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Factors of R&D spillovers and European integration

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Abstract

We investigate factors of total factor productivity (TFP) interdependencies in a sample of 19 OECD countries for the period 1981-2009. Rolling cointegration relationships are estimated between TFP's level in order to measure productivity interdependencies across countries and over time. Besides the standard catch-up effect in productivity, results show that the R&D capital stock of a country is the main determinant of its technological catch-up within European countries. In contrast, those spillovers are mainly driven by trade and technological proximity for non-European countries.

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1. Introduction

Coe and Helpman (1995) have emphasized the role of international trade in the process of technological diffusion among OECD countries. Their seminal results have been enriched by additional factors explaining technological diffusion such as the importance of intra-industry trade (Hakura and Jaumotte, 1999) or the importance of human capital accumulation (*inter alia* Benhabib and Spiegel, 1994; Engelbrecht, 1997). A common feature of these papers is to analyze determinants of the total factor productivity (TFP) in panel regressions without allowing differences between countries and variations over time. This paper provides a new assessment of spillover determinants that consists first in estimating country-by-country co-movements of the TFP among OECD countries. Then, the purpose is to investigate which channels of transmission might explain those co-movements. We also pay a specific attention to European countries in order to assess if geographical proximity, common policies and institutions may affect significantly TFP interdependencies.
In the section 2, we describe some features of the data and estimate TFP interdependencies by cointegration techniques. In the section 3, we report results from estimations of the determinants of TFP interdependencies. The section 4 summarizes our results and provides concluding remarks.

2. TFP interdependencies

2.1 Data

The total factor productivity (A) represents the contribution of technology to the real GDP (Y) when taking into account the stock of physical capital (K) and the labor force (L) available in the economy. Using the standard Cobb-Douglas production function leads to the following expression of TFP in log difference[1]:

$$\Delta \ln A_{i,t} = \Delta \ln Y_{i,t} - \theta \ln L_{i,t} - (1-\theta) \ln K_{i,t}$$

European TFPs are computed for each country (i) as the average of remaining European countries' TFPs (denoted j) weighted by bilateral import shares ($w_{ij,t}$).

$$\ln A_{i,t}^{EUR} = \sum_{j \neq i} w_{ij,t} \ln A_{j,t}$$

Table 1 presents the evolution of domestic TFP and those of European counterparts. Figures report a catch-up effect of TFP: standard deviations of TFP growth rates are declining during the period. Country level data documents a negative relationship between initial levels of TFPs and their growth of rates.

[1] As in Coe and Helpman (1995), the labor share θ is equal to 2/3.
[2] Results are available upon request.

Table 1: TFP Evolution 1981-2008

	(1) ln A		(2) ln A^{EUR}	
	1995/1981	2008/1995	1995/1981	2008/1995
Austria	5.25	3.98	8.34	2.86
Bel./Lux.	7.67	3.63	8.84	3.83
Denmark	10.57	3.21	6.92	3.69
Finland	6.25	5.32	8.94	4.57
France	6.86	3.39	8.56	3.56
Germany	8.50	2.35	8.32	3.84
Greece	3.47	6.17	9.07	2.71
Ireland	7.19	4.64	8.98	5.11
Italy	6.57	1.76	8.77	3.47
Netherlands	9.76	4.09	8.15	3.27
Portugal	8.09	2.87	10.64	4.23
Spain	11.29	5.04	10.71	3.49
Sweden	9.49	5.00	9.40	3.40
United Kingdom	12.17	4.08	9.04	3.69
E.U. Average	**8,08**	**3,97**	**9,04**	**3,69**
E.U. Standard Error	**2,32**	**1,17**	**0,79**	**0,61**
Canada	7.03	3.81	8.25	6.96
Japan	7.02	0.99	11.86	4.89
Norway	7.00	2.56	9.66	3.77
United States	8.77	3.45	8.77	6.25
Non E.U. Average	**7,45**	**2,70**	**9,63**	**5,47**

European countries: Austria, Luxembourg-Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.
Non-European countries: Canada, Japan, Norway and the United States.
Sources: OECD Economic Outlook, authors' calculations.

