to differ from the sample average for the G7 countries because their estimated coefficients were not significantly different from zero, as shown in the empirical section.

Third, domestic stock of knowledge is normalised by population to obtain a logical correspondence to TFP. Since TFP is normalised relative to factor inputs, it follows that imports of technology also need to be normalised by population. In the studies referred to above this lack of normalisation is probably not crucial to the results because the considered time-span is relatively short. However, when more than a century of data is used, the normalisation becomes paramount. The populations of Australia and the USA, for instance, have increased more than eight-fold and five-fold, respectively, over the period from 1883 to 2002. Without the normalisation by population in the estimates, this would have meant that the stock of knowledge in Australia would have increased eight times as much as it would otherwise have done, purely due to population growth, provided that the propensity to patent is independent of the size of the population. Consequently, the population adjustment becomes vital in estimates with long data. Fourth, S^f is also normalised with population as shown in Section 2.1.

Caution has to be exercised in the interpretation of the panel cointegration estimates because their statistical properties are derived under the assumption of cross-country independence. Clearly this is not a tenable assumption since countries have been constantly hit by the same shocks such as the oil price shocks, the monetary and agricultural shocks during the Great Depression, technological revolutions, exchange rate shocks, world wars, and so on. It cannot, therefore, be assumed that TFP growth in the OECD countries has been driven by forces that are entirely independent. The consequence of violation of the independence assumption is that the test statistics are biased and that the coefficient estimates may not be super consistent as usually assumed in panel cointegration estimates. The alternative of estimating the cointegration equations for each individual country is not considered here as a viable alternative to the panel estimates because the time-dummies cannot be included in single-country estimates and the findings below show that the time-dummies explain the majority of the increase in TFP.

To shed supplementing light on the long-run relationship between the variables Equation (2) is also estimated in non-overlapping five-year differences without the error-correction term to filter out the potential influence of cyclical forces. Baltagi and Griffin (1984), for instance, advocate long differences as a method to capture long-run relationships because they shave off short-run influences from the estimates.

2.1 Data

As stated in the introduction, the data cover the following 13 OECD countries over the period from 1883 to 2002: Canada, the US, Japan, Australia, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Sweden and the UK. TFP data are backdated for Japan before 1885 using TFP growth for Australia and backdated for France before 1894 using TFP growth for the UK in the graphical presentations. Details of data availability and data sources are relegated to the data appendix. The 13 OECD countries are referred to as the OECD countries for simplicity.

Imports of knowledge from country *j* to country *i* are computed from the following weighting scheme:

$$S_{it}^{f} = \sum_{j} \frac{m_{ijt}^{r}}{pop_{it}} \frac{S_{jt}^{d}}{Y_{jt}^{r}}, \qquad i \neq j \tag{3}$$

where m_{ij}^{r} is imports volume of high technological products from country j to country i, S_{j}^{d} is the stock of domestic knowledge in country j, and Y_{j}^{r} is real GDP at USD purchasing power parity for country j. The stock of knowledge is computed using the inventory perpetual method on the domestic patent applications with a 20% geometric depreciation rate. This depreciation rate for patents and R&D follow the estimates by Parkes and Schankerman (1984).

