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North - South R&D Spillovers and Student Flows

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Abstract

In global context, as human capital embodies technology, international student flows may play an important role as a channel of R&D spillovers from developed countries to less developed ones. Empirical study on a data set of 76 developing countries during 1998-2005 lends strong support to this hypothesis.

Keywords: Foreign students, foreign education, R&D spillovers, total factor productivity, trade.

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1- Introduction

Previous studies have demonstrated that the accumulation of knowledge through R&D activities is not only good for the long-run productivity growth of the source country but can also benefit other countries through knowledge diffusion. These studies have focused on identifying potential channels through which knowledge transmits across borders. The main channels that have been studied include import flows (e.g., Coe and Helpman 1995, Coe *et al.* 1997, Lee 2006), foreign direct investment (e.g., van Pottelsberghe and Lichtenberg 2001, Lee 2006, Bodman and Le 2007a), and human capital acquisition (e.g., Park 2004, Bodman and Le 2007b, Le 2008).

Of these channels, human capital acquisition is a newly established channel. As human capital is embodied in people and contains knowledge about new technologies and materials, production methods, or organizational structures, it is expected that the international mobility of people will help diffuse knowledge among countries. However, this channel has not been fully examined. In particular, very little has been done to characterize the impact of technology embodied in student flows on total factor productivity (TFP) of student sending countries. Park (2004) is the only paper so far that considers this specific issue, nevertheless, in a context of OECD countries. Therefore, the main purpose of this paper is to extend the work by Park (2004) by considering developing countries. With the existence of student flows from developing countries to developed countries, foreign students who acquire R&D-induced technological knowledge through education and post-schooling work experience in the country they study may contribute to productivity improvement of their home country upon returning or maintaining close and frequent contact with people back home. This hypothesis is tested based on cointegration method using pooled time series data of 76 developing countries for the period 1998-2005. Empirical findings lend strong support to the idea that besides import flows, student flows can act as a significant channel for R&D spillovers from developed countries to developing ones.

2- Empirical framework

To measure the significance of R&D spillovers through student flows, this paper constructs student-embodied foreign R&D capital stock, SF_{it}^{f} :

$$SF_{it}^{f} = \sum_{j=1}^{16} \frac{f_{ijt}}{n_{jt}}.SD_{jt} \tag{1}$$

where f_{ijt} is the number of tertiary students originating from developing country i and studying in developed country j, n_{jt} is the total number of tertiary students enrolled in developed country j, and SD_{jt} is total domestic R&D capital stock in developed country j at time t. The weights reflect the general notion that the extent to which country i benefits from country j's R&D investment depends on the degree of access by country i's students to knowledge available in country j.[1] Because student flows are volatile, this paper considers 3-year moving average. The foreign R&D capital stock is then lagged for 2 years to allow for time spent studying, working, and returning. To see whether the result is robust to the inclusions of other R&D spillover variables introduced in the literature, an alternative version of foreign R&D, import-embodied SF_{it}^{m}, is also considered. It is constructed following Lichtenberg and van Pottelsberghe's (1998) method:

$$SF_{it}^{m} = \sum_{j=1}^{16} \frac{m_{ijt}}{y_{jt}}.SD_{jt} \tag{2}$$

[1] It can be imagined that whenever an innovation is made in country i, the knowledge spreads thinly among all tertiary students enrolled in that country. Country j will benefit more from this knowledge if it has more students studying in country i.

where m_{ijt} is the value of imported goods and services of developing country i from developed country j, and y_{jt} is the developed country j's GDP at time t.

To examine the degree of international R&D spillovers on TFP where student flows are considered as a significant conduit, this paper studies the following regression equation:

$$TFP_{it} = g\left(SF_{it}^{m}, SF_{it}^{f}, \frac{M_{it}}{Y_{it}}, \frac{F_{it}}{L_{it}} \right) \tag{3}$$

where $\frac{M_{it}}{Y_{it}}$ is the ratio of imports of goods and services to GDP, and $\frac{F_{it}}{L_{it}}$ is the ratio of total number of students studying overseas to domestic population. This regression equation also allows for important interactions between each kind of foreign R&D with its corresponding (import or student) intensity. By doing so, it is expected to capture the impact of the levels of imports and student flows on knowledge diffusion.[2] Although the theory suggests that domestic R&D strongly affects productivity, this paper, following Coe *et al.* (1997), opts not to consider this factor here since in most developing countries, R&D expenditures are sufficiently small that they can be ignored.

