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CAN MONETARY INTEGRATION IMPROVE PRODUCTIVITY? EMPIRICAL EVIDENCE OF EUROZONE

León Padilla

Abstract

European monetary integration must be understood as an additional step towards strengthening the close ties that have been fostered after the Second World War. The aim of this research is to determine the effect of adopting the euro in terms of productivity growth, measured as the total factor productivity (TPF) variation. We used a panel data analysis with two-way fixed effects to estimate the effects of Euro adoption on the productivity growth. Two panels from 1996 to 2016 were used –one comprised 28 countries of EU members; the other only included 13 countries which joined the EU since 2004. Our findings suggest that the productivity growth of the countries that joined in 2004 and adopted the euro was higher compared to those that maintained their own currency. In addition, we find that FDI was the main channel through which the adoption of the euro influenced productivity growth.

Keywords: *Productivity growth, Economic integration, Eurozone, Panel data*

JEL Classification: *O4; F02; F15; E52; O3*

1 INTRODUCTION

Economic integration seeks to promote economic efficiency by reducing costs for consumers and producers and by increasing trade among countries that take part in the integration process. There are different levels of economic integration, which may include preferential trade arrangements (PTA), free trade agreements (FTA), custom unions, common markets, and monetary unions. Hence, as economies become more integrated, existing trade barriers lower, making it necessary to strengthen the economic and political coordination among member countries and thus leading to a loss of sovereignty among national governments.

In recent history, the European Union (EU) represents the most important economic integration project on a global scale. After the Second World War, Europe began an economic integration process

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with the creation of the European Coal and Steel Community, made up of Belgium, France, Germany, Italy, Luxembourg, and the Netherlands. It was later named the European Economic Community (EEC), which was succeeded by the EU. In the following years, Europe witnessed a deepening in this process of economic integration. In addition to fully liberalizing their internal trade relations, these states formed a single market, established common institutions (the European Council, the European Commission, and the Court of Justice of the European Union) with supranational powers, and adopted joined policies in key areas (foreign trade, energy, agriculture, monetary policy, etc.). By 1995, after five enlargements, the EU consisted of 15 member states.

The conventional arguments to join a monetary area, established in the optimum currency area (OCA) theory, include: (1) the business cycles synchronization, (2) factor mobility and labor market flexibility, (3) the degree of economic openness, (4) the product diversification and (5) the ability to use fiscal policy in a countercyclical fashion (Buiter 2008; De Grauwe 2016; Kenen 1969; McKinnon 1963; Mundell 1961). However, in the case of the Economic and Monetary Union (EMU) to join the Eurozone a candidate country has to fulfil five nominal Maastricht convergence criteria and ensure compliance of national legislation with the acquis communautaire (Kolodko and Postuła, 2018). Moreover, although the reasons for monetary integration in Europe are mostly economic, there are also important political ones. De Grauwe (2016) point out that the political will was evident when many countries did not meet one or more of the convergence criteria and despite this the union started including countries like Belgium, Greece and Italy which did not satisfy the government debt criterion.

In 1999 twelve member states adopted a single currency, and the EMU would be later formalized on January 1, 2002[1], when euro notes and coins first began circulating. In that sense, the monetary integration process must be understood as an additional step toward strengthening the economic integration process in Europe. After 2007, another seven countries joined the eurozone[2]. Nevertheless, it is important to note that it may be expected that in the 2020s all countries that are still using their national currencies will join the EMU and that the EU will be extended to include new member states (with the exception of the United Kingdom that exited the EU and Denmark which has an exclusion clause), which will cause the enlargement of the Eurozone (Kolodko and Postuła 2018).

The literature has focused on establishing the correlation between integration and economic growth in Europe. These researches suggest that European economic integration has a positive impact on growth. Landau (1995) found no impact of belonging to the EEC, unlike Torstensson (1999), who suggested that being a member of the EEC did impact the rise of the investment rates as well as the total factor productivity through spillovers. Henrekson et al. (1997) found a permanent impact on the growth rate, ranging from 0.6 to 1.3% annually. Major factors contributing to this impact include institutional considerations, goods trade, free mobility of factors of production, and the imposition of mutual obligations and commitments. In his study on both temporary and permanent impacts on the growth of fifteen members of the EU between 1950 and 2000, Badinger (2005) proved that although the hypothesis assuming a permanent impact on growth was rejected, European integration has significantly contributed to growth performance, though only in a permanent way for EU members after the Second World War. Badinger estimated that, EU-15 GDP per capita would be approximately one-fifth lower today if economic integration had not taken place beginning in 1950. In a later study, Badinger (2008), through a cointegration analysis of panel data on 14 EU countries for the 1960-2000 period, assessed the impact of European integration on growth. The results showed major increases (approximately 44%) in technology and capital stock as a result of the economic integration process.

In more recent research, Campos et al. (2018) found that the European integration, including the 2004 enlargements, have had positive net benefits from that per capita GDP and labor productivity increase. According to authors, the results suggest that one of the main factors that explain the positive benefits in European integration process was the adoption of the Euro. Hence, regional integration not only promotes economic growth but also has different effects, including driving technological change. In that regard, the main purpose of this research is to determine the role that the adoption of the euro has had in the European economic integration process and its impact on productivity growth (or technological change), particularly in countries that held the lowest degree of integration. For this purpose, we focused on countries whose accession to the EU occurred as of 2004, drawing a distinction between those that adopted the euro and those that maintained their monetary autonomy[3].

2 THEORETICAL FRAMEWORK

First, the calculation of the total factor productivity (TPF) derives from the estimation of the production function. By using the Cobb-Douglas production function, based on the neoclassical standard model and assuming constant returns to scale, the following equation was obtained:

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

Where Y_{it} represents the aggregate value of a country i during the period t and is determined by the stock of physical capital (K_{it}) and by the level of labor (L_{it}). A_{it} is a Hicks neutral technical efficiency index or a country's TPF i over a period t (Van Beveren 2012). Labor intensity is ϕ_{it} of a country i during the period t and capital intensity is $1-\phi_{it}$.