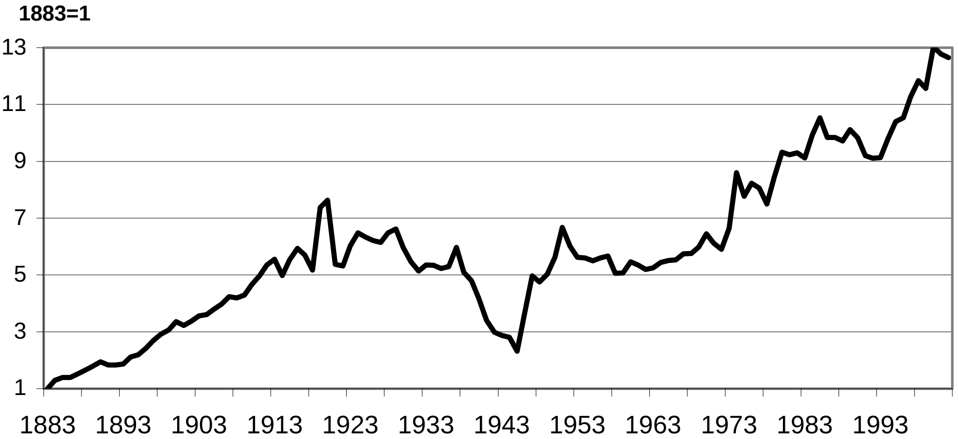
Here m_{ij}^{r} is computed as nominal imports of high technological products deflated by the economy-wide value added price-deflator because the available historical import price-deflators are severely biased by being computed as import value divided by the metric weight of imports. This computation implies that compositional changes and quality changes of imported products are not embodied into the import price deflators. The bias is likely to be particularly serious in long-term analysis where imports have changed from being predominantly low value added products to highly sophisticated merchandise over the course of the past century. While the economy-wide deflator is far from being an ideal import deflator it, nevertheless, allows for quality changes. Furthermore, the tradable sector has a disproportionally high weight in historical GDP data (Maddison, 1982). The high technological products are SITC Section 5, chemicals and related products, Section 7, machinery and transport equipment, and Section 8.7, professional and scientific instruments. The OECD (1995) finds these sections to have a high or medium-high R&D intensity.

The weighting scheme given by (3) follows the suggestion of Lichtenberg and van Potterie (1998) except that imports are weighted by population in their scheme. Import volume is divided by population of the importing country in (3) to avoid the problem that imports of technology are proportional to the size of the country and, therefore, to achieve a reasonable correspondence between S^f and TFP. As argued above, this normalisation is crucial when the size of the population changes significantly in the estimation period. GDP or import volume could, alternatively, have been used as normalising factors. However, this would have resulted in an S^f that would converge to an almost constant level in the long run because the propensity to import converge to a constant in the long run and the S^d/Y^r-ratio converges to a constant in the steady state as predicted by the Solow-Ramsey model of economic growth under the assumption of a constant discount factor. Consequently, S^f normalised by GDP or total imports would not be able to account for some of the TFP increase experienced in the OECD countries over the past century or more.

From (3) it can now be seen why $\ln S^f$ is not multiplied by openness in (1) and (2). The term (m^r/pop) in (3) is a measure of openness, although not in the usual meaning of the ratio of imports to total income. Multiplying $\ln S^f$ with openness would, consequently, impact on TFP with the power of two.

Figure 1 displays imports of knowledge for the OECD countries following the weighting scheme given by (3). The figure shows that imports of knowledge have fluctuated substantially over the past 120 years. Three periods stand out: the stagnation and decline from 1913 to 1973 and the two periods of almost uninterrupted increase from 1883 to 1913 and from 1973 to the present. In the two periods of increase trade expanded and industrial revolutions took place (Jovanovic and Rousseau, 2003, Perez, 2002, Gordon, 2000). The industrial revolution before 1913 was within the steel and chemical industries and the great inventions such as the dynamo, light bulb, the automobile among were introduced at that time. The recent ICT revolution has also been related to infrastructure and was initiated by the invention of the microprocessor by Intel in 1971 (Jovanovic and Rousseau, 2003).

