Technology Spillover Effects and Economic Integration:

Evidence from Integrating Countries

Kurt A. Hafner*

August 2012

University of Heilbronn, Germany

Abstract

The paper focuses on the impact of R&D expenditure on labor productivity of economically integrating countries using patent-, trade- and FDI-related technology diffusion channels. Time series for Greece, Ireland, Portugal and Spain representing European integration and for Mexico joining the free trade agreement with the USA and Canada are based on a set of 32 OECD countries for a time period from 1981 to 2008. Accounting for nonstationary data and cointegration, the paper uses the single equation EC model and finds empirical evidence for foreign technology spillover effects for Ireland (patent- and trade-related), Portugal (patent-related) and Spain (FDI-related). Moreover, there are significant impacts of foreign technology spillover effects for Ireland and Portugal from European economic integration no matter if technology diffusion is restricted to EU-12 or EU-15 countries, whereas for Mexico no such evidence from joining NAFTA is found.

JEL Classification: C22, O30, R12

Keywords: Technology Diffusion, Economic Integration, Nonstationary Time Series, Cointegration, Single Equation EC Model

* Hafner: University of Heilbronn, Department W2, Max-Planck-Straße 39, 74081 Heilbronn, Germany. Tel: +49-7131-504516; Fax: +49-7131-252470; Email: kurt.hafner@hs-heilbronn.de.

1 Introduction

In May 2004 and January 2007, Central and Eastern European Countries joined the European Union (EU) thus augmenting the membership to 27 countries. In the decades before, several waves of integration steadily increased the number from originally six founding members in 1957 to 15 member countries by the end of the last century. Amongst the first countries to join the post-formed European Community were Greece, Ireland, Portugal and Spain, which experienced a remarkable economic development since then and prior to the financial crisis in 2008/2009. Moreover, the North American Free Trade Agreement (NAFTA) between the USA, Canada and Mexico became effective by January 1994 allowing goods, capital and (to some degree) factors to flow almost freely. According to Hufbauer and Schott (1993), NAFTA was the first reciprocal free trade agreement between a developing country and developed countries outside the EU. Since then Canada and Mexico have become the US's first and second largest trading partner respectively with a direct impact on the US-economy ranging from relocation of industrial activity towards the US-Mexican border to outsourcing of labor-intensive production to Mexico.

Economic integration seems to benefit acceding countries in catching up economically. However, it is not the only source of growth and prosperity. Following Keller (2004), the adoption of foreign technology is understood to promote and strengthen economic development as well. Again, further economic integration may spur technology diffusion through a tighter relationship, but not necessarily. Bilateral trade, for example, is considered to transfer technology between trading countries regardless of geographical proximity. If technology is mainly embedded in intermediate goods, then trade in intermediate goods gives countries access to foreign know-how. Multinational firms, as another example discussed by Kleinert and Tobal (2010), diffuse technological know-how and technology through FDI and their affiliates abroad. And finally, the pattern of international patenting according to Eaton and Kortum (1999) indicate of where ideas are going and therefore reflect the link between the source and the destination of transferred technology. Since relationships between countries are getting closer within economically integrating regions, spatial integration and technology diffusion lead to self-reinforcing processes spurring and fostering economic development.

According to Keller (2004) empirical work looking for macro (and micro) evidence for technology spillover effects is mainly based on bilateral trade and FDI as traditional approaches like in Coe and Helpman (1995) and Branstetter (2005) rather than on foreign patents. Studies from Jaffe and Trajtenberg (2002) and Hafner (2008) use the pattern of international patenting to determine the flow of technology but ignore the impact of economic integration on acceding countries. To address these issues, the paper uses time series based on a set of 32 OECD countries for the period 1981-2008 and refers these to Greece, Ireland, Portugal and Spain representing European integration and to Mexico joining the free trade agreement with the USA and Canada. The empirical analysis focuses on the impact of R&D expenditure on labor productivity and uses patent-, trade- and FDI-related technology diffusion channels. It is tested first if the time series are of the same integrated order and second if cointegration relationships amongst two or more time series exists. In cases where time series are near integrated, and cointegration might or might not exist, the use of Engle and Granger (1987)'s two-step EC model becomes problematic and estimation results are likely to be spurious. To avoid such problems, dynamic single equation regressions like ADL models or–equivalent–single equation EC models leads to unbiased estimates of long-run relationships.

The paper is organized as follows. The next section reviews the literature on technology spillover effects. Section 3 outlines the theoretical framework, whereas Section 4 discusses the data. Nonstationary issues and estimation techniques are covered in Section 5. The results of the testing procedures and empirical estimations are given in Section 6. Section 7 presents conclusions.

2 Technology Spillover Effects

Are international R&D spillovers trade-related and is technology mainly embodied in intermediate goods? Coe and Helpman (1995), among others, confront this question empirically by relating the direction of technology diffusion to bilateral trade shares and analyzing the impact on total factor productivity (TFP) of a panel of 22 OECD countries over 1971-90. They find that trade-related spillover effects are present and are stronger the more open an economy to international trade and that causation runs mainly from R&D to productivity than vice versa. Keller (1998), however, shows by Monte Carlo simulations that randomly created bilateral trade patterns explain more of the variation in TFP than those empirically observed. Additionally, long-run trended data such as productivity and R&D expenditure require appropriate estimation techniques to avoid spurious results. In applying a more sophisticated estimation technique on the data set of Coe and Helpman (1995) and through re-examining their econometric findings, Kao, Chiang and Chen (1999) confirm the impact of domestic R&D on TFP but reject any diffusion of foreign technology. Recently, Savvides and Zachariadis (2005) find in their study with a panel of 32 countries for the period 1965-92 that foreign

R&D has the biggest impact on domestic productivity if technology is embedded in intermediate goods rather than in capital goods or FDI. Kramer (2010) comes to the same result using a panel with 47 countries for the period 1990-2006 and applying panel unit roots and cointegration techniques. Moreover, the same study concludes that transition countries from Eastern Europe and Central Asia have higher productivity gains from international technology diffusion than Western countries. At the country study level, empirical work on trade-related spillover effects, for example, have been done for Malaysia by Ghatak, Milner and Utkulu (1997), for Taiwan by Biswal and Dhawan (1998) and for Mexico by Cabral and Mollick (2011). In particular, the first two studies confirm at the macro level learning-by exporting spillovers dealing with East and Southeast Asia's export success, whereas the latter study suggests at the micro level an increase of technology spillovers on Mexican manufacturing productivity from joining NAFTA. While there might be a theoretical consensus about trade-related spillover effects and the importance of a country's openness to trade, empirically it seems to be difficult to quantify the extent and direction of technology diffusion from trade.[1]

The same criticism applies to a second strand of the literature that considers FDI as a channel for technology diffusion. Following Keller (2004), such subsidiaries might pick up new technologies from their host countries (outward FDI technology transfer) or provide technology to domestic firms (inward FDI technology transfer). Much of the literature on FDI spillovers uses micro (firm or plant level) data and account for heterogeneity across sectors and firms within a country. Recently, empirical micro evidence for economically important FDI spillover effects have been found by Haskel, Pereira, and Slaughter (2002) for the United Kingdom, by Keller and Yeaple (2009) for the United States and by Khalifah and Adam for Malaysia (2009). Evidence for FDI spillover both from and to investing Japanese firms in the United States is found by Branstetter (2005). However, studies that use both bilateral trade and FDI as technology diffusion channels like in Savvides and Zachariadis (2005) and Kramer (2010) usually find trade-related rather than FDI-related spillover effects.

Turning to foreign patents as an alternative diffusion channel to the traditional approaches, the pattern of international patenting according to Eaton and Kortum (1999) indicate of where ideas are going and therefore reflect the link between the source and the destination of transferred technology. The idea is that patenting domestic research efforts abroad determines the transfer of technology. Local firms may take legal advantage of patented foreign knowledge by paying royalties. Adding foreign knowledge to a country's own R&D stock,

---

[1] Unel (2010), for example, shows recently by a product innovation growth model that exposure to trade leads to an increase of average productivity model, but has an ambiguous effect on economic growth.

even in the case of limited domestic R&D spending, is likely to increase the efficiency of domestic input factors. In particular, international patent statistics by the World Intellectual Property Organization (WIPO) and OECD usually provide count numbers, whereas specific information about the value of patents is not given. However, some patents are more valuable and their economic impact differs between countries. Hence, using patent count data may serve to determine the direction rather than the magnitude of international technology diffusion. In this context, international spillover effects are patent-related. Hafner (2008) find that patent-related spillover effects are present for a panel of 18 OECD countries over 1981-2001. The same study shows that there are no significant spillover effects from bilateral trade, but confirm the impact of FDI on domestic labor productivity. Moreover, the study from Xu and Chiang (2005) confirms significant spillover effects from foreign patents and imported capital goods for middle-income countries, whereas low-income countries benefit mainly from patent-related spillover effects. At the country study level, Branstetter and Sakakibara (2001) find no empirical evidence in the case of Japan that stronger patents induce more innovation and therefore more patents.

While each study offers fruitful insights on foreign spillover effects given their specifics of data selection and estimation techniques, this paper quantifies the impact of technology diffusion on labor productivity of economically integrating countries using patent-, trade- and FDI-related technology diffusion channels. Hence, foreign spillover effects are not restricted to a specific diffusion channel. Since relationships between countries are getting closer within economically integrating regions like the EU and NAFTA, the paper focuses on the interaction of spatial integration and technology diffusion by analyzing foreign technology spillover effects from economic integration.

3 Theoretical Framework

This section outlines the theoretical framework. To quantify the impact of foreign technology diffusion, one can divide the available capital stock of R&D (*A*) in country *i* (or its technological knowledge) according to:

$$A_{i,t} = \left(S_{i,t}^{d} + S_{i,t}^{f}\right), \tag{1}$$

where $S_{i,t}^{d}$ and $S_{i,t}^{f} = \sum_{j \neq i} \Gamma_{ji,t} S_{j,t}^{d}$ (for $j = 1,...,N$) represents domestic (*d*) and foreign (*f*) R&D capital stocks (*S*) used in country *i* at time *t* respectively. Note that Γ_{ji} defines country *j*'s technology diffusion rate to country *i*. Hence, $A_{i,t}$ is determined by domestic and foreign R&D, the latter according to the technological spillover effect and its diffusion channel.

