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# On the Determinants of Absorptive Capacity: Evidence from OECD Countries

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## 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). There does however appear to be large differences in how effective countries are in adopting foreign technology. Given that the bulk of new technology is created in a handful of the world's richest countries,[4] it is easy to see that differences in the ability of countries to take advantage of foreign technologies could be an important determinant of the world income distribution, which underlines the importance of identifying the major determinants of successful technology diffusion.

In this paper we add to the empirical literature on technology diffusion by

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[4]In 1990, 96% of the world's R&D expenditures took place in industrial countries (see Coe et al. 1997).

investigating the determinants of absorptive capacity in industrialized countries. In particular, we allow the absorption of foreign knowledge to be affected by variables that have been proposed in the theoretical literature. Our paper is related to two strands of the literature: namely, the literature dealing with trade-related knowledge spillovers and the literature on absorptive capacity.

A large and growing literature empirically investigating the role of trade in the diffusion of knowledge across countries has developed following the seminal contribution of Coe and Helpman 1995.[5] The approach adopted in empirical work has been to construct a "stock of knowledge" for each developed country and then measure access to this by weighting these stocks by some measure of the volume or share of bilateral trade. Using this approach evidence of knowledge spillovers on trading partners' rates of total factor productivity (TFP) or GDP growth have been found among developed countries (for example, Coe and Helpman, 1995) and from developed to developing countries (see Coe et al. 1997 for example).

The notion of absorptive capacity refers to the various factors that affect the ability of a country to take advantage of technology developed abroad.[6] Amongst the many determinants of absorptive capacity that have been proposed we analyze relative backwardness as proposed by Gerschenkron (1962) and Kuznets (1973), human capital, R&D expenditures and institutions as possible absorption barriers. The role of human capital in this context has been analyzed extensively in the empirical literature.[7] The general conclusion is that technology diffusion is positively affected by the availability of human capital. A small number of papers examine the impact of R&D on absorptive capacity. Griffith et al. (2000) use industry-level data from twelve OECD countries to study the main determinants of productivity dynamics and find that conditional on a certain productivity gap to the leader country, subsequent productivity growth in an industry is higher, the higher are its R&D expenditures. This is consistent with R&D playing a similar role to human capital. In a series of papers, Parente and Prescott (1994), (1999) and (2003) argue that absorptive capacity is to a large extent determined by institutional aspects that give rise to so called absorption barriers. That is, the costs of implementing new technologies faced by firms depend on the institutional setting. 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

[5]See Keller (2001) for a recent survey.

[6]Abramovitz (1986) discusses in detail the many factors that can be considered important for absorptive capacity.

[7]See for instance Benhabib and Spiegel (1994), Eaton and Kortum (1996), Engelbrecht (1997), Engelbrecht (2000) and Xu and Wang (2000).

technology have to spend in order to enter the industry. This suggests that more competitive economies are likely to be characterized by higher absorptive capacity.

In this paper we estimate the impact of foreign knowledge spillovers on growth using a method similar to Coe and Helpman (1995) for a sample of 21 OECD countries over the period 1973 to 1997. The paper differs from the previous literature by allowing the relationship between foreign knowledge spillovers and growth to depend on a third variable; absorptive capacity. Using a number of variables measuring absorptive capacity we employ threshold regression techniques to identify different regimes based on the level of absorptive capacity, with the impact of foreign knowledge spillovers on growth allowed to vary across regimes.

We find that human capital and in particular domestic R&D increases a country's absorptive capacity. Moreover, our results suggest that absorptive capacity depends on institutional variables as argued by Parente and Prescott (1994), (1999) and (2003). In particular, we find that countries with less regulated goods and labor markets tend to be characterized by a relatively higher absorptive capacity. We do not however find evidence that countries with relatively low initial levels of GDP per capita benefit more from spillovers than other countries. Thus, relative backwardness alone does not appear to facilitate foreign knowledge spillovers for our sample of industrialized countries.

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

## 2. Related Literature

In this paper we combine two strands of existing empirical literature, the literature on absorptive capacity and that on foreign knowledge stocks. A review of the literature shows that to date there has been little systematic analysis on the impact of absorptive capacity on foreign knowledge spillovers. In this section we begin by reviewing the existing (largely theoretical) literature on absorptive capacity before discussing the (largely empirical) literature on foreign knowledge spillovers.

It has long been recognized that international technology transfer is an important source of growth. Early theoretical contributions to the literature focused on the role of technology diffusion in the convergence process. Gerschenkron (1962) and Kuznets (1973) talked of the so-called "advantages of backwardness''. They argued that being a technological laggard had the advantage that it would be possible to ``borrow'' new technology from the leading edge countries. According to this argument we would expect that poorer countries gain more from foreign technology than richer countries. Others such as Abramovitz (1986), argued that in order to obtain such benefits other factors that affect the ability to adopt such technology needed to be in place, these factors being termed ``social capability'' or ``absorptive capacity''.

Abramovitz identifies a large number of factors that could be considered important for a country's absorptive capacity. Three general categories were identified; (1) Facilities for the diffusion of knowledge (for example channels of international technical communication, MNCs, the state of trade and of direct capital investment); (2)Conditions facilitating or hindering structural change in the composition of output, in the occupational and industrial distribution of the workforce, and in the geographical location of industry and population; (3) Macroeconomic and monetary conditions encouraging and sustaining capital investment and the level and growth of effective demand. Abramovitz also argued that the obstacles to change raised by vested interests, established positions, and customary relations among firms and between employers and employees may contribute to a country's absorptive capacity. As such a large number of factors may be considered important for a country's absorptive capacity. Despite this fact studies exist that consider a subset of such factors.