The TPF growth is $\Delta \ln Y_{it} = \ln Y_{it} - \ln Y_{it-1}$ and is defined as the variation of the logarithm of value added in real terms between the period t–1 and t, $\Delta \ln L_{it} = \ln L_{it} - \ln L_{it-1}$ as the variation of the logarithm of labor, $\Delta \ln K_{it} = \ln K_{it} - \ln K_{it-1}$ as the variation of the logarithm of the physical capital stock, and $\tilde{\phi}_{it} = \frac{1}{2}(\phi_{it} + \phi_{it-1})$ as the average cost of labor in the value added between the period t and t–1. Therefore, the productivity growth can be defined as

$$TPF\ growth_{it} = \Delta \ln A_{it} = \Delta \ln Y_{it} - \tilde{\phi}_{it}\, \Delta \ln L_{it} - \left(1 - \tilde{\phi}_{it}\right) \Delta \ln K_{it} \tag{2}$$

The theoretical framework used in this research is based on the theoretical proposals of Bernard and Jones (1996, 2001), Griffith et al. (2004), and Cameron et al. (2005), who suggest that the productivity growth of a country is the result of the internal (own innovation efforts) and external innovative capacity (factors related to the technological transfer of the most advanced countries or frontier countries). The next equation was obtained:

$$\Delta \ln A_{it} = \upsilon_{it} + \tau_{it} + \chi_i \ln \frac{A_{Ft}}{A_{it}} \tag{3}$$

Where υ_{it} is a vector that integrates variables related to the country's capacity for innovation i in time t, τ_{it} is a vector of external technological factors, χ_{it} is the technology transfer rate of the leading country, and A_{Ft} and A_{it} represent the technical efficiency of the frontier country or technology leader F with country i, respectively. Domestic innovation efforts refer to human capital, education, investment — or fixed gross capital formation—, and research and development (R&D) expenditure, while external innovation factors refer to imports, exports, and foreign direct investment (FDI). Moreover, technology distance refers to technology transfer capability.

As for domestic factors, Nelson and Phelps (1966) integrated the role of human capital in technical progress, given that the education process can be seen as an investment and educated people are included in human capital; thus, education can thereby accelerate the process of technological diffusion. Krueger and Lindahl (2001) showed that changes in education are positively related to economic growth. Similarly, Kutan and Yigit (2009) found a positive relation between human capital and technical progress in countries that joined the EU as of in 2004. Griffith et al. (2004) showed that both R&D expenditure and human capital play an important role in the level of convergence of the TPF in countries that are part of the Organization for Economic Co-operation and Development (OECD). Coe and Helpman (1995) found a straight relation between R&D capital stock, which is in turn linked to R&D expenditure and productivity in EU-15 countries. However, they also found a relation between productivity and external R&D or technological capacity of the trading partners. More specifically, 1) the TPF relies not only on local R&D but also on capital stock in foreign R&D; 2) foreign R&D has a positive impact on local productivity and grows stronger as the economy becomes more open in terms of foreign trade; 3) capital stock in foreign R&D can be at least as important as the capital stock of internal R&D in smaller economies, while capital stock of internal R&D may be more important in larger economies (the G7). In a later study, Coe et al. (2009) found evidence confirming the impact of the capital stock of local and foreign R&D in the TPF (even controlled by the impact of human capital). The authors also found that institutional differences impact the degree of R&D spillovers and are determining factors in the TFP.

Hence, the benefits of foreign R&D can be both direct and indirect. The former benefits consist of learning about new technologies and materials, as well as production processes or organizational methods, while the latter benefits come from imports of goods and services that have been developed by trading partners. Regarding external factors, Badinger (2005, 2008) showed that another external channel for technological spillovers is economic integration because it provides a country with more opportunities to increase its efficiency by participating in the technological progress of other countries. Melitz (2003) found that greater trade openness (especially in exports)

increases the productivity of the industry through the selection and production of reassignment effects. By using a gravitational model for 22 countries in Europe, Fracasso and Marzetti (2015) showed that particularly intense trade flows lead to a greater cross-border transmission of knowledge.

Another key factor of technological diffusion is FDI. In fact, these external capital flows could be the main channel by which advanced technology is transferred to developing economies, and its greater efficiency could be the result of mixing advanced management skills with modern technology (Borensztein et al. 1998). Haskel et al. (2007) found spillover effects between FDI and local firms. The results showed a positive and significant correlation between the TPF in domestic companies and the participation of the foreign subsidiary in industry in the UK. Yazdan and Hossein (2013) concluded that FDI has a positive and significant impact on productivity growth in developed countries. However, the authors did not find any positive results in developing countries.

Furthermore, the role of technology distance in technical change has also been widely documented. Cameron et al. (2005) integrated a technology distance variable to measure the role that the technology frontier's transfer potential (the United States) played in the UK. The authors found that the distance to the technology frontier has a positive and statistically significant impact on the productivity growth rate. Badinger et al. (2019) found that technology leader spillover effects are stronger in regions within an industry where the technology gap is very small or sufficiently wide, at least in Europe. Kutan and Yigit (2009) also found a positive relationship between technology distance and productivity change in countries that have joined the EU since 2004. Additionally, the evidence suggests that companies located in economic areas closer to the global technology frontier tend to benefit more from pure knowledge spillovers (Aldieri et al. 2018). Finally, Miller and Upadhyay (2000) and Griffith et al. (2004) showed that including time variables allows control of the cyclical effect when analyzing the factors that determine the change in productivity.

Based on the discussion, the proposed model to establish the factors that determine technological change in a country is given by:

$$\ln A_{it} = \beta_1 + \beta_2 Euro_{it} + \beta_3 \ln \frac{A_{Ft}}{A_{it}} + \delta \gamma_{it} + \lambda \eta_{it} + \mu_{it} \qquad (4)$$

Where the variation in the TFP ($\Delta \ln A_{it)}$ is explained by $Euro_{it}$ which is a dummy variable which takes a value of 1 from the year of adoption of the euro as the legal currency, the technology distance is a proxy for the rate of technology transfer from the frontier — this variable is measured by the absolute value of the log ratio of productivity of country i to the productivity of EU-15 for all countries—, Y_{it} is a vector of variables that corresponds to external factors (imports, exports and FDI) and to internal factors (education, investment and R&D expenditure), η_{it} is a vector of interaction effects between $Euro_{it}$ and variables that are related to monetary integration (FDI, investment, imports, and exports), and μ_{it} is a composite error term. Following Griffith et al. (2004), to control the unobserved heterogeneity that is correlated with the explanatory variables we allow the error term (μ_{it}) include a country specific fixed effect (v_i) and a full set of time dummies (T_t) — taking account the possible presence of common macroeconomic shocks that affect rates of TFP growth in all countries.