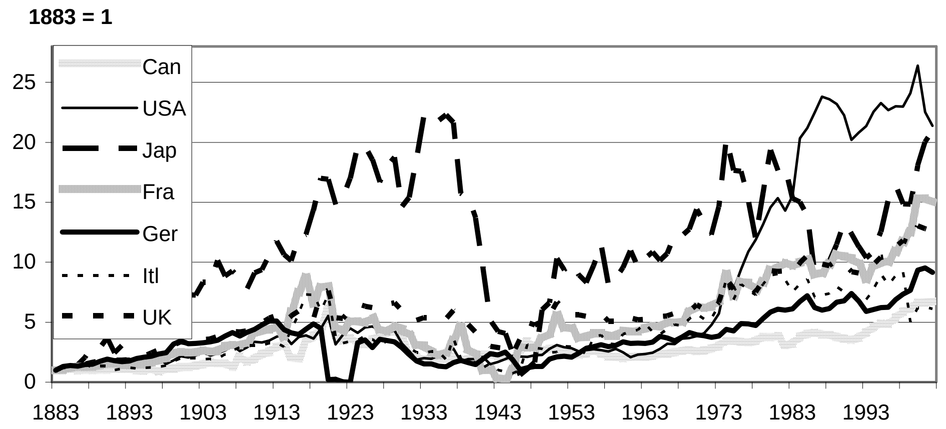
Figure 1. Imports of Knowledge, OECD



Note. Unweighted average of the OECD countries used here.

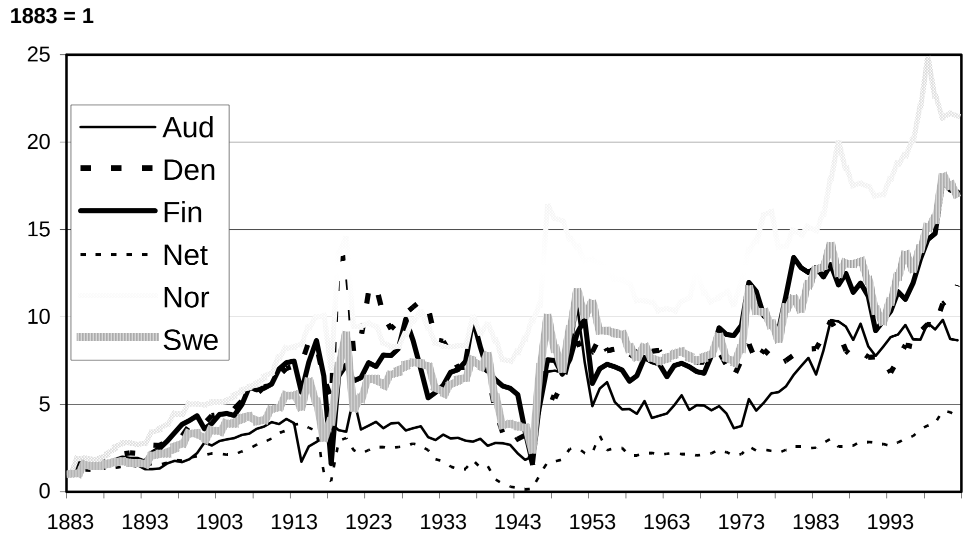
Consider the period in-between the Great Depression and WWII, which shows a marked decline in the imports of knowledge to a low in 1945. The fall during the Great Depression was not because of a slowdown in the innovative activity on a worldwide scale but because imports imploded to almost a third during the first years of the Depression. The decline during WWII, which was due to both lower innovative activity and declining trade, was reversed only after a few years after the war. Despite being the golden period for the OECD countries in terms of per capita growth, imports of knowledge remained almost constant in the 1950-1973 period due to stagnating world innovative activity. The literature on innovations and technological revolutions generally agree that the postwar period up to the beginning of the 1970s was a period of low innovative activity (Jovanovic and Rousseau, 2003, Perez, 2002, Gordon, 2000). That per capita output growth was so spectacular in the OECD countries in the 1950-1973 period was predominantly because the great inventions in the past were improved upon and were put to use (Gordon, 2000).

