E C O N O M I C S B U L L E T I N

Barriers to technology adoption, international R and D spillovers and growth

Jesus Crespo-Cuaresma
University of Innsbruck

Neil Foster
University of Vienna

Johann Scharler
Johannes Kepler University of Linz

Abstract

Panel data is used to investigate the extent of R and D spillovers between OECD countries, and the importance of barriers to technology adoption in affecting the benefits of such spillovers. Our results indicate that countries with less regulated goods and labour markets benefit more from foreign R and D.

Citation: Crespo-Cuaresma, Jesus, Neil Foster, and Johann Scharler, (2008) "Barriers to technology adoption, international R and D spillovers and growth." *Economics Bulletin*, Vol. 15, No. 3 pp. 1-7
Submitted: January 18, 2008. **Accepted:** March 6, 2008.
URL: http://economicsbulletin.vanderbilt.edu/2008/volume15/EB-08O30001A.pdf

1. Introduction

It has long been recognised that international technology transfer in the form of knowledge spillovers is an important source of growth, and that the progress of both developed and developing nations may be determined in part by its extent (Gerschenkron, 1962). This is particularly the case for countries situated away from the technological frontier that tend to undertake little innovative activity.[1]

While technology may diffuse through numerous channels, international trade has been emphasised in much of the empirical literature as being a significant source of technology diffusion. The approach often adopted in empirical work follows the seminal contribution of Coe and Helpman (1995), in which a `stock of knowledge' for each developed country is constructed with access of other countries to this stock being measured by weighting the stock with some measure of the volume or share of bilateral trade. Using this approach evidence of foreign knowledge spillovers on trading partner's rates of Total Factor Productivity (TFP) or GDP growth have been found among developed countries (Coe and Helpman, 1995) and from developed to developing countries (Coe, Helpman and Hoffmaister, 1997).

The general approach of Coe and Helpman (1995) has been adapted in a number of ways. One extension of the literature has been to consider alternative weights when constructing the foreign knowledge variable. In addition to imports, capital goods imports (Xu and Wang, 1999), inward and outward FDI (Xu and Wang, 2000), exports (Funk, 2001) and geographic distance (Keller, 2002) have all been used as weights. While the importance of numerous channels of knowledge spillovers has been examined empirically in this setting, little empirical evidence addresses the importance of domestic factors in the absorption of foreign knowledge through these channels.[2] Yet there are numerous theoretical arguments suggesting that the ability of a country to absorb and assimilate foreign knowledge is likely to be an important determinant of the extent of foreign knowledge spillovers. Cinera and Pottelsberghe (2001) argue for instance that `in order to gauge the importance of international spillover effects, it may also be worth it to examine the factors improving the absorptive capabilities of foreign R&D such as education, training, mobility of the human capital or R&D collaborations'. Given the concentration of R&D activity in a small number of developed countries the ability of countries to take advantage of foreign technologies is likely to be an important determinant of the world income distribution.

In this paper we add to the existing empirical literature on international R&D spillovers by considering a further domestic factor that may affect a country's absorptive capacity, namely institutions and institutional barriers to technology adoption. In a series of papers (Parente and Prescott; 1994, 1999) and a monograph (Parente and Prescott, 2003) Parente and Prescott argue that absorptive capacity is to a large extent determined by institutional aspects that give rise to so called absorption barriers. In particular, Parente and Prescott (1999) argue that monopoly rights may represent a barrier to the adoption of foreign technologies in the sense that industry insiders with monopoly rights to the current technology will resist the adoption of better production techniques. The greater the strength of protection granted to insiders, the greater the amount of resources that potential entrants with superior technology have to spend

[1] The share of R&D financed by enterprises in advanced countries was 98 percent in the 1980s and 94 percent in the 1990s (UNIDO, 2002). Even within developed countries however R&D is concentrated, with Eaton and Kortum (1999) noting that in the late 1980s, 80 percent of OECD research scientists and engineers were employed in five countries (US, UK, Germany, Japan and France).

[2] See Keller (2004) for a survey of empirical studies of technology diffusion. The major exceptions are Kneller (2005) and Kneller and Stevens (2006) who consider the importance of human capital and domestic R&D as indicators of absorptive capacity in developed countries, and Falvey et al (2007) who look at the importance of human capital and relative backwardness in a North-South context.

in order to enter the industry. This view that barriers may prevent technology adoption and may delay economic development is not new. Rosenberg and Birdzell (1986) and Mokyr (1990) also argue that lower barriers to the adoption of technology help explain why modern economic growth began in the West rather than the East.

