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Regional integration and economic development: An empirical approach

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Regional integration and economic development: An empirical approach

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Abstract

This paper contributes to the empirical literature by providing a quantitative measurement of the influence of regional trade integration on productivity. For this purpose we address the link between trade and productivity thanks to knowledge spillovers in a multi-country model. The interdependence that connects countries in an international web promotes exchanges of goods, services, people, capital and hence ideas, knowledge, innovation, and technology. Economic integration encourages thus both new ideas and their diffusion. We observe that a country's productivity depends on its own R&D efforts as well as the R&D efforts of its trading partners. These R&D spillovers can then spread across countries and sectors. Thanks to the transfer of technology allowed by bilateral trade and investment, regional trade integration has a positive impact on long-term growth.

Keywords: regional economic integration, endogenous growth, economic geography

JEL classification: F12, F15, F43, O18, O30, O41, R11, R12, R13

1 Introduction

The topic of this paper is trade-led productivity. Due to the small number of theoretical and empirical papers trying to assess the impact of regional trade integration, we propose in this paper a model whose purpose is the measurement of the effects of a regional trade area (RTA) as the European Union on the growth of its members. Whereas Baldwin and Venables (1995) recognize the probable long-term effects of regional integration, the Cecchini report (1988) did not mention them. Here, we test some of Dion (2004) key assumptions and conclusions, i.e. the role of an RTA in fostering trade and growth.

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Economic geography by combining insights from international trade and industrial organization theories has provided a framework to analyze the effects in terms of localization of activities following economic integration. Empirically speaking, current RTAs provide interesting examples to test whether the theoretical developments conform to the observed reality. Traditionally, expectations for the European integration have considered that the peripheral nations will experience a convergence process catching up with the central economies. The models of new economic geography however consider that further integration might in the contrary reinforce the concentration of the economic activity in the center of the continent.

We are thus interested in two issues related to knowledge spillovers : 1) the respective influence of RTA membership and geographic distance on trade and 2) the impact of trade on knowledge capital. To estimate these effects, we first examine the geographic dimension in terms of flows of goods and capital at the international level. And then, we test whether knowledge capital is related to foreign trade and investment. Knowledge spillovers are limited by geographic distance, in the sense that knowledge spreads through formal and informal contacts. The geographic component of knowledge is present of course in the geographic theory but also in the growth theory. Grossman and Helpman (1991) have insisted that knowledge has to be a public good spreading to other regions to be the motor of international convergence in growth rates.

Indeed, the existence of spillovers implies that a country's total factor productivity (TFP) will be determined by both domestic and foreign R&D conducting to a convergence of growth rates across countries. At the sectorial and national level, it has been established that spillovers do exist (Griliches, 1992). International spillovers have also been noticed in several studies (Coe and Helpman, 1995; Nadiri and Kim, 1996). The link between domestic and foreign R&D expenditures is an expression of a common stock of knowledge shared by trade partners exchanging goods containing ideas. It appears in our analysis that flows in goods and capital are indeed an important channel of international diffusion of R&D. Thanks to trade, knowledge can spill over trading partners and investment recipients. Interestingly, and as described in the literature on gravity equations, trade and foreign direct investment (FDI) patterns rely strongly on distance. These spatial conditions provide potential measures of the extent of knowledge spillovers as channels of technology diffusion.

Our framework will allow us to draw a link between regional integration, geography and growth. Indeed, the primal goal of this paper is to estimate a regression of knowledge on trade and other variables, instrumenting for trade using geographic variables. The model, along the lines of Frankel and Romer (1999), consists then of two main steps. The first uses gravity equations to construct the instruments for trade, and the second uses the instruments to examine the relationship between trade and knowledge. That is: we will first use gravity equations to assess to which extent distance (or geography) and the membership to an RTA affect the flows of goods and foreign direct investment (FDI). We will then investigate the impact of trade on total factor productivity (TFP) thanks to a knowledge production function based on bilateral trade and investment. We will thus be able to tell whether trade and FDI are channels of technological diffusion in promoting growth [1].

Distance is supposed to determine the volume of trade between two trade partners. So, we shall control whether the distance between countries affects the magnitude of productivity gains obtained from each others' R&D spending. In a case of global spillovers, respective stocks of knowledge or spatial factors play no role. Conversely, if spillovers are predominantly local, then distance has an impact and stocks of knowledge are essentially domestic in nature although augmented by the eventuality of trade (in that acceptation trade exemplifies exchanges in assets containing "knowledge"). According to our model, technology diffusion is related to international trade, itself geographically localized. Geography (distance corrected by the development of transaction costs) affects trade and thus knowledge spillovers.

The remainder of the chapter is as follows. Section 2 establishes the empirical setting in which we build our analysis and describes the equations of the model. Section 3 presents the results. Section 4 concludes and suggests directions for further work.

2 Empirical model

This section addresses the theoretical underpinning directly leading to the formation of the empirical equations. Our model consists of fourteen econometric models : a model for each of the EU countries [2]. In that way we can provide a much more accurate and sharp picture of the effects we want to show than in a compact analysis that does not allow for a proper distinction between countries. The model is composed of four equations : two gravity equations and two knowledge production functions. Each pair of equations is indeed composed of one equation for bilateral trade and one equation for bilateral investment.

Current EU countries have all pursued liberalizing policies but the degree and magnitude of their trade policies overtime still allow us to distinguish among them and isolate the impact of their membership to a specific RTA. We will focus in our empirical exercise on the European case for several reasons. First of all, the European Union has been the most effectual preferential trading arrangement over the last forty years when compared with other groups such as the East African Common Market or the Latin American Free Trade Association [3]. Secondly, the EU can propose robust data over a long period and facilitate hence econometric testing and estimation. Thirdly, the European integration proposes a framework rather close to the specification of our theoretical model (see Dion 2004).

We estimate the following equations on a cross-section time-series analysis over a period of twenty-five years (from 1975 to 2000). We have been looking for

[1] The case of previously lagging countries joining a regional agreement (such as the cohesion countries for the EU) will be explicitely addressed.

[2] Belgian and Luxembourg are combined; see the whole list of countries in the Appendix.

[3] However, the new breed of free trade areas (e.g. NAFTA) seems to have real effects.

the longest period possible since the steps of further integration (both deeper and larger) are numerous in the case of the European Union. Since we are going to study each country, we will be able to distinguish the ones taking the most advantage of openness. Our objective is to use the two sets of approaches, gravity and knowledge equations, to build a model that determines the impact of regional integration on trade and productivity. We also look for the respective effects of RTA on small and big economies since the theoretical literature has not always been conclusive on that issue.

2.1 Gravity equations

We use gravity equations to discuss the impact of distance and RTA membership on bilateral flows of goods and capital. The gravity equation allows us to discuss the specific effect of an RTA on trade along the traditional economic variables such as GDP, population or distance between pairs of countries. We are interested in distance since we want to check whether the marginal cost of transferring knowledge rises with distance. To test the importance of spatial proximity (the influence of geography symbolizes the effect of transport costs) we thus use distance variables.

The effect of the RTA is captured by the inclusion of a dummy variable. The use of dummies helps to discuss the role of voluntary biases or policies taken by countries to reinforce their bilateral trade such as in the case of an RTA. Our dummies are equal to one when we want them to display the impact of an RTA membership, share of a border or of the language. As control variables we use GDP. We also use market size variables in terms of size effects thanks to population/area parameters : to measure the size of countries we can either rely on population or land area. Since trade theory does not provide clear guidance about the best measure of size, we use alternatively these two natural measures. Usually, the larger the country, the less open it is due to economies of scale or access to natural resources.

