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European Models for Regional Integration: Implications for International R&D Spillovers*

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As the countries in Europe have successfully managed to move forward the region's integration step by step, the European experiences offer three possible models for regional integration with different depths: a free trade arrangement, a single market, and a common currency area. We study in this paper the effect of the three different models of regional integration on total factor productivity to examine the long-run growth implication of individual models. Our evidence suggests that the entry into regional groupings clearly changes the way participating economies grow, no matter which model of regional integration the groupings take. Domestically powered growth becomes less important, and regionally powered growth comes to be the new source of growth. In particular, countries stand to benefit from considerable inter-regional R&D spillovers in addition to intra-regional R&D spillovers if their regional groupings take the form of a single market or a common currency area.

Keywords: regional integration, economic growth, total factor productivity, R&D, Europe

1. INTRODUCTION

The world is now crisscrossed with a complex web of bilateral and regional trade agreements. The rise in this web of preferential trade arrangements has coincided with the lack of tangible progress in multilateral trade liberalization in the past decade as the Doha round of trade talks has stalled over the years. At the same time, growing interest in promoting economic integration in many regions is also behind the recent mushrooming of regional trade arrangements. A wide range of factors accounts for the rising interest in regional integration, including geopolitical motivations that often lurk behind some of high-profile regional arrangements. Nonetheless, no initiative of regional economic integration is likely to be sustainable if it fails to raise the standards of living in member economies in the long run. Subsequently, the implications for long-term economic growth deserve serious attention in discussions of any regional integration initiatives.

Most economists believe that knowledge plays a central role in the improvement of standards of living. For example, historical investigations such as Rosenberg (1982) demonstrate that the creation and dissemination of knowledge are crucial in promoting long-term economic growth. The neoclassical theory dating back to Solow (1956) and Swan (1956) has identified total factor productivity (TFP) as the key to long-term growth. With the development of the endogenous growth models in the 1990s (among others, Romer, 1990; Grossman and Helpman, 1991; and Aghion and Howitt, 1992), it is now widely accepted that

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TFP depends crucially on knowledge creation and knowledge spillovers. To understand the implications for long-term economic growth, therefore, it is important to understand how regional integration affects the process in which knowledge creation and spillovers translate into TFP of the countries involved.

In designing the framework for regional economic integration, policymakers face different options depending on the depth of integration. As Europe has progressed into increasingly deeper stages of economic integration since the end of World War II, the European experience over this period provides different models for regional integration. That is, European integration initially started as a free trade arrangement that mainly focused on removing customs duties among member countries. Then, following the Single European Act of 1986, liberalization in trade and investment further accelerated within the region, culminating in the establishment of the single market in 1993 that allows the free movement of goods, services, people, and money. Finally, part of Europe has achieved even deeper integration since 1999 by forming a common currency area.

We study in this paper the effect of the different stages of European integration on total factor productivity to examine the long-run growth implication of individual models of regional integration. Our analysis focuses on the process in which knowledge creation and its cross-border spillovers translate into TFP by building upon the empirical specifications that explain a country's TFP as a function of the domestic and foreign stocks of knowledge. In line with much of the existing literature, cumulative R&D expenditure serves as a proxy for a stock of knowledge. Based on a sample of 24 countries from the Organization for Economic Co-operation and Development (OECD), we find that different models for regional integration have clearly different effects on the extent to which a participating country's TFP depends on domestic and foreign R&D capital stocks.[1]

2. DIFFERENT MODELS FOR REGIONAL INTEGRATION

The six European countries – Belgium, Luxembourg, France, Germany, Italy, and the Netherlands that signed the Treaty of Rome to create the European Economic Community (EEC) in 1957 – started the customs union in July 1968. Accordingly, customs duties were removed among these six countries and other members that later joined the union (Denmark, Ireland, and the United Kingdom in 1973; Greece in 1981; Spain and Portugal in 1986). However, the removal of customs duties alone was far from warranting free flows of trade because considerable differences in national regulations were still in place among member countries. Subsequently, an extensive six-year program to examine these regulatory differences was introduced following the Single European Act of 1986. Since then more than 200 laws have been agreed covering a wide range of areas including tax policy, business regulations, and professional qualification. As a result, technical, legal, and bureaucratic barriers to cross-border transactions and labor mobility were largely phased out, culminating in the establishment of the single market with its four freedoms – the free movement of

[1] It should be noted that our sample of 24 OECD countries does not include all current members of the European Union. Of EU members as of January 2014, our sample includes: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.

goods, services, people and money – in January 1993.[2] The name 'European Community' was also officially replaced by 'European Union' under the Maastricht Treaty signed in February 1992, and its membership further expanded in 1995 as Austria, Finland, and Sweden newly joined.[3] At the beginning of 1999, the euro was introduced in 11 European Union countries: Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. Greece also joined the eurozone in 2001.[4]

As described, European integration has been a continuous process in which both its membership and depth have gradually expanded over the years. Nonetheless, its integration process can be divided broadly into three discrete steps. The first is the step taken in 1968 when the customs union was created. In this step European integration mainly took the form of a free trade arrangement that focused on promoting intra-regional trade in goods and some services. The second step is the establishment of the single market in 1993, in which the scope of European integration extended beyond the intra-regional trade in goods and services and covered the movement of money and people as well. Finally, the third step is the introduction of a common currency when the euro was adopted in 1999. Viewed as discrete steps, the European experiences offer three possible models for regional integration with different depths: a free trade arrangement, a single market, and a common currency area.