Next, aggregated production function using the income approach in its simplest form is given by:

$$Y_{i,t} = A_{i,t} * F(K_{i,t}, L_{i,t}), \tag{2}$$

where $Y_{i,t}$ is the aggregate output, $K_{i,t}$ is the capital stock, and $L_{i,t}$ is the workforce. Hence, an increase of domestic and foreign R&D expenditure leads to higher R&D capital stocks, which–used as a proxy for the unobservable $A_{i,t}$–augments the efficiency of input factors in final output production. As a result, domestic output is likely to increase. Following Coe and Helpman (1995), one can define total factor productivity as aggregated output divided by the functional form of input factors to estimate the impact of foreign technology diffusion on economic development. However, total factor productivity figures are susceptible to calculation and measurement errors and estimated coefficients might be less reliable due to inherent biases. Due to the more reliable data on labor input and to a lack of data for an adequate stock of business sector capital, labor productivity (LP) figures are used.[2] Hence, substitution of equation (1) in equation (2) and taking the logarithm leads to:

$$\log(Y_{i,t} / F(L_{i,t})) \equiv \log LP_{i,t} = \log S^d_{i,t} + \log S^f_{i,t}. \tag{3}$$

Note that the right hand side of equation (3) is a proxy for the unobservable technological knowledge $A_{i,t}$.

R&D Capital Stocks

With respect to the domestic R&D capital stock of country *i*, the paper follows Coe and Helpman (1995) and uses the perpetual inventory method proposed by Griliches (1979) to convert R&D flow (expenditure) figures (*F*) into R&D stock variables (*S*):

$$S^d_{i,t} = (1-\delta) S^d_{i,t-1} + F^d_{i,t-1}, \tag{4}$$

---

[2] Coe and Helpman (1995) assume a Cobb-Douglas functional form with constant returns and define total factor productivity as output divided by the elasticity weighted input factors labor and capital. To keep the analysis comparable, aggregated output is only produced by labor and therefore by a single input factor in this paper.

where δ is the time- and country-invariant depreciation rate. Hence, the domestic R&D capital stock of country *i* in period *t* is calculated by the depreciated R&D capital stock plus the R&D flow (expenditure) of *t-1*. Note that the benchmark $S_{i,0}^{d}$ for the subsequent stock data is calculated by the first flow figure, for which the data is available, divided by its annual growth rate and depreciation rate. Detailed information is given in Table A.1 in the appendix.

Turning to the foreign R&D capital stock of country *i*, definitions of $S_{i,t}^{f}$ differ according to the diffusion channel. Hence, foreign R&D capital stocks are related first to foreign patent applications (*P*), second to bilateral trade (*M*) and third to FDI (*F*).

For *patent-related spillover effects*, foreign R&D capital stock $S_{i,t}^{f,P}$ is defined as the patent weighted average of domestic R&D capital stocks from abroad:

$$S_{i,t}^{f} \equiv S_{i,t}^{f,P} = \frac{1}{\sum_{j \neq i} a_{ji,t}} \sum_{j \neq i} (a_{ji,t} S_{j,t}^{d}), \qquad j = 1,...,N, \tag{5}$$

where $a_{ji,t}$ is country *j*'s patent application in country *i*. Note that the ratio of $a_{ji,t} / \sum_{j \neq i} a_{ji,t}$ defines the patent-related diffusion channel Γ^{P} for country *i*.

To capture *trade-related spillover effects*, the paper follows Coe and Helpman (1995) and define foreign R&D capital stock $S_{i,t}^{f,M}$ to be the average of domestic R&D capital stocks from abroad weighted by bilateral import shares:

$$S_{i,t}^{f} \equiv S_{i,t}^{f,M} = M_{i,t} \frac{1}{\sum_{j \neq i} m_{ji,t}} \sum_{j \neq i} (m_{ji,t} S_{j,t}^{d}), \qquad j = 1,...,N, \tag{6}$$

where $m_{ji,t}$ is country *i*'s import from country *j*. Again, the ratio of $m_{ji,t} / \sum_{j \neq i} m_{ji,t}$ defines the trade-related diffusion channel Γ^{M} for country *i*. Moreover, Coe and Helpman (1995) also propose the use of an additional measure to capture technology intensity and therefore openness to trade. Hence, a country that imports more relative to its GDP (i.e. $M_{i,t} = m_{i,t} / Y_{i,t}$) should benefit more from foreign R&D spillover effects, thus given the same composition of imports and a similar trade pattern between countries.

The procedure to determine foreign R&D capital stocks $S_{i,t}^{f,F}$ differs in the case of *FDI-related spillover effects* due to the lack of adequate bilateral FDI inflow data. Instead of calculating technology diffusion channels and relating them to domestic R&D capital stocks from abroad, aggregate FDI inflow figures to calculate FDI inflow stocks are used according to:

$$S_{i,t}^{f} \equiv S_{i,t}^{f,F} = (1-\delta)S_{i,t-1}^{f,F} + \sum_{j \neq i} FDI_{ji,t-1}\,, \qquad j = 1,\ldots,N\,, \tag{7}$$

where $FDI_{ji,t}$ is foreign direct investment from country *j* to country *i* and δ is the time- and country-invariant depreciation rate. Again, the perpetual inventory method proposed by Griliches (1979) is used to calculate the benchmark $S_{i,0}^{f,F}$ for subsequent FDI inflow stocks as shown in Table A.2 in the Appendix.

4 The Data

The data used to measure the impact of technology diffusion and economic integration for Greece, Ireland, Portugal and Spain and for Mexico is based on a set of 32 OECD countries for a time period from 1981 to 2008. Availability of data reduces the number of observations respectively. According to the literature, I use worked hours as labor input to determine labor productivity. Figures on labor productivity per hour worked in constant 2009 US$ (constant prices and PPP) are from the *Total Economy Database,* provided by the Groningen Growth and Development Center (GGDC (2010)). Following Coe and Helpman (1995), I calculate labor productivity as indexed figures with 2005 being the reference year.

The OECD has published data on business-related R&D expenditure (BERD) since about 1965 mainly for the G7 countries as well as for Switzerland. In order to get a data set for all OECD countries from 1965 onwards, one has to estimate missing R&D expenditure figures as Coe and Helpman (1995) did. However, the lack of R&D data (as well as missing patent figures) limits the analysis to 32 OECD countries $(N = 32)$[3] and to 1982 and 2008 for Greece, to 1981 and 2008 for Ireland, Portugal, and Spain and to 1989 and 2007 for Mexico. As a benchmark, technology diffusion is neither limited to the European core countries in the case of the European acceding countries nor to the USA and Canada in the case of Mexico. However, in quantifying the impact of economic integration, I restrict technology diffusion for the European countries first to EU-12 countries and second to EU-15 countries, and for

---

[3] There is no sufficient data for Chile and Estonia, which reduces the number of current 34 OECD countries accordingly.

Mexico first to the USA and second to the USA and Canada. R&D expenditure flows are converted into R&D capital stocks using the perpetual inventory method suggested by Griliches (1979). R&D expenditure data in million constant 2000 US$ (constant prices and PPP) is from the OECD (2010a) *Main Science and Technology Database*.

As discussed above, the paper uses country specific patent data as one of the main technology diffusion channels. Since 1975 the World Intellectual Property Organization (WIPO) offered in its *Industrial Property Statistics Publication B Part I* (WIPO, 2001) bilateral annual figures on foreign patent application and grants broken down by country. As figures based on patent applications are more reliable and complete than grants, patent applications are preferred. However, the WIPO recently changed methods of calculation and now publishes bilateral data about patent applications by country of origin starting in 1995 in its *Statistics Database* (WIPO, 2009). In quantifying the impact of technology diffusion and economic integration since the early 1980s, the two data sets are merged by using data from both publications accordingly. Although the data are used to calculate relative figures to represent each year's patent-related diffusion channel from abroad, there is a structural break between 2001 and 2002, where the former data set ends and data from the recent data set have first been used to complete the time series.

For trade- and FDI-related spillover effects, the paper uses bilateral import flows and FDI flows by partner country published by the OECD (2010b, 2009) in the *Monthly Statistics of International Trade* and the *International Direct Investment Statistics,* respectively. In order to relate domestic R&D capital stocks to bilateral trade patterns, I use figures on import as well as GDP both in million current US$, where GDP data (expenditure approach, market price, value) is from the OECD (2011) *Economic Outlook Database*. Due to the lack of adequate bilateral FDI inflow data, aggregate FDI inflow data are used to calculate FDI inflow stocks instead of calculating technology diffusion channels and relating them to domestic R&D capital stocks from abroad.

5 Nonstationary Issues and Estimation Techniques

In general, many macroeconomic indicators such as GDP, R&D expenditure, bilateral trade and FDI flows, and even the pattern of international patenting show a clear trend and unit root tests usually confirm nonstationarity, whereas the error term of the regression equation may or may not be stationary. If the error term is stationary, variables are cointegrated and there is common trend binding all variables. If not, the estimated relationship is likely to be spurious and no long-run relationship between such variables might exist. Moreover, there could be feedback from the endogenous variable to the explanatory variables as well as serial correlation, which usually drives and biases estimators. To address such problems, unit root tests and error-correction based cointegration tests test whether time series are integrated by the same order with a linear relationship between them or not.[4] If integrated time series are cointegrated, error correction (EC) models allow estimating the long-run relationships between time series, otherwise dynamic single equation regressions like autoregressive distributed lag (ADL) models or–equivalent–single equation EC models lead to unbiased estimates of causal long-run relationships.