Our empirical analysis follows the approach of Coe and Helpman (1995) using data on R&D to estimate the impact of foreign R&D spillovers for a sample of 21 OECD countries over the period 1973-1997. Following Coe and Helpman the weights used in the construction of the spillover variables are bilateral import shares. As such we consider the spillover of knowledge related to R&D spending through the specific channel of trade, and imports in particular. Where our paper differs from the existing literature on foreign R&D spillovers is that we use threshold regression techniques to allow the coefficient on R&D spillovers to depend upon variables accounting for barriers to technology adoption. Our results suggest that lower adoption barriers are important in explaining differences in the impact of foreign R&D on growth, with countries with lower barriers benefiting to a greater extent from foreign knowledge.

The remainder of the paper is organised as follows: Section 2 gives an overview of related literature. Section 3 discusses our empirical specification and the data employed. Section 4 discusses our results and Section 5 concludes.

2. Background

Coe, Helpman and Hoffmaister (1997) (CHH) identify several channels whereby foreign knowledge can be transferred including: imports of intermediate and capital goods; cross-border learning of production methods, product design and organization; imitation of new products; development of technologies and imitation of foreign technology. These arguments underlie tests of links between knowledge spillovers through trade and output or productivity growth. In a seminal paper Coe and Helpman (1995) test for trade related R&D spillovers among 22 OECD countries for 1971-1990. A stock of knowledge is constructed for each country with access measured by weighting stocks with trade flows. They conclude that both foreign and domestic stocks are important for productivity growth, with more open economies gaining most. CHH find similar results for North-South spillovers.

Parente and Prescott (1994, 1999, and 2003) argue that barriers to technology adoption lead to the inefficient use of inferior technologies. This argument is based on the fact that many of these barriers are assumed to be put in place to protect the interests of groups vested in current production processes. Intuitively, as long as firms are not threatened by the prospect that their competitors might introduce more productive technologies, they may prefer to stick to their current technology, although better ones are available. While barriers protecting industry insiders are likely to be considerable, labour market institutions are likely to be a further relevant barrier to technology adoption. Labour unions are another group with vested interests that may potentially oppose the introduction of possibly labour-saving technologies and could also be considered to be a group with vested interests in limiting technology adoption.

In this paper we combine these two strands of literature, examining whether the extent of international R&D spillovers through trade is influenced by indices capturing institutional characteristics of product and labour markets that may give rise to barriers to technology adoption. The following section describes the method employed.

3. Empirical Specification

We consider the importance of trade-related spillovers and the importance of vested interests for such spillovers between a sample of 21 OECD countries using data on five-year averages over the period 1973-1997.

The approach we adopt is similar to that of Coe and Helpman (1995), but rather than construct a measure of TFP we choose not to impose coefficients on the share of capital and labour, allowing the data to determine the coefficients. The initial estimating equation is thus,

$$\Delta \ln y_{it} = \alpha \Delta \ln k_{it} + \gamma_1 \Delta \ln S_{it}^D + \gamma_2 \ln S_{it}^F + \mu_i + \upsilon_t + \varepsilon_{it},$$

where $\Delta \ln y$ is the average growth of per capita GDP in each five year period, $\Delta \ln k$ is the growth in the capital-labour ratio, S^D and S^F are the domestic and foreign knowledge stocks, μ_i and ν_t are country and time specific effects and ε_{it} the remaining error term.

As in Coe and Helpman (1995) the foreign R&D stock is defined as the import-weighted R&D stocks of a country's trade partners. Where our approach differs from the Coe and Helpman approach is by assuming that the benefits from foreign R&D depend upon the parameter, γ_2, capturing the absorption of foreign knowledge. To account for the importance of barriers to technology adoption, we allow the coefficient associated with foreign knowledge to depend on variables representing barriers to adoption in a potentially non-linear way. In the case of a two-regime model we can write,

$$\Delta \ln y_{it} = \alpha \Delta \ln k_{it} + \gamma_1 \Delta \ln S_{it}^D + \gamma_{2,1} I(B_{it} \le \lambda) S_{it}^F + \gamma_{2,2} I(B_{it} > \lambda) S_{it}^F + \mu_i + \upsilon_t + \varepsilon_{it},$$

where B_{it} is the index of absorption barriers, I is the indicator function, and λ is the estimated threshold. Here the impact of foreign R&D spillovers is given by $\gamma_{2,1}$ for observations with $B_{it} \le \lambda$ and by $\gamma_{2,2}$ for observations with $B_{it} > \lambda$. The threshold model can be easily extended to consider the possibility of more than one threshold.