Figure 1 follows intra-regional trade among nine eurozone countries over the period 1986-2011.[5] During the period, these eurozone countries went through all three steps of European integration: a free trade arrangement for 1986-1992, a single market for 1993-1998, and a common currency for 1999-2011. According to Figure 1, intra-regional imports as a share of GDP tend to increase in most eurozone countries – except for a brief downturn following the global financial crisis of 2008 – as integration among these countries increasingly deepens by starting from a free trade arrangement, moving up to a single market, and further up to a common currency area. However, Figure 1 does not prove that intra-regional dependence in eurozone trade clearly increased as the region's integration process progressed into deeper stages. It is possible that imports from outside the eurozone increased even faster than those from the inside over the period.

To examine intra-regional dependence in eurozone trade, we calculate the ratio of intra-regional imports to total imports in each country. The results shown in Figure 2 fail to provide consistent evidence that intra-regional dependence is rising with the depth of regional integration. Although Portugal appears to have persistently increased its dependence on imports from inside the region as European integration advanced to higher stages, the degree of dependence is found to be stable at best in other eurozone countries and in fact declines in many countries. Instead of signaling a decline in intra-regional dependence across

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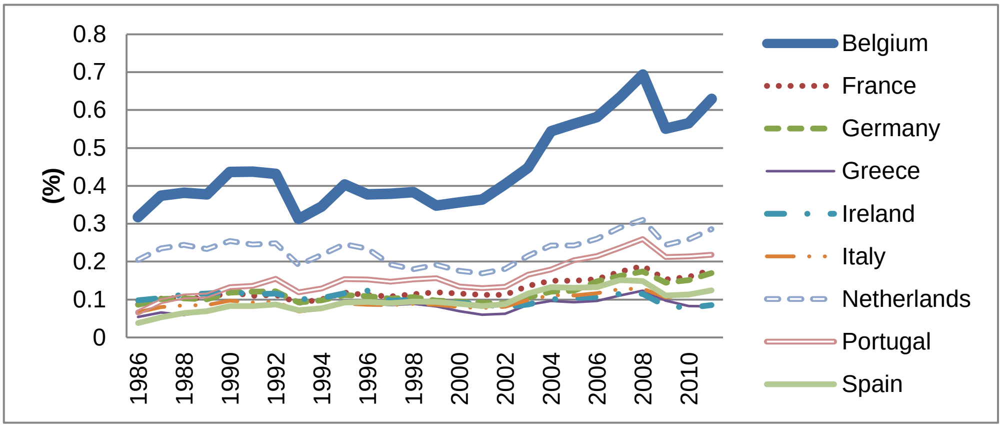
[2] European Central Bank (2013) provides a comprehensive overview of financial integration in Europe.

[3] There were three more waves of enlargement of the European Union: 10 countries (Czech Republic, Cyprus, Estonia, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia and Slovakia) in May 2004; Bulgaria and Romania in January 2007; and Croatia in July 2013.

[4] Six more countries joined the eurozone: Slovenia (January 2007), Cyprus and Malta (January 2008), Slovakia (January 2009), Estonia (January 2011) and Latvia (January 2014). For a summary of the eurozone's experience, see Alesina and Giavazzi (2010) and Kenen and Meade (2008) among others.

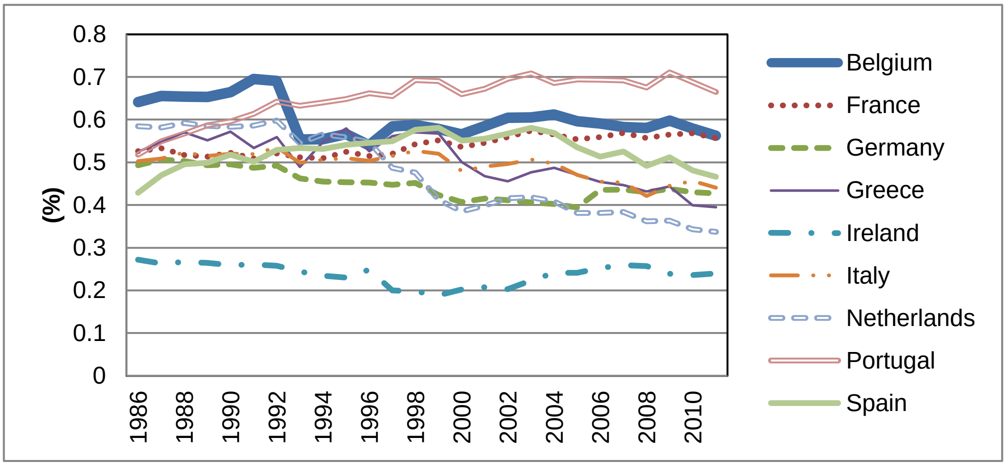
[5] Of the original eurozone countries, Luxembourg is not included in the sample for Figure 1. We also exclude Austria and Finland that joined the European Union only in 1995 because Figure 1 covers the period during which the two countries were not part of the European Union.

Figure 1. Total Intra-Regional Imports as a Share of GDP



Source: IMF (Direction of Trade Statistics)

Figure 2. Total Intra-Regional Imports as a Share of Total Imports



Source: IMF (Direction of Trade Statistics)

the board, this may be more likely to reflect possible shifts in the pattern of trade and foreign direct investment inside the region over time as producers in member countries have tried to cope with deepening integration.[6] Subsequently, Figure 2 illustrates the limitation of any single measure in effectively capturing the degree of overall intra-regional dependence, and hence highlights the danger of simply following a single measure to gauge changes in the depth of regional integration over time.

[6] For example, liberalization may induce cross-border firm relocations in the long run (see Venables, 1985, 1987; Horstmann and Markusen, 1986). Melitz and Ottaviano (2008) also show how liberalization affects firm selection and causes shifts in the pattern of entry in the long run by allowing heterogeneous firms in their models.