$$\mu_{it} = v_i + T_t + \varepsilon_{it} \qquad (5)$$

3 METHODOLOGY, DATA AND RESULTS

The sample is composed of a panel of the 28 countries of the EU (including the UK), from which 19 countries are members of the Eurozone and 9 are countries that maintained their national currency between 1996 and 2016 (annual frequency). In addition, the sample was split into two panels. The panels A was represented by the 28 countries of the EU, while the panel B corresponds to 13 countries that became part of the EU since 2004. This strategy was adopted bearing in mind that the process of European economic integration has been heterogeneous. The variables for productivity growth calculation (Y_{it}, L_{it}, K_{it}, ϕ_{it}), investment (or fixed gross capital formation), and exports and imports were obtained from the database of the European Commission (AMECO). The education index and FDI come from the United Nations database. R&D expenditure was taken from EUROSTAT. All monetary variables are found in real terms based on 2010 prices. FDI, imports, exports, investment and R&D expenditure are calculated as a percentage of GDP.

Tables A1 and A2 (see Appendix) shows the descriptive statistics of all the variables for Panels A and B. One problem with the database is that FDI (as a percentage of GDP) has high dispersion values. For this

reason, we take the logarithm of this variable to reduce its dispersion. On the other hand, Tables A3 and A4 (see Appendix) presents the correlation matrix between the variables of the model. According to Table A3 and A4, the education index with R&D, FDI with imports, and FDI with exports are positively associated (with coefficients higher than 0.5). However, the only variables that show a high correlation, predictably, are exports with imports (with coefficients close to 1) for both Panels.

Before running the estimates, we first test the seasonality of the variables. We applied the Im,Pesaran and Shin (2003) test, the Augmented DF (ADF) test (Dickey and Fuller 1981), and the Phillips and Perron (1988) test to verify the presence of a unit root in the panel (Tables A5 and A6 in Appendix). The IPS, ADF, and PP results show that most variables are non-stationary. Only TFP growth and the logarithm of FDI are stationary at level for both Panels. Therefore, we apply the first difference to the remaining variables — distance, education, R&D, investment, exports and imports — and we verified that the first difference of these variables is stationary.

We used a panel data analysis with two-way fixed effects (to control the unobserved unit-specific and time-specific confounders at the same time) and corrected for heteroscedasticity. Following Kutan and Yigit (2009), we use one lag were for import given (i) the lagging effect expected of this variable on the variation of the TFP growth and (ii) the larger contribution of this variable to the explanatory power of the model.

According to estimations the technology distance (Distance) presented a positive and significant impact in all the models for both Panels. That is, as the technological gap regarding the technological border increases, TFP growth increases. This result is consistent with previous studies (Badinger et al. 2019; Kutan and Yigit 2009; Nelson and Phelps 1966) and the economic theory that states that as the technology gap increases, follower countries will obtain more benefits from copying the leading countries or the technological frontier because the cost of imitating[4] decreases by the augmentation of the technological difference between the follower and the leader. The variable that represented human capital (education index) also maintain a positive and significant relationship with TFP growth for both Panels. This result is similar to those of other studies (Benhabib and Spiegel 1994; Griffith et al. 2004; Kneller and Stevens 2006; Nelson and Phelps 1966). Investment (for Panel A) and imports (for Panel B) showed a positive relation and significant. For time variables, the results showed that European countries have been affected by common events such as the sixth enlargement since 2004, the economic crisis that negatively affected the group of European countries in 2008 and 2009, and economic adjustment program in some EU countries in 2012 and 2013.

On the other hand, after incorporating control variables, the variable of interest (euro) showed that the adoption of the euro did have correlation with higher productivity growth for the group of 28 countries (see Table 1). In addition, this result is even stronger for the estimations of Panel B (see Table 2). We found that the productivity growth of the countries that joined in 2004 and also adopted the euro was higher compared to those that maintained their own currency. Finally, to determine the main channels through which the adoption of the euro could influence the increase in productivity, we examined the interaction between the variable *Euro* and variables by which the adoption of a common currency could have an influence (i.e. FDI, and investment, exports and imports). The estimations showed that FDI (as percent of GDP) was the main channel through which the adoption of the euro influenced technical change for both Panels.

4 ROBUSTNESS CHECKS

To ensure robust results, we present the "leave-one-out" approach for Panel B. That is, we exclude a country at a time from the database to ensure that the positive effect of the FDI logarithm does not depend on a country in particular. The results show that by excluding a country in each estimate, the positive relationship between the adoption of the euro and FDI remains. The robustness checks confirmed the validity of the model's specifications and the consistency of our findings. Therefore, we can conclude that the main channel for increasing productivity in the countries of the sixth, seventh, and eighth enlargements of the European Union and that adopted the euro was FDI (see Table 3).

Table 1. Panel A estimations (UE 28).