Figure 2. Imports of Knowledge, G7



Over the whole period considered the imports of knowledge have increased 13-fold for the average country; however, the increase has been quite different across countries (Figures 2 and 3). The countries experiencing the largest growth in imports of knowledge are the US, Japan, the Scandinavian countries, and France. The increase in France and the US, particularly, has been due to increasing propensity to import whereas Japan and the Scandinavian countries have imported from countries that have experienced a large growth in knowledge. Interestingly, during the period considered Japan has lowered its propensity to import, which has deterred some of the knowledge spillover benefits from its trade partners. The countries that have experienced the least increase in imports of knowledge are Germany, the UK, Australia, the Netherlands, Canada and Italy. The significance of the cross-country variation over the whole period is that Japan, the US and Norway have experienced a four times as strong increase in imports of knowledge as Canada, the Netherlands and Italy. As shown in the figures below these trends are reflected in the TFP growth rates.

Figure 3. Imports of Knowledge, Non-G7

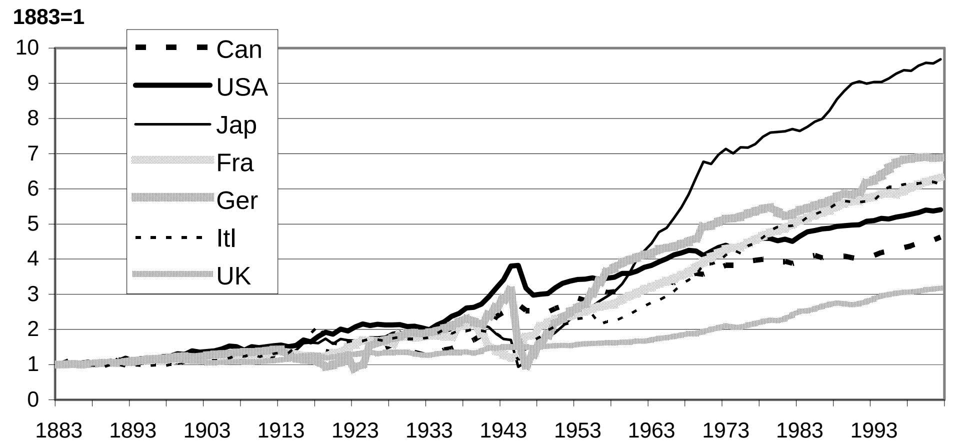


The construction of the TFP data based on homogenous Cobb-Douglass technology where factors shares are allowed to vary across countries

$$TFP_{it} = Y_{it}^{r} / L_{it}^{\bar{\alpha}_i^L} K_{it}^{(1-\bar{\alpha}_i^L)}$$

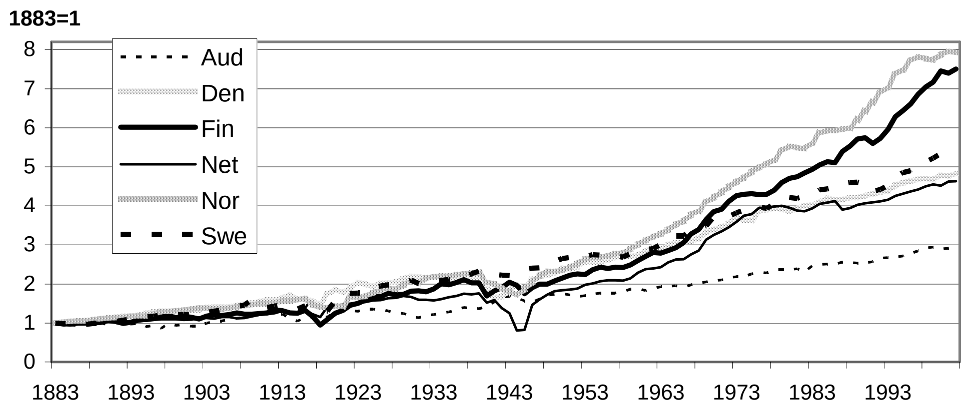
where *L* is labour inputs measured as annual hours worked per worker times economy-wide employment, *K* is capital stock based on the inventory perpetual method for economy-wide real investment, and $\bar{\alpha}_i^L$ is labour's average income share over the data period. Labour's income share is calculated as the economy-wide compensation to employees divided by nominal GDP, where compensation is corrected for imputed payments to the self-employed. The problem associated with national account factor shares is that earnings from self-employment are counted as profits although the labour of the self-employed should be counted as labour income. To correct for this bias the average earnings per employee multiplied by the number of self-employed is added to the compensation to employees. Capital stock and GDP are measured at purchasing power parities in USD, which is important when the TFP convergence is examined.