3. REGIONAL INTEGRATION AND TOTAL FACTOR PRODUCTIVITY

3.1 Empirical Specifications

The standard neoclassical framework treats TFP changes as exogenous even though the theory recognizes TFP to be a key determinant of long-run economic growth. A wave of more recent theoretical models of economic growth has tried to endogenize technological progress so that TFP changes can be explained within the model. These so-called endogenous growth models are broadly grouped into two varieties: the horizontally-differentiated inputs (HDI) approach in line with Romer (1990) and the vertically-differentiated inputs (VDI) approach in line with Aghion and Howitt (1992). In these models, TFP growth is determined endogenously, instead of being exogenous, depending on the number of available intermediate inputs in the HDI approach and on the number of improvements in the quality of a given input in the VDI approach.

Since research and development (R&D) expands the number of available inputs (HDI approach) or improves the quality of inputs (VDI approach), both approaches imply that TFP is rising with cumulative past R&D spending. If there is no international trade in intermediate inputs, then changes in a country's TFP would be explained by changes in its domestic R&D capital stock. In contrast, TFP of an individual country would depend on the entire world's R&D capital stock if trade in intermediate inputs is completely free with no transportation cost. Obviously neither one of these two cases is realistic, and sensible specifications for empirical implementation of endogenous growth models involve a mix of both tradable and nontradable inputs. Subsequently, we follow empirical specifications proposed initially by Coe and Helpman (1995) in which variations in TFP are explained by variations in both the domestic and foreign R&D capital stocks. The baseline specification takes the following form:

$$\log A_i = \phi_i^0 + \phi_i^D \log D_i + \phi_i^F \log F_i + \varepsilon_i \quad (1)$$

where i is a country index, A is TFP, D represents the real domestic R&D capital stock, F represents the real foreign R&D capital stock, and ε is a well-defined error.

In addition to R&D capital stocks, another key long-run determinant of TFP that has been widely recognized in the literature is human capital.[7] Therefore, we also consider the following specification that includes human capital as an additional explanatory variable:

$$\log A_i = \phi_i^0 + \phi_i^D \log D_i + \phi_i^F \log F_i + \phi_i^H \log H_i + \varepsilon_i \quad (2)$$

where H is a measure of human capital proxied by average years of schooling from Barro and Lee (2013). Since the original data are reported for every 5 years, we interpolated them to acquire a series of annual data.[8] Our measure represents the average level of human

[7] For example, see Engelbrecht (1997).

[8] The data of Barro and Lee (2013) is also available only up to 2010. We extrapolated the series to 2011 by using the annual change over 2005-2010.

capital.[9]

Based on Eqs. (1) and (2), we examine how the progress of European integration affects the region's total factor productivity by introducing three dummy variables: *EC*, *EU*, and *EURO*. *EC* represents the membership of a free trade arrangement in Europe; *EU* represents the membership of a single market in Europe; and *EURO* represents the membership of the eurozone. *EU* captures the effect of achieving the free movement of money and people in addition to free trade, and *EURO* captures the additional effect of forming a common currency area inside the single market. To take Austria as an example, both *EC* and *EU* variables become 1 from 1995 when the country joined the European Union,[10] and *EURO* becomes 1 from 1999 when it joined the eurozone.

In our analysis we use discrete dummy variables such as *EC*, *EU*, and *EURO* instead of continuous variable indicators to measure the depth of regional integration, mainly because we are interested in examining different models of integration rather than ascertaining the effects of economic integration per se. It is also very likely that the depth of integration measured by continuous variable indicators reflects not only the effects of regional integration but also those of the general trend of globalization over the same time period. Furthermore, Figure 2 shows the limitation of any single continuous variable measure of trade or investment in effectively capturing changes in the overall depth of regional integration over time, possibly due to dynamic adjustments taking place in trade and investment along the integration process.

In our regressions the three dummy variables enter Eqs. (1) and (2) to account for any windfall effects on TFP from the transition to a deeper model of economic integration. It is also possible that different models of regional integration have differing effects on TFP of member countries mainly by altering the extent to which a country's TFP depends on each of the two types – domestic and foreign – of R&D capital stocks of the country. Subsequently, our three dummy variables are interacted with the domestic and foreign R&D capital stocks in Eqs. (1) and (2).

3.2 Data

We have chosen a sample of 24 countries from the Organization for Economic Co-operation and Development (OECD). They include: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom (UK), and the United States (US). For each country, total factor productivity *A* is defined as

$$A = Y / [K^{\propto} L^{(1-\propto)}] \tag{3}$$

where *Y* is constant price gross domestic product adjusted in 2005 prices, *K* is productive capital stock measured in volume, and *L* is total hours worked (except for Austria where *L* is total employment). All variables are constructed as indices with 2005 = 1. The coefficient (1

[9] For example, Lucas (1988) assumes that each producer benefits from the average level of human capital in the economy, rather than the aggregate, in his analysis of the knowledge spillovers.

[10] In this setup, the European Union can be seen as a combination of a free trade arrangement and an arrangement that allows the free movement of money and people.

- ∝) is the average share of labor income from 2005-2008. All data are from the OECD's Annual National Accounts database or the OECD Economic Outlook database.[11] Missing data for the productive capital stock of Germany, Greece, and Ireland in certain years are filled in using the growth rate of the government and private non-residential net capital stock estimated by Kamps (2005) while correcting for the difference in the growth rate between the productive and net capital stocks based on the past trend.[12]

R&D capital stocks are estimated using R&D expenditure data from the OECD's Science, Technology and Patents statistics. R&D expenditures are constant price (adjusted in 2005 prices) US dollar expenditures based on the 2005 purchasing power parity exchange rate in US dollars per local currency. For a number of countries in our sample, R&D expenditure data are not available over the entire 1981-2010 period. In line with Coe et al. (2009), missing observations for R&D expenditures are estimated using the predicted values from ordinary least squares (OLS) regressions relating real R&D expenditures to real GDP and real non-residential fixed capital formation (all in logarithms). A time trend and its square, if found to be statistically significant, are also included in the regressions.