Two variables often associated with the idea that a firm or country needs to have a certain type of skill in order to be able to successfully adopt foreign technology are human capital and R&D expenditures (Keller, 1996, formalizes this idea). Such skills can come in the form of human capital (see Nelson, 1966) or in the form of R&D, as emphasized by Cohen. and Levinthal (1996). Cohen and Levinthal (1996) argue that in order to acquire outside technology a firm may itself need to invest in R&D. These authors argue that own R&D expenditures are critical for enabling the firm to understand and evaluate new technological trends and innovations.

A further aspect of absorptive capacity raised by Abramovitz has also been emphasized in the literature recently, namely institutional barriers to the adoption of new technology. Parente and Prescott (1994) argue that although the global pool of knowledge is readily accessible by each country, not all countries employ the best available technologies, because implementing new technologies and work practices involves costs. These costs are to some extent determined by institutional constraints such as the regulatory environment and competition policy. In their model, firms have to invest in order to increase the quality of their plants. However, the amount of investment required to achieve a certain level of quality depends on the institutional environment and therefore differs across countries. They find that even small variations in the costs imposed by the institutional environment give rise to large differences in income levels.

In a related paper, Parente and Prescott (1999) focus on monopoly rights as the main institutional feature that acts as a barrier to the adoption of foreign technologies. If industry insiders have monopoly rights to the current technology they will resist the adoption of better production techniques. The greater the strength of protection granted to the insiders, the greater the amount of resources that potential entrants with superior technology have to spend in order to enter the industry. Thus, more competitive economies are likely to benefit from spillovers to a larger extent.

Nelson and Phelps (2002) argue that the rate of technology absorption depends on the technology gap between the leading country and the follower. In this spirit, Benhabib and Spiegel (1994) and Engelbrecht (1997) include a human capital/productivity catch-up interaction term in regressions on the growth of either TFP or GDP, which also include a separate human capital variable to account for domestic innovation. Benhabib and Spiegel (1994) find that the interaction term is significant and has the expected sign only for developing countries, while the domestic innovation rate for these countries is negative but insignificant. The opposite result is found for the wealthiest third of countries. In contrast Engelbrecht (1997) finds that for OECD countries both variables enter significantly and with the expected sign. When including this interaction term, Engelbrecht (2000) finds for a sample of developing countries results similar to Benhabib and Spiegel (1994), namely a negative but insignificant coefficient on the education variable and a positive and significant coefficient on the interaction term. The results obtained suggest the sensible conclusion that for countries at lower levels of development general human capital accumulation is relatively more important, whereas for more developed countries embodied R&D spillovers and more specific human capital become crucial.

The development of theories of endogenous growth has revived the interest in the relationship between trade and growth and in to the role of foreign knowledge spillovers in growth. Recent theories of endogenous technological change provide a rationale for examining foreign knowledge spillovers through trade.[8] In a simple variant of these models, final output is produced using intermediate inputs, which may be horizontally or vertically differentiated. R&D affects output by increasing the number, or improving the quality, of available intermediates. In the absence of trade, a country's output is determined by its own cumulative past R&D. With trade a relationship between cumulative R&D and output remains, but the relevant measure is now the world R&D stock.[9]

From the theoretical literature, Coe et al. (1997) identify four channels through which international contacts may allow knowledge produced in one country to affect productivity and growth in others. First, they allow a country to employ intermediate and capital goods from abroad, which may enhance the productivity

[8]See for instance Romer (1986), Aghion and Howitt (1992), Grossman and Helpman (1991a) and (1991b).

[9]To date the literature has concentrated on the role of imports as a channel for foreign knowledge spillovers. Other channels are also likely to be important however, examples including exports, FDI, migration, technology licensing and electronic exchange.

of domestic resources. Second, by increasing communication between countries, they can encourage a more efficient employment of domestic resources through cross-border learning of production methods, product design, organizational structures and market conditions. Third, they can also assist countries inside the technological frontier in imitating the products of countries at the frontier. Finally, they can raise a country's productivity in the development of new technologies or the imitation of foreign technology.

An empirical literature has been in existence for some time examining knowledge spillovers among industries and firms within countries.[10] Recently, in response to the endogenous theories of trade and growth, a literature aiming to testing for the presence of international knowledge spillovers has emerged. The approach in empirical work has generally been to construct a stock a knowledge" based on past cumulative R&D for each country and then to measure the access of other countries to this by weighting these stocks by some measure of the volume or share of bilateral trade

This is the approach taken by Coe and Helpman (1995) who test for the presence of international knowledge spillovers among a sample of 22 developed countries over the period from 1971 to 1990. They study the extent to which a country's productivity depends upon both domestic and foreign knowledge stocks. The foreign knowledge stock is constructed using the weighted sum of trade partners' cumulative R&D spending. The weights used are bilateral import shares, since it is assumed that it is a country's imports that act as the conduit for knowledge spillovers and that the composition of imports is important (i.e. with whom a country trades). The import share weighted foreign knowledge stock is also interacted with the overall import share to examine the importance of the volume of trade as well as its composition. This specification is justified by referring to Grossman and Helpman (1991a), who relate productivity gains to trade volumes. The results suggest that both domestic and foreign knowledge stocks are important sources of productivity growth, although the former has a much larger impact on productivity in the larger countries. Smaller countries, it is argued, tend to be more open and benefit more from foreign knowledge than larger countries. A number of the results also suggest that foreign R&D capital stocks have stronger effects on domestic productivity the larger the share of imports in GDP. From these results Coe and Helpman (1995) conclude that a relationship between productivity and both the foreign and domestic knowledge stocks exists, with the countries gaining most from foreign knowledge being those that are more open to trade.