Unit Root and Cointegration Tests

In testing integrated time series, one usually comes across with the work of Fuller (1976), Dickey Fuller (1979) and Kwiatkowski, Phillips, Schmidt and Shin (1992). Suppose that a variable is driven by its lagged value, an autoregressive coefficient, a deterministic component and an error term. If there is no evidence to assume autocorrelation of the error term, the Dickey Fuller (DF) test allows for three different specifications of the deterministic component: no deterministic component, an individual-specific component, and individual-specific component as well as a time trend. Testing for unit roots, the DF test proposes a null hypothesis of unit roots or nonstationarity $(H_0 : \rho = 1)$ against the alternative hypothesis that the time series is stationary $(H_1 : \rho < 1)$. Relaxing the restrictive assumptions of no autocorrelation, the augmented Dickey Fuller (ADF) testing procedure accounts for autocorrelation by introducing lags of the time series' first differences to the test regression. Again, there might be no deterministic component, an individual-specific component and, in addition, a time trend. The ADF testing procedure also tests the null hypothesis of unit roots against the alternative hypothesis of stationarity. Test statistics from both tests are compared to the asymptotic quintiles proposed by Fuller (1976) and differ according to the specification of the deterministic component. By comparison, the testing procedure from Kwiatkowski, Phillips, Schmidt and Shin (KPSS) change the null hypothesis and test if time series are stationary allowing the deterministic component to become zero, non-zero or a time trend. Test statistics are compared to the asymptotic quintiles in Kwiatkowski, Phillips, Schmidt and Shin (1992). Following Baum (2005), a well-known weakness of unit root tests with nonstationarity as the null hypothesis– like the Dickey-Fuller type tests– are the low power in the case of time series with structural-

---

[4] Hassler (2000) and Wolters (2008) provide an excellent overview for nonstationary issues of time series such as unit root tests, cointegration tests and EC models.

breaks, which are often mistaken as being integrated when they are not. Allowing for some sort of structural instability, Clemente, Montañés, and Reyes (1998) amongst others propose testing procedures dealing with structural breaks in time series. In particular, they propose unit root tests allowing for one or two structural breaks for time series either with additive outliers (AO) (i.e. with a sudden change in the mean) or innovational outliers (IO) (i.e. with a gradual shift of the mean) and test the null hypothesis of unit root against the alternative of break-stationarity. Critical values are taken from Perron and Vogelsang (1992) and differ according to the test specification.

Once confirmed that the time series are of the same integrated order and before turning to the estimation techniques, a regression equation containing all variables including a time trend must have a stationary error term in order to avoid spurious results. To test for the long-run cointegration relationship (i.e. stationarity of the error term), one can either collect the empirical residuals to test for stationarity of the error term ("residual-based tests"), or use the corresponding EC term in EC models to test whether the EC term is significant ("error-correction based tests"). In general, each unit root test can be used to test against (or for) cointegration of two or more time series as nonstationarity of the residual means that there is no equilibrium state and no long run relationship, while stationarity of the residual confirms cointegration. Hence, residual-based tests as the (augmented) Dickey-Fuller type test the null hypothesis of no cointegration, whereas the KPSS type test tests the null hypothesis of cointegration. All tests have in common that residuals are derived by estimating the long-run relationship amongst the cointegrated variables. While DF and ADF tests derive residuals from OLS estimations, the KPSS test rely on efficient estimation techniques other than OLS and introduces leads and lags of the first differences to the test equation. Test statistics from residual-based tests are compared to the asymptotic quintiles proposed by MacKinnon (1991) in the first two cases and Kwiatkowski, Phillips, Schmidt and Shin (1992) in the latter case. Turning to the use of the error correction term in EC models, error-correction based test such as Engle and Granger (1987) two-step EC model tests the null hypothesis of no cointegration by the significance of the corresponding EC term in EC models using the test statistics from the lagged EC term. Again, residuals are derived from OLS estimations.

Estimation Techniques: Error Correction Models

In the case of integrated time series, Engle and Granger (1987) suggest the well-known two-step EC model as an appropriate estimation technique to quantify the long-run relationship between two or more time series. Accounting for short term effects of a shock on the equilibrium state and its long term adjustment (i.e. the speed of error correction), the EC model allows estimating the long-run relationships between cointegrated variables by transferring the data into differences to avoid spurious regression results. As discussed, the EC model also allows testing of cointegration by the significance of the lagged EC term.

However, in cases where time series are near integrated, and cointegration might or might not exist, the use of Engle and Granger (1987)'s two-step EC model becomes problematic and estimation results are likely to be spurious. To avoid such problems, dynamic single equation regressions like ADL models or equivalent single equation EC models leads to unbiased estimates of causal long-run relationships. In particular, the single equation EC model can be easily derived from a general ADF model with one lag. Moreover, Hassler and Wolters (2006) shows that both models are equivalent in estimating the cointegration vector and standard errors for the long term coefficients can be estimated by the Bewley (1979) transformation. Since the single equation EC model is appropriate for both stationary and nonstationary data and provide the same information about short term and long term effects on the equilibrium state as Engle and Granger (1987)'s two-step EC model, it is used as the appropriate estimation technique for estimating the impact of technology diffusion in case of doubt. Hence, using the first differences of $x_{i,t}$ and the lagged EC term, the regression equation of the single equation EC model is given as:

$$\Delta y_{i,t} = \alpha_i + \beta_{0,i}^{'} \Delta x_{i,t} + \beta_{1,i}^{'} (y_{i,t-1} - \beta_{2,i}^{'} x_{i,t-1}) + e_{i,t}, \qquad i = 1,\ldots,5 \text{ and } t = 1,\ldots,T, \qquad (8)$$

where α_i is the constant, $x_{i,t}$ is a *K*-dimensional column-vector (i.e. *K* being the number of explanatory variables), and $e_{i,t}$ is the error term. Note that *K* depends on the number of technology diffusion channels used to estimate the impact of foreign R&D capital stocks. As the focus of the paper is the long-run relationship between labor productivity and R&D capital stocks as discussed by equation (3), *y* on the left hand side of equation (8) denotes labor productivity, while *x* on the right hand side of equation (8) represents domestic and foreign R&D capital stocks defined by equations (4)-(7).

6 Empirical Results

In estimating the long-run relationship between labor productivity and R&D capital stocks and therefore the impact of technology diffusion and economic integration, the paper uses the single equation EC model to deal with both nonstationary and stationary time series. Hence, it is tested first if the time series are of the same integrated order and second if cointegration relationships amongst two or more time series exists. If so, the use of (single equation) EC models is always appropriate, whereas in the case of near integrated time series with possible cointegration relationships, the single EC model provides the same information about short and long term effects as Engle and Granger (1987)'s two-step EC model and standard deviations are easy to obtain by the Bewley (1979) transformation.

Unit Root Tests: ADF (1979) and AO/IO (1998)

Unit roots test have to confirm that the time series of labor productivity, domestic and foreign R&D capital stocks are integrated of the same order. Allowing for autocorrelation of the error term, the ADF testing procedure tests the null hypothesis of unit roots against the alternative hypothesis that the time series is stationary. Test statistics and *p*-values in parenthesis from the ADF test for one or two lags in the test regression are shown in Table 1. In the case of structural breaks, the AO/IO tests analyse the null hypothesis of unit roots against the alternative of break-stationarity. As discussed in Section 4, patent-related diffusion channels are calculated using two different data sets and figures are likely to exhibit structural breaks between 2001 and 2002, where data sets have been merged. Hence, test statistics from AO/IO testing procedures for patent-related time series are also given in Table 1 and differ according to the number of significant structural breaks. All time series are assumed to have a constant and a time trend in the test regression. Once confirmed that the time series are I(1), one has to be sure that the time series' first differences are I(0). Table 2 shows the test results from ADF for the first differences assuming one lag and taking into account that differencing a time trend gives a constant. Turning to the impact of economic integration and therefore to the restriction of technology diffusion, Table A.3 and Table A.4 in the appendix show by the same way unit root test statistics from ADF and AO/IO testing procedures for patent-, trade, and FDI-related spillover effects if technology diffusion is restricted for European countries to EU-12 and EU-15 countries and for Mexico to the USA and Canada.

Test results assuming autocorrelation of the error term in Table1 show that the ADF testing procedures confirm the null hypothesis of nonstationarity at least at the 5% level for all time series, if variables are lagged by two periods. Assuming one lag instead, the ADF test now reject at least at the 5% level the null hypothesis of nonstationarity for labor productivity of Spain, for domestic R&D capital stocks of Ireland and Spain, and for trade-related foreign R&D capital stocks of Portugal. Moreover, patent-related foreign R&D capital stocks of Portugal are also shown by the AO/IO test statistics to be break-stationary at a 5% level, whereas both models (except the IO(1) model for Ireland) confirm the null hypothesis of nonstationarity for the remaining countries as the ADF test statistics do.

Table 1: ADF Test (Levels) by Fuller (1976) and Dickey Fuller (1979)
(Annual data for Greece (1981-2008), Ireland (1981-2008), Portugal (1982-2008), Spain (1981-2008) and Mexico (1989-2007))

Intercept and Time Trend:	**Greece**	**Ireland**	**Portugal**	**Spain**	**Mexico**
$\log LP$					
…ADF, Lag(1)	-1.29 (0.89)	-0.55 (0.98)	-1.97 (0.62)	-3.71 (0.02)**	-2.6 (0.28)
…ADF, Lag(2)	-1.29 (0.89)	-0.14 (0.99)	-2.12 (0.54)	-3.36 (0.06)*	-2.26 (0.46)
$\log S^{d}$					
…ADF, Lag(1)	-2.14 (0.53)	-4.17 (0.01)**	-0.07 (0.99)	-3.4 (0.05)**	-1.06 (0.94)
…ADF, Lag(2)	-2.3 (0.44)	-1.48 (0.84)	0.9 (1)	-2.92 (0.16)	-1.02 (0.94)
$\log S^{f,P}$					
…ADF, Lag(1)	-2.26 (0.45)	-1.93 (0.64)	-1.06 (0.94)	-1.54 (0.82)	-2.34 (0.41)
…ADF, Lag(2)	-2.46 (0.35)	-1.96 (0.62)	-0.18 (0.99)	-1.44 (0.85)	-2.06 (0.57)
…AO (Break)	(2): -1.281	(2): 1.048	(1): -4.827**	(2): 1.159	(2): -3.765
…IO (Break)	(2): -1.319	(1): -15.596**	(1): -5.895**	(1): -0.646	(2): -4.362
$\log S^{f,M}$					
…ADF, Lag(1)	-2.55 (0.3)	-1.12 (0.93)	-3.75 (0.02)**	-1.99 (0.61)	-0.87 (0.96)
…ADF, Lag(2)	-2.2 (0.49)	-0.84 (0.96)	-3.22 (0.08)*	-1.54 (0.81)	-1.01 (0.94)
$\log S^{f,F}$					
…ADF, Lag(1)	-1.32 (0.88)	-2.57 (0.29)	-1.84 (0.69)	-2.24 (0.47)	-2.21 (0.49)
…ADF, Lag(2)	-2.99 (0.14)	-2.2 (0.49)	-1.94 (0.63)	-2.24 (0.47)	-2.1 (0.54)

Notes: * (**) [***] denotes that the time series is stationary at 10% (5%) [1%] level. The null hypothesis is nonstationarity, while the alternative hypothesis is stationarity (ADF-tests) or break-stationarity (AO/IO-tests). ADF-test statistics are compared to the asymptotic quintiles proposed by Fuller (1976) and p-values are given in parenthesis. AO/IO-test statistics are compared to the critical values proposed by Perron and Vogelsang (1992) for a 5% level: -5.490 (AO(2)); IO(2)), -3.560 (AO(1)) and -4.270 (IO(1)). Tests are implemented with a constant and trend in the test regression. Time series are assumed to have auto-correlated error terms.