Real domestic R&D capital stocks (*D*), defined as beginning of period stocks, are calculated from real R&D expenditures (*R*) based on the perpetual inventory method.

$$D_t = (1 - \delta)\, D_{t-1} + R_{t-1} \tag{4}$$

where the depreciation rate, δ, was assumed to be 5 percent. The benchmark was calculated as

$$D_0 = R_0 \,/\, (g + \delta) \tag{5}$$

where g is the annual average logarithmic growth rate of R&D expenditures (*R*) over the period for which published R&D data are available, and R_0 is R&D expenditures in the first year for which the data are available. The benchmarks for most countries are calculated for 1981 except for Belgium (1983) and Portugal (1982). For Israel and Korea for which R&D data are available only from 1991, the benchmarks are calculated for 1981 using the predicted values of real R&D expenditures for 1981.

The real foreign R&D capital stock is constructed using the domestic R&D capital stocks of each country's 23 trade partners. Following Coe and Helpman (1995) and Coe et al. (2009), we use a bilateral import-share weighted average of the domestic R&D capital stocks of trade partners as an estimate of the foreign R&D capital stock. The bilateral import shares are calculated for each year based on the Direction of Trade database from the International Monetary Fund (IMF). Formally the real foreign R&D capital stock for country i is defined as

$$F_i = \sum_{j \neq i} \left(\frac{M_{ij}}{\sum_{j \neq i} M_{ij}}\right) D_j \tag{6}$$

[11] Official data for unified Germany is available only from 1991. Up to 1990, OECD estimates data for the whole of Germany based on data for West Germany.

[12] Kamps (2005) provides net capital stock estimates for 22 OECD countries over 1960-2001. Data are available from: https://www.ifw-kiel.de/forschung/datenbanken/netcap.

Table 1. Summary Statistics

	A_{11}/A_{85}	D_{11}/D_{85}	F_{11}/F_{85}	H_{85}	H_{11}
Australia	5.07	2.10	2.90	11.54	12.17
Austria	4.12	1.88	3.26	7.51	9.58
Belgium	2.32	1.99	2.88	9.04	10.65
Canada	3.11	2.35	2.74	10.00	12.07
Denmark	4.56	1.60	1.91	10.04	10.09
Finland	5.97	1.44	2.45	8.18	10.01
France	1.96	1.59	2.53	6.76	10.66
Germany	2.00	1.64	2.63	6.03	11.82
Greece	7.45	1.52	1.89	7.89	10.83
Iceland	9.74	2.89	1.91	8.30	10.86
Ireland	8.08	1.89	2.23	10.55	11.72
Israel	10.28	1.85	2.98	10.30	11.38
Italy	2.18	1.72	2.07	7.21	9.58
Japan	2.69	1.65	2.77	9.75	11.65
Korea	12.77	1.98	5.56	9.15	11.92
Netherlands	2.05	2.20	2.58	9.80	11.07
New Zealand	2.36	2.15	1.92	11.82	12.74
Norway	3.00	2.04	2.10	9.95	12.29
Portugal	8.90	0.97	4.13	6.20	8.07
Spain	6.55	1.20	5.13	6.40	10.51
Sweden	2.99	1.48	2.11	9.77	11.58
Switzerland	2.12	2.06	2.49	9.81	9.97
United Kingdom	1.47	1.96	2.04	8.00	9.84
United States	2.49	1.78	1.91	12.09	13.13
Average	4.76	1.83	2.71	9.00	11.01
Standard Deviation	3.21	0.39	0.97	1.75	1.18

Note: *A* is total factor productivity; *D* is the real domestic R&D capital stock; *F* is the real foreign R&D capital stock; *H* is average years of schooling.

where $\sum_{j\neq i}(M_{ij}/\sum_{j\neq i}M_{ij})=1$, and M_{ij} is country i's imports of goods and services from country j. Table 1 provides summary statistics of the domestic and foreign R&D capital stocks as well as TFP and human capital for our sample of 24 OECD countries.

3.3 Empirical Results

Table 2 presents the results of fixed effects regressions based on the specification of Eq. (1). The regression results reported in equation (i) show that a country's total factor productivity depends not only on the domestic R&D effort but also on R&D spillovers from abroad, consistent with theoretical predictions. Both the domestic and foreign R&D capital stocks are found to be highly significant contributors to TFP with similar effects. Based on the same sample of OECD countries as used in our study, Coe et al. (2009) find a smaller

Table 2. Total Factor Productivity Estimation (Three Stages of European Integration)

	with no year-specific constants		with year-specific constants	
	(i)	(ii)	(iii)	(iv)
EC		0.7959		1.0100
		(0.209)		(0.113)
EU		-1.4628**		-1.5590***
		(0.011)		(0.005)
EURO		-1.3171***		-1.9332***
		(0.006)		(0.000)
log *D*	0.1213***	0.1076***	0.0623***	0.0573***
	(0.000)	(0.000)	(0.000)	(0.000)
EC log *D*		-0.0315**		-0.0378***
		(0.013)		(0.003)
EU log *D*		0.0011		-0.0036
		(0.825)		(0.474)
EURO log *D*		-0.0152***		-0.0210***
		(0.007)		(0.000)
log *F*	0.1126***	0.0666***	0.0067	-0.0421
	(0.000)	(0.002)	(0.764)	(0.106)
EC log *F*		-0.0324		-0.0456
		(0.515)		(0.355)
EU log *F*		0.1137***		0.1246***
		(0.009)		(0.003)
EURO log *F*		0.1128***		0.1622***
		(0.002)		(0.000)
Within $\mathbf{R}^2$	0.6063	0.6811	0.6678	0.7298
Observation	648	648	648	648
F	478.88***	119.01***	42.78***	42.85***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: *, **, *** stand for, respectively, 10%, 5%, and 1% level of significance. The p-values are reported below the coefficient estimates. The dependent Variable is log(*total factor productivity*). *D* is the real domestic R&D capital stock; *F* is the real foreign R&D capital stock. *EC* represents the membership of a free trade arrangement in Europe; *EU* the membership of a single market in Europe; *EURO* the membership of the eurozone.