Figure 4. TFP, G7



The TFP series are displayed in Figures 4 and 5. Again there is a marked cross-country variation in TFP growth over the whole period considered. The UK and Australia stand out as the low performers, whereas Japan stands out as the top performer. The Scandinavian countries, Germany, France and Italy have also performed well. From looking at the figures it appears that the trade spillover can explain at least some of the cross-country variations. The countries that have experienced the strongest TFP growth are also the countries that experience the largest increase in imports of knowledge and *vice versa*. Therefore, technology spillovers via imports appear to have been an important contributor to TFP growth over the past century.

Figure 5. TFP, Non-G7



2.2 Estimation method

Equation (1) is estimated using the dynamic least squares estimator of Stock and Watson (1993), where the first-differences of one-period lags and leads and concurrent values of the explanatory variables are included as an additional regressor to capture the dynamic path around the long-run equilibrium. The advantage of using this estimator over the OLS estimator, is that it possesses an asymptotic normal distribution and, therefore, the associated standard errors allow for valid calculation of *t*-tests, and that, in contrast to the OLS estimator, yields unbiased coefficient estimates in panels (Kao and Chiang, 2000). The Dickey-Fuller test for panel cointegration suggested by Kao (1999) is used to test for cointegration.

To gain efficiency in the estimates of (2) the covariance matrix is weighted by the correlation of the disturbance terms using the variance-covariance structure as follows:

$$E\{\varepsilon_{it}^2\} = \sigma_i^2, \quad i = 1, 2, \ldots N,$$
$$E\{\varepsilon_{it}, \varepsilon_{jt}\} = \sigma_{ij}, \quad i \neq j,$$

where σ_i^2 is the variance of the disturbance terms for country i = 1, 2,... N; σ_{ij} is the covariance of the disturbance terms across countries i and j; and ε is the disturbance term. The variance σ_i^2 is assumed to be constant over time but to vary across countries and the error terms are assumed to be mutually correlated across countries, σ_{ij}, as random shocks are likely to impact all countries at the same time. The parameters σ_i^2 and σ_{ij}, are estimated using feasible generalized least squares.

3 Empirical estimates

The results of estimating (1) and (2) are presented in Table 1. Considering the cointegration estimates in the first column the cointegration Dickey-Fuller panel cointegration test strongly rejects the null hypothesis of no cointegration, which suggests that the estimates are super consistent and that the associated *t*-statistics are unbiased. Note that the *t*-statistics in the estimates of (1) are autocorrelation-corrected using the Barlett kernel. Excluding the time-dummies from the estimates renders the cointegration test insignificant at any conventional significance level ($N(0,1) = -0.57$). This reinforces the importance of including the time-dummies to account for some of the increase in TFP over the past 120 years. The estimated coefficient of imports of knowledge is statistically highly significant and the estimated elasticity is 0.15. The coefficient of domestic knowledge is just significantly different from zero and the estimated elasticity is 0.05. However, care has to be taken when this coefficient estimate is compared to the coefficient estimate of imports of knowledge, because the inputs of researchers and research capital have already been accounted for in the TFP estimates under the assumption that they are paid their marginal products. Thus, the influence on TFP of domestic knowledge measures the excess returns to R&D activities and, consequently, we would expect elasticity for imported knowledge to exceed the elasticity of domestic knowledge.