Turning to the impact of economic integration and therefore to the restriction of technology diffusion, test statistics in Table A.3 in the appendix show that patent-related foreign R&D capital stocks are confirmed to be nonstationary for all countries except Portugal, for which test statistics of the AO/IO models once again indicate break-stationarity. While trade-related foreign R&D capital stocks are I(1) for almost all countries–except technology diffusion from EU-15 countries in the case of Portugal–, unit roots for FDP-related foreign R&D capital stocks are not confirmed for Spain no matter if one or two lags are assumed.

Turning to the first differences next, tests results from ADF tests shown by Table 2 reject the null hypothesis of nonstationarity for the first differences of labor productivity and patent- or trade-related foreign R&D capital stocks for all countries. However, in the case of domestic R&D capital stocks and FDI-related foreign R&D capital stocks first differences are still confirmed to be nonstationary for almost every country except for Ireland and FDI-related foreign R&D capital stocks. Restricting technology diffusion, test results by Table A.4 in the appendix confirm stationarity for the first differences of patent- and trade-related foreign R&D capital stocks for Greece, Ireland, Portugal and Mexico, but for Spain only in the case of patent-related foreign R&D capital stocks. Moreover, first differences of FDI-related foreign R&D capital stocks are still I(1) in the case of European acceding countries, but I(0) in the case of Mexico.

Table 2: ADF Test (Differences) by Fuller (1976) and Dickey Fuller (1979)
(Annual data for Greece (1981-2008), Ireland (1981-2008), Portugal (1982-2008), Spain (1981-2008) and Mexico (1989-2007))

Intercept	Greece	Ireland	Portugal	Spain	Mexico
$d.\log LP$	-3.01 (0.03)**	-2.68 (0.08)*	-3.63 (0.01)***	-2.72 (0.07)*	-3.11 (0.03)**
$d.\log S^{d}$	-2.13 (0.23)	-2.23 (0.2)	-1.38 (0.59)	-1.48 (0.54)	-1.92 (0.32)
$d.\log S^{f,P}$	-3.7 (0)***	-3.41 (0.01)***	-4.28 (0)***	-3.58 (0.01)***	-3.53 (0.01)***
$d.\log S^{f,M}$	-4.12 (0)***	-3.19 (0.02)**	-5.88 (0)***	-3.81 (0)***	-2.65 (0.08)*
$d.\log S^{f,F}$	-1.47 (0.55)	-2.81 (0.06)*	-2.48 (0.12)	-1.89 (0.34)	-2.32 (0.17)

Notes: * (**) [***] denotes that the time series' first difference is stationary at 10% (5%) [1%] level. The null hypothesis is nonstationarity while the alternative hypothesis is stationarity. Test statistics are compared to the asymptotic quintiles proposed by Fuller (1976) and p-values are given in parenthesis. Tests are implemented with a constant and one lag in the test regression. Time series are assumed to have auto-correlated error terms.

Bearing in mind that autocorrelation and structural breaks as the main problems of time series are taken into account by the ADF model and AO/IO model, I conclude that the time series including a time trend are I(1) except for patent-related foreign R&D capital stocks of Portugal (no matter if restricted of not) and for restricted trade-related foreign R&D capital stocks from EU-12 and EU-15 countries of Spain. With regard to the first differences, domestic R&D capital stocks and FDI-related foreign R&D capital stocks are not confirmed to be I(0). Hence, most of the data is shown to be integrated of the same order. Before turning to the estimation results of the long-run relationships, a regression containing all variables including a time trend must have a stationary error term in order to avoid spurious.

Cointegration Test: KPSS (1992)

Test results are based on the KPSS testing procedure and are compared to the asymptotic quintiles at the 5% level proposed by Kwiatkowski, Phillips, Schmidt and Shin (1992). The null hypothesis is that there is cointegration (i.e. residual is stationary), while the alternative hypothesis is that there is no cointegration. As discussed, the KPSS testing procedures allows for autocorrelation of the error term by introducing leads and lags of the first differences to the test regression. By definition, the unit root equation for the estimated residuum from the long-run relationship does not include a constant and a time trend. Tests have been conducted for different technology diffusion channels (i.e. equation (3) in combination with patent-, trade- and FDI-related diffusion channels by equations (5)-(7)). Table 3 shows test statistics of the different model specifications if technology diffusion is unrestricted. In the case where technology diffusion is restricted to EU-12 and EU-15 countries for European acceding countries and to the USA and Canada for Mexico, Table A.5 and Table A.6 in the appendix shows test statistics respectively.

Starting with unrestricted technology diffusion, test statistics in Table 3 confirm the null hypothesis of cointegration at a 5% level for almost every country and each model specification except for Greece analyzing patent- and trade-related spillover effects and for Ireland analyzing all three technology diffusion channels. Almost the same conclusion can be drawn by the test statistics shown in Table A.5 in the appendix, where technology diffusion is restricted to the EU-12 countries and to the USA accordingly. The only difference is that it is Portugal, where the null hypothesis of cointegration is rejected in the case of all three technology diffusion channels. Allowing technology diffusion from EU-15 countries and from USA and Canada, there is no cointegration for Greece in the case of patent- and trade related spillover effects according to the test statistics shown by Table A.6 in the appendix.

Although all time series of the sample have been shown to be I(1) in levels, some have failed to be I(0) in first differences reducing the cointegration analysis from above to those time series with the same integrated order. Hence, to get a complete picture of the impact of technology diffusion and economic integration on all integrating countries, estimates of the long-run relationship between productivity and domestic and foreign R&D activity using Engle and Granger (1987)'s two step EC model would lead to spurious results in cases where stationary and nonstationary time series are combined. In case of doubt, the single equation EC model is appropriate for both stationary and nonstationary data and provides information about short term and long term effects on the equilibrium state. Therefore, it will be used as the appropriate estimation technique for estimating the impact of technology diffusion and economic integration of the sample.

Table 3: Cointegration Test Results by KPSS
(Annual data for Greece (1981-2008), Ireland (1981-2008), Portugal (1982-2008), Spain (1981-2008) and Mexico (1989-2007))

Equation:	**(3) with (5)**	**(3) with (6)**	**(3) with (7)**	**(3) with (5)/(6)/(7)**
Greece:				
KPSS, Lag (1), Lead (1)	0.126	0.204	0.094*	0.062*
KPSS, Lag (2), Lead (1)	0.099*	0.137	0.085*	n.a.
Ireland:				
KPSS, Lag (1), Lead (1)	0.091*	0.055*	0.087*	0.052*
KPSS, Lag (2), Lead (1)	0.079*	0.084*	0.064*	0.108
Portugal:				
KPSS, Lag (1), Lead (1)	0.068*	0.065*	0.041*	0.042*
KPSS, Lag (2), Lead (1)	0.052*	0.061*	0.051*	0.0502*
Spain:				
KPSS, Lag (1), Lead (1)	0.052*	0.05*	0.048*	0.045*
KPSS, Lag (2), Lead (1)	0.043*	0.046*	0.046*	0.058*
Mexico				
KPSS, Lag (1), Lead (1)	0.053*	0.051*	0.061*	0.058*
KPSS, Lag (2), Lead (1)	0.061*	0.076*	0.078*	n.a.

Notes: * denotes that the cointegration is statistically significant at least at a 5% level. Test statistics are compared to the asymptotic quintiles from Kwiatkowski, Phillips, Schmidt and Shin (1992) for two and four I(1)-regressors. The null hypothesis is that there is cointegration (i.e. residual is stationary), while the alternative hypothesis is that there is no cointegration. KPSS-test statistics are compared to the critical values for a 5% level: 0.101 for two I(1) regressors and 0.073 for four I(1) regressors. By definition, the unit root equation for the resulting error term from the long-run relationship does not include a constant and a time trend.

Estimation Results: Single Equation EC Model

Accounting for short term effects of a shock on the equilibrium state and its long term adjustment (i.e. the speed of error correction), the single equation EC model by equation (7) introduces lags and estimates the long-run relationships between two and more time series no matter if time series are integrated or not. As usual, the error correction approach is correct, if the estimated coefficient $\beta_{1,i}$ of the lagged dependent variable (i.e. the speed of return to equilibrium after a shock) is significant and between -1 and zero. Standard errors of the long term coefficients are estimated according to the Bewley (1979) transformation. Taking into account that technology diffusion might be patent-, trade- and FDI-related, equation (3) is estimated by four different models: with one out of three technology diffusion channels (i.e. equation (3) with (5)-(7)) and with all three diffusion channels combined (i.e. equation (3) with (5)/(6)/(7)). Estimates from the single equation EC model are shown in case of unrestricted technology diffusion in Table 4 for the European acceding countries and in Table 5 for Mexico accordingly. If technology diffusion is restricted, Table 6 and Table 7 show the estimated coefficient for foreign R&D capital stocks only, whereas the other estimated coefficients are postponed to the appendix and listed in Table A.7 and A.8 for the European countries and in A.9 for Mexico.