coefficient on domestic R&D capital but a larger coefficient on foreign R&D capital relative to our estimates. This difference may stem from the fact that they consider the different time period (1971-2004) and focus on the business sector instead of the entire economy. In running regressions on Eq. (1), we also included unreported year-specific constants in equation (iii). Including year-specific constants reduces the size of the estimated coefficients on both the domestic and foreign R&D capital stocks, and in particular makes the coefficient on foreign R&D capital highly insignificant.

To test for the potential impact of different models of regional integration on total factor productivity, three dummy variables each representing different models of European integration – *EC*, *EU*, and *EURO* – enter separately and also interacted with R&D capital stocks in Eq. (1). The estimated constant *EC* reported in equation (ii) suggests the possibility that the membership of a free trade arrangement in Europe has produced positive windfall effects on TFP of participating countries. However, it appears that advancing the integration process beyond the free trade arrangement has failed to bring any additional windfall benefits to the TFP level of individual member countries. The estimates of *EU* and *EURO* constants, respectively representing the additional effects of joining a single market and a common currency area in the region, are actually negative and highly significant.

The results reported in equation (ii) also show that different models of regional integration affect TFP through their impact on R&D. The estimated coefficients on *EC* and *EURO* interacted with domestic R&D capital are negative and statistically significant. In contrast, *EU* and *EURO* interacted with foreign R&D capital enter equation (ii) positively and significantly. These results can be interpreted to imply that a country's TFP tends to depend increasingly less on its own R&D effort and more on international R&D spillovers as the country takes part in increasingly deeper forms of regional integration. The same trend is also detected in equation (iv) that includes unreported year-specific constants.

Table 3 reports the estimates of fixed effects regressions we ran on Eq. (2) that includes the logarithm of human capital as an additional explanatory variable. The estimated coefficients on a measure of human capital – average years of schooling – in equations (i) and (ii) indicate that human capital formation has highly significant and positive effects on total factor productivity, consistent with the theoretical literature. However, our measure of human capital enters with the incorrect sign in equation (iii) or becomes insignificant in equation (iv) if we include year-specific constants. Turning to the impact of different models of regional integration on TFP, the results in equations (ii) and (iv) provide more or less the same picture as the one painted by our previous estimates based on Eq. (1). As shown in Table 3, the estimated coefficients on individual dummies of European integration and these dummies interacted with R&D capital stocks are in close sync with their counterparts reported in Table 2.

The regression results in Tables 2 and 3 show how the adoption of a deeper model for regional integration is likely to change the extent to which an individual member country's TFP depends on each of its domestic and foreign R&D capital stocks. We find the declining importance of domestic R&D accompanied by the rising influence of R&D spillovers from abroad. It may be expected that the transition to a deeper form of economic integration enables a participating country to depend less on the domestic source of R&D by enjoying more opportunities to take advantage of R&D capital outside the country. However, our findings of the increasing dependence on foreign R&D capital do not necessarily imply a rise in intra-regional dependence in cross-border R&D spillovers with the advancement of regional integration. It is because our measure of the foreign R&D capital stock includes not only the R&D stocks of members of a particular European regional arrangement in question but also those of non-member countries.

In order to examine intra-regional dependence in cross-border R&D spillovers, therefore, we break down the foreign R&D spillovers into two components: R&D spillovers from members and those from non-members. Subsequently, we estimate a modified specification of Eq. (2) that allows for this breakdown.

$$\log A_i = \phi_i^0 + \phi_i^D \log D_i + \phi_i^{FE} \log F_i^E + \phi_i^{FN} \log F_i^N + \phi_i^H \log H_i + \varepsilon_i \tag{7}$$

Table 3. Total Factor Productivity Estimation (Three Stages of European Integration)

	with no year-specific constants		with year-specific constants	
	(i)	(ii)	(iii)	(iv)
EC		0.8296		1.0048
		(0.190)		(0.114)
EU		-1.5031***		-1.5664***
		(0.009)		(0.005)
EURO		-1.4178***		-1.9914***
		(0.003)		(0.000)
log *D*	0.1132***	0.0975***	0.0616***	0.0524***
	(0.000)	(0.000)	(0.000)	(0.000)
EC log *D*		-0.0332***		-0.0385***
		(0.009)		(0.002)
EU log *D*		-0.0030		-0.0060
		(0.598)		(0.274)
EURO log *D*		-0.0198***		-0.0236***
		(0.001)		(0.000)
log *F*	0.1058***	0.0651***	-0.0012	-0.0408
	(0.000)	(0.003)	(0.956)	(0.118)
EC log *F*		-0.0336		-0.0445
		(0.499)		(0.367)
EU log *F*		0.1199***		0.1270***
		(0.006)		(0.003)
EURO log *F*		0.1238***		0.1685***
		(0.001)		(0.000)
log *H*	0.0793*	0.1073*	-0.0922**	0.0648
	(0.063)	(0.084)	(0.046)	(0.281)
Within R^2	0.6085	0.6826	0.6700	0.7303
Observation	648	648	648	648
F	321.69***	109.70***	41.65***	41.76***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: *, **, *** stand for, respectively, 10%, 5%, and 1% level of significance. The p-values are reported below the coefficient estimates. The dependent Variable is log(*total factor productivity*). *D* is the real domestic R&D capital stock; *F* is the real foreign R&D capital stock; *H* is average years of schooling. *EC* represents the membership of a free trade arrangement in Europe; *EU* the membership of a single market in Europe; *EURO* the membership of the eurozone.

where F_i^E represents the part of the foreign R&D capital stock, F_i, in Eq. (2) that originates from countries within a particular regional arrangement in Europe, and F_i^N represents the foreign R&D capital stock from countries outside the arrangement ($F_i = F_i^E + F_i^N$).