The influence of language has as much to do with the easiness to communicate in the same idiom as a cultural factor to display common interests with individuals sharing a pool of the same values [4]. Some of the variables increase the cost of doing business abroad, while some others reduce it. In order to gather the maximum of information at once we choose to pool time-series and cross-country data. We can also perform more meaningful tests due to the large amount of observations that are now at our disposal. We display below the functions we wish to study:

$$M^{ij} = f(Y^j, Pop^j, Dist^{ij}, Border^{ij}, Lang^{ij}, RTA^{ij}) \quad (1)$$

[4] Here, we do not need to test for remoteness (also called "overall distance") since we strictly consider one model per country. Moreover, all the countries considered belong to the same continent. We do not need either to include a measure of per-capita GDP since mathematically this is equivalent to use GDP and per-capita GDP or GDP and population. Furthermore, we have not introduced a measure of landlockedness since all these countries (apart from Austria) have access to the sea and possess harbors.

$$M^{ij} = f(Y^j, Area^j, Dist^{ij}, Border^{ij}, Lang^{ij}, RTA^{ij}) \quad (2)$$

$$FDI^{ij} = f(Y^j, Pop^j, Dist^{ij}, Border^{ij}, Lang^{ij}, RTA^{ij}) \quad (3)$$

$$FDI^{ij} = f(Y^j, Area^j, Dist^{ij}, Border^{ij}, Lang^{ij}, RTA^{ij}) \quad (4)$$

with M^{ij} and FDI^{ij} respectively bilateral trade and investment between i and j; Y: GDP; Pop: population; $Area$: area; $Dist^{ij}$: distance between the two capitals; $Border^{ij}$: common border; $Lang^{ij}$: common language; RTA^{ij}: common RTA [5]. We are then able to sort out the respective influence of geographical proximity versus preferential trading policies in creating regional concentration of trade.

The evolution of investment as measured by bilateral FDI inflows is complicate since investment and trade are partly substitutes and partly complements (although the latter seems to overtake the former). To check the degree of substitutability or complementarity we could introduce a measure of bilateral investment as an explicative variable of bilateral trade. The trouble is that we might face endogeneity problems since several factors affecting trade also affect investment. In order to avoid such trouble we could rely on lagged data. Unfortunately, this trick may be useless since FDI might be caused by trade rather than the other way round. Frankel (1997) observed that whereas bilateral investment has a positive impact on trade, the other gravity variables keep their strength or are slightly weaker. In any case, we choose to run the same kind of regressions for both bilateral trade and bilateral investment since they both appear as channels in our theoretical model (see Dion 2004).

2.1.1 Bilateral trade equations

We display below the equations we estimate [6]:

$$\log M_t^{ij} = \left[\begin{array}{c} \alpha + \beta_1 \log(Y_t^j) + \beta_2 \log(Pop_t^j) + \\ \beta_3 \log Dist^{ij} + \beta_4 Border^{ij} + \beta_5 Lang^{ij} + \\ \beta_6 RTA^{ij} + \epsilon_t^i \end{array} \right] \quad (5)$$

$$\log M_t^{ij} = \left[\begin{array}{c} \alpha + \beta_1 \log(Y_t^j) + \beta_2 \log(Area_t^j) + \\ \beta_3 \log Dist^{ij} + \beta_4 Border^{ij} + \beta_5 Lang^{ij} + \\ \beta_6 RTA^{ij} + \epsilon_t^i \end{array} \right] \quad (6)$$

[5] Domestic features such as domestic GDP or population do not appear in the equation due to their endogeneity with the trade variable. However, they will be captured by the intercept. Indeed, by running regressions using a country dummy, we have noticed that the influence of domestic characteristics were well captured by the intercept.

[6] We can use the log of either the trade share over domestic GDP or the trade level without modifying the interpretation of our results.

2.1.2 Bilateral investment equations

$$\log FDI_t^{ij} = \left[\begin{array}{c} \alpha + \beta_1 \log(Y_t^j) + \beta_2 \log(Pop_t^j) + \\ \beta_3 \log Dist^{ij} + \beta_4 Border^{ij} + \beta_5 Lang^{ij} + \\ \beta_6 RTA^{ij} + \epsilon_t^i \end{array} \right] \quad (7)$$

$$\log FDI_t^{ij} = \left[\begin{array}{c} \alpha + \beta_1 \log(Y_t^j) + \beta_2 \log(Area_t^j) + \\ \beta_3 \log Dist^{ij} + \beta_4 Border^{ij} + \beta_5 Lang^{ij} + \\ \beta_6 RTA^{ij} + \epsilon_t^i \end{array} \right] \quad (8)$$

2.2 Knowledge equations

In order to build our knowledge equations, we need to rely on fitted gravity equations (Section 2.2.1) in order to measure the impact of trade on knowledge (Section 2.2.2).

2.2.1 Fitted gravity equations

In order to determine the implications of our estimates for the geographic and trade policy component of countries' trade, we use the fitted values from the estimated bilateral trade equation. We can then obtain a geographic and trade policy (the membership to the EU) component of country's i trade, T^{ij}. This means that we first rewrite our bilateral trade equations along the lines of Frankel and Romer (1999) under the following form:

$$\log T_t^{ij} = \alpha' X_{ij} + \varepsilon_{ij} \quad (9)$$

where T^{ij} being either bilateral trade, M^{ij}, or bilateral investment, FDI^{ij}. Furthermore, α is the vector of coefficients in the gravity equations and X_{ij} is the vector of right-hand side variables. By definition, T^{ij} is country i's bilateral trade with each other country in the world. Our strategy is therefore to begin with an equation for T_t^{ij} as a function of the distance between countries, their sizes, their RTA membership, and so on. We then use the estimated equation to find a fitted value of T_t^{ij} in order to find a geographic and trade policy component of T_t^{ij}. In that sense, the variation in openness that is due to geographic and membership factors can be used to determine the effects of trade [7].

Because the variables in our gravity equations are close to being exogenous while strongly correlated with trade, they could play the role of adequate instrumental variables. By using the values predicted by the gravity model in order to instrument for the trade variable in the knowledge equation we are able to stress a link between trade and growth. If indeed trade appears to be a significant determinant of available knowledge, then we will have identified a causal and not spurious effect. The correlation between the fitted trade values and

[7] We build the instruments for trade using two approaches. In each case, we first estimate a bilateral trade equation and then use the fitted values of the equation to estimate countries' bilateral trade. The two approaches differ in the size variables of the economy included in the bilateral equation. In the first, we consider the area of the partner country whereas in the second we use the population of the partner.

actual trade values is indeed rather high (around 0.7 according to the country). Depending on the country, the t-statistic in a regression of the actual trade on the fitted value is around 10.

Note also that in their paper, Frankel and Romer (1999) recognize that they are unable to identify the specific mechanisms through which trade affects growth. However, we will see in the next section that, by modifying Frankel and Romer's model, it is possible to describe the functioning of one of the main channels through which trade fosters long-term growth, that is through knowledge spillovers. We can then also answer two questions raised in Frankel, Romer and Cyrus (1996, p. 5) in the case of East Asian countries although with similar implications for the EU countries.

That is, in their own words : "To the extent that there is a Solow residual in the growth equation and it is associated with trade, how much of it can be explained by the proximity of the East Asian countries to trading partners (...) ?" And "Is part of the growth residual explained by the trade share residual, i.e. to outward oriented policies, or to other unknown factors excluding proximity to rapidly growing trade partners ?" In the following analysis, we will be able to specify the effects of trade policies such as membership to an RTA as well as identify the transmission channels.

2.2.2 Knowledge production equations

We propose two knowledge equations; one for imports and one for FDI. Indeed, our theoretical model (see Dion 2004) had shown that both imports of goods and services and inflows of FDI were acting as channels for technology transfers and convergence. Our knowledge functions are built in a traditional manner. Obviously, we could use growth terms in order to better measure the intensity of the explicative variables. In the case of R&D, it would allow us to use R&D intensity to measure the social rate of return of R&D. In that case, we do not need to estimate the rate of depreciation of the R&D stock.