The empirical results in this paper are based on annual data series created for 76 developing countries over the 1998-2005 period. Raw data on GDP, gross fixed capital formation, and population for the computation of TFP of these developing countries are from the United Nations Statistic Division's Database. Foreign R&D for each developing country is a weighted average of the domestic R&D of 16 OECD countries. Domestic R&D of each OECD country is constructed based on Coe and Helpman's (1995) method from R&D expenditure data in OECD STAN Database (2006). Data on total number of tertiary students

[2] Whenever two developing countries have the same composition of students studying overseas and face the same composition of R&D capital stocks among developed partner countries, the country that send more students studying overseas relative to its domestic population may benefit more from foreign R&D.

enrolled in the OECD countries are obtained from OECD Education and Training Database. Finally, data on bilateral imports come from the United Nations Comtrade Database.

3- Empirical findings

The purpose of this paper is to estimate the long-run relationship between TFP and foreign R&D capital stock when student flows are considered as a channel for technological transmission. The main econometric technique used is panel cointegration method in which the relationship between dependent variable and explanatory variables is estimated in (log) level terms. As discussed in Coe and Helpman (1995) and applied in most TFP research papers, when estimating nonstationary variables in level, the estimated equations should reflect coinintegrating relationship, otherwise they are spurious. Hence, this paper first examines whether data series are nonstationary by performing unit root tests put forward by Im *et al.* (2003). It can be seen in Table 1 that most of the variables are nonstationary except for import intensity, student intensity, and the interaction term between import intensity and its corresponding foreign R&D (each case, the null hypothesis of panel unit root is rejected). According to Edmond (2001), regressions using these variables do not fulfill a necessary condition for cointegration and should no longer be considered.

Table 1- ***Group mean panel unit root tests (annual data 1998-2005 for 76 countries– Im et al. 2003)***

Variable	Statistic	Decision
$\log TFP$	-1.803	$I(1)$
$\log SF^{m}$	-1.226	$I(1)$
$\log SF^{f}$	3.079	$I(1)$
M/Y	-3.908	$I(0)$
F/L	-2.351	$I(0)$
$(M/Y).\log SF^{m}$	-3.902	$I(0)$
$(F/L).\log SF^{f}$	4.488	$I(1)$

Note: $\log X$ is logarithm of X. TFP, SF^{m}, SF^{f}, M/Y, and F/L are total factor productivity, foreign R&D capital stock based on import weights, foreign R&D capital stock based on student flows, import as share of GDP, and student flows as share of total domestic population respectively. Panel unit root test statistic is from Im *et al.* (2003) which has asymptotic normal distribution. Decisions are based on one-sided test at 5% significance level.

This paper is then extended to a panel cointegration test by Pedroni (1999) to see if various models based on regression equation (3) have cointegrating relationships. Results in Table 2 indicate that the null of no cointegration cannot be rejected in regression (3) and (5). Their results are, therefore, disregarded.

Regression (1) confirms the findings in Coe and Helpman (1995) and many subsequent papers that trade is an important conduit of technological transmission. In regression (2), it is shown that there may be significant international R&D spillovers and students from developing countries studying in developed countries may induce substantial knowledge transfers. By allowing students to go to developed countries to study, developing countries seem to be able to enhance their stock of knowledge, thereby increasing their productivity. The result about the positive and significant impact of student-embodied foreign R&D on TFP is still robust when the import-embodied foreign R&D is included as an additional regressor in regression (4). Here, the coefficients on both kinds of foreign R&D are positive and significant. In regression (6), the interaction term between student-weighted foreign R&D and its intensity is also considered. As the coefficient on this term is positive and significant, it implies that higher proportion of students studying in more advanced countries leads to a quicker learning process and, hence, a higher technological base. Regression (7) takes into account all three explanatory variables. Here, the coefficients on both kinds of foreign R&D are positive and significant although they reduce somewhat in terms of magnitude. The coefficient on the interaction term is still positive but insignificant.