Patent-, trade and FDI-related spillover effects

Starting with unrestricted technology diffusion in the case of Greece, Ireland, Portugal and Spain, the error correction approach is correct as the lagged coefficient of labor productivity is significant and between -1 and zero for all countries except for Greece according to Table 4. Ignoring therefore the estimation results of Greece, the coefficients of domestic R&D capital stocks are significant at least at a 5% level for almost every country and each model specification. Moreover, the signs are positive and fairly comparable to the results from Kao, Chiang and Chen (1999) re-estimating Coe and Helpman (1995)'s paper and to Hafner (2008).[5] While both use panel data of OECD countries and dynamic OLS estimation techniques to estimate the impact of foreign technology, the use of time series and single equation EC models lead to higher coefficients of domestic R&D capital stocks for European acceding countries. As these countries usually accounts for a certain degree of industrialization, they rely much more on domestic R&D capital stocks than other (developing) OECD countries do. Turning to the coefficient of foreign R&D capital stocks and therefore to technology diffusion, patent- and trade-related spillover effects are significantly positive at least at a 5% level in the case of Portugal for the first and Ireland for the second spillover effect if all four models are compared. Hence, a 1% increase in R&D spending abroad raises labor productivity either between 0.02% and 0.05% in Portugal (i.e. equation (3) with (5) or with (5)/(6)/(7)) or between 0.19% and 0.3% in Ireland (i.e. equation (3) with (6) or with (5)/(6)/(7)). With a focus of only one single technology diffusion channel, patent-related spillover effects are significantly found for Ireland with an impact of 0.02% on its labor productivity if foreign R&D capital stocks are increased by 1%, whereas Spain's labor productivity increases significantly from FDI-related spillover effects by 0.04%.

Estimation results for Mexico by Table 5 show that the error correction model is correct for those models where one out of three technology diffusion channels are used. While there is no empirical evidence for technology diffusion from abroad, the coefficient of domestic R&D capital stocks is significantly positive but lower than in Table 4 – fairly comparable to those from Kao, Chiang and Chen (1999) and Hafner (2008) as already discussed.

---

[5] Both papers estimate the impact of domestic R&D capital stock amongst other variables. While Kao, Chiang and Chen (1999) estimates the impact on total factor productivity by 0.107, the coefficients in Hafner (2008) varies between 0.05 and 0.11 for Non-G7 OECD countries and between 0.128 and 0.144 for G7 countries.

Table 4: Technology Diffusion: Estimation Results for Greece, Ireland, Portugal and Spain by the Single Equation EC Model

(Annual data for Greece (1981-2008), Ireland (1981-2008), Portugal (1982-2008) and Spain (1981-2008))

Equation:	**(3) with (5)**	**(3) with (6)**	**(3) with (7)**	**(3) with (5)/(6)/(7)**
Greece:				
$\log S^{d}$	0.31 (18.82)***	0.45 (18.26)***	0.49 (13.63)***	0.49 (10.6)***
$\log S^{f,P}$	-0.01 (-1.73)*			0.03 (2.68)**
$\log S^{f,M}$		-0.48 (-8.04)***		0.13 (1.44)
$\log S^{f,F}$			-0.93 (-5.74)***	-0.8 (-4.63)***
$\log LP^{d}_{t-1}$	-0.1 (-0.71)	-0.13 (-1.26)	0.13 (0.54)	0.24 (0.58)
R^2 : OLS; ECM	0.96; 0.10	0.92; 0.19	0.95; 0.32	0.95; 0.38
No. of Obs. : OLS; ECM	27; 26	27; 26	21; 20	21; 20
Ireland:				
$\log S^{d}$	0.38 (58.27)***	0.33 (34.66)***	0.36 (15.75)***	0.35 (16.71)***
$\log S^{f,P}$	0.02 (2.41)**			-0.02 (-1.59)
$\log S^{f,M}$		0.19 (4.06)***		0.3 (3.64)**
$\log S^{f,F}$			0 (0.05)	-0.02 (-1.42)
$\log LP^{d}_{t-1}$	-0.37 (-1.84)*	-0.42 (-2.33)**	-0.48 (-2.15)**	-0.41 (-1.90)*
R^2 : OLS; ECM	1; 0.37	1; 0.48	1; 0.35	1; 0.57
No. of Obs. : OLS; ECM	28; 27	28; 27	26; 25	26; 25
Portugal:				
$\log S^{d}$	0.23 (24.31)***	0.23 (25.31)***	0.30 (7.34)**	0.42 (7.37)***
$\log S^{f,P}$	0.02 (2.87)***			0.05 (4.46)***
$\log S^{f,M}$		-0.29 (-4.05)***		-0.13 (-2.04)*
$\log S^{f,F}$			-0.02 (-1.52)	-0.07 (-3.27)***
$\log LP^{d}_{t-1}$	-0.42 (-2.52)**	-0.23 (-1.88)*	-0.33 (-2.70)***	-0.45 (-2.43)**
R^2 : OLS; ECM	0.94; 0.39	0.87; 0.41	0.91; 0,43	0.94; 055
No. of Obs. : OLS; ECM	27; 26	27; 26	27; 26	27; 26
Spain:				
$\log S^{d}$	0.10 (11.64)***	0.19 (20.79)***	0.04 (1.42)	0.2 (4.96)***
$\log S^{f,P}$	0.01 (-1.80)*			0 (0.92)
$\log S^{f,M}$		-0.19 (-8.03)***		-0.2 (-6.03)***
$\log S^{f,F}$			0.04 (3.07)***	0 (0.01)
$\log LP^{d}_{t-1}$	-0.23 (-2.86)***	-0.26 (-4.57)***	-0.25 (-4.07)***	-0.28 (-3.28)**
R^2 : OLS; ECM	0.96; 0.69	0.94; 0.75	0.94; 0.71	0.96; 0.75
No. of Obs. : OLS; ECM	28; 27	28; 27	28; 27	28; 27

Notes: The *t*-statistics of the coefficients are reported in parentheses. * (**) [***] denotes that the coefficient is significantly different from zero at a 10% (5%) [1%] level. All equations include unreported country-specific constants.

Table 5: Technology Diffusion: Estimation Results for Mexico by the Single Equation EC Model
(Annual data for Mexico from 1989-2007)

Equation:	**(3) with (5)**	**(3) with (6)**	**(3) with (7)**	**(3) with (5)/(6)/(7)**
Mexcio				
$\log S^{d}$	0.07 (1.46)	0.12 (5.01)***	0.13 (2.44)**	0.08 (0.65)
$\log S^{f,P}$	0.12 (0.95)			0.24 (1.06)
$\log S^{f,M}$		-0.03 (-1.15)		0.06 (0.81)
$\log S^{f,F}$			-0.01 (-0.19)	-0.08 (-0.83)
$\log LP_{t-1}^{d}$	-0.73 (-2.62)**	-0.78 (-2.87)**	-0.63 (-2.09)*	-0.65 (-1.61)
R^2 : OLS; ECM	0.83; 0.45	0.81; 0.42	0.81; 0,44	0.83; 0.52
No. of Obs. : OLS; ECM	19; 18	19; 18	19; 18	19; 18

Notes: The *t*-statistics of the coefficients are reported in parentheses. * (**) [***] denotes that the coefficient is significantly different from zero at a 10% (5%) [1%] level. All equations include unreported country-specific constants.

Technology Diffusion and Economic Integration

Turning to restricted technology diffusion and therefore to the impact of economic integration, the significance of the results shown in Table 6 for the sample of European acceding countries are almost the same no matter if technology diffusion is restricted to EU-12 or EU-15 countries and the estimated coefficients are comparable to those in Table 4. Again, the focus is on Ireland, Portugal and Spain as the lagged coefficient of labor productivity is shown to be significant by Table A.7 and A.8 in the appendix and therefore estimates by the single equation EC model are reliable for these countries. According to the estimated results of the foreign R&D capital stocks in Table 6, patent-related spillover effects are significant in the case of Portugal, whereas trade-related spillover effects are found for Ireland. Moreover, the coefficients for both spillover effects are higher than those in Table 4 indicating that there are significant impacts of foreign technology spillover effects for Ireland and Portugal from European economic integration respectively no matter if technology diffusion is restricted to EU-12 or EU-15 countries. In the case of one single technology diffusion channel, the coefficient of foreign R&D capital stock is positively significant for Ireland in the case of patent-related spillover effects from both EU-12 and EU-15 and higher than the corresponding coefficient in Table 4. Again, Ireland benefits from patent-related spillover effects spurred by economic integration. However, the coefficient of trade-related foreign R&D capital stock for Portugal is significant and positive if technology diffusion is restricted to the EU-12 countries but negative in the case of the EU-15 countries.

Finally, restricted technology diffusion for Mexico first from the USA and second from the USA and Canada is shown by Table 7. There is no significant impact on Mexico’s labor productivity no matter if technology diffusion is patent-, trade- or FDI-related. According to Table A.9 in the appendix, the error correction models are correct and the coefficients of domestic R&D capital stocks are positive and significant at least at a 5% level.