However, since we want to check whether the endogenous growth models are consistent, we ought to rely on level terms and build an error correction mechanism (ECM frameworks). The presence of lagged TFP allows us to consider the presence of a conditional convergence effect. In order to measure the delay of transmission, our formulation gives us the lags attached to the foreign R&D variable before it affects the domestic R&D. Every country can potentially benefit from foreign R&D through trade since they can cumulate their own domestic R&D with the trade-weighted R&D of their partners. They thus have access to an available stock of knowledge higher than their own.

The general setting Trade-related foreign R&D is the weighted average of foreign-produced R&D, where the weights are calculated thanks to bilateral import shares.

$$A^i = f\left(A^d; M^{ij}A^j\right) \tag{10}$$

where A^i is the stock of knowledge available to the i country, A^d is the stock of domestic knowledge owned by i, A^j is the stock of foreign knowledge available to j and M^{ij} is a matrix of bilateral trade weighted by import shares (the ratio of imports from j to i on total imports from all j's to i and/or on domestic GDP and/or on foreign GDP depending on the variable of interest). The use of import-share weighted sum of the foreign R&D capital stocks imply that the more imports, the more R&D spillovers potential benefits.

At the international level, part of the technological diffusion is cross-country and travels notably through trade and FDI and any other channel of communication allowing the exchange of new ideas and innovation. We consider that foreign knowledge and domestic knowledge combine and do not cancel out each other due to the trade filter. Indeed, if the exact same products with the exact same features were produced in two different locations, none of the partners would have any incentive to trade it. So that domestic and foreign knowledge enter our equation as complements and not substitutes. Moreover, since the time lags of each form of knowledge can differ, they can hardly be pure substitutes.

The weights attributed to each foreign stock of knowledge are calculated in terms of bilateral imports shares or FDI inflows. Most of imports and FDI are indeed related to intermediate and investment goods, exactly those that are most surely carrying the most technology. Moreover, the presence of consumption goods is still important to assess the impact of disembodied knowledge (Frantzen, 2000). Here we consider true knowledge spillovers : true externalities since they are not strictly covered by market transactions due to their public good features.

R&D takes time to bear fruits, so that the use of lagged variables is useful to reflect the presence of a stock of knowledge in which past R&D still has a role even if decreasing in importance. Likewise, the impact of innovation on present output also takes a lag, time for the patents to transform into new goods. Moreover, the time lags should be longer for the foreign than for the domestic R&D.

The way Coe and Helpman (1995) built their TFP variable means that they did not try to determine the elasticities of labor and capital but inferred what α and A in a traditional Cobb-Douglas production function should be in a world of constant returns and perfect competition. Instead of using reconstructed TFP data, we prefer to proxy A thanks to patents as a measure of the residual and let the model determine the elasticity coefficients [8].

[8] Patents despite their inconveniences are still the best measure of the output of knowledge and of the inventive activity for which we have data (statistics on new products unfortunately do not exist). Patents express well the idea of partially public and private knowledge, since although made public, they still keep secret part of their specific innovative features. Obviously it is problematic to consider patents as our sole TFP variable since learning by doing (LBD) and human capital also play a major role. But LBD and human capital are more inputs than outputs of R&D and they in any case appear in the production inputs. Finally, patents are complicate measures, since they cannot simply add up to form a stock of knowledge. Indeed, some new patents can cancel out older ones instead of complementing them. However, former patents indeed enter the output function through their impact on the traditional factors.

The specific setting We use the traditional knowledge-driven production function in order to capture the impact of R&D spillovers on domestic TFP, itself measured by patents (P) generated in the domestic economy. Patents award its inventor a temporary monopoly power for the commercialization of a specific device.

$$\log P_t^i = \left[\alpha + \beta_1 \log A_{t-1}^d + \beta_2 \left(\frac{\log \hat{M}_{t-1}^{ij} * \log P_{t-2}^j}{\log Y_{t-1}^i}\right) + \epsilon_t^i\right] \quad (11)$$

$$\log P_t^i = \left[\alpha' + \beta_1' \log A_{t-1}^d + \beta_2' \left(\frac{\log \hat{I}_{t-1}^{ij} * \log P_{t-2}^j}{\log Y_{t-1}^i}\right) + \epsilon_t^i\right] \quad (12)$$

where α is a country specific constant. β_1 is the output elasticity of the domestic R&D capital stock A_t^d. β_2 is the output elasticity of the foreign R&D capital stock interacted with either trade imports or FDI inflows. $\hat{M}^{ii} = 0$ and $\hat{I}^{ii} = 0$. $\hat{M}$ is a matrix of the imports of country i from country j constructed from the fitted gravity equations (and similarly with $\hat{I}$ for FDI).

In order to measure both the direction and the intensity of the imports, the import matrix should be corrected thanks to a ratio of bilateral imports over domestic GDP (Coe and Helpman, 1995 and Lichtenberg and de la Potterie, 1998). This specification allows the elasticity to vary across countries in proportion to their import shares. An alternative measure is to use the ratio of total imports over domestic GDP measuring then the global intensity to import. These different combinations allow us to figure out the impact of openness on domestic TFP but also the impact of R&D in the trade partner on domestic TFP. What is essential is both the intensity of imports and the direction of these imports from highly R&D-endowed trade partners [9].

We therefore obtain an equation where TFP relies on domestic and foreign stocks of knowledge. The latter being channeled through bilateral trade and investment. Our explicative variables are in effect all lagged in order to take into account the time lag of knowledge spillovers. The spillovers work through the matrices of bilateral trade and investment relations. Since, by estimating the two main channels in the same equation we face the risk of multi-collinearity between the channels, our regressions indeed separate the two channels.

Strictly speaking we get parameters measuring the propensity to patent. The use of patents as pointed out in Jaffe (1986) can lead to two opposite effects: positive when patent is a true vehicle of spillover and negative in case of a patent race (harsh competition for a limited pool of available patents). With low flows of patents and strong rivalry, we might even experience a negative impact of foreign or domestic R&D. In a global approach, we would not be able to distinguish between the various European countries. Here, we can check which countries are victims of a patent race.

[9] As in Lichtenberg and de la Potterie (1998), we reject the indexation procedure used by Coe and Helpman (1995) [where the foreign R&D capital stocks are indexed] since it would lead to misspecification where the use of an index year misses the level effect. It is indeed unnecessary since all our variables are in the same constant prices and currency.

Because of the lack of bilateral matrices at the sectorial level, we restrict our present work to the aggregate level. However, we do distinguish between the national and international stocks of knowledge that are at the basis of our analysis. We are thus more in the literature assessing the role of trade as a mechanism of international spillovers (Coe and Helpman, 1995; and Keller, 1998) than in the literature trying to measure the magnitude of these spillovers within and across countries (Jaffe and al. 1993; and Eaton and Kortum, 1999). In our model, bilateral trade is also country-specific (the impact of domestic and foreign R&D differs according to the country) and is endogenously determined in the model thanks to gravity equations.

3 Empirical results

Rather than discussing each single country case, we prefer drawing a global picture although pointing out a few particular cases when necessary. The coefficients of the variables are of the expected signs and statistically significant. Tables 1, 2, 3 and 4 present the parameter estimates of the model and their t statistics [10]. All the ones mentioned in plain text are statistically significant at the 95% level of confidence. The fact that previously lagging economies such as the cohesion countries (Portugal, Ireland, Greece and Spain) partially caught up implies that a center-periphery pattern is no fatality and that, seen dynamically, regional integration can break the tendency to concentrate the whole production in the former richer and bigger countries. For the cohesion countries (except Ireland [11]), the impact of the membership to the EU is at its strongest in comparison with the other member countries.