The results of Coe and Helpman (1995) have been controversial. Lichtenberg and van Pottelsberghe de la potterie (1998) alter the basic specification of Coe and Helpman's foreign knowledge variable to correct for an aggregation bias, while Keller (1998) re-examines the results of Coe and Helpman and in particular the

[10]See for example Terleckyj (1974) and Griliches (1984).

assertion that a country's benefit from knowledge created abroad is taken to be a trade weighted average of foreign countries knowledge stocks. He compares the estimated results of Coe and Helpman with those obtained from assigning bilateral trade partners randomly and finds that regressions based on simulated data generate on average larger estimated foreign knowledge spillovers, as well as a better fit in terms of $R^2$ , suggesting that the import composition of a country does not have a strong influence on the extent of foreign knowledge spillovers. Coe and Hoffmaister (1999) re-examine the work of Keller noting that the bilateral import shares constructed in the latter are similar to equal weights, or simple averages of trading partners knowledge stocks, suggesting that Keller's weights are not in fact random. Coe and Hoffmaister (1999) derive alternative sets of random weights that do not exhibit this property and find that using these weights the estimated foreign knowledge spillover estimates are extremely small and the equations explain less of the variation in productivity than when the true bilateral import shares are used.

Lumenga-Neso et al. (2002) extend the work of Coe and Helpman (1995) which considers ``direct'' foreign knowledge spillovers by considering also ``indirect'' foreign knowledge spillovers. Such ``indirect'' effects are based on the notion that a country can benefit from another country's knowledge stock even if they do not trade with each other as long as they both trade with a third country. The results of this study are stronger than those found in Coe and Helpman (1995) and show that "indirect" foreign knowledge spillovers are as important as "direct'' ones.

Coe et al (1997) adapt the analysis of Coe and Helpman to examine the extent of North-South R&D spillovers. They test for the presence of foreign knowledge spillovers from 22 developed countries to a sample of 77 developing countries over the period 1971-1990. The method used is similar to that in Coe and Helpman with the results suggesting that foreign knowledge spillovers from the North to the South are substantial. On average, a 1 percent increase in the knowledge stocks of the industrial countries raises productivity growth in developing countries by 0.06 percent. These results have been broadly supported by Engelbrecht (2000) and Falvey et al (2000).

## 3. Model Setup and Estimation

We begin our analysis by setting up a simple, empirically tractable model similar to those put forward extensively in the growth accounting literature. The model allows us to examine the importance of foreign knowledge spillovers for growth in a sample of OECD countries, and to examine whether the extent of such knowledge spillovers is influenced by several educational and institutional variables.

Consider a Cobb-Douglas production function with constant returns to scale and

Hicks neutral technological progress,

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{1-\alpha}, \tag{1}$$

where $Y_{it}$ refers to total production at time $t$ in country $i$, $K_{it}$ is physical capital and $L_{it}$ refers to the labour input. Technological progress, that is the growth of $A_{it}$ between period $t$ and period $t+\tau$ will be assumed to depend on the changes of domestic and foreign stocks of R&D as in Coe and Helpman (1995),

$$\log A_{it+\tau} - \log A_{it} = \gamma_1 (\log RD_{it+\tau}^{d} - \log RD_{it}^{d}) + \gamma_2 (X_{it})(m_{it+\tau} \log RD_{it+\tau}^{f} - m_{it} \log RD_{it}^{f}), \tag{2}$$

where $RD_{it}^{d}$ and $RD_{it}^{f}$ are, respectively, the domestic and foreign R&D capital stock. As in Coe and Helpman (1995), the elasticity of labour-augmenting technology with respect to the foreign R&D capital stock is postulated to depend linearly on the the import share, $m_{it}$. We will further assume that the parameter capturing the absorption of knowledge, $\gamma_2$, may depend on a set of economic and institutional variables ( $X_{it}$ ). In principle, we assume that the diffusion of new technologies is a two stage process. In the first stage, knowledge is transmitted through trade flows, whilst in the second stage it is absorbed by the recipient country. Thus our empirical specification treats trade differently from the other determinants of absorptive capacity, since we assume that trade is necessary for the transmission of knowledge, but does not guarantee absorption.[11]

It should be noted that we will not consider human capital as a standard input of production as has occurred extensively in the growth literature (see for example Mankiw, 1992). Instead, in line with Nelson and Phelps (2002) and Benhabib and Spiegel (1994) and (2003), we will assume that human capital levels affect the ability of a nation to adopt foreign technology, and therefore human capital proxies will be incorporated to the set of variables affecting absorptive capacity in (2).

