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R&D spillovers through student flows, institutions, and economic growth: What can we learn from African countries?

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Abstract

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Using modern panel cointegration estimation techniques, this paper examines whether tertiary student flows can effectively transmit technological knowledge from industrialized countries to African countries. The results obtained lend strong support to this hypothesis. In addition, this paper extends the analysis to include institutional variables such as the ease of doing business, legal origins, and religious majority in order to see if institutional characteristics affect the way knowledge diffusion affecting total factor productivity. However, it is not clear that institutional differences are important factors that influence the degree of R&D spillovers and, hence, the total factor productivity of African countries.

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1- Introduction

Nowadays, one of the most important economic policies facing economies is how to increase the long-run growth rate of output. Many economists believe that technological progress is the factor that drives output growth and economic integration in our modern world. Technology is fundamental to the economy as it affects all areas of economic activity and all aspects of economic performance such as output level, product quality, employment, real wages, and profits. The new growth theory starting with Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992) suggests that technological progress is the direct outcome of an innovation process which involves cumulative research and development experience. These R&D activities account for much of the increase in output in the last century through the creation of either horizontally brand-new varieties or higher quality versions of existing products.

The interesting feature of technology lies in its nonrival characteristics. Investment in R&D is not only good for its own investors but also good for others as technological products contribute to the general technological base which is then publicly available to everyone (technological spillovers). These externalities imply that a country actually benefits from domestic R&D activities that it conducts as well as foreign R&D activities conducted in other countries. Many economists have attempted to investigate the channel through which technology diffuses across countries. So far, the literature has characterized the following as the main conduit for technological transfer: (i) trade (for example, Coe and Helpman 1995, Engelbrecht 1997, Keller 1998, 1999, 2002, Lee 2006, Zhu and Jeon 2007); (ii) foreign direct investment (for example, van Pottelsberghe and Lichtenberg 2001, Lee 2006, Zhu and Jeon 2007); and (iii) pure proximity in the technological space (for example, Park 1995, Frantzen 2002, Lee 2006). Another potential channel for international R&D spillovers is the movement of highly skilled workers. However, this channel has not been fully considered in the literature. Park (2004) and Le (2008) have so far been the two recognized studies that examine this specific channel. While park (2004) confirms R&D spillovers through student flows, Le (2008) finds evidence on the existence of R&D spillovers through flows of highly skilled workers. Both papers employ a pooled time series data set of OECD countries obtained from the work by Coe and Helpman (1995).

This paper contributes to the literature of international R&D spillovers by investigating if the flow of highly skilled workers is an important international R&D spillover channel. In particular, it examines whether the flow of tertiary students significantly helps diffuse knowledge from advanced countries to less developed countries in Africa. Through education and post-schooling job experience in an advanced country of study, students from a developing country may be able to learn and contribute to the productivity growth of their home country by returning home or maintaining close contacts with people back home. The main findings of the paper are as follows. There is robust evidence that total factor productivity (TFP) and foreign R&D capital stocks, either based on imports or tertiary student flows, are cointegrated. Measure of foreign R&D capital based on student flows exerts a positive and significant impact on a country's TFP. This finding is in line with that of Park (2004) who investigates the issue within a developed countries' context. The study in this paper is different from Park (2004) in the sense that it is conducted within a context of knowledge diffusion from developed to developing countries. This is a novel aspect of this paper. The results of this paper are obtained using first ordinary least squares (OLS) method and then dynamic ordinary least squares (DOLS) method, an advanced econometric technique on pooled data.

The second aim of the paper is to extend its analysis to consider the impact of institutional factors on the degree of R&D spillovers across national borders from industrial countries to those countries in Africa. By doing so, it contributes to the literature on the role of institutions to economic growth in an R&D-based context. The interesting thing is that in contrast to the conventional wisdom, this paper does not find any strong evidence which supports the hypothesis that countries where the ease of doing business is relatively high tend to benefit more from international R&D spillovers. There is also no evidence that the legal origins and the religious majority factor of an African country influence the extent to which it benefits from foreign knowledge base.