	(1a)	(2a)	(3a)	(4a)	(5a)	(6a)	(7a)	(8a)	(9a)	(10a)	(11a)
Constant	0.959***	0.914**	0.791*	0.742	0.571	0.281	0.146	0.460	0.658	0.621	0.730
	(2.876)	(2.734)	(1.943)	(1.572)	(0.905)	(0.459)	(0.213)	(0.744)	(1.158)	(1.104)	(1.586)
Distance	2.985*	3.012*	3.032*	2.261*	2.156**	3.689***	3.379***	3.199***	3.511***	3.706***	3.689***
	(1.940)	(1.935)	(1.933)	(1.838)	(2.086)	(4.075)	(4.131)	(3.987)	(3.486)	(3.730)	(3.646)
Education		0.232**	0.235**	0.205**	0.156*	0.143*	0.151*	0.148	0.154*	0.164*	0.156*
		(2.292)	(2.462)	(2.345)	(1.763)	(1.729)	(1.715)	(1.691)	(1.800)	(1.877)	(1.745)
R&D			-1.384	-2.179	-1.616	-1.802	-2.076	-1.856	-1.768	-1.668	-1.724
			(-0.814)	(-1.299)	(-1.002)	(-1.190)	(-1.258)	(-1.136)	(-1.066)	(-0.992)	(-0.988)
Investment				0.297***	0.257***	0.235***	0.266***	0.266***	0.376***	0.353**	0.349**
				(3.592)	(3.503)	(3.077)	(3.607)	(3.690)	(2.839)	(2.419)	(2.412)
LnFDI					0.156	0.130	0.111	-0.089	-0.121	-0.155	-0.134
					(1.014)	(0.793)	(0.722)	(-0.649)	(-0.939)	(-1.137)	(-0.864)
Imports (–1)						0.043	0.042	0.045	0.032	0.075	0.072
						(1.540)	(1.239)	(1.337)	(0.880)	(1.344)	(1.268)
Exports							0.081	0.082	0.085	0.087	0.045
							(1.306)	(1.301)	(1.365)	(1.402)	(1.658)
Euro	0.219	0.205	0.293	0.259	0.375	**0.700***	**0.757****	0.260	0.181	0.283	0.125
	(0.617)	(0.592)	(0.788)	(0.667)	(0.976)	(2.017)	(2.179)	(0.578)	(0.439)	(0.690)	(0.271)
Euro x LnFDI								**0.348****	**0.396****	**0.424****	**0.396****
								(2.068)	(2.593)	(2.660)	(2.582)
Euro x Investment									-0.277	-0.257	-0.256
									(-1.630)	(-1.450)	(-1.417)
Euro x Imports(–1)										-0.083	-0.077
										(-1.259)	(-1.074)
Euro x Exports											0.085
											(0.743)
2000	1.839***	1.664***	1.620***	1.713***	1.586**	1.863***	1.862***	1.906***	1.739***	1.806***	1.746***
	(3.930)	(3.631)	(3.038)	(2.820)	(2.679)	(3.321)	(3.255)	(3.360)	(3.358)	(3.577)	(3.652)
2004	1.233***	1.101***	1.237***	1.221***	1.319**	1.470***	1.376***	1.431***	1.267**	1.269**	1.244**
	(4.469)	(3.711)	(3.494)	(2.990)	(2.700)	(2.832)	(2.912)	(3.006)	(2.634)	(2.647)	(2.700)
2006	0.773***	0.680**	0.864**	0.724*	0.749	0.887*	0.769*	0.810**	0.630	0.633	0.617
	(2.898)	(2.558)	(2.410)	(1.762)	(1.583)	(1.866)	(1.930)	(2.054)	(1.643)	(1.667)	(1.615)
2008	-2.718***	-2.800***	-2.567***	-2.397***	-2.526***	-2.482***	-2.487***	-2.498***	-2.633***	-2.668***	-2.735***
	(-5.746)	(-5.641)	(-4.399)	(-3.707)	(-3.194)	(-3.223)	(-3.311)	(-3.401)	(-3.686)	(-3.715)	(-3.967)
2009	-6.306***	-6.355***	-6.149***	-5.148***	-4.798***	-4.804***	-4.362***	-4.430***	-4.540***	-4.536***	-4.541***
	(-9.431)	(-9.282)	(-7.411)	(-6.095)	(-5.529)	(-5.531)	(-4.056)	(-4.187)	(-4.489)	(-4.509)	(-4.606)
2012	-1.828***	-1.802***	-1.654***	-1.445***	-1.521***	-1.520***	-1.516***	-1.567***	-1.768***	-1.797***	-1.837***
	(-6.064)	(-6.061)	(-4.315)	(-3.217)	(-3.360)	(-3.198)	(-3.181)	(-3.492)	(-4.060)	(-4.107)	(-4.288)
2013	-0.992***	-1.178***	-1.069***	-0.850*	-0.665	-0.566	-0.537	-0.653	-0.844*	-0.860*	-0.857*
	(-3.599)	(-3.935)	(-2.987)	(-2.024)	(-1.460)	(-1.195)	(-1.079)	(-1.410)	(-1.962)	(-2.020)	(-1.993)
Observations	560	560	523	523	492	471	471	471	471	471	471
Adj. R^2	0.434	0.440	0.438	0.467	0.427	0.468	0.475	0.480	0.487	0.489	0.491
Num. of countries	28	28	28	28	28	28	28	28	28	28	28

Note: t-statistic is reported in parentheses and the significance levels are denoted as follows: *** p<0.01, ** p<0.05 and * p<0.1. We tested the validity of using two-way fixed effects model. The null hypothesis that individual effects are uncorrelated with any regressor in the model was rejected. So, the difference between the coefficients of random and fixed effects is systematic. Therefore, the fixed effects method should be used. For time dichotomous variables we rejected the null that the coefficients for all years are jointly equal to zero. Consequently, time fixed effects are needed. We only include the years that were statistically significant.

Table 2. Panel B estimations (UE 13).