Using (1) and (2), the expression for the growth rate of income per capita between period $t$ and period $t+\tau$ is given by

[11] An alternative view of the role of trade in this context is presented in Holmes and Schmitz (1995) who argue 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).

$$\log y_{it+\tau} - \log y_{it} = \alpha(\log K_{it+\tau} - \log K_{it}) + \gamma_1(\log RD^d_{it+\tau} - \log RD^d_{it}) + \\ + \gamma_2(X_{it})(m_{it+\tau}\log RD^f_{it+\tau} - m_{it}\log RD^f_{it}) - \alpha(\log L_{it+\tau} - \log L_{it}), \qquad (3)$$

where $y_t$ denotes GDP per capita. Equation (3) is the specification that will be implemented empirically for different variables in $X_{it}$ .

We will proceed by estimating (3) for a panel of 21 OECD countries assuming different specifications for the absorptive capacity parameter. The natural baseline estimation is given by assuming constant absorptive capacity, that is, $\gamma_2(X_{it}) = \gamma_2$ . The countries included in the analysis are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States. The yearly data, spanning the period from 1973 to 1997, were aggregated to five-year non-overlapping sub-periods. The panel has, thus, five observations per country and 105 observations in total. Details concerning data sources and computation of variables are given in the appendix. In all cases, a two-way fixed effects model was used in order to account for cross-country unmodeled heterogeneity and common shocks.

## 4. Estimation Results

The first column of table 1 presents the estimates of the baseline model. The null of constant returns to scale in the aggregate production function cannot be rejected by the data (the corresponding $F$ -statistic equals 1.89 for the baseline model), and is therefore imposed in all estimations. The estimate of $\alpha$ is in line with those widely reported in the literature, and the significantly positive parameter attached to the change in domestic R&D, $\gamma_1$ , provides evidence on the importance of innovation-driven technological progress for a nation's growth performance. The parameter corresponding to the variable capturing foreign knowledge spillovers, $\gamma_2$ , however, although positive is not significant, suggesting that foreign knowledge spillovers are not an important source of growth.[12] Moreover, if the absorptive capacity parameter is assumed country-specific (while keeping the other two parameters equal across countries), none of the estimates appears 5% significant, and only the absorption parameter estimates for the United Kingdom and Norway

[12]Multicollinearity does not seem to play a major role in the lack of significance of the parameter estimate. The correlation between the domestic and foreign R&D variables, although significant at the 5% level is only 0.167.

are 10% significant and positive.[13]

The residuals of the baseline model present significant deviations from Gaussianity, as measured by the Jarque-Bera test statistic. The lack of normality seems to be caused by the observation corresponding to the deep recession experienced by Finland at the beginning of the nineties, for which the baseline model strongly overestimates the growth rate of GDP per capita. The second column of table 1 presents the estimation results if a dummy is included for this observation. The dummy is highly significant and negative, as expected, and the goodness of fit of the model increases enormously. Furthermore, the null of normal distribution of the residuals cannot be rejected now at any reasonable significance level. For all estimations reported henceforth, the dummy will be included.

Our hypothesis is that differences through time and across countries in variables representing the degree of absorptive capacity may be responsible for the lack of significance of the parameter estimates corresponding to foreign R&D spillovers. In order to obtain some evidence on the impact of the variables under consideration on absorptive capacity, we begin by modeling a level-dependent absorption parameter, where the absorptive capacity for foreign R&D depends upon the value of some other variable. The simplest way of assessing the influence of these variables on absorptive capacity is by dividing the sample according to the level of the variable being studied and estimating different absorption parameters for each sub-sample. The model we estimate is thus similar to (3) with

$$\gamma_2(X_{it}) = \sum_{k=1}^{\overline{K}} \gamma_{2,k} \mathrm{I}(X_{it} \in [q_{X,100(k-1)/\overline{K}}, q_{X,100k/\overline{K}})), \tag{4}$$

where $\mathcal{I}(\bullet)$ is the Heavyside function and $q_{X,n}$ is the $n$ -th percentile of the distribution of $X_{it}$ . The choice of regimes with equal number of observations is in principle unjustified, and we will later proceed to estimate and test optimal thresholds (in the sense of least square estimates). However, this simple method should help shed some light on the shape of the relationship between absorptive capacity and institutional and educational variables.

## 4.1 Relative Backwardness

We begin by exploring whether countries with comparatively low levels of per capita GDP benefit more from foreign R&D than rich countries. As such, we test the claim of Gerschenkron (1962) and Kuznets (1973) that technological laggards have the advantage that they can borrow technology from countries at the

[13] The goodness of fit of the model with country-specific absorptive capacities, as measured by the adjusted $R^2$ , is considerably smaller than the one of the baseline model.

technological frontier.

Table 2 reports the results for either real GDP per capita and or relative real GDP per capita as the variable that determines the absorption parameter. Relative GDP per capita is calculated with respect to the richest country in our sample, which is Switzerland. We obtain estimates for $\alpha$ and $\gamma_1$ that are similar to the baseline case. The equation is estimated with two regimes, as suggested by model selection criteria. The absorption parameter is found to be positive and significantly different from zero (at the 10 % level) in the first regime only. As such, the results suggest that foreign knowledge spillovers are important sources of growth in the most backward countries in our sample, but that there are no significant gains from knowledge spillovers in the most advanced countries in our sample.