Furthermore, the share of foreign R&D to their available R&D is for the cohesion countries also relatively stronger than for the more advanced economies, suggesting convergence thanks to international knowledge spillovers. Industrialization with high growth rates has thus been observed in several countries after joining other trade partners. Trade appears indeed to be the main channel of diffusion. It infers that the decline in the degree of localization is due to the increased openness of the EU economies with each other. A more recent reason of the decrease in the degree of localization might be found in the development of new technologies of information and communication (TIC).

3.1 Gravity functions

It appears that in our framework regional trade integration increases bilateral imports of goods, services and capital (i.e. exports of the partners) [12]. An

[10] Results are displayed in tables that contain two lines per country. The first line presents the parameter values and the second line the t-values.

[11] In the Irish case, the effects of the EU integration have been mostly indirect through massive FDI from non-member countries such as the USA or Japan eager to invest in the European community.

[12] However, the case for trade diversion does exist. Indeed, we do observe a negative impact of RTAs on 2 members, GBR and DNK, but only in the case of FDI.

interesting distinction is between population and area parameters. We observe two interesting results : 1) The impact of population is stronger than area size on both bilateral trade and bilateral FDI, 2) The use of population reinforces the impact of GDP in both cases and attenuates the impact of the RTA membership in the case of FDI. These results are linked and lead to a possible conclusion that population by better reflecting the size factor also better reflects the market size effect of the economies than the area parameter.

In addition, the coefficients on exporter's GDPs are often above 1 and statistically significant. They are particularly strong for small countries and in the case of FDI inflows. This indicates that rich and small economies trade more but also that trade in goods, services and especially capital can increase more than proportionately as GDP expands. However, we shall notice that this interpretation relies on our specification allowing the distinction between GDP and population as two measures of size. The tendency of trade to rise less than proportionately with size is reflected in the population coefficient that is less than zero.

Note also the strong discrepancies in the coefficients according to the countries considered. Between the weakest and the strongest coefficient for a same variable in two different countries, the impact of GDP may almost double. This provides evidence that a global study grouping together different economies erases the margin of differentiation among the EU members. However, two results appear relatively troublesome. Although in general positive, the share of a common border and of a common language displays in a couple of cases a negative influence.

In the case of language, this surprising result concerns three countries (Belgium, France and Italy) but only for the trade in goods and services. Part of the explanation may come from the fact that their trade partners sharing their language also share a common border. The negative sign for the sharing of a common border in the case of bilateral investment would suggest that adjacency could create a negative bias towards higher inflows but here again it may be due to the simultaneous sharing of a common language. Indeed, after testing for this restriction, it appears that the negative sign disappears and that the coefficient on adjacency and common language clusters around 0.5.

We notice that distance displays as expected a strong negative effect on the volume of trade. Our distance coefficient clusters around respectively -0.7 and -0.8 in the bilateral trade function with *pop* and with *area*. They reach -1 in the case for bilateral investment. Note however, that the latter results may be partly explained by the almost non-significance of the coefficients for common border. In any case, such estimates imply that when the distance is increased by 1 percent, trade falls by about 0.7 to 1 percent. The strong impact of proximity (although not adjacency in the case for investment) may also stress the importance of local features; let them be localized knowledge spillovers, local cultures, habits or tastes. These local features obviously vary slowly overtime and it seems quite difficult to weaken their strong influence or encourage their spreading.

3.1.1 Bilateral trade function

The results are straightforward and show the very positive impact of an RTA membership as the EU. The positive impacts of GDP (wealth factor), border and language are conform to our expectations since wealth, proximity and cultural links encourage the commerce between close and similar partners. Likewise, the negative impact of distance on bilateral trade is as expected, as well as the negative effects of size variables (population and area). Trade decreases with a partner country's population. This is a confirmation of the statement made above that smaller countries trade relatively more than larger ones simply because they engage less in within-country trade. Moreover, population is usually more significant than area as a way to benefit from scale economies or "natural" resources.

Since bilateral flows are expressed in logarithms, we need to take the exponent of the coefficient on a dummy variable to interpret it. For instance in the case of the RTA variable, it appears that since its coefficient reaches 0.63 in the case of Spain for bilateral trade with *pop*, we can then establish that its membership to the EU has increased its bilateral trade by more than 80% [exp(0.6)=1.82]. Broadly speaking, we note that Portugal, Greece and Spain have experienced the strongest impact of the membership to the EU on their bilateral trade.

3.1.2 Table 1a : Bilateral trade equation with *pop*

	gdp	dist	rta	pop	border	lang	c	$\bar{R}^2$	s.e.r.
AUT	0,98	-1,24	0,22	0,05	0,43	0,18	-11,69	0,9	0,64
t	24,22	-30,97	3,04	1,05	4,9	2,23	-22,8		
BEX	1,05	-0,51	0,21	-0,17	0,99	-0,13	-13,99	0,91	0,51
t	33,15	-17,8	2,93	-4,78	10,89	-2,64	-33,74		
DEU	0,87	-0,78	0,34	-0,07	0,19	0,19	-7,45	0,9	0,46
t	30,94	-30,29	7,83	-2,29	2,77	2,75	-20,81		
DNK	1,13	-0,54	0,19	-0,63	0,85		-9,23	0,7	0,82
t	20,29	-13,25	2,2	-10,34	5,37		-13,16		
ESP	1,23	-0,73	0,63	-0,43	0,45	1,92	-12,85	0,89	0,54
t	31,19	-18,91	9,35	-10,6	4,41	12,09	-26,03		
FIN	1,44	-1,22	0,11	-0,71	-0,12		-10,87	0,84	0,72
t	19,72	-23,01	1,06	-8,35	-1,24		-18,18		
FRA	0,97	-0,66	0,43	-0,17	0,68	-0,35	-9,96	0,94	0,41
t	34,57	-30,58	7,73	-5,79	14,94	-6,49	-27,93		
GBR	1,13	-0,57	0,16	-0,53		0,6	-8,69	0,85	0,52
t	33,65	-17,74	2,33	-15,38		8,58	-19,2		
GRC	1,17	-0,85	0,69	-0,46			-11.01	0,84	0,64
t	21,84	-14,64	13,1	-8,11			-23,46		
IRL	1,43	-0,78	0,01	-0,39	1,75	-0,2	-20,18	0,87	0,73
t	27,32	-10,8	0,11	-6,88	9,89	-1,62	-28,04		
ITA	1,02	-0,77	0,53	-0,22	0,33	-0,13	-10	0,91	0,45
t	31,75	-18,14	11,03	-6,18	6,7	-2,84	-29,29		
NLD	1,08	-0,62	0,11	-0,21	0,43	0,63	-13,04	0,9	0,52
t	31,5	-25,36	1,69	-5,34	7,68	10,93	-28,21		
PRT	1,36	-0,9	0,33	-0,64	0,67		-12,53	0,84	0,67
t	26,42	-19,04	4,06	-11,66	5,34		-16,92		
SWE	1,32	-1,18	-0,14	-0,55	0,18		-9,85	0,87	0,65
t	20,47	-32,66	-1,3	-7,51	2,38		-17,31		