	(1b)	(2b)	(3b)	(4b)	(5b)	(6b)	(7b)	(8b)	(9b)	(10b)	(11b)
Constant	1.138**	1.088*	1.050	1.209*	1.163	1.123	1.123	1.577**	1.704**	1.557**	1.553**
	(2.202)	(2.124)	(1.661)	(1.987)	(1.629)	(1.757)	(1.649)	(2.539)	(2.752)	(2.413)	(2.397)
Distance	2.153	2.162	2.025	1.574	1.853	3.883***	3.885***	3.747***	3.841***	4.013***	4.008***
	(1.518)	(1.489)	(1.564)	(1.488)	(1.603)	(3.692)	(3.692)	(3.669)	(3.375)	(3.551)	(3.533)
Education		0.460**	0.477***	0.424**	0.383**	0.351**	0.350**	0.340**	0.356**	0.385**	0.385**
		(2.861)	(3.193)	(2.890)	(2.474)	(2.262)	(2.304)	(2.331)	(2.301)	(2.446)	(2.445)
R&D			-0.166	-1.012	-0.560	-0.858	-0.856	-0.378	-0.130	-0.290	-0.262
			(-0.114)	(-0.688)	(-0.362)	(-0.699)	(-0.660)	(-0.264)	(-0.102)	(-0.243)	(-0.215)
Investment				0.211*	0.183*	0.144	0.144	0.138	0.192	0.183	0.184
				(2.048)	(1.964)	(1.296)	(1.260)	(1.203)	(1.211)	(1.136)	(1.133)
LnFDI					0.083	-0.042	-0.042	-0.294	-0.310	-0.357	-0.358
					(0.536)	(-0.266)	(-0.268)	(-1.270)	(-1.388)	(-1.476)	(-1.460)
Imports (–1)						0.047	0.047	0.051	0.046	0.095*	0.095*
						(1.232)	(1.153)	(1.359)	(1.160)	(1.809)	(1.803)
Exports							-0.000	-0.004	-0.003	0.014	0.016
							(-0.013)	(-0.118)	(-0.094)	(0.480)	(0.467)
Euro	**1.113****	**1.043****	**1.175****	**1.018****	**1.147****	**1.408****	**1.408****	0.634	0.543	0.744	0.760
	(2.619)	(2.758)	(2.892)	(2.418)	(2.320)	(2.635)	(2.647)	(0.861)	(0.782)	(1.057)	(1.117)
Euro x LnFDI								**0.514***	**0.541****	**0.546****	**0.547****
								(2.014)	(2.361)	(2.338)	(2.314)
Euro x Investment									-0.212	-0.192	-0.194
									(-1.165)	(-1.184)	(-1.190)
Euro x Imports(–1)										-0.131	-0.130
										(-1.715)	(-1.712)
Euro x Exports											-0.007
											(-0.227)
2000	2.713***	2.278**	2.146**	2.064**	1.981**	2.237**	2.237**	2.182**	2.057**	2.245***	2.248***
	(3.631)	(3.040)	(2.613)	(2.442)	(2.242)	(2.908)	(2.815)	(2.827)	(2.805)	(3.125)	(3.106)
2002	2.219**	1.695*	1.600*	1.481	1.416	1.573	1.573	1.535	1.413	1.490	1.494
	(2.837)	(2.133)	(1.846)	(1.643)	(1.580)	(1.672)	(1.618)	(1.673)	(1.410)	(1.477)	(1.477)
2003	1.833**	1.239*	1.317*	1.051	1.086	1.326	1.326	1.231*	1.070	1.184*	1.187*
	(2.460)	(1.824)	(1.884)	(1.666)	(1.480)	(1.780)	(1.753)	(1.960)	(1.706)	(1.863)	(1.846)
2004	1.950***	1.614***	1.713***	1.500**	1.431**	1.689**	1.689**	1.713**	1.567**	1.656**	1.654**
	(3.948)	(3.340)	(3.125)	(2.709)	(2.271)	(2.633)	(2.667)	(2.746)	(2.287)	(2.416)	(2.411)
2008	-2.889**	-3.141**	-3.070**	-3.154**	-3.267**	-3.213**	-3.214**	-3.350***	-3.461***	-3.392***	-3.387***
	(-2.839)	(-2.920)	(-2.826)	(-2.802)	(-2.722)	(-2.817)	(-2.797)	(-3.206)	(-3.257)	(-3.188)	(-3.129)
2009	-8.166***	-8.321***	-8.250***	-7.371***	-6.774***	-7.080***	-7.082***	-7.383***	-7.375***	-7.041***	-7.035***
	(-8.162)	(-8.034)	(-7.523)	(-6.060)	(-4.741)	(-5.140)	(-4.905)	(-5.222)	(-5.402)	(-4.935)	(-4.880)
2012	-1.672**	-1.528**	-1.457**	-1.417*	-1.603**	-1.694**	-1.694**	-1.965***	-2.120***	-2.013***	-2.012***
	(-3.023)	(-2.851)	(-2.222)	(-2.150)	(-2.447)	(-2.538)	(-2.448)	(-3.412)	(-3.581)	(-3.492)	(-3.479)
2013	-1.285**	-1.746**	-1.712**	-1.673**	-1.378*	-1.330	-1.330	-1.651**	-1.759**	-1.635**	-1.640**
	(-2.216)	(-2.827)	(-2.739)	(-2.710)	(-1.812)	(-1.746)	(-1.724)	(-2.442)	(-2.543)	(-2.229)	(-2.241)
Observations	260	260	244	244	232	223	223	223	223	223	223
Adj. R^2	0.504	0.519	0.520	0.534	0.463	0.538	0.536	0.545	0.547	0.553	0.551
Num. of countries	13	13	13	13	13	13	13	13	13	13	13

Note: t-statistic is reported in parentheses and the significance levels are denoted as follows: *** p<0.01, ** p<0.05 and * p<0.1. We tested the validity of using two-way fixed effects model. The null hypothesis that individual effects are uncorrelated with any regressor in the model was rejected. So, the difference between the coefficients of random and fixed effects is systematic. Therefore, the fixed effects method should be used. For time dichotomous variables we rejected the null that the coefficients for all years are jointly equal to zero. Consequently, time fixed effects are needed. We only include the years that were statistically significant.