2.2 Long-run elasticities of TFP

The elasticity of the domestic productivity $A_{i,t}$ with respect to its European counterpart $A_{i,t}^{EUR}$ is given by the coefficient β_i^1 in the following equation:

$$\ln A_{i,t} = \alpha_i + \beta_i^1 \ln A_{i,t}^{EUR} + \beta_i^2 \ln A_{i,t}^{RoW} + \varepsilon_{i,t} \qquad (1)$$

$A_{i,t}^{RoW}$ stands for the weighted average productivity of non European countries included in the sample and is used as a control variable. We first test the significance of the cointegration relationship between the three variables of equation (1) with the trace test of Johansen. Results show that all countries admit one cointegration relationship between their TFP and their European and non-European counterparts for the full sample (1975-2009)[2].
Cointegration relationships are then estimated by Fully-Modified Ordinary Least Squares (FM-OLS)[3]. FM-OLS method accounts for a possible endogeneity of regressors and serial correlation of errors. Moreover, it does not depend on the cointegration dimensionality and

[2] Results are available upon request.
[3] For more details, see Phillips (1995) and Hurlin and N'Diaye (1998).

no restriction of identification has to be imposed. Furthermore, t-ratios are asymptotically normally distributed and are not dependant on the correct choice of lag length.
In the table 2, estimated coefficients β^1 go from -0.6 for Japan to 2.59 for Ireland, most of them are positive but exhibit a large volatility. The CUSUM FM-OLS test proposed by Hao and Inder (1996) shows a break in the European coefficient for 7 countries. These breaks confirm the choice of the FM-OLS estimator.
Coefficients β^2 (relative to non-European TFP) go from -0.89 for Spain to 3.36 for Italy. Most of them are positive except for Spain and Sweden.

Table 2: Estimation and stability test for the period 1975:2009

	FMOLS		CUSUM FMOLS for β^1	
	β^1	β^2	Stat.	Date
Austria	0.52***	0.01	0,41	
Lux-Bel	0.82***	0.87***	0,08	
Canada	0.97*	0.89***	0,56	
Denmark	0.94***	0.37***	0,14	
Finland	1.40***	-0.02	-1,72***	1987:4
France	0.93***	0.64***	0,04	
Germany	0.35***	2.24***	0,48	
Greece	1.04***	-0.40	3,42***	1993:2
Ireland	2.59***	0.90***	4,92***	1992:3
Italy	0.45***	3.36***	-1,17***	1987:1
Japan	-0.60**	1.91***	-3,19***	1994:1
Netherlands	0.87***	1.54***	1,64***	1988:4
Norway	1.19***	1.11***	0,39	
Portugal	1.15***	1.97***	-1,13***	1995:2
Spain	1.42***	-0.89***	0,69	
Sweden	1.30***	-0.57***	0,68	
United-Kingdom	1.44***	-0.07	0,46	
United-States	1.73***	0.79***	0,28	
Average EU	1.09	0.75		
Average N-EU	0.82	1.18		

*, **, *** significant at 10%, 5% and 1%.

3. Explanatory models of TFP interdependencies

3.1 Trade, specialization and R&D Capital Stock

We now turn to the explanation of productivity interdependencies measured by elasticities between the domestic TFP and its European counterpart.

These elasticities can be seen first as a measure of "productivity spillovers" which are generated endogenously by the accumulation of knowledge in the economy[4]. The level of knowledge is measured by the R&D capital stock in each country (**KRD**). The R&D capital stock is computed from investments in R&D using the perpetual inventory model and a depreciation rate of 15%. Following Benhabib and Spiegel (1994) and Crespo *et al.* (2004) the stock of knowledge may also explain the capacity of an economy to absorb the technical progress from foreign countries. This effect is captured by an interaction term between KRD and the productivity gap $A_{i,t}^{EUR} / A_{i,t}$ (**KRD***).

Second, trade is widely recognized to be a key channel for technological transfers and therefore could explain co-movements in production. The degree of openness (**OPEN**) is measured by the sum of real imports and exports divided by twice real GDP. Nevertheless, the degree of openness may dissimulate some disparities in the pattern of trade that can affect spillovers. Theoretically, Rivera-Batiz and Romer (1991) and Romer (1994) argue that when knowledge is incorporated into new varieties of goods, trade can lead to technological transfers without knowledge transfers. Consequently, inter-industry trade does not explain productivity spillovers across country. On the contrary, Hakura and Jaumotte (1999) have shown empirically that intra-industry trade promotes technology diffusion. In this paper, we link TFP interdependencies with the degree of openness and with the specialization index of production structure measured with the Krugman index (**SPE**). Using data for 30 sectors, we compare the domestic sectoral shares with European sectoral shares. The Krugman index increases with specialization. Data are extracted from OECD STAN indicators database. Following Hakura and Jaumotte (1999), we might expect productivity spillovers to be negatively related with the Krugman index, the more diversified countries, the stronger technological absorption.

Finally, estimated equations can be written as follows:

$$\hat{\beta}^{1}_{i,[t,t+5]} = \alpha_i + \Gamma X_{i,t} + \varepsilon_{i,t} \quad t = [1981;2003]$$

$\hat{\beta}^{1}_{i,[t,t+5]}$ is the rolling estimates of β^{1}_{i} in equation (1). The individual fixed effect α_i captures unobservable features that may explain TFP interdependencies such as legislation and cultural characteristics. The matrix $X_{i,t}$ contains explanatory variables of TFP interdependences: **KRD**, **KRD***, **OPEN** and **SPE**.