3.1.3 Table 1b : Bilateral trade equation with *area*

	gdp	dist	rta	area	border	lang	c	$\bar{R}^2$	s.e.r.
AUT	1,13	-1	0,18	-0,28	0,64	-0,17	-13,03	0,92	0,55
t	52,53	-28,36	3,03	-13,3	6,58	-1,61	-26,56		
BEX	0,92	-0,49	0,24	-0,04	0,94	-0,03	-13,21	0,91	0,52
t	54,67	-13	3,33	-2,07	10,8	-0,63	-34,77		
DEU	0,94	-0,67	0,07	-0,27	0,03	-0,03	-7,62	0,93	0,38
t	80,66	-32,44	1,63	-21,63	0,45	-0,44	-30,72		
DNK	0,64	-0,58	0,13	-0,06	1,11		-5,88	0,61	0,93
t	17,83	-10,64	1,43	-1,52	6,04		-7,2		
ESP	0,93	-0,47	0,79	-0,19	0,54	1,38	-11,95	0,88	0,57
t	40,35	-13,18	11,84	-8,97	6,95	9,98	-21,92		
FIN	0,99	-0,89	0,5	-0,27	0,8		-10,48	0,8	0,79
t	39,65	-13,97	7,69	-8,77	6,75		-15,15		
FRA	0,84	-0,63	0,48	-0,04	0,63	-0,23	-9,28	0,93	0,42
t	59,52	-23,86	8,59	-3,09	13,91	-4,66	-27,94		
GBR	0,79	-0,61	0,01	-0,19		1,08	-5,78	0,8	0,61
t	39,37	-16,26	0,12	-7,19		14,59	-13,27		
GRC	0,91	-0,55	0,54	-0,32			-10,45	0,85	0,61
t	41,75	-10,72	10,17	-15,61			-20,25		
IRL	1,23	-0,9	-0,21	-0,32	0,51	0,84	-16,4	0,88	0,7
t	40,63	-13,32	-1,7	-7,89	2,52	4,96	-29,23		
ITA	0,88	-0,67	0,49	-0,09	0,42	-0,14	-9,34	0,91	0,47
t	46,14	-15,48	9,32	-4,39	9,26	-2,49	-25,49		
NLD	0,92	-0,63	0,09	-0,02	0,48	0,58	-11,91	0,9	0,54
t	47,48	-21,12	1,32	-1,28	8,96	10,81	-26,48		
PRT	0,88	-0,68	0,66	-0,16	0,76		-10,55	0,8	0,76
t	22,91	-14,72	7,01	-7,99	5,24		-10,66		
SWE	1,01	-0,86	0,15	-0,31	1,07		-9,65	0,86	0,65
t	50,46	-19,22	2,35	12,77	12,1		-17,49		

3.1.4 Bilateral investment function

Although, we use the same variables as in the former function, we note that RTA seems to be less significant as a determinant of FDI inflows in most of the cases than in the case of trade in goods and services. Since FDI are partly complements partly substitutes for trade, the membership to an RTA does not imply an automatic increase in the flows of capital. This might also depend on the existence of an agreement allowing for the mobility of capital within the regional trade area. In the EU case, the free movement of capital were implemented in 1993.

However, it was observed that FDI inflows augmented before each significant step of the European integration process. And finally, the true efficiency of the capital markets may be put into doubt. Nevertheless, we find the same signs for the other variables included in the gravity equation, although the sharing of a common border does not seem to affect FDI inflows. Conversely, distance keeps its strong negative effect on capital flows. This is evidence that despite the progresses in technology, investment is still affected by a geographic component. More traditionally, richness and cultural proximity still favor capital flows [13].

3.1.5 Table 2a : Bilateral investment equation with *area*

	gdp	dist	rta	area	border	lang	c	$\bar{R}^2$	s.e.r.
AUT	1,4	-0,85	1,18	-0,29	-1,25	2,4	-25,46	0,55	1,42
t	11	-4,68	4,67	-2,46	-2,54	5,31	-9,94		
BEX	1,41	-0,43	-0,06	-0,38	-0,01	0,7	-26,84	0,67	1,33
t	13,36	-2,45	-0,19	-3,63	-0,03	2,27	-14,39		
DEU	1,6	-1,05	-0,37	-0,32	-0,24	0,07	-25,92	0,64	1,38
t	15,83	-7,15	-1,24	-3,78	-0,87	0,19	-15,51		
DNK	0,91	-1,83	-1,91	0,02	-0,02		-7,41	0,44	1,71
t	6,96	-8,3	-5,29	0,15	-0,06		-3,25		
ESP	1,14	-0,65	0,69	-0,06	0,16		-20,67	0,66	1,24
t	11,49	-4,06	2,71	-0,62	0,62		-11,59		
FIN	1,41	-1,32	0,94	-0,35	1,75		-21,64	0,38	1,57
t	5,78	-4,2	2,27	-1,59	2,18		-4,53		
FRA	1,21	-0,85	0,47	0,05	-0,68	0,74	-21,79	0,69	1,24
t	15	-6,52	1,58	0,5	-3,5	2,19	-14,74		
GBR	1,32	-0,89	-0,81	-0,5		2,69	-16,65	0,62	1,39
t	19,67	-7,64	-3,11	-5,34		7,35	-10,72		
GRC	1,71	-0,72	-0,06	-0,71			-29,36	0,55	1,38
t	9,34	-2,36	-0,16	-4,08			-8,11		
IRL	1,54	-1,08	-0,72	-0,91	-3,52	3,58	-17,96	0,5	1,74
t	12,17	-4,59	-1,49	-5,66	-5,67	6,35	-6,68		
ITA	1,77	-1,58	-0,34	-0,1	-0,43	0,68	-29,46	0,68	1,28
t	16,53	-6,58	-1,11	-1,16	-1,47	1,39	-16,07		
NLD	1,37	-0,49	-0,23	-0,15	-0,29	1,15	-25,71	0,54	1,74
t	10,9	-2,24	-0,63	-1,22	-1,03	3,43	-12,62		
PRT	0,96	-0,99	1	-0,06	0,09		-14,65	0,57	1,31
t	9,96	-4,9	4,11	-0,62	0,21		-6,41		
SWE	1,58	-1,87	0,23	-0,58	1,7		-17,69	0,47	1,57
t	9,43	-7,49	0,69	-2,97	2,97		-5,52		

[13] The relatively stronger impact of these variables in comparison with the bilateral trade case might justify the introduction of additional regressors more specific to FDI such as exchange rates and interest rates.

3.1.6 Table 2b : Bilateral investment equation with *pop*

	gdp	dist	rta	pop	border	lang	c	$\bar{R}^2$	s.e.r.
AUT	2,04	-0,91	0,54	-0,97	-0,9	2,11	-28,95	0,57	1,38
t	6,65	-5,52	2,16	-3,01	-1,76	4,31	-8,83		
BEX	2,02	-0,66	-0,13	-0,9	-0,02	0,59	-28,92	0,7	1,26
t	14,73	-3,29	-0,58	-6,23	-0,05	1,99	-17,11		
DEU	2,35	-0,82	0,01	-1,09	0,14	0	-33,23	0,71	1,23
t	17,61	-5,12	0,03	-7,2	0,58	-0,01	-20,99		
DNK	2,46	-1,53	-1,39	-1,66	0,13		-22,92	0,55	1,55
t	7,66	-6,94	-4,06	-4,91	0,42		-6,17		
ESP	1,91	-0,93	0,25	-0,81	0,32		-25,84	0,68	1,19
t	9,85	-6,22	1,04	-3,84	1,37		-13,38		
FIN	3,22	-1,48	0,07	-2,37	0,86		-32,85	0,54	1,35
t	8,85	-5,19	0,2	-6,79	2,13		-8,07		
FRA	2,07	-0,87	0,17	-0,96	-0,28	0,14	-27,62	0,75	1,11
t	16,59	-6,78	0,67	-7,02	-1,81	0,51	-18,52		
GBR	2,38	-0,57	-0,27	-1,48		0,79	-28,28	0,74	1,14
t	20,49	-5,34	-1,38	-11,98		3,21	-17,55		
GRC	2,25	-0,57	1,12	-1,22			-33,89	0,53	1,42
t	8,17	-1,89	3,41	-4,31			-9,98		
IRL	3,26	-0,69	0,06	-2,29	0,44	0,9	-39,76	0,62	1,54
t	10,88	-3,17	0,17	-7,72	0,9	2,54	-12,71		
ITA	2,53	-1,48	-0,07	-0,99	-0,44	0,19	-35,39	0,72	1,18
t	15,42	-6,34	-0,25	-5,37	-1,71	0,41	-17,59		
NLD	2,29	-0,41	0	-1,1	-0,55	1,7	-34,18	0,59	1,64
t	12,99	-1,84	0,01	-5,57	-2,04	5,91	-15,87		
PRT	2,28	-1,49	0,44	-1,35	0,35		-23,91	0,63	1,21
t	9,21	-8,16	1,79	-5,42	0,93		-8,47		
SWE	3,05	-2,14	-0,23	-1,9	0,71		-30,13	0,6	1,36
t	9,44	-8,33	-0,65	-5,71	1,82		-7,44		

3.2 Knowledge functions

Description of the results The results of our econometric exercise are broadly consistent across the samples and the specifications we considered : trade raises knowledge. The relationship between the geographic component and RTA membership for trade on the one side and knowledge on the other side implies that a rise in the shares of imports in GDP increases knowledge. It also appears that both types of R&D, domestic and foreign, combine and are both highly significant, although their respective magnitude depends on the size of the economy. The smaller the economy (the more open), the higher the impact of foreign R&D [14].