The rest of the paper is organised as follows. Section 2 summarizes the key features of data and the construction of some key variables used for the regression estimation of the paper. Section 3 presents the empirical model and findings which includes a brief description of the econometric techniques of panel cointegration. Section 4 addresses the importance of institutions on the extent of international R&D spillovers. Section 5 ends the paper with some concluding remarks.

2- Data and variables

2.1- Total factor productivity and domestic R&D capital stocks

Under the assumptions that the production function is Cobb-Douglas and exhibits constant returns to scale and that the product market is perfectly competitive, the $\log TFP$ is defined as:

$$\log TFP_{it} = \log Y_{it} - \alpha \log K_{it} - (1-\alpha)\log L_{it}$$

where i is a country index and t is a time index. Y, K, and L represent value-added, physical capital stock, and labor services employment respectively. Raw data for the computation of TFP of 41 African countries are from the United Nations Statistics Division's Database.

Endogenous growth theory suggests that growth in TFP is strongly dependent on cumulative domestic R&D capital stocks. However, in most of the African countries in this study, R&D expenditures are negligible which makes it difficult to construct domestic R&D capital stocks for the testing purposes. As a result, following Coe *et al.* (1997), it is assumed that domestic R&D capital stocks in the developing countries are sufficiently small that they can be ignored.

2.2- Foreign R&D capital stocks

For an African country to benefit from R&D investment deployed overseas, it needs to have trading partners that are capable of providing it with more advanced products and knowledge that it is in short. Hence, by trading with an industrial country that possesses a larger stock of knowledge, an African developing country will gain much more in terms of knowledge than it would by trading with another developing country. For this reason, foreign R&D capital stocks that spill over by means of import flows are constructed in the way proposed by Lichtenberg and van Pottelsberghe (1998) and are equivalent to trade-weighted foreign R&D capital stock initiated by Coe and Helpman (1995):

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

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.

By the same token, to measure the significance of R&D spillovers through student flows, this paper constructs student-embodied foreign R&D capital stock, SF_{it}^{f}, in the following way:

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

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. Because student flows are volatile, this paper considers 3-year moving average.

The foreign R&D capital stock for each developing country is a weighted average of the domestic R&D capital stocks of 16 OECD countries (Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Spain, Sweden, United Kingdom, and the United States). The domestic R&D capital stocks of these OECD countries are constructed based on the method described in Coe and Helpman (1995) from data on R&D expenditures extracted from the OECD STAN Database (2006). Data on total number of tertiary students enrolled in the selected OECD countries are obtained from OECD Education and Training Database. Finally, data on bilateral imports come from the United Nations Comtrade Database.

2.3- Institutional variables

In order to check if institutional factor plays a vital role in affecting technological diffusion across borders, this paper focuses its attention to three different measures of institutions which are largely employed in the literature:

+ *The ease of doing business*. This is an average ranking of countries provided by the World Bank (2007). This ranking is based on several criteria such as starting a business, dealing with licenses, trading across borders, enforcing contracts, and so forth. Given that the rankings are not available as time series, this paper divides the sample into two groups of 20 and 21 countries with highest and lowest rank respectively. These rankings are then used to define a dummy variable Hi that is interacted with alternative foreign R&D capital stocks.

+ *The origins of legal systems in either French or English law*. The data are extracted from La Porta *et al.* (1999). Because this measure is time invariant, countries in the sample are classified into two groups: 16 countries with English law origin and 25 countries with French law origin. This defines a new dummy variable Fre which will be used in the form of interactions with determinants of TFP.

+ *The religious majority in Catholic, Muslim, or others*. The data also come from La Porta *et al.* (1999). Similar to the two above mentioned measures of institutions, religious majority is very much time invariant. As a result, countries are sorted into different groups where religious majority is Catholic, Muslim, or others. New dummy variables (Ca, Mus) are created to see if they affect the determinants of TFP in this paper.