Turning to the error-correction estimates in the second column, the estimated coefficients of imported knowledge stock are statistically highly significantly different from zero. The sum of the estimated coefficients is 0.06 for imports of knowledge and 0.04 for domestic knowledge. Coupled with the findings from the cointegration estimates, this result suggests that imports of knowledge can take a considerable time to work through to TFP. Furthermore, the error-correction term is statistically different from zero, which is consistent with the finding of cointegration in the cointegration estimates.

Finally, the five-year difference estimates in the third column show that the estimated coefficient of foreign knowledge is economically and statistically highly significantly different from zero at conventional levels. The estimated coefficient of imports of knowledge is close to that of the cointegration estimates and, therefore, suggests that there is a robust long-run relationship between TFP and imports of knowledge. The estimated coefficient of domestic knowledge is economically and statistically barely significantly differently from zero, which reinforces the results from the other estimates that the social returns from investment in domestic knowledge are quite close to the private returns.

Table 1. Parameter estimates of Equations (1) and (2).

	Equation (1)	Equation (2)	
		1-Year Diff.	**5-Year Diff.**
$(S^d / pop)_t$	0.046(4.49)	0.023(1.99)	0.016(2.00)
$(S^d / pop)_{t-1}$		0.014(1.31)	
S_t^f	0.137(10.9)	0.041(8.98)	0.155(19.1)
S_{t-1}^f		0.016(3.45)	
$\hat{\varepsilon}_{2,t-1}$		-0.085(6.02)	
Est Per	1894-2001	1895-2001	1895-2001
R^2	0.99	0.94	0.66
DF_ρ	-3.65		

Note. The numbers in parentheses are absolute *t*-statistics. Constant terms and time-dummies are included and fixed-effect dummies (Equation (1)) are included in the estimates but not shown. The estimates of Equation (1) are based on a regression that includes as additional variables, one-period lags and leads and concurrent values of the explanatory variables in first-differences. The *t*-statistics associated with the estimates of Equation (1) are corrected for autocorrelation following Stock and Watson (1993). DF_ρ is Kao's (1999) panel Dickey-Fuller test for cointegration, distributed as $N(0,1)$ under the null hypothesis of no cointegration.

As indicated in Section 2, $\ln S^f$ is not multiplied by the propensity to import to avoid double counting. If $\ln S^f$ is multiplied by the propensity to import in the estimates of (2) in the first column, the sum of the estimated coefficients of imports of knowledge reduces to 0.04 and becomes statistically insignificant (t = 1.10).

Furthermore, allowing the coefficient of domestic knowledge to differ for the G7 countries does not change the results. A Wald test for the hypothesis that the sum of the coefficients of domestic knowledge for the G7 countries is different from zero, could not be rejected at conventional significance levels ($\chi^2(1) = 0.469$).

The estimates show consistently that imports of knowledge are important for TFP growth. It is noteworthy that the estimated elasticities are close to the elasticities estimated in the literature using R&D data, which suggests that knowledge-induced TFP growth through imports is not a recent phenomenon but has prevailed since 1883 and possibly before then, and that the estimation results are not sensitive to whether patent stock or R&D stock are used as measures of knowledge. The estimates, furthermore, suggest that imports of knowledge have contributed significantly to TFP growth in the average OECD country. Using an estimated coefficient of imports of knowledge of 0.15 results in an almost 200% imports-of-knowledge-induced TFP-growth over the period from 1883 to 2002. The gain over the period considered has, as noted in the previous section, varied considerably across countries. The US, Japan and the Scandinavian countries have experienced approximately a 300% TFP growth due to technology spillovers. The corresponding number is 75% for Italy, Canada, and the Netherlands. The question is whether these cross-country disparities have contributed to TFP convergence or TFP divergence among the OECD countries.