Table 6: Technology Diffusion: Estimation Results for Greece, Ireland, Portugal and Spain by the Single Equation EC Model; Economic Integration: EU-12 and EU-15
(Annual data for Greece (1981-2008), Ireland (1981-2008), Portugal (1982-2008) and Spain (1981-2008))

Equation:	**(3) with (5)**	**(3) with (6)**	**(3) with (7)**	**(3) with (5)/(6)/(7)**
Greece:				
$\log S^{f,P}_{EU-12}$	0 (-0.6)			0.05 (2.63)**
$\log S^{f,M}_{EU-12}$		-0.44 (-8.97)***		-0.34 (-1.79)*
$\log S^{f,F}_{EU-12}$			0.41 (2.19)**	-0.15 (-4.04)**
$\log S^{f,P}_{EU-15}$	0 (-0.63)			0.05 (2.68)***
$\log S^{f,M}_{EU-15}$		-0.44 (-8.92)***		-0.35 (-1.8)*
$\log S^{f,F}_{EU-15}$			1.09 (2.72)***	-0.16 (-3.92)***
Ireland:				
$\log S^{f,P}_{EU-12}$	0.04 (2.61)**			-0.05 (-1.19)
$\log S^{f,M}_{EU-12}$		0.24 (3.18)***		0.4 (2.02)**
$\log S^{f,F}_{EU-12}$			0.01 (0.68)	0.02 (1.44)
$\log S^{f,P}_{EU-15}$	0.04 (2.61)**			-0.05 (-1.22)
$\log S^{f,M}_{EU-15}$		0.25 (3.19)***		0.4 (2.04)**
$\log S^{f,F}_{EU-15}$			0.01 (0.8)	0.02 (1.51)
Portugal:				
$\log S^{f,P}_{EU-12}$	0.06 (4.91)***			0.07 (2.21)**
$\log S^{f,M}_{EU-12}$		0.16 (4.25)***		0.07 (0.84)
$\log S^{f,F}_{EU-12}$			-0.01 (-0.79)	-0.03 (-1.09)
$\log S^{f,P}_{EU-15}$	0.06 (4.89)***			0.03 (0.62)
$\log S^{f,M}_{EU-15}$		-0.28 (-4.05)***		0.16 (0.85)
$\log S^{f,F}_{EU-15}$			0 (-0.4)	-0.01 (-0.38)
Spain:				
$\log S^{f,P}_{EU-12}$	0.01 (0.49)			0.02 (2.54)**
$\log S^{f,M}_{EU-12}$		-0.35 (-9.48)***		-0.06 (-2.71)**
$\log S^{f,F}_{EU-12}$			0.01 (1.27)	0.01 (1.82)*
$\log S^{f,P}_{EU-15}$	0 (0.32)			0.02 (2.47)**
$\log S^{f,M}_{EU-15}$		-0.35 (-9.49)***		-0.06 (-2.67)**
$\log S^{f,F}_{EU-15}$			0.01 (1.37)	0.01 (1.71)*

Notes: The *t*-statistics of the coefficients are reported in parentheses. * (**) [***] denotes that the coefficient is significantly different from zero at a 10% (5%) [1%] level. All equations include unreported country-specific constants.

Table 7: Technology Diffusion: Estimation Results for Mexico by the Single Equation EC Model; Economic Integration: USA and USA/CAN
(Annual data for Mexico from 1989-2007)

Equation:	**(3) with (5)**	**(3) with (6)**	**(3) with (7)**	**(3) with (5)/(6)/(7)**
Mexico:				
$\log S_{USA}^{f,P}$	0.08 (0.7)			0.23 (1.07)
$\log S_{USA}^{f,M}$		-0.02 (-1.1)		0.06 (0.86)
$\log S_{USA}^{f,F}$			-0.04 (-1.32)	-0.09 (-1.08)
$\log S_{USA/CAN}^{f,P}$	0.08 (0.7)			0.23 (1.04)
$\log S_{USA/CAN}^{f,M}$		-0.02 (-1.1)		0.06 (0.86)
$\log S_{USA/CAN}^{f,F}$			-0.04 (-1.28)	-0.09 (-1.07)

Notes: The *t*-statistics of the coefficients are reported in parentheses. * (**) [***] denotes that the coefficient is significantly different from zero at a 10% (5%) [1%] level. All equations include unreported country-specific constants.

To sum up, the paper finds empirical evidence for foreign technology spillover effects. Foreign R&D capital stocks are trade-related in the case of Ireland, patent-related in the case of Portugal and FDI-related in the case of Spain. Moreover, there are significant impacts of foreign technology spillover effects for Ireland and Portugal from European economic integration no matter if technology diffusion is restricted to EU-12 or EU-15 countries, whereas in the case of Mexico no such evidence from joining NAFTA is found.

7 Conclusions

Research activity and its technological spillover effects are widely believed to be crucial for structural backward countries within economically integrating regions. In such regions, countries compete not only for manufacturing activities but also for mobile factors such as skilled labor and capital. Moreover, further economic integration according to Hafner (2011) spur technology diffusion through tighter relationships. However, such technology diffusion and the adoption of foreign technological knowledge may have different impacts on countries. While for industrialized countries technology diffusion towards integrating countries may result in a loss of industry shares and mobile factors, structurally backward countries certainly gain by technology diffusion especially those with low domestic R&D spending. Hence, it turns out to be essential for structurally backward countries to gain access to technological knowledge to increase industrial activity and upgrade local industries. A better access to foreign R&D knowledge improves the possibilities to close the gap toward the technological frontier and to participate in world markets.

Is it all about investing in R&D and foreign technology spillover effects? Returning to the empirical results, the answer is definitely yes at least for the European countries. In addition to the significant impacts of domestic R&D spending on labor productivity, there is empirical evidence for foreign technology spillover effects for Ireland, Portugal and Spain, but not for Greece, where estimation results are spurious and therefore have been ignored. Patent-related spillover effects are found for Portugal and Ireland such that a 1% increase in R&D spending abroad raises labor productivity between 0.02% and 0.05% in Portugal and 0.02% in Ireland. Moreover, there is empirical evidence for trade-related spillover effects for Ireland estimated between 0.19% and 0.3% and for FDI-related spillover effects for Spain estimated by 0.04% respectively. Comparing the estimated results of foreign technology spillover effects in cases of unrestricted and restricted technology diffusion, the paper finds significant impacts from European economic integration. In particular, Portugal and Ireland benefit most from joining the EU as coefficients are higher for patent- and trade-related spillover effects in the case of restricted technology diffusion from EU-12 or EU-15 countries. Turning to Mexico, there is no significant impact on Mexico's labor productivity no matter if technology diffusion is patent-, trade- or FDI-related. Moreover, there is no evidence that joining the free trade agreement with the USA and Canada has a significant positive effect. According to the analysis, it is only domestic R&D spending which has a major significant impact on labor productivity in Mexico.

References

Banerjee, A., Dolado, J.J., Mestre, R., 1998. Error-correction mechanism tests for cointegration in a single-equation framework, *Journal of Time Series Analysis* 19, 267-283.

Baum, C.F., 2005. Stata: The language of choice for time-series analysis?, *The Stata Journal* 5, 46-63.

Bewley, R., 1979. The direct estimation of the equilibrium response in a linear dynamic model, *Economics Letters* 3, 357-361.

Biswal, B., Dhawan, U., 1998. Export-led growth hypothesis: cointegration and causality analysis for Taiwan, *Applied Economics Letters* 5, 699–701.

Branstetter, L., 2005. Is foreign direct investment a channel of knowledge spillover? Evidence from Japan's FDI in the United States, *Journal of International Economics* 68, 325-344.

Branstetter, L., Sakakibara, M., 2001. Do stronger patents induce more innovation? Evidence from the 1988 Japanese patent law reforms. *RAND Journal of Economics* 32, 77–100.

Ghatak, S., Milner, C., Utkulu, U., 1997. Exports, export composition and growth: cointegration and causality evidence for Malaysia, *Applied Economics* 29, 213–223.

Cabral, R., Mollick, A.V., 2011. Intra-industry trade effects on Mexican manufacturing productivity before and after NAFTA, *The Journal of International Trade & Economic Development* 20, 87-112.

Clemente, J., Montañés, A., Reyes, M., 1998. Testing for a unit root in variables with a double change in the mean, *Economics Letters* 59, 175-182.

Coe, D.T., Helpman, E., 1995. International R&D spillovers, *European Economic Review* 39, 859–887.

Dickey, D.A., Fuller, W.A., 1979. Distribution of the estimators for autoregressive time series with a unit root, *Journal of the American Statistical Association* 74, 427–431.

Eaton, J., Kortum, S., 1999. International technology diffusion: theory and measurement, *International Economic Review* 40, 537–570.

Engle, R.F., Granger, C.W.J., 1987. Co-integration and error correction: representation, estimation, and testing, *Econometrica* 55, 12-26.

Fuller, W., 1976. *Introduction to Statistical Time Series*, Wiley New York, NY.

Griliches, Z., 1979. Issues in assessing the contribution of R&D to productivity growth, *Bell Journal of Economics* 10, 92–116.

GGDC, 2010. *Total Economy Database*, Groningen Growth and Development Center, Groningen.

Hafner, K.A., 2008. The pattern of international patenting and technology diffusion, *Applied Economics* 40, 2819-2837.

Hafner, K.A., 2011. Trade liberalization and technology diffusion, *Review of International Economics* 19, 963-978.

Haskel, J., Pereira, S., Slaughter, M., 2007. Does inward foreign direct investment boost the productivity of domestic firms?, *The Review of Economics and Statistics* 89, 482-496.

Hassler, U., Wolters, J., 2006. Autoregressive distributed lag models and cointegration, *AStA Advances in Statistical Analysis* 90, 59-74.

Hufbauer, G., Schott, J., 1993. *NAFTA: An Assessment*. Washington DC: Institute for International Economics.

Jaffe, A.B., Trajtenberg, M., 2002. *Patents, Citations, and Innovations: A window on the Knowledge Economy*, MIT Press, Cambrigde, MA.

Khalifah, N.A., Adam, R., 2009. Productivity spillovers from FDI in Malaysian manufacturing: evidence from micro-panel data, *Asian Economic Journal* 23, 143-167.

Kao, C., Chiang, M.-H., Chen, B., 1999. International R&D spillovers: an application of estimation and inference in panel cointegration, *Oxford Bulletin of Economics and Statistics* 61, 691–709.

Keller, W., 2004. International technology diffusion, *Journal of Economic Literature* 42, 752–782.

Keller, W., Yeaple, S.R., 2009. Multinational enterprises, international trade, and productivity growth: firm-level evidence from the United States. *The Review of Economics and Statistics* 91, 821-831.

Kleinert, J., Toubal, F., 2010. Gravity for FDI, *Review of International Economics* 18, 1-13.

Kramer, S.M.S., 2010. International R&D spillovers in emerging markets: the impact of trade and foreign direct investment, *The Journal of International Trade & Economic Develepement* 19, 591-623.

Kwiatkowski, D., Phillips, P.C.B, Schmidt, P., Shin, Y., 1992. Testing the null hypothesis of stationarity against the alternative of a unit root, *Journal of Econometrics* 54, 159-178.

MacKinnon, J.G., 1991. Critical values for cointegration tests, in R.F. Engle and C.W.J. Granger (eds.), *Long-run Economic Relationships: Readings in Cointegration*, Oxford University Press, Oxford.

OECD, 2011. *Economic Outlook Database*, Organisation of Economic Co-operation and Development, Paris.