3- Empirical model of R&D spillovers and findings

One of the main purposes of this paper is to examine the degree of international R&D spillovers on TFP where student flows are considered as a significant conduit. In order to achieve this goal, this paper extends the Coe and Helpman's (1995) econometric framework by adding a new sort of foreign R&D capital stock – foreign R&D capital stocks weighted by student flows. Basically, this paper studies the following regression equation:

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

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 the important interactions between each kind of foreign R&D capital stocks with its corresponding (import or student) intensity. Implicit in the above specification is the assumption that TFP is affected by the latest changes in technology. However, the diffusion of technology and the effect of changes often take time. To take into account this fact, foreign R&D capital stock weighted by imports is introduced into the regression equation with one lag to better identify its impact on TFP. By the same way, foreign R&D capital stock based on student-weights is lagged by 2 years to allow for time students spend on studying, working, and returning. It should be noted that qualitative findings do not change with alternative lag structure.

Before estimating any equations, it is important to examine the variables in order to avoid the possibility of spurious regressions. To this end, the panel unit roots tests suggested by Hadri (2000) and Im *et al.* (2003) are conducted (at 5% level of significance) to see if the variables are non-stationary or not. The test by Hadri (2000) starts with the null hypothesis of stationarity for the variable under consideration. By contrast, Im *et al.* (2003) tests for the null hypothesis of unit root existence.

Results in Table 1 indicate that both tests confirm the non-stationarity for most variables. The only exception is $\log(SF^{f})$ when the Hadri's (2000) test shows that the variable is non-stationary. This is in contrast with the result obtained by using the Im *et al.*'s (2003) test. In this case, this paper is inclined to the result of the test by Hadri (2000) because with the purpose of proving a certain variable to be non-stationary, its hypothesis seems more appropriate.

Table 1- Panel unit root tests (at 5% level of significance, 41 countries, 1998-2006)

Variable	Hadri (2000) test		Im *et al.* (2003) test		Decision
	Statistics	Implication	Statistics	Implication	
$\log(TFP)$	18.658 (0.000)	$I(1)$	1.161 (0.877)	$I(1)$	$I(1)$
$\log(SF^m)$	44.225 (0.000)	$I(1)$	0.224 (0.412)	$I(1)$	$I(1)$
$\log(SF^f)$	35.533 (0.000)	$I(1)$	-2.650 (0.004)	$I(0)$	$I(1)$
$m.\log(SF^m)$	38.368 (0.000)	$I(1)$	-0.179 (0.429)	$I(1)$	$I(1)$
$f.\log(SF^f)$	37.419 (0.000)	$I(1)$	4.025 (1.000)	$I(1)$	$I(1)$

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on international student flows, imports as share of GDP (import intensity), and tertiary students studying overseas as share of population (student intensity) respectively. p - values are in parentheses.

The next step is to check if the variables exhibit any cointegrating relationship by using some panel cointegration tests. This paper conducts two panel cointegration tests proposed by Pedroni (1999) at 5% level of significance. The results are reported in Table 2.

Table 2 – Panel cointegration tests (based on Pedroni 1999 at 5% level of significance, 41 countries, 1998-2006)

	Panel t-statistics	Group t-statistics	Decision
$\log(TFP)$, $\log(SF^m)$	-2.571 (0.015)	-2.129 (0.041)	*CI*
$\log(TFP)$, $\log(SF^f)$	-5.175 (0.000)	-5.553 (0.000)	*CI*
$\log(TFP)$, $m.\log(SF^m)$	-2.667 (0.011)	-0.926 (0.260)	*CI*
$\log(TFP)$, $f.\log(SF^f)$	-2.899 (0.006)	-1.683 (0.097)	*CI*
$\log(TFP)$, $\log(SF^m)$, $\log(SF^f)$	-5.590 (0.000)	-5.701 (0.000)	*CI*
$\log(TFP)$, $m.\log(SF^m)$, $f.\log(SF^f)$	-4.993 (0.000)	-4.469 (0.000)	*CI*

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on international student flows, imports as share of GDP (import intensity), and tertiary students studying overseas as share of population (student intensity) respectively. p -values are in parentheses.