[14] The best results are obtained with a lag of one to three years for the effect of knowledge to current domestic innovation.

The impact of domestic R&D in big countries is higher than the impact of foreign R&D. Then, it appears that knowledge spillovers, despite further integration, are (still) more local than global but only in the case of trade in goods and services. And vice-versa for small countries. The size factor does not interfere in the case of knowledge through FDI. Through the impact of R&D expenditures on patents, we see that R&D indeed fosters innovation. The coefficients of domestic and foreign R&D imply an important social rate of return at the domestic and international levels. As expected, large countries benefit relatively less from foreign R&D than smaller countries for two main reasons. First of all, they are in the average less open and so receive less knowledge spillovers from abroad. Secondly, being large, these countries build domestic stocks of knowledge of large size that might be of comparably higher importance than foreign stocks.

The presence of lagged TFP catches the conditional convergence effect due to technological diffusion. Indeed, we notice an interesting distinction between bilateral trade and bilateral investment influences. In the case of bilateral trade, coefficients on the short-term variables (the ones in first differences) are usually of a lesser magnitude than the ones on the long-term variables (the ones in levels). Whereas in the case of bilateral investment, we observe the opposite results. This would imply that changes in terms of both foreign and domestic R&D investments over the short-run did not strongly affect the long-term relationship in the case of bilateral trade. However, there is much more volatility in the case of bilateral investment since we observe that short-run changes have a strong impact on the long-run equilibrium.

Each channel appears to be associated with knowledge spillovers, although trade in comparison with FDI has a much more significant impact. We are able to assess a significant impact of FDI on domestic TFP although of a smaller magnitude than the one of trade. The somehow surprising low impact of FDI might be explained in several ways. Our main explanation is that FDI inflows usually precedes official implementations of further integration. So that its impact might be significant but is difficult to measure empirically since its development appears some time before the agreement comes into action. This is also possible that the R&D content of FDI is less R&D intensive than usually expected or is restricted to the subsidiaries without reaching the whole economy.

Interpretation of the results In rare cases, we observe a negative spillover impact of R&D on patents. This phenomena has been already observed in several studies (Jaffe, 1986; Branstetter, 1996; Bottazzi and Peri, 1999 among others). They explain it by the technological rivalry and secrecy characteristics embedded in patents that might overtake the benefits of patenting. This argument had been previously discussed in several theoretical contributions [15]. Forced into a patent race and competing for a limited pool of available patents, the R&D coefficient can become negative. The opposite effects introduced by the patent race and stronger competition also reflect the imitation effect that

[15] See Tirole (1988) for a reminder.

crowds out part of the monopoly profits.

Only a few countries seem to be concerned by patent races. Apart from the cases of Greece and Portugal that, due to a lack of data, could not provide estimates for some variables, three countries may be of interest. In the knowledge equation with bilateral trade (*pop*), Denmark has a significant negative coefficient on the short-term impact of foreign R&D. Likewise, in the knowledge equation with bilateral investment (*pop*), we also find a significant negative coefficient on long-term domestic R&D for France and Great Britain. This might be evidence for a patent race, although some further analyses focused on their respective patent systems would be necessary to ascertain that fact.

By combining our previous analysis of the gravity equations with our current one we can point out several results. First of all, it seems that international knowledge spillovers are geographically localized. Distance, as expected, has a negative impact, meaning that knowledge is localized, since it implies that the R&D of countries far away contribute to domestic TFP less than the R&D of countries closer. Confirming the assumption of the new theories of growth, it appears that levels of R&D determine the growth of productivity. We recall that the traditional theories of growth would have thought that growth in R&D would have explained that result. Furthermore, it appears that bilateral trade flows are the main channel of transmission for technological transfer and it depreciates along geographic distance. So, your trading partners should have a high stock of knowledge that you can add to your own.

We have thus been able to correct some of the caveats encountered in the previous literature. First of all, the combination of geographic, RTA membership and size parameters did not erase the impact of each of this factor on trade since they all remained highly significant. They thus all provide a large amount of information about the relationship between trade and knowledge and emphasize the benefits of trade for TFP. Secondly, the introduction of the RTA membership variable allows us to qualify the effects of trade policies. Among the different ways through which trade affects knowledge, we are thus able to distinguish between variations in openness due to geography and variations due to policies. Since changes in policies are easier to implement than changes in geography, our results suggest that trade policies fostering trade shall be encouraged.

Thirdly, we have been able to identify one of the channels through which trade affects growth, namely technology in the sense of TFP. We already know that trade affects growth through several channels : comparative advantage (classical trade theory), greater exploitation of IRS (new trade theory), new policies disabling trade restrictions related to lobbying and rent-seeking actions (public choice and trade theory), technology (new growth theory). Here, access to FDI, commercial contacts, share of a common knowledge pool are all providing incentives to boost technology in the partner countries. Geographic features are, by definition, hard to modify. Conversely, policies towards freer trade and R&D investment are easier to implement and allow important benefits [16].

[16] Due to the lack of homogenous R&D data for Germany over the sample considered, the

3.2.1 Table 3a : Knowledge equation with bilateral trade (*pop*)

	dR&D$_f$	R&D$_f$	dR&D$_h$	R&D$_h$	pat	c	$\bar{R}^2$	s.e.r.
AUT	-0,09	1,13	0,55	0,2	-0,9	10,19	0,73	0,05
t	-2,76	24,78	0,2	3,37	-13,51	23,53		
BEX	4,02	5,66	-7.98	-3,85	-0,59	42,23	0,95	0,02
t	62,58	52,63	-45,02	-27,64	-7,16	52,31		
DNK	-3,69	7,69	4,86	-2,18	-1,45	47,66	0,8	0,15
t	-11,82	17,92	10,3	-12,72	-21,36	17,4		
ESP	0,49	0,24	1,3	0,52	-0,45	0,98	0,63	0,09
t	9,08	6,5	14,1	7,41	-9,84	3,09		
FIN	0,58	0,37	6,47	1,21	-0,68	-2,13	0,6	0,16
t	3,16	5,94	10,9	10,21	-10,5	-3,59		
FRA	0,29	0,38	0,1	0,16	-0,72	7,29	0,66	0,02
t	13,67	17,67	2,05	8,79	-17,24	17,41		
GBR	0,06	0,25	0,73	0,17	-0,57	5,3	0,92	0,01
t	5,48	46,6	41,74	11,66	-40,42	41,47		
GRC	-2,96	2,41		0,44	-1,18	14,14	0,76	0,09
t	-10,75	12,57		6,46	-17,21	12,64		
ITA	0,23	0,49	0,72	1,19	-1,88	10,73	0,64	0,04
t	6,97	13,15	9,13	17,31	-15,57	13,56		
NLD	0,39	0,57	0,89	0,21	-0,57	4,88	0,73	0,04
t	8,94	11,47	10,86	7,58	-20,4	10,67		
PRT	3,66	-2,38		3,51	-0,9	-16,51	0,83	0,18
t	16,3	-15,68		28,83	-28,89	-21,74		

results for that country are not displayed. Likewise, Ireland and Sweden failed to appear due to restrictions on the fitted gravity equations for *pop*.