We also consider another specification that reflects the potential role to be played by the level of imports in determining the degree of cross-border R&D spillovers. In the existing theoretical and empirical literature international trade is widely assumed to be a main channel of cross-border R&D spillovers. This assumption is in fact behind the construction of our measure of the foreign R&D capital stock that is a bilateral import-share weighted average of the domestic R&D capital stock of trade partners. If international trade is the potent channel, it is also plausible that the degree of cross-border R&D spillovers may depend on the level of imports of the recipient country. That is, the country that imports more (relative to its GDP) from a certain group of countries may benefit more from their R&D. Subsequently, we estimate the following specification that allows the impact of R&D spillovers to vary with the level of imports from the source country:

$$\log A_i = \phi_i^0 + \phi_i^D \log D_i + \phi_i^{FEm} m_i^E \log F_i^E + \phi_i^{FNm} m_i^N \log F_i^N + \phi_i^H \log H_i + \varepsilon_i \qquad (8)$$

where m_i^E stands for the fraction of imports in GDP that come from a particular regional arrangement in Europe, and m_i^N stands for the share of imports that come from outside the arrangement. We only consider the imports of 24 countries in our sample.

In conducting regression analysis based on Eqs. (7) and (8), we divide our sample period into three sub-periods: (I) 1985-1992; (II) 1993-2011; and (III) 1999-2011. In period (I), European integration mainly took the form of a free trade arrangement focusing on intra-regional trade in goods and some services. To represent the membership of the customs union in Europe during the period, we introduce a dummy variable *EC* that equals 1 if the country is a member of the union. The customs union in Europe moved to the next phase of regional integration with the establishment of the single market in 1993, in which the scope of European integration extended beyond the intra-regional trade in goods and services and covered the movement of money and people as well. The membership of the single market during period (II) is denoted by a dummy variable *EU´* that equals 1 if the country is the member of the European single market.[13] Finally, period (III) represents the period of the eurozone whose membership is represented by a dummy variable *EURO´* that becomes 1 for eurozone countries.[14] For each of the three sub-periods, a relevant dummy variable enters separately and also interacted with domestic R&D capital as well as the two types of foreign R&D capital in regressions based on Eqs. (7) and (8).

Table 4 presents the regression results for period (1) of 1985-1992. We divide foreign R&D capital into two types – R&D capital located inside the customs union in Europe and R&D capital outside it – to separate out intra-regional R&D spillovers. To facilitate comparisons, the basic specification for equations (i) and (iv) corresponds to Eq. (2) that includes a single measure of the foreign R&D capital stock before its breakdown into the two types. Estimation results in equations (i) and (iv) indicate that the members of a customs union tend to be less dependent on their own domestic R&D than non-members but there is no significant difference in the degree of reliance on international R&D spillovers between the two groups, consistent with previous findings reported in Table 3. However, the breakdown of foreign R&D capital into the two types as reported in equations (ii) and (v) suggests a change in the makeup of R&D spillovers into a country after the country enters a

[13] *EU´* is different from *EU* used in Tables 2 and 3. *EU´* measures the whole effect of the single market including the effect of its free trade component, whereas *EU* only captures the additional effect of achieving the free movement of money and people, not including the effect of the free trade component.

[14] Again, *EURO´* is different from *EURO* (in Tables 2 and 3) that only captures the additional effect of forming a common currency area inside the single market, not including the effect of the single market itself.

Table 4. Total Factor Productivity Estimation (Free Trade Arrangement in Europe)

	with no year-specific constants			with year-specific constants		
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
EC	-0.0692	-0.8052	0.4033***	-0.0331	-1.4661*	0.3954***
	(0.906)	(0.271)	(0.007)	(0.960)	(0.066)	(0.009)
log *D*	0.1739***	0.1101***	0.1520***	0.1765***	0.1589***	0.1788***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EC log *D*	-0.0437**	-0.0468**	-0.0434***	-0.0423*	-0.0568***	-0.0429***
	(0.034)	(0.023)	*(0.008)*	(0.051)	(0.007)	(0.009)
log *F*	-0.0080			-0.0043		
	(0.612)			(0.795)		
EC log *F*	0.0383			0.0344		
	(0.469)			(0.568)		
log $\boldsymbol{F^E}$		0.0971***			0.1330***	
		(0.008)			(0.001)	
EC log F^E		0.1484**			0.2142***	
		(0.016)			(0.001)	
log $\boldsymbol{F^N}$		0.0138			0.0267**	
		(0.196)			(0.021)	
EC log F^N		-0.0455*			-0.0500*	
		(0.098)			(0.073)	
$\boldsymbol{m^E}$ log $\boldsymbol{F^E}$			-0.0008			0.0031
			(0.958)			(0.851)
EC m^E log F^E			0.0373**			0.0347*
			(0.050)			(0.072)
$\boldsymbol{m^N}$ log $\boldsymbol{F^N}$			0.0064			-0.0104
			(0.798)			(0.702)
EC m^N logF^N			-0.0337			-0.0369
			(0.477)			(0.447)
log *H*	0.2396***	0.1682**	0.2102***	0.2512***	0.1890**	0.2377***
	(0.003)	(0.028)	(0.004)	(0.002)	(0.012)	(0.002)
Within R^2	0.5751	0.6214	0.6094	0.5925	0.6564	0.6268
Observation	192	192	192	192	192	192
F	36.55***	32.83***	31.21***	17.34***	19.49***	17.13***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: *, **, *** stand for, respectively, 10%, 5%, and 1% level of significance. The p-values are reported below the coefficient estimates. The dependent Variable is log(*total factor productivity*). D is the real domestic R&D capital stock; F is the real foreign R&D capital stock; H is average years of schooling. F^E represents the part of F that originates from countries within the free trade arrangement in Europe; F^N the part of F from countries outside the arrangement. m^E stands for the fraction of imports in GDP that comes from countries within the free trade arrangement in Europe; m^N the fraction of imports from countries outside the arrangement. *EC* represents the membership of a free trade arrangement in Europe.