The remaining columns in table 2 present the estimates of the model if the cutting point of the distribution of (relative) real GDP per capita is explicitly estimated. Maintaining the hypothesis of a two-regime absorption parameter, the $\gamma_2(X_{it})$ function used is

$$\gamma_2(X_{it}) = \gamma_{2,1}\mathcal{I}(X_{it} \leq \lambda) + \gamma_{2,2}\mathcal{I}(X_{it} > \lambda). \qquad (5)$$

The threshold parameter $\lambda$ will be estimated as

$$\hat{\lambda} = {}_{\tilde{\lambda}\in[q_{X,20},q_{X,80}]} \sum_i \sum_t [\hat{\varepsilon}_{i,t}(\tilde{\lambda})]^2,$$

that is, as the least squares threshold in the central 60% of the empirical distribution of $X_{it}$ .[14]

Similar results are obtained when the threshold is estimated, with a positive and significant absorption parameter found in the low-income regime, but an insignificant coefficient found for the high-income regime. The threshold estimate for both, absolute and relative GDP per capita corresponds to the 78th percentile of the empirical distribution. For the models where the threshold was estimated, table 3 also presents the likelihood ratio test statistic for the null of linearity ( $\gamma_{2,1} = \gamma_{2,2}$ ) together with the bootstrap $p$ -value obtained using the methodology described in Hansen (2000).[15] Despite the differences in the absorption coefficient in the two regimes the null of parameter constancy across the regimes cannot be rejected at conventional levels of significance. Overall the results for backwardness suggest that there may be limited gains from foreign knowledge spillovers for relatively backward countries, but that backwardness doesn't appear to be a

[14]For more details on the techniques employed here see Hansen (1996) and Hansen (2000).

[15]The bootstrap distribution of the test statistic was computed using 500 replications of the procedure proposed in Hansen (2000).

sufficient condition for spillovers as suggested by Gerschenkron (1962). In what follows we address notion proposed by Abramovitz (1986) that factors other than backwardness may be needed in order to benefit from foreign knowledge.

## 4.2 Absorptive Capacity, Human Capital and R&D

As discussed in Section 2 human capital and domestic R&D are two additional determinants of absorptive capacity that have been proposed in the literature. The general idea is that a country has to have a well trained workforce and perform some R&D itself in order to successfully absorb foreign technology and knowledge.

Table 3 presents the parameter estimates using educational attainment and domestic R&D investment as the variables that trigger differences in absorptive capacity. The $X$ variable in the second column is "Average years of secondary schooling in the total population over 25", and in the third column, "Average years of higher schooling in the total population over 25". Results for R&D investment as the $X$ variable are reported in the fourth column.

Concerning the educational variables, in both cases, usual model selection criteria choose the two-regime specification ( $\bar{K}$ =2) among models with the number of regimes ranging between two and four.[16] The estimates of $\alpha$ and $\gamma_1$ are largely unchanged by the inclusion of the break in the absorption parameter. The results indicate that significant absorptive capacity tends to be related to higher levels of educational attainment. The sub-sample specific absorption parameters are significantly different from each other (at the 10% significance level) for the case of secondary education, but the model with higher education fails to reject the null of equal parameters across regimes when using a standard $F$ test.

A similar picture emerges for R&D investment. For this variable, model selection criteria indicate three regimes. The point estimates for $\alpha$ and $\gamma_1$ are once again largely unaffected by defining the absorption parameter as a function of R&D investment. According to the results in table 3 countries with relatively high R&D investment (i.e. in the high-regime) are characterized by a significantly larger absorption parameter than countries in the other two regimes.

The results are not qualitatively affected if the cutting points are estimated instead of being set *ad hoc*. When the threshold is estimated, the absorption parameter corresponding to the high education regime is also significant and

[16]This will be the range of models considered in the whole analysis. For the variables studied in the empirical analysis which present time variation, models with more regimes (up to ten) were also tried, but model selection criteria did not tend to choose models outside the range proposed.

positive, while the sub-sample belonging to the regime with low education levels is characterized by insignificant absorptive capacity. The same is true for R&D investment as an explanatory variable, with a positive and significant absorption parameter found for the high R&D investment regime and an insignificant parameter found in the low regime. The least squares estimate of the threshold for secondary schooling corresponds to the 35th percentile of the distribution of secondary schooling across countries in the period from 1976 to 1990 (approximately 2.37 years). For the case of higher education schooling, the estimate corresponds to the 53rd percentile of the distribution (approximately 0.43 years of higher education). For R&D investment, the threshold corresponds to the 70th percentile.

The evidence of a human capital dependent absorption parameter seems to be empirically observable when using secondary education as a proxy, suggesting that countries with higher levels of secondary schooling benefit to a greater extent from foreign knowledge. For higher education the LR test suggests that differences across regimes are not significant. For R&D investment the LR test indicates that linearity is rejected at a high level of significance showing that countries can benefit substantially from foreign knowledge spillovers by investing in R&D themselves.

## 4.3 Absorptive Capacity and Institutional Aspects

Parente and Prescott (2003) argue that market regulation that results in protecting the monopoly rights of industry insiders can act as a barrier to technology adoption. Intuitively, as long as firms are not threatened by the prospect that their competitors might introduce more productive technologies, the firms may prefer to stick to their current technology, although better ones are available. This is particularly likely since the adoption of new technology usually involves significant costs.

In order to test this view we include proxies for the intensity of regulation in $X_{it}$ . We use data on regulatory indicators for product market regulation (collected in Nicoletti et al.,2000) for this purpose. The indicators measure restrictions on competition and private governance on a scale from 0 to 6 (from least to most restrictive). In our analysis, we employ summary indicators for product market regulation and indicators for barriers to entrepreneurship and employment protection.