Table 3. Robustness check: Leave-one-out approach Panel B

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Excluded country	Bulgaria	Cyprus	Croatia	Slovakia	Slovenia	Estonia	Hungary	Latvia	Lithuania	Poland	Czech R.	Romania	Malta
Constant	1.146*	1.645**	1.365*	1.332*	1.901**	1.712**	1.634**	1.367*	1.626**	1.581*	1.395*	1.618*	1.952**
	(1.800)	(2.270)	(2.082)	(2.156)	(2.874)	(2.505)	(2.463)	(2.000)	(2.492)	(2.190)	(1.933)	(2.093)	(3.065)
Distance	3.858**	3.901***	4.132***	4.078***	3.927***	3.751**	4.112***	3.308***	3.872***	4.258***	3.916***	5.706***	4.065***
	(3.009)	(3.168)	(3.527)	(4.224)	(3.508)	(3.081)	(3.365)	(3.769)	(3.184)	(3.607)	(3.437)	(4.329)	(3.571)
Education	0.354*	0.420**	0.411**	0.298**	0.417**	0.316*	0.404**	0.333*	0.373**	0.505***	0.383**	0.441**	0.406**
	(1.989)	(2.585)	(2.518)	(2.218)	(2.384)	(2.075)	(2.377)	(2.105)	(2.271)	(3.328)	(2.277)	(2.634)	(2.206)
R&D	-0.258	-0.091	-0.596	-0.889	-0.333	0.751	-0.085	-0.358	-0.482	-0.448	0.160	-0.452	0.100
	(-0.198)	(-0.072)	(-0.463)	(-0.812)	(-0.195)	(0.519)	(-0.065)	(-0.294)	(-0.423)	(-0.393)	(0.124)	(-0.376)	(0.071)
Investment	0.264	0.157	0.184	0.200	0.193	0.112	0.188	0.118	0.183	0.134	0.183	0.327**	0.166
	(1.628)	(0.912)	(1.121)	(1.238)	(1.171)	(0.717)	(1.059)	(0.644)	(1.087)	(0.808)	(1.092)	(2.353)	(0.945)
LnFDI	-0.264	-0.319	-0.326	-0.269	-0.493	-0.440	-0.418	-0.478*	-0.312	-0.435	-0.238	-0.351	-0.304
	(-1.102)	(-1.256)	(-1.230)	(-1.127)	(-1.770)	(-1.789)	(-1.491)	(-1.977)	(-1.211)	(-1.755)	(-0.899)	(-1.450)	(-0.989)
Imports(−1)	0.079	0.105*	0.101*	0.081	0.104*	0.138***	0.099	0.102	0.079	0.092	0.089	0.070	0.103*
	(1.338)	(1.988)	(1.860)	(1.528)	(1.939)	(3.515)	(1.687)	(1.577)	(1.301)	(1.741)	(1.675)	(1.514)	(1.798)
Exports	3.164	0.425	1.955	2.014	2.838	1.565	2.937	1.939	1.076	2.474	1.507	-0.007	-0.988
	(0.819)	(0.114)	(0.556)	(0.589)	(0.764)	(0.489)	(0.859)	(0.488)	(0.285)	(0.582)	(0.426)	(-0.002)	(-0.271)
Euro	1.046	0.790	0.830	0.910	0.126	0.959	0.795	0.500	0.914	0.721	0.951	0.585	0.710
	(1.605)	(1.161)	(1.154)	(1.131)	(0.211)	(1.319)	(1.095)	(0.688)	(1.317)	(0.949)	(1.312)	(0.861)	(0.948)
Euro x LnFDI	**0.494***	**0.666*****	**0.515***	**0.464***	**0.712****	**0.530****	**0.588****	**0.660****	**0.474***	**0.596****	**0.462***	**0.530****	**0.431***
	(1.991)	(3.392)	(2.035)	(1.871)	(2.995)	(2.227)	(2.303)	(2.940)	(1.975)	(2.446)	(1.815)	(2.287)	(1.810)
Euro x Investment	-0.250	-0.200	-0.174	-0.158	-0.192	-0.167	-0.203	-0.097	-0.194	-0.186	-0.190	-0.377**	-0.236
	(-1.440)	(-1.048)	(-1.094)	(-0.997)	(-1.066)	(-1.033)	(-1.174)	(-0.680)	(-1.152)	(-1.068)	(-1.132)	(-2.515)	(-1.473)
Euro x Imports(−1)	-0.1281	-0.161**	-0.139*	-0.095	-0.137	-0.193**	-0.139	-0.130	-0.107	-0.120	-0.127	-0.105	-0.100
	(-1.546)	(-2.269)	(-1.832)	(-1.320)	(-1.675)	(-3.020)	(-1.724)	(-1.502)	(-1.273)	(-1.581)	(-1.641)	(-1.462)	(-0.878)
Euro x Exports	-1.776	0.439	0.233	0.055	-2.175	-1.805	-2.002	-1.629	0.234	-0.705	-0.832	-0.953	-0.974
	(-0.497)	(0.106)	(0.078)	(0.014)	(-0.559)	(-0.466)	(-0.628)	(-0.392)	(0.074)	(-0.169)	(-0.264)	(-0.278)	(-0.119)
2000	2.364**	1.997**	2.427***	2.644***	2.389**	2.004**	2.407***	2.302**	2.042**	2.260**	2.298**	2.010**	1.839**
	(2.958)	(2.807)	(3.340)	(4.245)	(3.104)	(2.797)	(3.180)	(2.926)	(2.674)	(2.682)	(2.816)	(2.341)	(2.751)
2003	1.533**	1.259	1.337*	1.274*	1.130	1.336*	1.222*	1.291*	0.795	1.108	1.159	1.132	0.822
	(2.475)	(1.784)	(1.876)	(1.839)	(1.736)	(2.051)	(1.890)	(2.039)	(1.451)	(1.484)	(1.536)	(1.535)	(1.326)
2004	1.881**	1.646**	1.871**	1.768**	1.582*	1.687**	1.551*	2.075***	1.451*	1.652*	1.497*	1.277*	1.469*
	(2.818)	(2.205)	(2.536)	(2.595)	(2.114)	(2.274)	(2.056)	(3.745)	(2.089)	(2.095)	(1.958)	(1.807)	(2.028)
2006	1.143*	0.902	1.213	0.886	0.819	1.001	0.946	1.324*	0.754	1.059	0.657	0.589	0.589
	(1.824)	(1.175)	(1.698)	(1.185)	(1.094)	(1.389)	(1.237)	(2.100)	(0.999)	(1.323)	(0.882)	(0.803)	(0.782)
2008	-3.122**	-3.507**	-3.304**	-3.564***	-3.546**	-3.037**	-3.518**	-2.573***	-3.572***	-3.476**	-3.567**	-3.387**	-3.951***
	(-2.916)	(-2.943)	(-2.802)	(-3.183)	(-2.937)	(-2.589)	(-3.043)	(-3.232)	(-3.116)	(-2.916)	(-2.960)	(-2.979)	(-3.687)
2009	-6.470***	-7.365***	-6.572***	-6.842***	-7.082***	-6.962***	-6.808***	-6.764***	-7.263***	-7.894***	-6.990***	-6.842***	-7.765***
	(-4.357)	(-4.470)	(-4.307)	(-4.676)	(-4.718)	(-4.631)	(-4.426)	(-4.128)	(-4.941)	(-5.925)	(-4.317)	(-4.567)	(-5.346)
2012	-1.794**	-1.940***	-1.830**	-1.941***	-1.997***	-2.308***	-1.999***	-1.859**	-2.268***	-2.023***	-1.998***	-2.028**	-2.409***
	(-2.988)	(-3.165)	(-3.024)	(-3.410)	(-3.145)	(-3.848)	(-3.417)	(-2.892)	(-4.097)	(-3.244)	(-3.198)	(-2.947)	(-4.400)
2013	-1.327	-1.704**	-1.475*	-1.445*	-1.813**	-1.585*	-1.854**	-1.569*	-1.812**	-1.516*	-1.375*	-1.872**	-2.085***
	(-1.753)	(-2.236)	(-1.838)	(-1.998)	(-2.423)	(-1.816)	(-2.479)	(-2.077)	(-2.387)	(-1.883)	(-1.842)	(-2.271)	(-3.188)
Observations	204	207	209	208	206	205	206	204	206	204	204	204	209
Adj. R^2	0.537	0.555	0.533	0.572	0.553	0.517	0.537	0.525	0.547	0.577	0.539	0.611	0.561
Num. of countries	12	12	12	12	12	12	12	12	12	12	12	12	12