Table 5. Total Factor Productivity Estimation (European Single Market)

	with no year-specific constants			with year-specific constants		
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
EU′	-1.2576**	-2.7575***	0.2079	-1.4679***	-3.3942***	0.0915
	(0.037)	(0.000)	(0.222)	(0.006)	(0.000)	(0.559)
log *D*	0.1337***	0.1218***	0.1132***	0.0995***	0.1500***	0.0536***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
EU′ log *D*	-0.0230	-0.0505**	-0.0101	-0.0421**	-0.0612***	-0.0011
	(0.263)	(0.016)	(0.524)	(0.022)	(0.001)	(0.939)
log *F*	-0.0339			-0.1890***		
	(0.474)			(0.000)		
EU′ log *F*	0.1199**			0.1477***		
	(0.031)			(0.003)		
log $\boldsymbol{F^E}$		0.1674***			0.2369***	
		(0.000)			(0.000)	
EU′ log F^E		0.0593			0.0915***	
		(0.102)			(0.007)	
log $\boldsymbol{F^N}$		-0.1419***			-0.1690***	
		(0.000)			(0.000)	
EU′ log F^N		0.2091***			0.2340***	
		(0.000)			(0.000)	
$\boldsymbol{m^E}$ log $\boldsymbol{F^E}$			0.0273***			0.0041
			(0.008)			(0.680)
EU′ m^E log F^E			-0.0106			0.0005
			(0.368)			(0.963)
$\boldsymbol{m^N}$ log $\boldsymbol{F^N}$			-0.0464**			-0.0182
			(0.014)			(0.320)
EU′ m^N log F^N			-0.0204			-0.0428
			(0.476)			(0.110)
log *H*	0.0664	-0.1357*	0.0641	-0.2144***	-0.1396**	-0.1832**
	(0.331)	(0.060)	(0.345)	(0.003)	(0.041)	(0.011)
Within $\mathbf{R^2}$	0.5068	0.5858	0.5191	0.6368	0.6885	0.6314
Observation	456	456	456	456	456	456
F	72.95***	74.95***	57.22***	29.81***	34.52***	26.75***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: *, **, *** stand for, respectively, 10%, 5%, and 1% level of significance. The p-values are reported below the coefficient estimates. The dependent Variable is log(*total factor productivity*). *D* is the real domestic R&D capital stock; *F* is the real foreign R&D capital stock; *H* is average years of schooling. F^E represents the part of F that originates from countries within the single market arrangement in Europe; F^N the part of F from countries outside the arrangement. m^E stands for the fraction of imports in GDP that comes from countries within the single market arrangement in Europe; m^N the fraction of imports from countries outside the arrangement. *EU´* represents the membership of a single market in Europe.

Table 6. Total Factor Productivity Estimation (Eurozone)

	with no year-specific constants			with year-specific constants		
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
EURO′	-0.8380	-1.7667***	0.9705***	-1.0640	-2.2837***	0.8492***
	(0.249)	(0.008)	(0.000)	(0.113)	(0.000)	(0.000)
log *D*	0.1414***	0.0979***	0.0756***	0.1140***	0.1374***	0.1067***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
EURO′ log *D*	-0.1257***	-0.1432***	-0.1031***	-0.1101***	-0.1430***	-0.0922***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
log *F*	-0.2243***			-0.2106***		
	(0.000)			(0.000)		
EURO′ log *F*	0.1517**			0.1577***		
	(0.017)			(0.007)		
log $\boldsymbol{F^E}$		0.0490*			0.0866***	
		(0.054)			(0.004)	
EURO′ log F^E		0.0905*			0.1110**	
		(0.056)			(0.012)	
log $\boldsymbol{F^N}$		-0.1664***			-0.1509***	
		(0.000)			(0.000)	
EURO′ log F^N		0.1576***			0.1770***	
		(0.000)			(0.000)	
$\boldsymbol{m^E}$ log $\boldsymbol{F^E}$			0.0223**			0.0199*
			(0.030)			(0.059)
EURO′ m^E log F^E			0.0020			-0.0030
			(0.882)			(0.808)
$\boldsymbol{m^N}$ log $\boldsymbol{F^N}$			-0.0064			-0.0195
			(0.590)			(0.101)
EURO′ m^N log F^N			-0.0016			0.0156
			(0.944)			(0.466)
log *H*	0.1902**	0.0396	0.1609*	0.0240	0.1302	0.1610
	(0.037)	(0.675)	(0.079)	(0.809)	(0.167)	(0.111)
Within $\mathbf{R^2}$	0.3063	0.3464	0.2854	0.4616	0.4905	0.4277
Observation	312	312	312	312	312	312
F	20.75***	18.55***	13.98***	12.86***	12.90***	10.01***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Note: *, **, *** stand for, respectively, 10%, 5%, and 1% level of significance. The p-values are reported below the coefficient estimates. The dependent Variable is log(*total factor productivity*). *D* is the real domestic R&D capital stock; *F* is the real foreign R&D capital stock; *H* is average years of schooling. F^E represents the part of *F* that originates from countries within the eurozone; F^N the part of *F* from countries outside the eurozone. m^E stands for the fraction of imports in GDP that comes from countries within the eurozone; m^N the fraction of imports from countries outside the eurozone. *EURO´* represents the membership of the eurozone.