In principle therefore, we assume that the diffusion of new technologies is a two stage process. In the first stage we follow the arguments of Coe and Helpman and assume that knowledge is transmitted through trade flows.[3] Whilst providing access to foreign R&D, trade need not be a sufficient condition for a country to absorb and benefit from foreign R&D spillovers. In the second stage therefore foreign R&D is absorbed by the recipient country.

For the indicators of absorption barriers (B_{it}) we focus on proxies for market regulation and wage bargaining. In particular, data are obtained from either Nicoletti et al (2000) or Nickell et al (2001) and are indices of product market regulation (PMR), inward-oriented product market regulation (IO-PMR), barriers to entrepreneurship (ENT), employment protection regulation (EPL) and coordination of wage bargaining (CO). Higher values of these variables imply increased regulation and increased coordination in the case of wage bargaining, and are thus associated with higher barriers to technology adoption.

We estimate the model using the approach advocated in Hansen (1999), which allows us to identify the value of the threshold, λ, and the regression coefficients. The threshold parameter is estimated as the value of λ that minimizes the concentrated sum of squared residuals from

[3] An alternative view of the role of trade in this context is presented in Holmes (1995) who argues that international trade and foreign competition force domestic interest groups to adopt the most efficient technologies. Thus, international trade facilitates the adoption of new technologies, but for a different reason than in Coe and Helpman (1995).

the above equation[4]. The test of whether the threshold is significant is not straightforward since the threshold is not identified under the null. We use the bootstrap procedure of Hansen (1999) to test this. If the threshold is found to be significant the method can be extended to consider more than one threshold.

Data on GDP and the labour force are taken from the World Development Indicators, while capital stock data is from the OECD's Economic Outlook. The domestic R&D stock is constructed using the perpetual inventory method with the data coming from the ANBERD database. Foreign R&D stocks are constructed, using the approach of Coe and Helpman, as the import-share weighted averages of the domestic R&D of country *i*'s trade partners,

$$S_{it}^{F} = \sum_{j \neq i} \frac{\eta_{ijt}}{\eta_i} S_j^D$$

where η_{ij} is the volume of total imports from country *j* to country *i* and η_i is the total volume of imports of country *i* from all countries in the sample. The trade data comes from the OECD's International Trade by Commodity Statistic database.

4. Results

The estimation results are presented in Table i. From the second column of Table i it can be seen that the results from the base specification are largely as expected. The coefficient on the capital-labour ratio, α, is in line with previous estimates. The coefficient on domestic R&D, γ_1, provides evidence on the importance of innovation-driven technological progress for a nation's growth performance. In this specification, the coefficient capturing the importance of foreign R&D, γ_2, does not depend on potential barriers to technology adoption. The point estimate for γ_2 is positive as expected, though not significant, a result in line with Kao et al (1999).

The results for the threshold model are reported in the final five columns.[5] Here we allow indices of product market regulation, entrepreneurship and employment protection to impact upon γ_2. For both PMR and IO-PMR we find evidence in favour of a two regime model. The results for both threshold variables are similar with a positive and significant coefficient found in the low-regime and a positive and insignificant coefficient found in the high-regime. The threshold values correspond to the 20th and 33rd percentile of the distributions for PMR and IO-PMR respectively. These results suggest that foreign R&D spillovers are significantly related to growth in countries with low values of the product market regulation index, but not for countries with high values of this index. As such, the results indicate that absorptive capacity is larger in countries with lower levels of product market regulation, which provides support for the arguments of Parente and Prescott (2003). It should be noted however, that only in the case of IO-PMR do we find significant differences in the coefficients on foreign R&D across regimes.

We continue by isolating the effect of barriers to entrepreneurship (ENT), as an alternative variable of interest in this context. This is done because IO-PMR also includes information on public ownership which is not necessarily a restriction on competition per se. Since it can be argued that incumbent firms do not have an incentive to adopt more productive technologies as long as they are protected by sufficiently high barriers to entry, we proceed to consider ENT as an alternative threshold variable.

[4] To ensure a reasonable number of observations in each regime we restrict our attention to the central 60 percent of the distribution.

[5] In addition to the endogenous threshold model we also used simple interaction terms and imposed the threshold exogenously. These results are consistent with the results reported here.

Column 5 reports the results for thresholds based on ENT. The results closely resemble those for PMR and IO-PMR, with a positive and significant coefficient on foreign R&D in countries with low barriers to entrepreneurship, but an insignificant coefficient on foreign R&D for countries with high barriers to entrepreneurship. The threshold is found at a value of 1.30, but as with the threshold on PMR is not significant at conventional levels.