The test results show that there is panel cointegration between variables for almost all model specifications and, hence, the associated regressions are not spurious.[1] Consequently, the estimated coefficients can be interpreted as representing the long-term relationship between interested variables. Long-run relationship can be estimated using pooled estimation technique and, to some extent, group mean estimation technique.

Table 3 presents panel OLS estimates of all possible specifications for 41 African countries over the period 1998-2006 (see the Appendix for the full list of countries used for this study). All equations include unreported fixed effects. As noted above, it is assumed that domestically generated R&D capital is negligible in all African developing countries included in the sample. The paper starts with the regression using import weighted foreign R&D capital as the explanatory variable which is regression (1). It then estimates the impact of international R&D spillovers on a country's TFP by regressing TFP on foreign R&D capital weighted by tertiary student flows in regression (2). The magnitude and significance of each alternative foreign R&D capital interacted with their corresponding (import or student) intensity is examined in regressions (3) and (4). Finally, the international R&D spillovers that are embodied in trade and student flows, combined together, are estimated in regressions (5) and (6).

The results show that the coefficients on foreign R&D capital stocks, either through the import channel or the student flow channel, are positive and statistically significant in all cases. The positive and significant impact of import embodied foreign R&D on TFP is consistent with Coe and Helpman (1995) and many subsequent papers in the literature. Results also support the hypothesis that the country benefits from technological spillovers embodied in tertiary student flows, which is clearly a novel aspect. Since the coefficients on foreign R&D stocks interacted with their openness measures are positive and statistically significant, it indicates that foreign R&D may have a stronger effect on domestic productivity if the economy is more open.

Table 3- OLS estimation results (fixed effects, 41 countries, 1998-2006)

Dependent variable: $\log(TFP)$	(1)	(2)	(3)	(4)	(5)	(6)
$\log(SF^m)$	0.184***				0.165***	
	(0.049)				(0.047)	
$\log(SF^f)$		0.196***			0.163***	
		(0.039)			(0.040)	
$m.\log(SF^m)$			0.018**			0.042**
			(0.008)			(0.018)
$100.f.\log(SF^f)$				0.598***		0.602***
				(0.145)		(0.145)
R^2	0.474	0.603	0.457	0.591	0.624	0.602
$Adj-R^2$	0.396	0.537	0.376	0.523	0.558	0.532
Number of observations	318	287	318	287	282	282

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on international student flows, imports as share of GDP (import intensity), and tertiary students studying overseas as share of population (student intensity) respectively. Standard errors are in parentheses. *, **, *** indicate parameters that are significant at 10%, 5%, and 1% levels of significance respectively. All regressions include unreported country specific constants.

Despite offering nice results as discussed above, the OLS estimation technique has been criticized by Kao *et al.* (1999) for having a second-order asymptotic bias that leads to invalid standard errors although its estimator is superconsistent. To avoid this problem, this paper employs the DOLS method proposed by Kao and Chiang (2000) to estimate the long-run relationships.[2] This econometric technique requires the appropriate selection of lead and lag terms. For the DOLS results presented in Table 4, this paper chooses one lead and one lag. This choice is sensible given the short time horizon of the sample used. In addition, for a range of lead and lag terms, it can be shown that the signs, significance, and relative magnitudes of the estimated coefficients do not change substantially.

All the DOLS estimation results are reported in Table 4. Here, this paper applies the DOLS estimation to the same regression equations considered in Table 3. Results obtained differ very much from the OLS estimation. It can be seen that the estimated coefficients on foreign

R&D capital stocks and the interaction term between foreign R&D through student flows and its student intensity increase substantially. However, the coefficients on the interaction term between foreign R&D by means of imports and its openness become negative and insignificant. These estimates confirm that TFP and foreign R&D capital are cointegrated and both measures of foreign R&D capital are significant determinant of TFP. It is worth noting that there is sufficient evidence to point out a potentially new channel of international knowledge diffusion, namely tertiary student flows.[3] This is one of the key contributions of this paper. It is shown that by sending students to study in tertiary institutions in technological advanced countries, developing countries in Africa gain as these student flows facilitate technology diffusion from developed countries where they study back to their home country.