free trade arrangement. We find that the members of a free trade arrangement clearly increase their dependence on intra-regional R&D spillovers but decrease their dependence on R&D spillovers from outside the arrangement. The results in equations (iii) and (vi), which are based on Eq. (8), show that the dependence on intra-regional R&D spillovers rises with the level of intra-regional imports. A member country that tends to import more (relative to GDP) from other member countries is expected to rely more on intra-regional R&D spillovers in promoting total factor productivity.

Turning to the European single market, we report estimation results for period (II) in Table 5. In equations (i) and (iv) that include a single measure of foreign R&D capital, we find the members of a single market tend to depend less on domestic R&D and benefit more from foreign R&D compared with its non-members, consistent with earlier findings based on Eq. (2). The breakdown into the two types of foreign R&D capital in equations (ii) and (v) shows that the members of the European single market were more likely to depend on R&D spillovers from the single market than non-members. However, the members of the single market were also found to benefit more from R&D spillovers from its non-members than the non-members themselves. In fact, the estimated coefficients on the interaction of the *EU´* dummy and foreign R&D capital from non-member countries are larger than the interaction with foreign R&D capital located in member countries. These results suggest that EU member countries reaped substantial benefits from inter-regional R&D spillovers as well as from intra-regional R&D spillovers by forming a single market. When the level of imports is included in measuring R&D spillovers from abroad as in equations (iii) and (vi), the coefficients on the *EU´* dummy interacted with foreign R&D spillovers – foreign R&D capital multiplied by the level of imports – become consistently insignificant, regardless of whether R&D spillovers are from inside the European single market or not.

Finally, Table 6 summarizes the results of our fixed effects regressions for period (III) in which European integration has advanced to its third step, a common currency area, following the previous steps of a free trade arrangement and a single market. As is the case with the two prior steps of European integration, we continue to find the trend of rising dependence on international R&D spillovers accompanied by declining dependence on domestic R&D for eurozone member countries, as reported in equations (i) and (iv). The breakdown of the source of R&D spillovers into eurozone and non-eurozone countries shows that the eurozone promotes considerable inter-regional R&D spillovers as well as intra-regional R&D spillovers as in the case of the European single market. In equations (ii) and (v), the estimated coefficients on the *EURO´* dummy interacted with foreign R&D capital located outside the eurozone are positive and larger than those on the interaction with foreign R&D capital located inside the eurozone.

4. CONCLUSION

European integration was widely touted as the biggest success story of regional integration over half a century after its inception, as the countries in Europe had successfully managed to move forward the region's integration step by step. At least before the onset of the eurozone crisis, the steps taken in Europe were viewed to represent a model progression in evolving regional integration with the creation of a common currency area generally regarded as the ideal conclusion of the whole process. In fact, we used to easily come upon the discussions about the possibility of a common currency in policy debate in other regional groupings outside Europe, including Asia. However, any excitement about a common currency area quickly died down in the wake of the eurozone crisis. The new conventional wisdom appears to be: Europe did everything right minus the euro.

Would this new conventional wisdom serve as proper lessons for various initiatives of regional integration including the ones in Asia? This question is indeed what motivated this study in the first place. In deriving lessons from Europe, we propose three models of regional integration based on their experience: a free trade arrangement, a single market, and a common currency area. To make sensible comparisons between the three different models, we use each model's effects on long-term economic growth as a basis for comparison. Long-term economic growth seems to be a reasonable yardstick given that no regional grouping is likely to be sustainable if it fails to improve participating countries' standards of living in the long run. In evaluating long-term growth implications of different models for regional integration, we focus on total factor productivity because its growth rate determines the slope of the long-term growth path.

The existing growth theory suggests that there exist close links between total factor productivity and R&D capital stocks. Consistent with theoretical predictions, our estimation results show that a country's total factor productivity depends not only on its own R&D capital stocks but also on the R&D capital stocks of its trade partners. A country's aggregate human capital measured by average years of schooling is also found to be a significant determinant of its total factor productivity. As European integration advanced to increasingly deeper stages, we find that a participating country tended to decrease its dependence on domestic R&D and instead increased its reliance on R&D spillovers from abroad. This rising reliance on foreign R&D mainly took the form of intra-regional R&D spillovers in the stage of the free trade arrangement, as its participating countries were found to switch from non-members to their fellow member countries in sourcing R&D spillovers from abroad. This pattern is analogous to trade diversion often observed under preferential trade arrangements. As a result, the net effect of the free trade arrangement on international R&D spillovers was not found to be significantly different from zero. However, EU member countries were found to derive substantial benefits from inter-regional R&D spillovers as well as from intra-regional R&D spillovers under the two models of the single market and the common currency area, thereby unequivocally increasing their reliance on international R&D spillovers.

Our evidence suggests that the entry into regional groupings changes the way participating economies grow. No matter which model of regional integration the groupings take, domestically powered growth becomes less important, and regionally powered growth comes to be the new source of growth. Countries oftentimes join regional groupings with the aim of finding new engines of economic growth. In particular, countries stand to benefit from considerable inter-regional R&D spillovers in addition to intra-regional R&D spillovers if their regional groupings take the form of a single market or a common currency area.

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