Table 2- ***Total factor productivity estimation results (pooled data 1998-2005 for 76 countries, 522 observations – in level)***

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\log SF^m$	0.166***			0.150***	0.160***		0.149***
	(0.038)			(0.048)	(0.051)		(0.048)
$\log SF^f$		0.101**		0.080**		0.098**	0.079**
		(0.041)		(0.039)		(0.041)	(0.039)
$\left(F/L\right).\log SF^f$			2.041***		1.227*	1.055***	0.488
			(0.607)		(0.631)	(0.346)	(0.429)
R^2	0.503	0.618	0.610	0.637	0.631	0.618	0.637
Adjusted R^2	0.418	0.541	0.532	0.562	0.556	0.541	0.561
Cointegration test							
Panel ADF statistic	-3.779	-3.594	-0.885	-1.998	-0.858	-4.594	-3.756
Decision	CI	CI	Retain null	CI	Retain null	CI	CI

Note: The dependent variable is $\log TFP$ (log of total factor productivity, indexed as 2000=1). All regression equations include unreported country-specific constants. White heteroskedasticity-consistent standard errors are given in parentheses. SF^m is foreign R&D capital stock based on import weights, SF^f is foreign R&D capital stock based on student flows, M/Y is import as share of GDP, and F/L is student flow as share of total domestic population. Panel cointegration test statistic is from Pedroni (1999) which is asymptotically normally distributed. Decisions are based on one-sided test at 5% level of significance.

In short, except for regressions (3) and (5) which are not cointegrating and, therefore, their results are disregarded, all regressions have quite substantial fits. In terms of comparison across models, regression (4) is the most preferable due to the highest value of adjusted R^2 it delivers.

4- Conclusion

This paper presents empirical evidence that TFP of less developed countries can benefit from R&D activities in industrial countries. While the beneficial effect of knowledge transmission through trade is established in the literature, the strong evidence that student flows play an important role as an effective conduit of technological transfer from developed countries to developing ones is new. The results obtained are quite encouraging as they indicate that having more students studying in industrialized countries may facilitate the learning and technological diffusion process. This emphasizes the importance of foreign education within the general framework of education policies as human capital obtained from studying in developed countries may embody a substantial degree of foreign technology which is good for the productivity improvement of the students' home country.

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Appendix 1: Countries included in the sample

Developing countries: Algeria, Angola, Argentina, Bangladesh, Benin, Bolivia, Botswana, Brazil, Burkina Faso, Burundi, Cameroon, Cape Verde, Chad, Chile, China, Colombia, Comoros, Congo, Costa Rica, Cote d'Ivoire, Democratic Republic of Congo, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Eritrea, Ethiopia, Fiji, Gabon, Gambia, Ghana, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, India, Indonesia, Jamaica, Kenya, Lesotho, Liberia, Madagascar, Malawi, Malaysia, Mali, Malta, Namibia, Nepal, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Rwanda, Senegal, Sierra Leon, South Africa, Sri Lanka, Sudan, Suriname, Swaziland, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Uganda, Uruguay, Venezuela, Vietnam, Zambia.

Developed countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, United Kingdom, and United States