4 Convergence

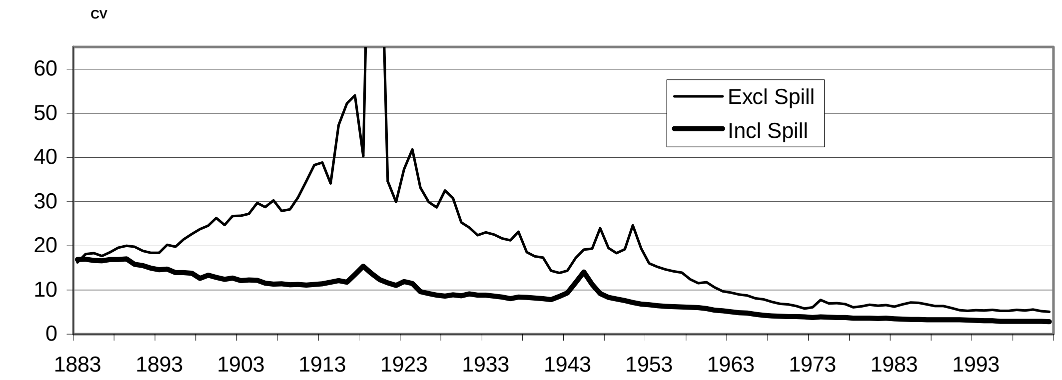
To investigate whether σ-convergence has taken place in the OECD countries and the influence of imports of knowledge spillovers on σ-convergence, the cross-country coefficient of variation, CV_t, of TFP is estimated as follows:

$$CV_t = \frac{1}{TFP_t}\sqrt{\frac{1}{n}\sum_{i}^{n}(TFP_{it}/TFP_t - 1)^2} \qquad (4)$$

where n is the number of countries. The coefficient of variation is displayed in Figure 6.

The bold line in Figure 6 shows clearly that σ-convergence has taken place in the industrialised countries over the past 120 years. The coefficient of variation has continually declined since the start of the data period in 1870 except for the interruptions around the two world wars. This conclusion is consistent with Wolff's (1991) finding of TFP convergence among the G7 countries based on Maddison's (1982) data in the snap-shot years 1870, 1880, 1890, 1900, 1913, 1929, 1938, 1950, 1960, 1970 and 1979.

Figure 6. Convergence



Notes. Original TFP data in USD purchasing power parities are used in the series 'Incl Spill', whereas the effects of international patent-induced TFP growth is removed from the TFP data used to construct the series 'Excl Spill'. The estimates are based on Equation (3).

The question is whether international patenting has contributed to the path of the TFP convergence. This can be investigated by removing the effects on TFP of the imports of knowledge using an elasticity of 0.15, which yields the thin line in Figure 6 under the assumption that imports of knowledge were not embodied in TFP at the start of the estimation period in 1883.

The thin line indicates that in the absence of import spillovers, convergence would have taken place but that it would have occurred first after WWI. Before then a strong divergence transpired despite the fact that the economies actually converged when import spillovers are allowed for. This strong widening of the gap between the two curves before WWI suggests that imports of knowledge were important contributors to the TFP convergence among the OECD countries. However, from the end of WWI to present, the gap between the two lines have narrowed considerably, which suggests that imports of knowledge has deterred convergence in this period; however, the deterrence was not sufficiently strong to override its contribution to convergence before the end of WWI. Therefore, on balance imports of knowledge have been a net contributor to convergence over the whole period considered.

5 Conclusion

This paper has put the Coe-Helpman hypothesis to the test using data for 13 OECD countries over the past 120 years, during which time imports of knowledge and TFP have been fluctuating substantially. The estimation results showed that international transmission of technology through imports has been a significant determinant of TFP growth over the past century. Simulations of the models showed that imports of knowledge have been responsible for an almost 200% increase in TFP in the OECD countries over the past 120 years. In other words, without the spillovers from imports of technology over the past century, the average person in the OECD would have had a third of the present income! Therefore, import technology spillovers have been a significant contributor to the income growth we have experienced over the past century, which highlights that imports should not be considered as debt creating, and hence a liability, but as a means of furthering per capita income.