3.2 Absorption of technological spillovers

Results are reported in table 3 and confirm the accumulation of knowledge explains the importance of international spillovers. The interaction term of R&D capital stock and the productivity gap is significant with a negative sign. The role of knowledge is reduced when a country's productivity is far above the one of its European partners. By contrast, for a given level of knowledge, low productive countries tend to absorb more spillovers from the rest of Europe. This result clearly supports the conventional catch-up effect of levels of productivity. We also find that the degree of openness enhances the TFP interdependencies while the specialization of production may reduce the ability of an economy to take advantage from foreign productivity gains. This result supports the idea that technological proximity facilitates technological spillovers. The degree of openness increases significantly TFP interdependences, even if the effect is of low magnitude.

[4] Klenow and Rodriguez Clare (2005) provide a complete survey of these models.

Table 3: Determinants of TFP Interdependencies

Variable	(1)	(2)	(3)	(4)
KRD	0,46**	0,24*	0,24**	0,05
	(0,08)	(0,14)	(0,10)	(0,15)
KRD*	-0,12***	-0,11***	-0,09***	-0,08***
	(0,03)	(0,03)	(0,03)	(0,03)
OPEN		0,01***		0,01***
		(0,005)		(0,006)
SPE			-1,55***	-1,50***
			(0,36)	(0,36)
Obs	450	440	449	439
R^2	0,22	0,24	0,25	0,27

Panel regressions with fixed individual effects (not reported).
Standard errors in brackets. Levels of significance: ***1% and ** 5%

3.3 Effects of European integration

In a second set of regressions, we pay attention to the impact of European Integration on TFP interdependencies. Previous explanatory variables are interacted with dummy variables that distinguish EU Member States (**UE**) from other countries (**NEU**). We also introduce time dummy variables according to enlargements of the EU. Those dummy variables take the value 1 from 1986 (**ENLARG1**) and from 1995 (**ENLARG2**).

Results are reported in table 4. For European Countries, we still observe a positive impact of knowledge accumulation (measured par R&D capital stock) on the TFP interdependencies. This effect declines with the productivity gap between one country and its European partner. Thus, we confirm the catch-up effect in productivity. Nevertheless, this result does not hold for extra-European countries. The effect of R&D capital stock on their sensibility to European productivity appears negative but insignificant. The interaction of R&D capital stock and the productivity gap is negative as expected, but its significance does not seem robust.

Remaining results show that the effect of international trade and proximity of production structure still have the expected sign on TFP interdependencies in both members and non members of the European Union. The size of effects is significantly different between the two groups of countries. On average, in the European Union, the degree of openness increases by 0.01 TFP interdependencies, while production specialization reduces it by 1.17; these effects are about one tenth of those observed for non-European countries.

The EU enlargement of 1995 has a negative impact on productivity interdependencies. This result can be due to the fact that EU enlargements lead to an increase of the EU market size and heterogeneity.

Table 4: Effects of European Integration

Variables	(1)	(2)	(3)	(4)
NEU-KRD	-0.24	-0.07	-1.75***	-0.27
	(0.3)	(0.35)	(0.66)	(0.33)
NEU-KRD*	-0.23*	-0.24*	0.02	-0.16
	(0.13)	(0.13)	(0.16)	(0.13)
EU-KRD	0.59***	0.71***	0.60***	0.58***
	(0.09)	(0.14)	(0.15)	(0.13)
EU-KRD*	-0.11***	-0.11***	-0.10	-0.08***
	(0.03)	(0.03)	(0.03)	(0.03)
ENLARG1		0.04		
		(0.10)		
ENLARG2		-0.15*	-0.23**	-0.19**
		(0.09)	(0.10)	(0.09)
NEU-OPEN			0.11***	
			(0.03)	
EU-OPEN			0.01*	
			(0.01)	
NEU-SPE				-8.45***
				(2.10)
EU-SPE				-1.17***
				(0.36)
Obs	450	450	440	449
R^2	0.26	0.26	0.30	0.31

Panel regressions with fixed individual effects (not reported).
Standard errors in brackets. Levels of significance: ***, **, * for 1, 5 and 10%.

4. Conclusion

Among the huge amount of contributions dealing with determinants of international spillovers, the originality of the paper is twofold. First, we examine productivity co-movements country by country, rather than in a homogenous panel. Second, various channels of transmission of foreign productivity and their relative importance are investigated. We find strong evidence of cointegration between TFPs in each country and their European counterpart.

Results also exhibit some differences in cointegrating coefficients across countries and over time. Technological spillovers from the European Union tend to be absorbed by European countries thanks to their investment in R&D: productivity gaps tend to be reduced. Other OECD countries benefit from European productivity thanks to international trade. Absorption is easiest when countries face the same technology as EU countries.

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