Note: t-statistic is reported in parentheses and the significance levels are denoted as follows: *** p<0.01, ** p<0.05 and * p<0.1. We tested the validity of using two-way fixed effects model. The null hypothesis that individual effects are uncorrelated with any regressor in the model was rejected. So, the difference between the coefficients of random and fixed effects is systematic. Therefore, the fixed effects method should be used. For time dichotomous variables we rejected the null that the coefficients for all years are jointly equal to zero. Consequently, time fixed effects are needed. We only include the years that were statistically significant.

5 CHANNELS THROUGH WHICH MONETARY INTEGRATION COULD INFLUENCE TECHNOLOGICAL CHANGE

Although the OCA theory does not integrate a direct impact on technical progress due to the adoption of a common currency (and therefore is not expected), this theory suggests an impact on trade, investment and FDI. The main benefit of monetary integration is the increase in intraregional trade due to the elimination of foreign exchange risk and the reduction of transaction costs (Mundell 1961). This benefit has been thoroughly documented. Most studies have shown that the increase in intraregional trade as a result of the adoption of the euro is between 5% and 20% (Berger and Nitsch 2005; de Nardis and Vicarelli 2003; Havránek 2010). In spite of this, relation between technical change and trade openness, including an interaction variable, was not found.

Additionally, the OCA theory also supposes a more favorable environment for consumption, investment and capital mobility because the elimination of foreign exchange risk. Therefore, economic agents have a higher confidence level about their future production, investment and consumption decisions; it also stimulates economies of scale and reduces the systemic risk for the real interest rate (De Grauwe 2012). In fact, the adoption of the euro promoted the FDI flow from outside the Eurozone, while inside the Eurozone, this effect was approximately half (Baldwin et al. 2008). Pradhan et al. (2017) showed that the economic integration of the Eurozone countries between 1988 and 2013 increased FDI entries due to market openness and financial strengthening. Moreover, the positive impact of FDI inflows on economic growth can be due to increasing supply of funds for domestic investment. Therefore, this was reflected in the improvement of physical infrastructure (roads, ports, information technology, and communications), science and technology, and human capital in the Eurozone. In this sense, the estimations of the interaction between the Euro and FDI variables showed that the main channel for productivity growth was FDI.

6 CONCLUSIONS

The main conclusion of this research is that the productivity growth of countries that adopted the euro was higher compared to those that maintained their own currency both for the countries that joined the European Union since its creation and for the countries of sixth, seventh, and eighth enlargements. According to the results for the countries which joined the EU since 2004 (sixth, seventh and eighth enlargement), the adoption of the euro is positively correlated with better performance in technical progress terms. In addition, we find that FDI was the main channel through which the adoption of the euro influenced productivity growth. This result holds even when we make estimates for Panel B with the leave-one-out approach. Another result showed that *technology distance* and *human capital variables* have positively influenced the growth of TFP within the EU. In addition, the presence of common temporal effects that have influenced the growth of TFP in all European countries was also found, especially in periods of economic crises.

In summary, the most significant contribution of this research was the evidence supporting the hypothesis that the adoption of a regional currency could contribute to a positive increase in productivity or technical progress. Although these results correspond to small European economies with a low degree of economic integration, the results suggest that productivity growth is greater while the stage of economic integration is deeper. Therefore, this result constitutes another argument in favor of the establishment of mechanisms that deepen the processes of economic integration, as is the case of monetary integration.

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APPENDIX

Table A1. Descriptive statics (by currency) (Panel A)

Variable	Unit of measurement	Obs	Mean			Std. Dev.			Min	Max
			Total	NC*	Euro	Total	NC*	Euro	Total	Total
$\Delta \ln A$	%	588	1.00	1.48	0.26	2.75	2.78	2.53	-12.76	22.14
Distance	Log of the Ratio	588	3.02	3.17	2.79	0.92	1.00	0.71	0.65	5.20
Education	Index	588	79.35	77.74	81.83	7.50	7.74	6.38	57.50	94.10
R&D	% of GDP	531	1.40	1.21	1.67	0.86	0.84	0.80	0.20	3.91
Investment	% of GDP	588	21.55	21.70	21.33	3.77	3.97	3.43	4.35	37.12
FDI	% of GDP	582	9.47	8.69	10.65	36.11	38.14	32.85	-58.33	499.60
LnFDI	Log of % of GDP	550	1.18	1.26	1.06	1.34	1.11	1.64	-5.41	6.21
Imports	% of GDP	588	52.30	47.91	59.05	28.12	20.81	35.62	11.45	181.92
Exports	% of GDP	588	53.71	47.82	62.74	32.87	22.75	42.60	13.47	212.46

(Notes). *Countries that maintain national currency.

Table A2. Descriptive statics (by currency) (Panel B)

Variable	Unit of measurement	Obs	Mean			Std. Dev.			Min	Max
			Total	NC*	Euro	Total	NC*	Euro	Total	Total
$\Delta \ln A$	%	273	1.48	1.69	0.47	3.17	3.25	2.51	-12.76	12.49
Distance	Log of the Ratio	273	3.37	3.51	2.65	1.01	0.96	0.93	0.65	5.20
Education	Index	273	77.36	76.28	82.70	7.12	7.07	4.52	57.50	89.30
R&D	% of GDP	247	0.83	0.77	1.10	0.46	0.36	0.70	0.20	2.58
Investment	% of GDP	273	22.13	22.31	21.24	4.42	4.46	4.13	4.35	37.12
FDI	% of GDP	273	13.53	10.86	26.71	48.84	46.95	55.97	-42.75	499.60
LnFDI	Log of % of GDP	260	1.51	1.45	1.84	1.20	0.97	2.10	-2.86	6.21
Imports	% of GDP	273	58.71	53.25	85.61	25.36	19.98	31.50	11.45	154.94
Exports	% of GDP	273	57.45	51.35	87.54	27.07	20.92	33.41	13.66	159.99

(Notes). *Countries that maintain national currency.