Table 4 – DOLS estimation results (fixed effects, 41 countries, 1998-2006)

Dependent variable: $\log(TFP)$	(1)	(2)	(3)	(4)	(5)	(6)
$\log(SF^m)$	0.415***				0.435***	
	(0.095)				(0.105)	
$\log(SF^f)$		0.292***			0.196**	
		(0.089)			(0.080)	
$m.\log(SF^m)$			-0.003			-0.065
			(0.035)			(0.044)
$100.f.\log(SF^f)$				1.740***		1.732***
				(0.454)		(0.395)
R^2	0.794	0.822	0.782	0.825	0.895	0.882
$Adj-R^2$	0.733	0.756	0.718	0.760	0.849	0.831
Number of observations	195	164	195	164	159	159

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on international student flows, imports as share of GDP (import intensity), and tertiary students studying overseas as share of population (student intensity) respectively. Standard errors are in parentheses. *, **, *** indicate parameters that are significant at 10%, 5%, and 1% levels of significance respectively. All regressions include unreported country specific constants. Here, the DOLS regressions include one lead and one lag of the first differenced independent variables.

4- Institutions and international R&D spillovers

Given that there is an expanding literature on institutions and growth (see, for example, Hall and Jones 1999, Acemoglu *et al.* 2001, and Rodrik *et al.* 2004) where institutions are considered as one of the key determinants of TFP, this paper examines if institutional factor really influences the knowledge transmission process from industrial countries to developing African countries. In particular, it focuses its analysis on three different proxies for institutions: the ease of doing business, the legal origins, and the religious majority.[4] These institutional variables could potentially affect the extent to which foreign R&D affects TFP in different ways. Countries with high degree of the ease of doing business are expected to trade and to do business more with foreign countries, hence, get access to more foreign R&D. Different legal system and religious factor may also affect productivity of foreign R&D to some extent.

Estimation results for the ease of doing business are provided in Table 5. Regression (1) in the table is identical to regression (5) in Table 4. In regression (2), the estimated coefficient on the interaction of the Hi ease of doing business with import-weighted foreign R&D is positive but insignificant. In regression (3), the coefficient on the interaction term between the Hi ease of doing business and student-weighted foreign R&D is negative and insignificant. When these interaction terms are considered together in regression (4), the coefficients on the interaction terms are both negative and insignificant. This implies that there is not enough evidence to support the claim that countries where it is relatively easy to do business benefit more from international R&D spillovers. It is not clear that country differences in the ease of doing business lead to differences in the estimated coefficients on foreign R&D capital stocks. This result is different from that of Coe *et al.* (2008) who find the ease of doing business plays an important role in affecting the way R&D, both domestic and foreign, influence TFP. However, that study is conducted in a developed countries' environment, not developing countries' environment as in this paper.

Table 5 – Ease of doing business (DOLS, fixed effects, 41 countries, 1998-2006)

Dependent variable: log(*TFP*)	(1)	(2)	(3)	(4)
$\log(SF^m)$	0.435***	0.414***	0.362***	0.381**
	(0.105)	(0.155)	(0.113)	(0.159)
$\log(SF^f)$	0.196**	0.192**	0.256***	0.250**
	(0.080)	(0.081)	(0.097)	(0.103)
$Hi.\log(SF^m)$		0.021		-0.065
		(0.202)		(0.232)
$Hi.\log(SF^f)$			-0.088	-0.088
			(0.148)	(0.172)
R^2	0.895	0.896	0.900	0.901
$Adj-R^2$	0.849	0.844	0.851	0.846
Number of observations	159	159	159	159

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on international student flows, imports as share of GDP (import intensity), and tertiary students studying overseas as share of population (student intensity) respectively. Hi is a dummy variable for countries that have high level of the ease of doing business. Standard errors are in parentheses. *, **, *** indicate parameters that are significant at 10%, 5%, and 1% levels of significance respectively. All regressions include unreported country specific constants. Here, the DOLS regressions include one lead and one lag of the first differenced independent variables.