3.2.2 Table 3b : Knowledge equation with bilateral trade (*area*)

	dR&D$_f$	R&D$_f$	dR&D$_h$	R&D$_h$	pat	c	$\bar{R}^2$	s.e.r.
AUT	0,4	1,19	0,73	0,12	-1,04	12,23	0,8	0,04
t	10,19	24,57	8,16	2,96	-19,02	25,21		
BEX	0,28	0,83	-1,76	-0,2	-0,16	4,29	0,79	0,05
t	4,45	9,7	-11,45	-2,59	-4,73	8,48		
DNK	2,97	1,52	2,13	1,22	-0,72	2,04	0,62	0,21
t	11,96	5,75	2,63	13,35	-14,96	2,28		
ESP	0,55	0,21	1,44	0,41	-0,32	0,42	0,66	0,09
t	17,63	5,98	15,38	6,02	-7,68	1,49		
FIN	1,19	0,23	6,33	1,29	-0,68	-3	0,75	0,13
t	8,88	4,97	14,33	14,84	-13,48	-6,92		
FRA	0,17	0,4	0,53	-0,02	-0,39	5,39	0,67	0,02
t	8,76	20,01	14,94	-1,11	-10,66	17,25		
GBR	0,04	0,24	0,89	0,36	-0,54	3	0,89	0,01
t	5,35	39,37	48	31,07	-50,01	37,76		
GRC	-6,58	3,67		0,17	-1,23	18,83	0,96	0,04
t	-56,24	47,06		6,23	-64,26	47,87		
IRL	0,52	0,91	2,48	0,26	-0,34	2,24	0,36	0,28
t	1,81	4,46	8,06	2,01	-7,89	2,85		
ITA	0,19	0,48	0,62	1,14	-1,74	9,68	0,6	0,04
t	6,26	11,96	7,85	15,59	-14,33	12,67		
NLD	0,24	0,74	0,9	0,29	-0,95	8,43	0,75	0,04
t	4,91	17,02	12,13	5,98	-20,01	18,54		
PRT	2,83	-2,13		2,9	-0,82	-13,07	0,91	0,13
t	29,42	-26,91		67,33	-42,84	-45,74		
SWE	0,49	0,46		0,35	-0,8	6,45	0,52	0,07
t	13,5	8,32		16,78	-18,47	11,02		

3.2.3 Table 4a : Knowledge equation with bilateral investment (*pop*)

	dR&D$_f$	R&D$_f$	dR&D$_h$	R&D$_h$	pat	c	$\bar{R}^2$	s.e.r.
AUT	0,27	0,56	0,86	0,39	-1,23	13,1	0,48	0,06
t	8,64	14,34	6,06	6,63	-11,24	14,17		
BEX	3,13	2,61	6,84	3,57	-5,9	44,69	0,72	0,05
t	16,33	16	12,55	12,84	-14,53	15,83		
DNK	0,16	0,4	5,67	0,74	-0,56	2,08	0,43	0,25
t	1,72	4,27	5,15	8,13	-7,8	1,54		
ESP	0,17	0,38	1,28	0,78	-0,78	3,62	0,57	0,1
t	2,66	11,99	14,64	11,09	-13,74	9,09		
FIN	0,14	0,11	5,17	1,1	-0,51	-2,91	0,57	0,17
t	4,25	1,98	10,1	6,45	-9,03	-2,21		
FRA	0,23	0,37	0,18	-0,3	-0,66	12,25	0,72	0,02
t	18,26	26,54	3,86	-8,73	-8,63	19,36		
GBR	0,08	0,27	0,11	-0,5	-0,54	12,21	0,79	0,02
t	3,88	20,38	2,8	-8,15	-18,23	23,25		
GRC	-0,12	1,15		0,38	-1,08	15,6	0,77	0,09
t	-1,87	12,4		5	-17,04	12,49		
ITA	0,51	0,3	0,49	1	-2,17	16,1	0,79	0,03
t	11,69	25,02	7,18	21,24	-26,01	25,46		
NLD	0,31	0,21	1,02	0,27	-0,56	4,32	0,59	0,05
t	7,76	4,21	11,89	3,49	-9,61	3,32		
PRT	1,05	-1,23		2,1	-0,25	-16,08	0,72	0,18
t	3,83	-7,2		9,76	-27,62	-7,64		

3.2.4 Table 4b : Knowledge equation with bilateral investment (*area*)

	$dR\&D_f$	$R\&D_f$	$dR\&D_h$	$R\&D_h$	pat	c	$\bar{R}^2$	s.e.r.
AUT	0,26	0,2	0,65	0,57	-0,79	5,29	0,81	0,04
t	3,65	3,06	5,31	6,36	-18,34	5,96		
BEX	2,15	1,43	1,88	0,15	-1,36	18,4	0,81	0,04
t	20,61	12,49	8,81	1,7	-12,6	11,8		
DNK	3,5	0,63	7,12	1,35	-0,62	-0,71	0,66	0,2
t	14,38	4,24	5,72	18,5	-14,13	-0,73		
ESP	0,63	0,23	1,52	0,5	-0,39	1,07	0,65	0,09
t	12,33	6,05	15,53	7,43	-9,22	2,6		
FIN	1,34	0,08	3,91	0,84	-0,43	-1,99	0,98	0,03
t	51,97	4,12	46,27	57,79	-36,65	-7,49		
FRA	0,26	0,33	0,48	-0,07	-0,41	7,08	0,68	0,02
t	10,2	15,3	8	-2,47	-10,2	15,81		
GBR	0,02	0,19	0,87	0,31	-0,57	4,16	0,88	0,01
t	2,67	36,55	44,69	25,59	-46,53	37,36		
GRC	-0,54	0,93		0,49	-0,86	11,21	0,51	0,13
t	-5,89	9,78		4,15	-13,29	9,9		
IRL	1,1	0,9	1	1,37	-0,6	3,89	0,54	0,23
t	11,94	4,72	4,17	13,6	-21,03	3,85		
ITA	0,26	0,38	0,76	1,11	-1,95	13,24	0,68	0,04
t	7,37	13,56	10,43	17,85	-16	14,04		
NLD	0,32	0,26	0,69	0,4	-0,56	3,49	0,62	0,05
t	4,15	4,41	5,32	6,25	-10,44	4,11		
PRT	5,01	0,6		0,17	-0,2	3,28	0,85	0,13
t	15,41	6,55		2,53	-21,13	4,58		
SWE	-0,08	0,06		0,13	-0,23	1,72	0,83	0,01
t	-13,28	8,86		13,67	-69,55	13,27		

4 Conclusion

In this chapter we have analyzed the effects of regional trade through international knowledge spillovers on the productivity of the EU countries. We find that regional economic integration has, through the liberalization of trade and its consequent international transmission of knowledge, a positive impact on growth. Knowledge spillovers contribute to the formation of a higher available stock of knowledge than the domestically produced one. The link between international trade and knowledge transfer seems to be strong, lending support to the endogenous growth view (Grossman and Helpman, 1991). Moreover, this knowledge transfer affects TFP and ultimately growth. We can thus confirm the view expressed in the parent theoretical chapter (Dion, 2004) that knowledge spillovers have a positive impact on growth through trade.