For the employment protection index (EPL) we find a single threshold at a value of 1.10 (the 25th percentile of the distribution), which is significant at the 10 percent level. The results on this measure of labour market regulation broadly support those on the measures of product market regulation discussed above. Foreign R&D is found to have a positive and significant impact on growth in countries with relatively low levels of employment protection, but an insignificant impact on growth in countries with relatively high levels of employment protection. The results presented using variables on both product and labour market regulation suggest therefore that greater regulation lowers a country's absorptive capacity, by reducing the incentives and increasing the barriers to adopting foreign technology.

Table i: Results

	Base	*PMR*	*IO-PMR*	*ENT*	*EPL*	*CO*
α	0.229	0.262	0.267	0.267	0.357	0.201
	(0.144)	(0.148)	(0.151)*	(0.149)*	(0.147)**	(0.145)
γ_1	0.352	0.319	0.322	0.315	0.320	0.367
	(0.100)***	(0.090)***	(0.093)***	(0.094)***	(0.088)***	(0.092)*
γ_2	0.014					
	(0.009)					
$\gamma_{2,1}$		0.036	0.032	0.032	0.035	0.034
		(0.021)*	(0.016)**	(0.016)*	(0.018)*	(0.012)*
$\gamma_{2,2}$		0.007	0.003	0.004	0.001	-0.002
		(0.010)	(0.011)	(0.011)	(0.01)	(0.011)
$\gamma_{2,3}$						0.04
						(0.017)**
λ		1.30	1.72	1.30	1.10	0.40, 2.11
(percentile)		(20^{th})	(33^{rd})	(25^{th})	(25^{th})	(33^{rd} and 55^{th})
p-value		0.15	0.10*	0.14	0.08*	0.04**
Obs	105	105	105	105	100	105
JB Test	0.606	1.31	1.08	1.16	1.24	0.982
$\overline{R}^2$	0.506	0.518	0.516	0.528	0.528	0.552

Notes: Robust standard errors in parenthesis. Significance at the 1, 5 and 10 percent levels is indicated by ***, ** and *. JB stands for the Jarque-Bera test statistic of the normal distribution of the residuals. The p-value for the likelihood ratio test of the significance of the model with threshold effects was computed using the bootstrap procedure of Hansen (1999) with 500 replications.

Finally, for the coordination of wage bargaining variable (CO) we find evidence of two significant thresholds suggesting a three regime. Interestingly, the relationship between the coordination index and absorptive capacity appears to be non-monotonic, with an insignificant coefficient on the foreign R&D variable found in the middle regime and positive and significant coefficients found in the low- and high-regimes. These findings are in line with the arguments of Dowrick and Spencer (1994) who argue that unions organised at intermediate levels welcome innovation less than unions organised either at the firm or national level. In their model a union's attitude towards innovation depends on the elasticity of the labour demand it faces, with unions that face less elastic labour demand resisting innovation more than others. The authors argue that the empirical literature in this area

suggests that unions organised at intermediate levels typically face less elastic labour demand than unions organised at the firm-level. In addition, unions that negotiate wages only for workers in an industry are likely to view the real income gains due to higher productivity and price reductions in their particular industry as small, while for a union that negotiates wages for all industries this real income effect becomes large and therefore unions organised at the national level might be more in favour of innovation.

5. Conclusions

This paper considers the importance of international R&D spillovers for growth in OECD countries. The paper builds upon the existing empirical work in this area by considering the determinants of absorptive capacity in industrialised countries. While empirical evidence indicates that international trade, and imports in particular, provide access to foreign knowledge, much less is known of the domestic factors that can aid in the absorption of such knowledge. In this paper we focus on institutional variables related to absorption barriers.

We present new evidence in favour of the arguments presented in Parente and Prescott (2003) concerning the relevance of institutional variables. Overall, our results are consistent across specifications, indicating a positive and statistically significant impact of foreign R&D on growth for countries with low values of the indices, and insignificant coefficients for countries with high levels of the indices. Hence, we find that countries with lower levels of product market regulation, employment protection and lower barriers to entrepreneurship benefit to a greater extent from foreign R&D. The one exception to this conclusion is for the coordination of wage bargaining, where foreign R&D is found to be less beneficial to growth in countries characterised by intermediate levels of coordination, a result in line with theoretical arguments. While these results are supportive of the Parente and Prescott hypothesis and suggest that absorptive capacity is higher in countries with more competitive goods and labour markets we find that the coefficients in the two regimes are not different from each other at standard levels of significance for the overall indicator of product market regulation and barriers to entrepreneurship.