Table A3. Correlation matrix (Panel A)

	$\Delta \ln A$	Distance	Education	R&D	Investment	FDI	Imports	Exports
$\Delta \ln A$	1							
Distance	0.0999	1						
Education	-0.0757	-0.135	1					
R&D	-0.1398	-0.3937	0.5954	1				
Investment	-0.0323	0.0622	-0.0154	-0.0065	1			
FDI	0.1115	0.0633	-0.129	-0.2422	0.0407	1		
Imports	-0.0365	-0.0174	0.162	-0.1211	0.0459	0.5599	1	
Exports	-0.0047	-0.0491	0.1967	-0.0217	-0.0344	0.5448	0.9709	1

Table A4. Correlation matrix (Panel B)

	Δln A	Distance	Education	R&D	Investment	FDI	Imports	Exports
Δln A	1							
Distance	-0.017	1						
Education	-0.1674	-0.0881	1					
R&D	-0.1354	-0.266	0.5863	1				
Investment	-0.1843	0.0096	0.3413	0.2774	1			
FDI	-0.0573	0.0986	-0.2562	-0.3309	-0.0713	1		
Imports	-0.1324	-0.0859	0.3438	0.1761	0.0931	0.4667	1	
Exports	-0.147	-0.0749	0.3275	0.2362	-0.037	0.4245	0.9724	1

Table A5. Panel unit root test (Panel A)

	IPS Im, Pesaran and Shin W-stat				ADF - Fisher Chi-square				PP - Fisher Chi-square			
	Constant		Constant + trend		Constant		Constant + trend		Constant		Constant + trend	
	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
Δln A	-10.3548***	-21.3674***	-7.70923***	-18.5886***	209.801***	446.865***	170.160***	349.869***	240.1559***	1573.05***	217.157***	593.486***
Distance	-5.86174***	-12.4692***	-6.00680***	-8.56299***	125.973***	251.902***	129.674***	168.404***	53.8077	166.081***	35.4135	107.850***
Education	-2.03857**	-10.9103***	1.60557	-13.3151***	115.138***	236.517***	49.8624	247.286***	285.274***	260.341***	64.3705	274.756***
R&D	3.97109	-9.93243***	-0.44700	-8.94181***	33.1713	200.542***	83.7401***	175.052***	34.7953	496.097***	72.1016*	239.864***
Investment	-3.28278***	-11.3567***	-3.24419***	-8.59755***	87.4749***	236.549***	92.6607***	177.313***	69.4930	243.097***	54.1155	204.058***
LnFDI	-8.44204***	-21.0171***	-8.73061***	-18.5400***	180.995***	428.268***	178.300***	334.713***	195.836***	1430.52***	203.836***	449.364***
Imports (−1)	2.11378	-16.9463***	-3.84218***	-13.3306***	35.8931	338.832**	94.1554***	248.915***	53.9281	412.943***	65.7370	357.662***
Exports	4.17573	-15.1614***	-1.14706	-12.6151***	24.9730	300.494***	66.4783	235.191***	34.7624	324.075***	48.5010	283.291***

(Notes). The asterisks ***, **, and * indicate the rejection of the unit root null hypothesis at the 1%, 5%, and 10% significance levels, respectively. The optimal lag length was elected by Schwarz Info Criterion (SIC). Probabilities for Fisher test are computed using an asymptotic Chi-square distribution. Probabilities for IPS test are computed using an asymptotic normality. The null hypothesis in all tests assumes individual unit root process.

Table A6. Panel unit root test (Panel B)

	IPS Im, Pesaran and Shin W-stat				ADF - Fisher Chi-square				PP - Fisher Chi-square			
	Constant		Constant + trend		Constant		Constant + trend		Constant		Constant + trend	
	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
Δln A	-6.20882 ***	-16.0961***	-5.65133***	-13.1342***	86.5696***	227.270***	74.6389***	167.473***	87.5469***	730.109***	78.2590***	266.285***
Distance	-3.56769***	-8.41194***	-4.18048***	-5.75519***	54.7678***	115.584***	59.3617***	76.8698***	23.7212***	78.5321***	16.9829	47.1151***
Education	-2.29122***	-7.74558***	1.17404	-8.85085***	64.7675***	110.712***	21.4350	113.296***	97.1267***	110.055***	20.8698	126.892***
R&D	3.89253	-7.06577 ***	1.21164	-7.49572***	13.7915	98.5507***	31.0826	98.1259***	16.6349	124.903***	22.8516	138.178**
Investment	-2.77668***	-8.81120***	-1.96477**	-6.89050***	46.3895***	121.317***	42.6763***	90.8672***	40.0279**	117.184***	19.5304	105.763***
LnFDI	-2.89403***	-15.0279***	-4.25022***	-13.8506***	51.9472***	209.413***	68.3044***	165.143***	71.9037***	334.040***	72.5367***	220.660***
Imports (−1)	1.50878	-11.4900***	-2.67021***	-9.17250***	13.8065	156.053***	45.6478.**	116.179***	22.8738	185.178***	24.6106	167.897***
Exports	4.13100	-9.43953***	-0.04707	-7.83913***	5.38328	127.219***	27.6291	99.7688***	4.37225	134.250***	17.1701	103.025***

(Notes). The asterisks ***, **, and * indicate the rejection of the unit root null hypothesis at the 1%, 5%, and 10% significance levels, respectively. The optimal lag length was elected by Schwarz Info Criterion (SIC). Probabilities for Fisher test are computed using an asymptotic Chi-square distribution. Probabilities for IPS test are computed using an asymptotic normality. The null hypothesis in all tests assumes individual unit root process.

Endnotes

1 Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain.

2 Countries that recently achieved accession to the EU and have adopted the euro are Slovenia (2007), Cyprus (2008), Malta (2008), Slovakia (2009), Estonia (2011), Latvia (2014), and Lithuania (2015).

3 Countries that joined in the sixth, seventh, and eighth enlargements: (6th) Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia; (7th) Bulgaria and Romania; (8th) Croatia.

4 According to Weil (2006), the assumptions of the function of imitation costs are (1) the imitation cost decreases as the technological difference between the two countries increases; (2) if the technological difference were infinitely large, the imitation would have no cost; and (3) if the follower country is very close to the technology leader, it obtains very little benefit from imitating technology instead of inventing it itself.

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