We begin by analyzing an index of product market regulation (PMR). The summary index of regulation includes information on entry barriers, state control (in particular public ownership) and barriers to trade and investment. Entry barriers cover regulatory restrictions on the number of companies in potentially-competitive markets. The indicator for state control measures the size and scope of the public enterprise sector as well as regulatory features, such as price controls.

Table 4 presents the results of the estimation when the absorption parameter is postulated to depend upon the overall level of market regulation, as measured by PMR. Since this index includes some aspects related to the degree of openness and international competition (e.g. tariffs) that are in some sense already captured in the construction of the foreign R&D stocks, we repeat the estimation with the index of inward oriented product market regulation (IO-PMR).

Using a specification for the absorption parameter such as (4) with $X_t$ = PMR (IO-PMR), AIC chooses for both cases a three-regime specification among those models ranging between two and four regimes. When product market regulation is measured by PMR, the absorption parameter is only positive and marginally significant for the sub-sample attached to low levels (corresponding to the first third of the empirical distribution of PMR) of market regulation. The evidence is stronger if IO-PMR is used as a measure; in this case the parameter corresponding to the sub-sample in the first third of the distribution of inward-oriented product market regulation is positive and 5% significant. Given that there are no significant results for the other regimes, a two-regime specification such as (5) was preferred for the endogenous estimation of the threshold value. The results of the model with a threshold level determined endogenously are presented in the third and fourth columns of table 4. The estimated value of the threshold for the case of PMR corresponds approximately to the 20th percentile of the distribution of the variable, and the picture drawn by the model is similar to that with exogenously set thresholds. The bootstrapped likelihood ratio test, however, cannot reject the null of no threshold effect in this variable. The estimate for the case of IO-PMR is the 33rd percentile of the empirical distribution of IO-PMR, so the results do not differ from the case with exogenous thresholds. The absorption parameter is positive and significant only in the sub-sample corresponding to low inward-oriented product market regulation, and the null of no threshold effect in the parameter is rejected at the 10% significance level.

Next, we isolate the effect of barriers to entrepreneurship (ENT), as an alternative variable that is 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. However, since one might argue that as long as the incumbent firms are protected by sufficiently high barriers to entry, they do not have an incentive to adopt more productive technologies.

We also analyze the impact of labor market institutions as a determinant of absorptive capacity since apart from firms with monopoly rights, unions are another group with vested interests that might potentially oppose the introduction of new (possibly labor-saving) technologies. Another reason why labor relations are important for the absorption of new technologies is that the introduction of new technologies typically involves some fixed costs and whether or not new technologies are implemented might depend on how these costs are shared between firms and workers. As a proxy for labor market institutions we use the index of employment protection regulation (EPL) from Nicoletti et al. (2000) and the data on union density (UD) from from Nickell et al. (2001).

Table 5 presents the results for ENT, EPL and UD.[17] The results presented complement those found for the product market regulation variables. In this case only EPL presents significant threshold effects (in the sense of rejection of the likelihood ratio test when the threshold was estimated endogenously) in the absorption parameter, with positive effects corresponding only to the sub-sample defined by observations of EPL in the first quartile of the distribution (the threshold estimate is roughly the 25th percentile of the empirical distribution of EPL). For UD the estimated threshold corresponds to the 50th percentile and is statistically significant. It appears that higher union density is associated with a higher absorptive capacity. Thus, we do not find that the bargaining power of unions acts as an adoption barrier in our sample.

For ENT the null of no threshold effects can not be rejected at conventional levels of significance although the point estimate for the absorption parameter is substantially larger for smaller values of the respective variables under consideration.

In short these findings appear to confirm that institutional aspects influence to some extent the absorptive capacity of a country. In particular, countries that are characterized by low degrees of product market regulation and employment protection are also characterized by a large degree of absorptive capacity. It has to be noted however that the statistical significance is not always overwhelming. Nevertheless, these results are in line with the ideas advocated by Parente and Prescott (2003) that institutional features that aim at protecting the vested interests of insiders can act as a barrier to technology absorption. In particular, countries that fall below the 33rd percentile of the empirical distribution of the index of inward oriented product market regulation can benefit from stronger spillovers than countries with more regulated product markets. The same is true for countries below the 25th percentile with regard to employment protection regulation. This suggests that countries need to achieve a certain minimum level of competitiveness in goods and labor markets in order to be able to take advantage of the global pool of knowledge.The bargaining power of unions on the other hand does not appear to be a significant absorption barrier.

[17] Data on EPL for Finland were not available, so the estimations including this variable are run excluding Finland from the sample. Similarly, Greece is dropped for the estimation with UD. There were also no available data on union density for Portugal in the period 1983 to 1987 and Spain in the period 1993 to 1997.

# 5. Concluding Remarks

This paper empirically evaluates the determinants of absorptive capacity in industrialized countries. In particular we analyze three broad groups of candidate variables that may affect the ability to benefit from foreign knowledge spillovers: relative backwardness, human capital and R&D expenditure and institutional variables related to absorption barriers.

According to our results, absorptive capacity appears to be increasing in human capital and domestic R&D. Moreover, we find some evidence in favor of the arguments presented in Parente and Prescott (2003) concerning the relevance of institutional variables. In our sample, countries with less regulated goods and labor markets tend to be characterized by high absorptive capacity. However, we find little evidence in favor of relative backwardness facilitating foreign knowledge spillovers. As such our results support the views of Abramovitz (1986) that it is not the ``advantages of backwardness'' that are important for international technology transfer, other factors need to be in place to be able to take advantage of such technology.