–, 2009. *International Direct Investment Statistics*, Organisation of Economic Co-operation and Development, Paris.

–. 2010a. *Main Science and Technology Database*, Organisation of Economic Co-operation and Development, Paris.

–. 2010b. *Monthly Statistics of International Trade*, Organisation of Economic Co-operation and Development, Paris.

Perron, P., Vogelsang, T., 1992. Nonstationarity and level shifts with an application to purchasing power parity, *Journal of Business and Economic Statistics* 10, 301-320.

Savvides, A., Zachariadis, M., 2005. International technology diffusion and the growth of TFP in the manufacturing sector of developing economies, *Review of Development Economies* 9, 482-501.

Unel, B., 2010. Technology diffusion trough trade with heterogeneous firms, *Review of International Economics* 18, 465-481.

WIPO, 2001. *Industrial Property Statistics Publication B Part I.* World Intellectual Property Organization, Geneva.

–, 2009. *Statistic Database*. World Intellectual Property Organization, Geneva.

Wolters, J., Kirchgaessner, G., 2008. *Introduction to Modern Time Series Analysis*, Springer Verlag, Berlin.

Xu, B., Chiang, E.P., 2005. Trade, patents and international technology diffusion, *The Journal of International Trade & Economic Development* 14, 114-135.

Appendix

Table A.1: R&D Capital Stock Data
(BERD Expenditure in million constant US$ (PPP))

	R&D Expenditure				**R&D Capital Stocks**	
	Period	Flow	Annual Growth	Depreciation	Year	Benchmark
Greece	1981-2007	50.5	8.1424	0.1	1981	278.6
Ireland	1981-2008	115.9	9.3872	0.1	1981	597.8
Portugal	1982-2008	87.3	10.8971	0.1	1982	417.6
Spain	1981-2007	887.6	8.2284	0.1	1981	4,869.6
Mexico	1989-2007	466.1	8.2099	0.1	1989	2,559.5

Notes: The benchmark is calculated following the procedure suggested by Griliches (1979). Depreciation rate is assumed to be 10%. Annual growth rates (%) are calculated according to the time period.

Table A.2: FDI Inflow Stock Data
(FDI Inflow in million current US$)

	FDI Inflow				**FDI Stock**	
Total World	Period	Flow	Annual Growth	Depreciation	Year	Benchmark
Greece	1987-2007	1,258.1	2.0430	0.1	1987	10,446.8
Ireland	1983-2007	237.5	21.4508	0.1	1983	755.1
Portugal	1981-2007	139.0	14.6951	0.1	1981	562.9
Spain	1981-2007	851.9	16.9036	0.1	1981	3,166.5
Mexico	1989-2007	3,881.5	7.7889	0.1	1989	21,819.7
EU-12; USA						
Greece	1987-2008	597.3	8.959	0.1	1987	3,161.1
Ireland	1985-2008	71.2	15.7006	0.1	1985	276.9
Portugal	1985-2008	111.0	14.7756	0.1	1985	448.0
Spain	1985-2008	641.7	21.4699	0.1	1985	2,039.2
Mexico	1985-2008	1.942,5	7.5077	0.1	1985	11,095.1
EU-15; USA-CAN						
Greece	1987-2008	641.8	8.4872	0.1	1987	3,471.6
Ireland	1985-2008	75.3	20.1588	0.1	1985	249.5
Portugal	1985-2008	114.0	15.2643	0.1	1985	451.2
Spain	1985-2008	670.4	21.3488	0.1	1985	2,138.5
Mexico	1985-2008	2,039.8	8.3869	0.1	1985	11,093.7

Notes: The benchmark is calculated following the procedure suggested by Griliches (1979). Depreciation rate is assumed to be 10%. Annual growth rates (%) are calculated according to the time period.

Table A.3: ADF Test (Levels) by Fuller (1976) and Dickey Fuller (1979); Economic Integration
(Annual data for Greece (1981-2008), Ireland (1981-2008), Portugal (1982-2008), Spain (1981-2008) and Mexico (1989-2007))

Intercept and Time Trend:	Greece	Ireland	Portugal	Spain	Mexico
$\log S^{f,P}_{EU-12}$, $\log S^{f,P}_{USA}$					
…ADF, Lag(1)	-2.25 (0.46)	-1.71 (0.75)	-0.94 (0.95)	-2.18 (0.5)	-2.4 (0.38)
…ADF, Lag(2)	-2.78 (0.2)	-1.93 (0.64)	-0.99 (0.95)	-2.58 (0.29)	-2.04 (0.58)
…Clem, AO	(2): -2.030	(2): 1.819	(2): -6.427**	(2): -2.659	(2) :-3.806
…Clem, IO	(2): -10.335**	(1): -0.492	(2): -9.405**	(1): -8.563**	(2): -4.716
$\log S^{f,M}_{EU-12}$, $\log S^{f,M}_{USA}$					
…ADF, Lag(1)	-2.49 (0.33)	-2.69 (0.24)	-2.58 (0.29)	-0.06 (0.99)	-0.86 (0.96)
…ADF, Lag(2)	-2.35 (0.41)	-1.81 (0.7)	-2.35 (0.4)	0.11 (1)	-1.00 (0.94)
$\log S^{f,F}_{EU-12}$, $\log S^{f,F}_{USA}$					
…ADF, Lag(1)	-1.12 (0.93)	-2.15 (0.52)	-2.19 (0.49)	-4.39 (0)***	-2.75 (0.22)
…ADF, Lag(2)	-2.48 (0.34)	-2.33 (0.42)	-2.27 (0.45)	-3.95 (0.01)***	-3.27 (0.07)*
$\log S^{f,P}_{EU-15}$, $\log S^{f,P}_{USA/CAN}$					
…ADF, Lag(1)	-2.25 (0.46)	-1.7 (0.75)	-0.92 (0.95)	-2.16 (0.51)	-2.4 (0.38)
…ADF, Lag(2)	-2.78 (0.2)	-1.92 (0.65)	-0.93 (0.95)	-2.54 (0.31)	-2.04 (0.58)
…AO (Break)	(2): -1.883	(2): 1.678	(2): -6.523**	(2): -2.548	(2): -3.808
…IO (Break)	(2): -10.335	(1): -0.459	(2):-9.9**	(1): -9.724**	(2): -4.716
$\log S^{f,M}_{EU-15}$, $\log S^{f,M}_{USA/CAN}$					
…ADF, Lag(1)	-2.5 (0.33)	-2.69 (0.24)	-4.38 (0)***	-0.08 (0.99)	-0.86 (0.96)
…ADF, Lag(2)	-2.36 (0.4)	-1.81 (0.7)	-5.51 (0)***	0.1 (1)	-1 (0.94)
$\log S^{f,F}_{EU-15}$, $\log S^{f,F}_{USA/CAN}$					
…ADF, Lag(1)	-1.13 (0.92)	-2.11 (0.54)	-2.36 (0.4)	-4.39 (0)***	-2.65 (0.26)
…ADF, Lag(2)	-2.5 (0.33)	-2.36 (0.4)	-2 (0.6)	-4.09 (0.01)***	-3.17 (0.09)*

Notes: * (**) [***] denotes that the time series is stationary at 10% (5%) [1%] level. The null hypothesis is nonstationarity, while the alternative hypothesis is stationarity (ADF-tests) or break-stationarity (AO/IO-tests). ADF-test statistics are compared to the asymptotic quintiles proposed by Fuller (1976) and p-values are given in parenthesis. AO/IO-test statistics are compared to the critical values proposed by Perron and Vogelsang (1992) for a 5% level: -5.490 (AO(2)); IO(2)), -3.560 (AO(1)) and -4.270 (IO(1)). Tests are implemented with a constant and trend in the test regression. Time series are assumed to have auto-correlated error terms.

Table A.4: ADF Test (Differences) by Fuller (1976) and Dickey Fuller (1979); Economic Integration
(Annual data for Greece (1981-2008), Ireland (1981-2008), Portugal (1982-2008), Spain (1981-2008) and Mexico (1989-2007))

Intercept	Greece	Ireland	Portugal	Spain	Mexico
d. $\log S^{f,P}_{EU-12;USA}$	-3.51 (0.01)***	-3.27 (0.02)**	-2.71 (0.07)*	-3.17 (0.02)**	-3.68 (0)**
d. $\log S^{f,M}_{EU-12;USA}$	-4.27 (0)***	-4.64 (0)***	-3.88 (0)***	-1.71 (0.43)	-2.63 (0.09)*
d. $\log S^{f,F}_{EU-12;USA}$	-1.47 (0.55)	-2.21 (0.2)	-2.43 (0.13)	-1.91 (0.33)	-2.74 (0.07)*
d. $\log S^{f,P}_{EU-15;USA/CAN}$	-3.51 (0.01)***	-3.28 (0.02)**	-2.76 (0.06)*	-3.22 (0.02)**	-3.68 (0)***
d. $\log S^{f,M}_{EU-15;USA/CAN}$	-4.27 (0)***	-4.63 (0)***	-4.17 (0)***	-1.71 (0.43)	-2.63 (0.09)*
d. $\log S^{f,F}_{EU-15;USA/CAN}$	-1.49 (0.54)	-2.19 (0.21)	-2.81 (0.06)*	-1.88 (0.34)	-2.71 (0.07)*

Notes: * (**) [***] denotes that the time series' first difference is stationary at 10% (5%) [1%] level. The null hypothesis is nonstationarity while the alternative hypothesis is stationarity. Test statistics are compared to the asymptotic quintiles proposed by Fuller (1976) and p-values are given in parenthesis. Tests are implemented with a constant and one lag in the test regression. Time series are assumed to have auto-correlated error terms.