Appendix 2: Summary statistics

	ΔTFP (%)	ΔSF^m (%)	ΔSF^f (%)	$\Delta\left(\frac{M}{Y}\right)$ (%)	$\Delta\left(\frac{F}{L}\right)$ (%)
Algeria	3.22	5.71		-1.47	3.22
Angola	-12.73	10.24		-6.57	8.91
Argentina	-11.86	-13.34		-0.87	0.55
Bangladesh	0.06	5.78		2.03	-1.24
Benin	2.72	-5.19		-10.22	6.73
Bolivia	1.94	-17.27		-16.29	0.37
Botswana	3.50	-0.93		-10.21	-11.66
Brazil	-5.42	-4.81		1.45	-5.00
Burkina Faso	4.77	4.73		-2.61	7.32
Burundi	-10.22	1.15		6.61	15.74
Cameroon	2.56	1.69		-3.94	7.29
Cape Verde	4.31	9.82		1.92	4.60
Chad	7.03	12.20		-2.17	2.36
Chile	1.79	-4.14		-5.33	1.48
China	4.90	18.21		9.55	10.81
Colombia	-1.75	-3.33		-1.97	3.40
Comoros	6.75	-3.98		-11.22	7.27
Congo	9.15	-2.20		-10.84	2.39
Costa Rica	-1.75	-0.53		-2.94	-14.99
Cote d’Ivoire	3.75	3.05		1.46	3.93
Dem. Rep. Congo	-42.42	5.74		6.96	8.44
Dominica	3.19	-3.76		-2.89	-3.89
Dominican Rep.	1.73	-0.99		-1.42	-5.25
Ecuador	1.64	-4.62		-8.03	3.96
Egypt	-1.84	-10.52		-7.28	-5.55
El Salvador	2.77	2.26		-0.22	-10.93
Eritrea	-0.05	-0.04		1.51	10.14
Ethiopia	-0.70	10.48		6.84	-5.06
Fiji	6.43	0.02		-4.72	-36.11
Gabon	7.89	-9.13		-13.43	5.78
Gambia	-7.88	-4.58		-3.24	-4.72
Ghana	-7.91	1.60		1.61	10.13
Guatemala	1.65	5.95		2.04	-15.37
Guinea	-5.04	2.64		5.78	11.98
Guinea-Bissau	0.48	1.18		-3.31	5.03
Guyana	-0.63	-3.40		-3.39	-5.13

Summary statistics (continued)

	ΔTFP (%)	ΔSF^{m} (%)	ΔSF^{f} (%)	$\Delta\left(\frac{M}{Y}\right)$ (%)	$\Delta\left(\frac{F}{L}\right)$ (%)
Haiti	-7.32	0.29		2.06	-4.38
Honduras	1.20	-0.25		-3.73	-19.65
India	1.83	7.40		0.91	-6.64
Indonesia	5.43	0.26		-12.95	-19.47
Jamaica	-2.41	-1.31		-1.40	-1.39
Kenya	-2.22	-2.42		-2.10	-6.78
Lesotho	3.01	28.30		21.06	-21.68
Liberia	-11.52	-9.50		-18.49	-11.98
Madagascar	-5.27	9.72		9.23	3.80
Malawi	-8.03	6.48		7.68	-1.74
Malaysia	4.69	5.20		-1.76	-19.60
Mali	2.40	1.65		-4.02	8.61
Malta	3.51	0.70		-0.78	5.48
Namibia	3.32	2.36		-1.80	-8.62
Nepal	2.22	-4.41		-10.01	-4.28
Niger	-0.08	2.04		-3.13	7.92
Nigeria	2.09	9.79		3.94	13.88
Pakistan	-0.02	6.33		3.30	0.95
Panama	3.10	23.83		22.63	-26.09
Paraguay	-6.17	-3.80		-0.64	-7.21
Peru	2.44	-4.54		-5.79	2.00
Philippines	1.98	2.56		-1.14	-1.61
Rwanda	-7.22	-5.03		-3.42	17.32
Senegal	2.20	1.71		-3.12	8.61
Sierra Leon	-7.30	11.24		5.92	14.28
South Africa	3.20	5.09		0.17	0.11
Sri Lanka	0.22	0.75		-1.05	0.38
Sudan	4.15	3.33		-4.57	0.64
Suriname	-9.64	-1.31		-3.84	32.65
Swaziland	4.77	7.29		-0.12	-10.61
Tanzania	-2.60	-0.89		-3.86	-3.61
Thailand	1.19	8.71		3.60	-15.35
Togo	1.11	-11.36		-13.32	3.74
Trinidad & Tobago	10.45	3.88		-5.66	-5.36
Tunisia	2.26	2.19		-0.62	7.26
Uganda	-2.48	4.34		2.07	5.43

Summary statistics (continued)

	ΔTFP **(%)**	ΔSF^{m} **(%)**	ΔSF^{f} **(%)**	$\Delta\left(\frac{M}{Y}\right)$ **(%)**	$\Delta\left(\frac{F}{L}\right)$ **(%)**
Uruguay	-6.89	-14.22		-3.79	0.47
Venezuela	-4.35	-6.26		-6.55	-10.23
Vietnam	2.89	12.44		1.31	6.15
Zambia	-1.76	6.61		0.72	-0.83