The TFP gain from imports of technology over the past century has varied markedly across countries. The largest beneficiaries of import spillovers over the past 120 years have been the US, Japan and the Scandinavian countries, whereas Italy, Canada, and the Netherlands have benefited the least from the knowledge spillovers among the 13 OECD countries considered in this paper. Since the largest beneficiaries from technological spillovers were predominantly the countries with the lowest TFP in 1883 and *vice versa*, the growth in imports of technology has been a factor that has contributed to TFP convergence of the OECD countries.

DATA APPENDIX

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Capital stock. The perpetual inventory method is used with an 8% depreciation rate. The initial capital stock is set equal to the initial investment divided by the depreciation rate of 8% plus the average geometric growth rate in real investment over the whole estimation period. The data are from OECD, *National Accounts*, after 1960. Before 1960 the following sources are used. Canada. 1870-1926. Urquhart, M. C, 1986, "New Estimates of Gross National Product, Canada, 1870-1926: Some Implications for Canadian Development," in S. Engermann, and R. E. Gallman (eds), *National Bureau of Economic Research, Studies in Income and Wealth 51: Long-Term Factors in American Economic Growth*, Chicago: University of Chicago, 9-94. T. Liesner, *One Hundred Years of Economic Statistics*, the Economist: Oxford. United States. 1834-1885. P Rhode, 2002, "Gallman's Annual Output Series for the United States, 1834-1909," NBER Working Paper No. 8860. 1885-1960. Liesner, *op. cit*. Japan: 1885-1949: K. Ohkawa, M. Shinchara and L. Meissner, 1979, *Patterns of Japanese Economic Development: A Quantitative Appraisal*, Yale University Press: New Haven. Australia: 1863-1939. W. Vamplew, 1987, *Australian Historical Statistics*, Broadway, N.S.W: Fairfax, Syme & Weldon Associates. 1940-1960. Liesner, *op. cit*. Denmark: 1834-1960. H C Johansen, 1985, *Dansk Historisk Statistik, 1814-1980*, København: Gyldendal. Finland: 1860-1960: R. Hjerppe, 1989, *The Finnish Economy, 1860-1985*, Bank of Finland, Helsinki:Government Printing Centre. France. 1820-1913. M. Lévy-Leboyer, 1978, "Capital Investment and Economic Growth in France, 1820-1930," in P. Mathias and M. M. Postan, *The Cambridge Economic History of Europe*, Vol VII, Cambridge: Cambridge University Press. 1913-1938. J.J. Carré, P. Dubois, and E. Malinvaud, 1972, *La croissance française. Un essai d'analyse économique causale de l'après-guerre*, Paris: Seuil. 1938-1946. Interpolated. 1946-1960. J. J. Carré, P. Dubois, and E. Malinvaud, 1976, *French Economic Growth*, Kingston, NY: Fine Books. Germany. 1850-1960. W. Kirner, 1968, *Zeitreihen fur das Anlagevermogen der Wirtschaftsbereiche in der Bundesreplublik Deutschland*, Deutsches Institut fur Wirtschaftsforschnung, Duncker & Humbolt: Berlin. The data are adjusted for war damage in the source. Italy. 1861-1960. G. Fua, 1965, *Notes on Italian Economic Growth 1861-1964*, Milano: Mvlta Pavcis. Netherlands.

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Labour's income share. Is calculated as the economy-wide compensation to employees plus imputed compensation to self-employed divided by nominal GDP. The imputed compensation to employees is computed as the number of self-employed multiplied by economy-wide compensation to employees divided by economy-wide employment. The output elasticities of inputs are computed from the average factor shares using data up to 2002. The following starting dates are used (in parentheses): Canada (1926), USA, (1899), Japan (1906), Australia (1870), Denmark (1900), Finland (1870), France (1920), Germany (1870), Italy (1950), Netherlands (1870), Norway (1930), Sweden (1870), and UK (1870). OECD *National Accounts* are used for the post 1950 data.

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