Table A.5: Cointegration Test Results by KPSS; Economic Integration: EU-12 and USA
(Annual data for Greece (1981-2008), Ireland (1981-2008), Portugal (1982-2008), Spain (1981-2008) and Mexico (1989-2007))

Equation:	**(3) with (5)**	**(3) with (6)**	**(3) with (7)**	**(3) with (5)/(6)/(7)**
Greece:				
KPSS, Lag (1), Lead (1)	0.155	0.17	0.082*	0.049*
KPSS, Lag (2), Lead (1)	0.108	0.115	0.096*	n.a.
Ireland:				
KPSS, Lag (1), Lead (1)	0.088*	0.084*	0.058*	0.042*
KPSS, Lag (2), Lead (1)	0.08*	0.084*	0.068*	0.057*
Portugal:				
KPSS, Lag (1), Lead (1)	0.041*	0.039*	0.036*	0.033*
KPSS, Lag (2), Lead (1)	0.049*	0.056*	0.062*	0.083
Spain:				
KPSS, Lag (1), Lead (1)	0.05*	0.047*	0.051*	0.036*
KPSS, Lag (2), Lead (1)	0.042*	0.054*	0.062*	0.055*
Mexico				
KPSS, Lag (1), Lead (1)	0.054*	0.052*	0.053*	0.069*
KPSS, Lag (2), Lead (1)	0.06*	0.076*	0.083*	n.a.

Notes: * denotes that the cointegration is statistically significant at least at a 5% level. Test statistics are compared to the asymptotic quintiles from Kwiatkowski, Phillips, Schmidt and Shin (1992) for two and four I(1)-regressors. The null hypothesis is that there is cointegration (i.e. residual is stationary), while the alternative hypothesis is that there is no cointegration. KPSS-test statistics are compared to the critical values for a 5% level: 0.101 for two I(1) regressors and 0.073 for four I(1) regressors. By definition, the unit root equation for the resulting error term from the long-run relationship does not include a constant and a time trend.

Table A.6: Cointegration Test Results by KPSS; Economic Integration: EU-15 and USA/CAN
(Annual data for Greece (1981-2008), Ireland (1981-2008), Portugal (1982-2008), Spain (1981-2008) and Mexico (1989-2007))

Equation:	**(3) with (5)**	**(3) with (6)**	**(3) with (7)**	**(3) with (5)/(6)/(7)**
Greece:				
KPSS, Lag (1), Lead (1)	.154	.171	0.0822*	0.0499*
KPSS, Lag (2), Lead (1)	.108	.116	0.0942*	n.a.
Ireland:				
KPSS, Lag (1), Lead (1)	0.0878*	0.0842*	0.0585*	0.0421*
KPSS, Lag (2), Lead (1)	0.0803*	0.0835*	0.0658*	0.0577*
Portugal:				
KPSS, Lag (1), Lead (1)	0.0418*	0.0646*	0.0331*	0.0307*
KPSS, Lag (2), Lead (1)	0.0482*	0.061*	0.0603*	0.0689*
Spain:				
KPSS, Lag (1), Lead (1)	0.0499*	0.0462*	0.0512*	0.0353*
KPSS, Lag (2), Lead (1)	0.0419*	0.0538*	0.0611*	0.0554*
Mexico				
KPSS, Lag (1), Lead (1)	0.054*	0.052*	0.054*	0.069*
KPSS, Lag (2), Lead (1)	0.06*	0.076*	0.084*	n.a.

Notes: * denotes that the cointegration is statistically significant at least at a 5% level. Test statistics are compared to the asymptotic quintiles from Kwiatkowski, Phillips, Schmidt and Shin (1992) for two and four I(1)-regressors. The null hypothesis is that there is cointegration (i.e. residual is stationary), while the alternative hypothesis is that there is no cointegration. KPSS-test statistics are compared to the critical values for a 5% level: 0.101 for two I(1) regressors and 0.073 for four I(1) regressors. By definition, the unit root equation for the resulting error term from the long-run relationship does not include a constant and a time trend.

Table A.7: Technology Diffusion: Estimation Results for Greece, Ireland, Portugal and Spain by the Single Equation EC Model; Economic Integration: EU-12

(Annual data for Greece (1981-2008), Ireland (1981-2008), Portugal (1982-2008) and Spain (1981-2008))

Equation:	**(3) with (5)**	**(3) with (6)**	**(3) with (7)**	**(3) with (5)/(6)/(7)**
Greece:				
$\log S^d$	0.33 (18.64)***	0.36 (23.87)***	0.05 (0.41)	0.48 (12.69)***
$\log LP^d_{t-1}$	-0.08 (-0.64)	-0.2 (-1.71)*	-0.06 (-0.2)	-0.44 (-1.08)
R^2 : OLS; ECM	0.95; 0.12	0.94; 0.22	0.96; 0.24	0.97; 0.47
No. of Obs. : OLS; ECM	27; 26	27; 26	21; 20	21; 20
Ireland:				
$\log S^d$	0.38 (56.49)***	0.37 (79.56)***	0.35 (18.05)***	0.31 (10.47)***
$\log LP^d_{t-1}$	-0.39 (-2.02)**	-0.37 (-1.84)*	-0.45 (-1.83)*	-0.41 (-1.51)
R^2 : OLS; ECM	1; 0.4	1; 0.4	0.99; 0.35	1; 0.47
No. of Obs. : OLS; ECM	28; 27	28; 27	24; 23	24; 23
Portugal:				
$\log S^{f,F}$			-0.01 (-0.79)	-0.03 (-1.09)
$\log LP^d_{t-1}$	-0.5 (-3.2)***	-0.44 (-2.63)***	-0.33 (-2.4)**	-0.53 (-1.89)*
R^2 : OLS; ECM	0.94; 0.44	0.95; 0.46	0.89; 0.38	0.94; 0.45
No. of Obs. : OLS; ECM	27; 26	27; 26	24; 23	24; 23
Spain:				
$\log S^{f,F}$			0.01 (1.27)	0.01 (1.82)*
$\log LP^d_{t-1}$	-0.26 (-3.12)***	-0.13 (-1.92)*	-0.67 (-3.69)***	-0.58 (-3.32)***
R^2 : OLS; ECM	0.96; 0.69	0.96; 0.77	0.97; 0.59	0.97; 0.79
No. of Obs. : OLS; ECM	28; 27	28; 27	24; 23	24; 23

Notes: The *t*-statistics of the coefficients are reported in parentheses. * (**) [***] denotes that the coefficient is significantly different from zero at a 10% (5%) [1%] level. All equations include unreported country-specific constants.

Table A.8: Technology Diffusion: Estimation Results for Greece, Ireland, Portugal and Spain by the Single Equation EC Model; Economic Integration: EU-15

(Annual data for Greece (1981-2008), Ireland (1981-2008), Portugal (1982-2008) and Spain (1981-2008))

Equation:	**(3) with (5)**	**(3) with (6)**	**(3) with (7)**	**(3) with (5)/(6)/(7)**
Greece:				
$\log S^d$	0.33 (18.66)***	0.36 (23.58)***	-0.34 (-1.42)	0.49 (12.41)***
$\log LP^d_{t-1}$	-0.08 (-0.64)	-0.2 (-1.7)*	-0.03 (-0.1)	-0.43 (-1.03)
R^2 : OLS; ECM	0.95; 0.12	0.94; 0.21	0.96; 0.25	0.97; 0.46
No. of Obs. : OLS; ECM	27; 26	27; 26	21; 20	21; 20
Ireland:				
$\log S^d$	0.38 (56.9)***	0.37 (79.49)***	0.35 (17.44)***	0.31 (10.35)***
$\log LP^d_{t-1}$	-0.39 (-2.02)**	-0.37 (-1.84)*	-0.45 (-1.84)*	-0.41 (-1.51)
R^2 : OLS; ECM	1; 0.4	1; 0.4	0.99; 0.35	1; 0.47
No. of Obs. : OLS; ECM	28; 27	28; 27	24; 23	24; 23
Portugal:				
$\log S^d$	0.26 (21.59)***	0.23 (25.31)***	0.2 (5.99)***	0.23 (1.55)

$\log LP_{t-1}^{d}$	-0.5 (-3.19)***	-0.23 (-1.88)*	-0.32 (-2.34)**	-0.57 (-1.86)*
R^2: OLS; ECM	0.94; 0.44	0.87; 0.41	0.89; 0.38	0.93; 0.42
No. of Obs. : OLS; ECM	27; 26	27; 26	24; 23	24; 23
Spain:				
$\log S^{d}$	0.12 (14.9)***	0.3 (14.93)***	0.1 (5.76)***	0.15 (7.82)***
$\log LP_{t-1}^{d}$	-0.25 (-3.09)***	-0.13 (-1.94)*	-0.67 (-3.66)***	-0.58 (-3.27)***
R^2: OLS; ECM	0.96; 0.69	0.96; 0.77	0.97; 0.59	0.97; 0.78
No. of Obs. : OLS; ECM	28; 27	28; 27	24; 23	24; 23

Notes: The *t*-statistics of the coefficients are reported in parentheses. * (**) [***] denotes that the coefficient is significantly different from zero at a 10% (5%) [1%] level. All equations include unreported country-specific constants.

Table A.9: Technology Diffusion: Estimation Results for Mexico by the Single Equation EC Model; Economic Integration: USA and USA/CAN
(Annual data for Mexico from 1989-2007)

Equation:	**(3) with (5)**	**(3) with (6)**	**(3) with (7)**	**(3) with (5)/(6)/(7)**
Mexico; USA				
$\log S^{d}$	0.09 (2.04)**	0.12 (5.01)***	0.17 (3.91)***	0.1 (0.9)
$\log LP_{t-1}^{d}$	-0.72 (-2.59)**	-0.78 (-2.86)***	-0.81 (-2.45)**	-0.81 (-1.74)*
R^2: OLS; ECM	0.82; 0.43	0.8; 0.42	0.8; 0.43	0.82; 0.52
No. of Obs. : OLS; ECM	19; 18	19; 18	19; 18	19; 18
Mexico; USA/CAN				
$\log S^{d}$	0.09 (2.02)**	0.12 (5.01)***	0.17 (3.92)***	0.1 (0.9)
$\log LP_{t-1}^{d}$	-0.72 (-2.59)**	-0.78 (-2.86)***	-0.79 (-2.39)**	-0.8 (-1.69)
R^2: OLS; ECM	0.82; 0.43	0.81; 0.42	0.81; 0.43	0.82; 0.52
No. of Obs. : OLS; ECM	19; 18	19; 18	19; 18	19; 18

Notes: The *t*-statistics of the coefficients are reported in parentheses. * (**) [***] denotes that the coefficient is significantly different from zero at a 10% (5%) [1%] level. All equations include unreported country-specific constants.