An important limitation of our analysis, is that due to a lack of data, we focus on the EU economies. Our conclusions might be different if we also consider the

Rest Of the World (ROW) economies. Moreover, at our high level of aggregation we cannot pretend to establish the precise type of the spillovers and the sectors and industries concerned. The further step will be to pursue the analysis at a more disaggregate level but by still relying on bilateral matrices of import shares at the industry level. Although some of the economies of scale, strong at the aggregate level, might partially disappear at a lower level.

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6 Appendices

6.1 Appendix 1 : Data sources

Data come from the World Bank, the WTO and the OECD. Main data sources are the OECD's Main Science and Technology Indicators (for the data on patents and R&D), the WTO Economic and Research Division (for the data on distance and on the dummies) and World Bank's World Development Indicators database (for all the other macro-economic data). The unit of observation is at the country and year level. Our measure of M is a country's total imports of goods and services. Likewise, FDI measures inflows of foreign direct investment. Both are in constant prices.

We consider for each EU country its exchanges with its OECD trade partners. The use of dummies such as language, borders and so on are included because they are supposed to influence the volume of trade and thus make transfers of knowledge through numerous channels more effective. The series on distance measures kilometers between the capital cities of the countries. Y is GDP in constant prices.

Total factor productivity is traditionally defined as value added divided by factor-share weighted capital and labor inputs $[TFP = Y/(K^{\beta}L^{1-\beta})]$. However, as explained earlier, we do not rely on this specification here and use patents as a proxy for TFP. Following much of the literature we use R&D expenditures to proxy the domestic (input) stock of knowledge. So that patents play the role of output while expenditures play the role of inputs. Using depreciation rates for R&D of 0%, 5% or 10% change slightly the magnitude of the impact but not our conclusions.

Country name	**Acronym**
Austria	AUT
Belgium-Luxembourg	BEX
Germany	DEU
Denmark	DNK
Spain	ESP
Finland	FIN
France	FRA
Great Britain	GBR
Greece	GRC
Ireland	IRL
Italy	ITA
Netherlands	NLD
Portugal	PRT
Sweden	SWE

Variable name	Acronym
Imports of goods and services	M
Inflows of foreign direct investment	FDI
Distance between capitals	$Dist$
Gross domestic product	Y
Population	Pop
Border (dummy)	$Border$
Language (dummy)	$Lang$
Membership to a regional trade area (dummy)	RTA
Area	$Area$
Domestic R&D	$R\&D_h$
Foreign R&D	$R\&D_f$
Patents	pat
Domestic R&D (first difference)	$dR\&D_h$
Foreign R&D (first difference)	$dR\&D_f$

6.2 Appendix 2 : Econometric analysis

Our econometric analysis makes use of pooled regression and error correction mechanism. It also displays a complete simultaneity, stability and sensitivity analysis.

6.2.1 Pooled regression and cointegration

We create one pool per country and its trade partners. So that we assume that the coefficients for each trade partner in each pool are the same for all i. So that - in the specification we present here - we do not allow for fixed, random or weight effects. The GLS estimator reduces to pooled ordinary least squares.

A couple of unit roots tests in panel data have been recently developed [17]. The objective has been to associate information from the time-series dimension with that from the cross-section dimension. The first approach is to test for a null hypothesis as a generalization of the standard Dickey-Fuller test, in that all series in the panel are assumed to exhibit non-stationarity. The presence of some stationary series in the panel would reject the null. The second approach is to consider that the null hypothesis expects some series in the panel to be $I(0)$ processes. Enough evidence of non-stationarity would lead to rejection.

The first approach has been proposed by Levin et al. (2002) and the second by Im et al. (1997) [18]. These two tests have also served as residual based test for cointegration. For instance, Pedroni (1999), has proposed a residual based test for the null of no cointegration similar to the Engle-Granger two-step estimation. Actually, these tests statistics for unit roots and cointegration are

[17] See Banerjee (1999) for an overview.

[18] However, we shall note that both tests encounter an important limitation since they assume away the eventual dependence between the sections of the panel. There is currently no standard accepted econometric model that corrects for this limitation.

in our specification all significant so that the hypothesis of stationarity and no cointegration are strongly rejected.

Although we chose to pursue this exercise in the case of the knowledge production function, we renounce to do it in the case of the gravity equations for two reasons. First of all, the unit root tests cannot handle the specific nature of dummy variables. Secondly, no gravity models have yet rely on cointegration and very few have introduced dynamics since they are mostly concerned by the space or geographic dimension and less by the time consideration. Nevertheless, some further research in that field may provide some potentially interesting results.

Due to the relative novelty of the approach and lack of standard procedures, our results shall thus be taken in a cautious way. Indeed, we do not currently dispose of strong enough econometric foundations to pretend having used the most absolute best technics. Due to the lack of standard cointegration tests for pooled data, we cannot expect drawing a finite line on the common best practice to test for cointegration in panel data. However, we do consider that our model is best specified relatively to our theoretical approach and that it does provide useful insights on the relationship between regional trade and economic growth.

6.2.2 Simultaneity, stability and sensitivity analysis

Simultaneity We have to correct for the possible simultaneity biases between trade and TFP and R&D and TFP. We correct the first by using ratios of bilateral imports over GDP. The TFP equations might also be subject to simultaneity bias, that would prevent the use of the OLS where the regressors and the error would be correlated. By lagging R&D, we can partially correct for simultaneity between R&D and TFP. In order to minimize the effects of eventual simultaneity, we rely on further specification choices. Our variables are not based on common (and too similar) bases.

We have tried to choose explicative variables independent from one another in order to avoid the risk of multi-collinearity. Indeed, whereas TFP is approximated by patents, R&D is measured by expenses in the sector. We checked it by noticing that the standard errors and the degree of partial correlation of the coefficients of the variables were low and performing the Hausman specification test. More generally, our use of aggregate data limits the risks of simultaneity. And finally, thanks to our ECM framework we are able to break the occurrence of spurious correlation. The use of instrumental variables (IV) is thus unnecessary [19].

Stability We have also performed a stability analysis to control whether the impacts have changed overtime. We have done so by dividing the whole

[19] In the case of the gravity equations, it has been shown (Frankel, 1997) that income variables or IV for income did not modify the results so that the endogeneity of income makes little difference. Here, moreover, by relying only on foreign income, we reduce even further the danger of endogeneity.

period into two shorter sub-periods delimited by a major step of further integration. In order to control whether the impact of distance had changed overtime, we have built segmented estimation of a deepening in the regional integration process (the Single Market of 1993), in order to assess whether integration "reduces" distance, or more correctly, whether the progressive phasing-out of trade barriers is expressed through a diminishing impact of distance.

We have used Hansen's test in order to distinguish between the different sub-periods. The decomposition in sub-periods allowed us to control the variation of the impact of several variables overtime. By separating the whole period in two subsections we have been able to measure the evolution and the intensity of the impact overtime and check whether there appears a discontinuity.

Indeed, it appears that gravity equations have not shown a decrease overtime in the effect of distance suggesting that geography still matters or that transaction costs have not declined. The lack of evolution in the impact of the distance variable might be at first troublesome. However, although transportation costs have obviously decreased overtime, it is still possible that it has decreased both over short and long distance. In that case, there is no reason why the variable should see its influence decrease, since it measures the marginal impact of distance (the marginal cost per percentage increase in distance). It appears that geography (or distance) has a strong limiting impact on the flows of goods and investment, but despite increased globalization, distance has kept its limiting power. After building two sub-samples, we noted that there are as many examples of a (almost imperceptible) decrease in the impact of distance as increase or neutral impact.

Sensitivity Our sensitivity analysis consists in distinguishing between two types of approaches. First of all, we propose equations based on either trade in goods and services or foreign direct investment. This allows us to appreciate the relative impact of each channel on TFP. Secondly, we provide estimations using either population or area as size parameters. This permits to point out the relative impact of each one of these a priori close substitutes in terms of size effects. We see indeed that the relative impact may considerably differ according to the variable we use.