# A - Data Description

The data on population, GDP per capita and the share of imports in GDP were taken from the World Bank's *World Development Indicators* Database. Education data was obtained from the Barro-Lee dataset (Barro and Lee, 2001). The source of the capital stock data is the OECD's *Economic Outlook* database for all countries except Portugal, whose data is taken from the European Commission's *AMECO* database. Domestic R&D stocks are constructed out of R&D flow data (source: Universidad Complutense, Madrid) using the perpetual inventory method as in Coe and Helpman (1995). A yearly depreciation rate of 5% was assumed for the computation of the stocks. Foreign R&D stocks for country $i$ were computed, following Coe and Helpman (1995), as the import-share weighted averages of the domestic R&D of country $i$ 's trade partners,

$$RD^f_{i,t} = \sum_{j \neq i} \frac{\eta_{ij,t}}{\eta_i} RD^d_{j,t},$$

where $\eta_{ij}$ is the volume of imports of goods and services from country $j$ to country $i$ and $\eta_i$ is the total volume of imports of country $i$ from all countries in the sample. The data on trade flows are taken from the OECD's *International Trade by Commodity Statistic*.

Data on regulatory indicators, PMR, IO-PMR, ENT and EPL are from Nicoletti et al. (2000). The indicator for union density is taken from Nickell et al. (2001).

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*Table 1: Baseline Model*

| Parameter | Baseline | Baseline with dummy |
|---|---|---|
| α | 0.244* (0.145) | 0.229 (0.144) |
| γ1 | 0.281** (0.127) | 0.352*** (0.100) |
| γ2 | 0.014 (0.009) | 0.014 (0.009) |
| Fin. rec. dummy | – | -0.200*** (0.038) |
| Obs | 105 | 105 |
| JB test | 8.27*** | 0.606 |
| $R^2$adj | 0.397 | 0.506 |

The dependent variable is the 5-year log change of GDP per capita in all specifications. Robust standard errors in parenthesis.***(**)[*] stands for 1% (5%) [10%] significant. Estimation carried out assuming a two-way fixed effects error term. JB test stands for the Jarque-Bera test statistic for normal distribution of the residuals, $\chi^2(2)$ distributed under the null of Gaussian residuals.

Table 2: Absorptive capacity and backwardness: Estimation results

| Parameter | Exogenous threshold | | Estimated threshold | |
|---|---|---|---|---|
| | $X$=GDP p.c. | $X$=Relative GDP p.c. | $X$=GDP p.c. | $X$=Relative GDP p.c. |
| $\alpha$ | 0.229 (0.146) | 0.229 (0.146) | 0.227 (0.143) | 0.223 (0.144) |
| $\gamma_1$ | 0.343*** (0.096) | 0.346*** (0.098) | 0.337*** (0.101) | 0.336*** (0.101) |
| $\gamma_{2,1}$ | 0.021* (0.012) | 0.021* (0.012) | 0.016* (0.009) | 0.017* (0.010) |
| $\gamma_{2,2}$ | 0.006 (0.011) | 0.006 (0.011) | -0.005 (0.018) | -0.006 (0.015) |
| $\lambda$ | – | – | 10.17 | -0.48 |
| LR test | – | – | 1.39 ($p$-val: 0.32) | 1.92 ($p$-val: 0.19) |
| Observations | 105 | 105 | 105 | 105 |
| JB test | 0.55 | 0.53 | 0.51 | 0.45 |
| $R^2_{adj}$ | 0.505 | 0.504 | 0.506 | 0.507 |

The dependent variable is the 5-year log change of GDP per capita in all specifications. Robust standard errors in parenthesis.$^{***(**)[*]}$ stands for 1% (5%) [10%] significant. Estimation carried out assuming a two-way fixed effects error term. JB test stands for the Jarque-Bera test statistic for normal distribution of the residuals, $\chi^2(2)$ distributed under the null of Gaussian residuals. The $p$-value for the likelihood ratio test statistic (LR) was computed using the bootstrap procedure in Hansen (2000) with 500 replications.

Table 3: Absorptive capacity, education levels and domestic R&D investment: Estimation results

| | Exogenous threshold | | | Estimated threshold | | |
|---|---|---|---|---|---|---|
| Parameter | $X$=Second. Educ. | $X$=Higher Educ. | $X$=Dom. R&D growth | $X$=Second. Educ. | $X$=Higher Educ. | $X$=Dom. R&D growth |
| $\alpha$ | 0.243* (0.143) | 0.248* (0.146) | 0.215 (0.149) | 0.250* (0.143) | 0.251* (0.147) | 0.216 (0.139) |
| $\gamma_1$ | 0.322*** (0.098) | 0.345*** (0.099) | 0.333*** (0.093) | 0.331*** (0.096) | 0.345*** (0.099) | 0.324*** (0.089) |
| $\gamma_{2,1}$ | 0.009 (0.010) | 0.008 (0.010) | 0.011 (0.016) | 0.005 (0.010) | 0.008 (0.010) | 0.010 (0.009) |
| $\gamma_{2,2}$ | 0.034** (0.015) | 0.026* (0.014) | 0.009 (0.012) | 0.033** (0.014) | 0.027* (0.015) | 0.054*** (0.019) |
| $\gamma_{2,3}$ | – | – | 0.052*** (0.019) | – | – | – |
| $\lambda$ | – | – | – | 2.37 | 0.43 | 0.17 |
| LR test | – | – | – | 4.08 ($p$-val: 0.08) | 1.89 ($p$-val: 0.26) | 6.96 ($p$-val: 0.02) |
| Observations | 105 | 105 | 105 | 105 | 105 | 105 |
| JB test | 1.13 | 0.94 | 0.82 | 1.31 | 0.89 | 0.91 |
| $R^2_{adj}$ | 0.513 | 0.507 | 0.522 | 0.518 | 0.508 | 0.530 |