Given the importance of technology and technological diffusion for growth there is great potential for future research in this area. Obvious avenues for future research include employing alternative measures of social capital and institutions, considering alternative channels for foreign spillovers (for example FDI and patent data) and considering the domestic determinants of foreign R&D spillovers in developing countries, which tend not to conduct significant levels of R&D and which tend to have low levels of human capital. A further possibility would be to consider whether the returns to domestic R&D are also affected by barriers to technology adoption.

References

Bridgman, B. R., Livshits, I. D., and J. MacGee (2007) "Vested Interests and Technology Adoption" *Journal of Monetary Economics* 54, 649-666.

Cinera, M., and B. van Pottelsberghe de la Potterie (2001) "International R&D: A Survey" *Cahiers Economiques de Bruxelles* 169, 3-32.

Coe, D. T., and E. Helpman (1995) "International R&D Spillovers" *European Economic Review* 39, 859-887.

Coe, D. T., Helpman, E., and A. W. Hoffmaister (1997) "North-South R&D Spillovers" *Economic Journal* 107, 134-150.

Dowrick, S., and B. J. Spencer (1994) "Union Attitudes to Labor-Saving Innovation: When are Unions Ludites?" *Journal of Labor Economics* 12, 316-344.

Eaton, J., and S. Kortum (1999) "International Technology Diffusion: Theory and Measurement" *International Economic Review* 40, 537-570.

Falvey, R. E., Foster, N., and D. Greenaway (2007) "Relative Backwardness or Absorptive Capacity: How Does Knowledge Flow Across Borders?" *Economics Letters* 85, 209-213.

Funk, M. (2001) "Trade and International R&D Spillovers among OECD Countries. *Southern Economic Journal* 67, 725-737.

Gerschenkron, A. (1962) *Economic Backwardness in Historical Perspective* Harvard University Press: Cambridge, MA.

Hansen, B. E. (1999) "Threshold Effects in Non-Dynamic Panels: Estimation, Testing and Inference" *Journal of Econometrics* 93, 345-368.

Holmes, T. J., and Schmitz, J. A. (1995) "Resistance to New Technologies and Trade between Areas" *Federal Reserve Bank of Minneapolis Quarterly Review* 19, 2-17.

Kao. C., Chiang, M-H., and B. Chen (1999) "International R&D Spillovers: An Application of Estimation and Inference in Panel Cointegration" *Oxford Bulletin of Economics and Statistics* 61, 693-711.

Keller, W. (2002) "Geographic Localization of International Technology Diffusion" *American Economic Review* 92, 120-142.

Keller, W. (2004) "International Technology Diffusion" *Journal of Economic Literature* 42, 752-782.

Kneller, R. (2005) "Frontier Technology, Absorptive Capacity and Distance" *Oxford Bulletin of Economics and Statistics* 67, 1-23.

Kneller, R., and P. Stevens (2006) "Frontier Technology and Absorptive Capacity: Evidence from OECD Manufacturing Industries" *Oxford Bulletin of Economics and Statistics* 68, 1-21.

Mokyr, J., (1990) *The Lever of Riches: Technological Creativity and Economic Progress* Oxford University Press: New York.

Nickell, S. J., Nunziata, L., Ochel, W., and G. Quintini (2001) "The Beveridge Curve" Discussion Paper 502, Centre for Economic Performance.

Nicoletti, G., Scarpetta, S., and O. Boyland (2000) "Summary Indicators of Product Market Regulation with an Extension to Employment Protection Legislation" Working Paper 226, Organisation for Economic Cooperation and Development.

Parente, S. L., and E. Prescott (1994) "Barriers to Technology Adoption and Development" *Journal of Political Economy* 102, 298-321.

Parente, S. L., and E. Prescott (1999) "Monopoly Rights: A Barrier to Riches" *American Economic Review* 89, 1216-1233.

Parente, S. L., and E. Prescott (2000) *Barriers to Riches* MIT Press: Cambridge, MA.

Rosenberg, N. and L. E. Birdzell (1986) *How the West Grew Rich: The Economic Transformation of the Industrial World* Basic Books: New York.

United Nations Industrial Development Organization, 2002. *Industrial Development Report 2002/2003*. UNIDO: Vienna

Xu and Wang (1999) "Capital Goods Trade and R&D Spillovers in the OECD" *Canadian Journal of Economics* 15, 585-601.

Xu, B., and J. Wang (2000) "Trade, FDI and International Technology Diffusion" *Journal of Economic Integration* 15, 585-601.