The dependent variable is the 5-year log change of GDP per capita in all specifications. Robust standard errors in parenthesis.$^{***(**)[*]}$ stands for 1% (5%) [10%] significant. Estimation carried out assuming a two-way fixed effects error term. JB test stands for the Jarque-Bera test statistic for normal distribution of the residuals, $\chi^2(2)$ distributed under the null of Gaussian residuals. The $p$-value for the likelihood ratio test statistic (LR) was computed using the bootstrap procedure in Hansen (2000) with 500 replications.

Table 4: Absorptive Capacity And Product Market Regulation: Estimation results

| | Exogenous threshold | | Estimated threshold | |
|---|---|---|---|---|
| Parameter | $X$=PMR | $X$=IO-PMR | $X$=PMR | $X$=IO-PMR |
| $\alpha$ | 0.254* (0.15) | 0.265* (0.15) | 0.262* (0.14) | 0.267* (0.15) |
| $\gamma_1$ | 0.321***(0.09) | 0.320***(0.09) | 0.319***(0.09) | 0.322***(0.09) |
| $\gamma_{2,1}$ | 0.035* (0.02) | 0.032** (0.01) | 0.036* (0.02) | 0.032** (0.01) |
| $\gamma_{2,2}$ | 0.003 (0.01) | -0.003 (0.01) | 0.007 (0.01) | 0.003 (0.01) |
| $\gamma_{2,3}$ | 0.009 (0.01) | 0.007 (0.01) | – | – |
| $\lambda$ | – | – | 1.30 | 1.72 |
| LR test | – | – | 2.88 ($p$-val: 0.15) | 3.69 ($p$-val: 0.10) |
| Obs | 105 | 105 | 105 | 105 |
| JB test | 1.12 | 1.25 | 1.31 | 1.08 |
| $R^2_{adj}$ | 0.506 | 0.511 | 0.518 | 0.516 |

The dependent variable is the 5-year log change of GDP per capita in all specifications. Robust standard errors in parenthesis.$^{***(**)[*]}$ stands for 1% (5%) [10%] significant. Estimation carried out assuming a two-way fixed effects error term. JB test stands for the Jarque-Bera test statistic for normal distribution of the residuals, $\chi^2(2)$ distributed under the null of Gaussian residuals. The $p$-value for the likelihood ratio test statistic (LR) was computed using the bootstrap procedure in Hansen (2000) with 500 replications.

Table 5: Absorptive Capacity, Barriers To Entrepreneurship And Employment Protection Legislation: Estimation Results

| | Exogenous threshold | | | Estimated threshold | | |
|---|---|---|---|---|---|---|
| Parameter | $X$=ENT | $X$=EPL | $X$=UD | $X$=ENT | $X$=EPL | $X$=UD |
| $\alpha$ | 0.279* (0.153) | 0.356** (0.151) | 0.183 (0.151) | 0.267* (0.149) | 0.357** (0.147) | 0.183 (0.151) |
| $\gamma_1$ | 0.321*** (0.092) | 0.321*** (0.090) | 0.353*** (0.098) | 0.315*** (0.094) | 0.320*** (0.088) | 0.353*** (0.098) |
| $\gamma_{2,1}$ | 0.032* (0.019) | 0.035* (0.018) | -0.011* (0.015) | 0.032* (0.016) | 0.035* (0.018) | -0.011* (0.015) |
| $\gamma_{2,2}$ | -0.001 (0.015) | 0.002 (0.011) | 0.025**(0.011) | 0.004 (0.011) | 0.001 (0.001) | 0.025**(0.011) |
| $\gamma_{2,3}$ | 0.014 (0.012) | 0.004 (0.018) | 0.015 (0.010) | – | – | – |
| $\lambda$ | – | – | – | 1.30 | 1.10 | 0.401 |
| LR test | – | – | – | 3.15 ($p$-val: 0.14) | 4.07 ($p$-val: 0.08) | 7.081 ($p$-val: 0.03) |
| Ob | 105 | 100 | 98 | 105 | 100 | 98 |
| JB test | 1.37 | 1.19 | 0.982 | 1.16 | 1.24 | 0.982 |
| $R^2_{adj}$ | 0.506 | 0.522 | 0.537 | 0.514 | 0.528 | 0.537 |

The dependent variable is the 5-year log change of GDP per capita in all specifications. Robust standard errors in parenthesis.$^{***(**)[*]}$ stands for 1% (5%) [10%] significant. Estimation carried out assuming a two-way fixed effects error term. JB test stands for the Jarque-Bera test statistic for normal distribution of the residuals, $\chi^2(2)$ distributed under the null of Gaussian residuals. The $p$-value for the likelihood ratio test statistic (LR) was computed using the bootstrap procedure in Hansen (2000) with 500 replications.