Generally similar results are also obtained for legal origin and religious majority as shown in Table 6 and Table 7 respectively. Countries with different legal system do not seem to benefit differently from foreign R&D capital stocks. This is reflected in the estimated coefficients on the interaction term between dummy variable for countries whose legal systems originate from French (Fre) and alternative definitions of foreign R&D capital stocks (in Table 6). The estimated coefficients for countries with legal systems based on French law are not significantly different from those based on English law.

Countries having different religious majority do not seem to benefit differently from foreign knowledge transmission either. Results in Table 7 suggest that the estimated coefficients on the interaction between dummy variables for countries whose religious majority is Catholic (Ca), Muslim (Mus), and others and different foreign R&D capital stocks are not statistically significant. Thus, religious majority has no significant impact on the way foreign R&D affects TFP of African countries.

Table 6 – Legal origin (DOLS, fixed effects, 41 countries, 1998-2006)

Dependent variable: log(*TFP*)	(1)	(2)	(3)	(4)
$\log(SF^m)$	0.435***	0.498***	0.439***	0.568***
	(0.105)	(0.153)	(0.104)	(0.162)
$\log(SF^f)$	0.196**	0.183**	0.164	0.074
	(0.080)	(0.079)	(0.161)	(0.169)
$Fre.\log(SF^m)$		-0.103		-0.244
		(0.198)		(0.211)
$Fre.\log(SF^f)$			0.130	0.234
			(0.179)	(0.192)
R^2	0.895	0.903	0.905	0.912
$Adj-R^2$	0.849	0.855	0.858	0.864
Number of observations	159	159	159	159

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on international student flows, imports as share of GDP (import intensity), and tertiary students studying overseas as share of population (student intensity) respectively. Fre is a dummy variable for countries whose legal origins are French. Standard errors are in parentheses. *, **, *** indicate parameters that are significant at 10%, 5%, and 1% levels of significance respectively. All regressions include unreported country specific constants. Here, the DOLS regressions include one lead and one lag of the first differenced independent variables.

[5]**Table 7 –** Religious majority (DOLS, fixed effects, 41 countries, 1998-2006)

Dependent variable: log(*TFP*)	(1)	(2)	(3)	(4)
$\log(SF^m)$	0.435***	0.362***	0.431***	0.320**
	(0.105)	(0.129)	(0.108)	(0.130)
$\log(SF^f)$	0.196**	0.144*	0.259**	0.306**
	(0.080)	(0.079)	(0.127)	(0.119)
$Ca.\log(SF^m)$		0.190		0.049
		(0.276)		(0.359)
$Mus.\log(SF^m)$		-0.054		0.016
		(0.229)		(0.232)
$Ca.\log(SF^f)$			0.064	0.109
			(0.196)	(0.276)
$Mus.\log(SF^f)$			-0.112	-0.242
			(0.164)	(0.161)
R^2	0.895	0.915	0.909	0.932
$Adj-R^2$	0.849	0.868	0.859	0.885
Number of observations	159	159	159	159

Note: $\log X$ is log of X. TFP, SF^m, SF^f, m, and f are total factor productivity, foreign R&D capital stock based on imports, foreign R&D capital stock based on international student flows, imports as share of GDP (import intensity), and tertiary students studying overseas as share of population (student intensity) respectively. Ca and Mus are dummy variables for countries where the religious majorities are Catholic and Muslim respectively. Standard errors are in parentheses. *, **, *** indicate parameters that are significant at 10%, 5%, and 1% levels of significance respectively. All regressions include unreported country specific constants. Here, the DOLS regressions include one lead and one lag of the first differenced independent variables.

5- Conclusion

This study examines whether tertiary student flows channel international R&D spillovers across national borders and contribute to the enhancement of TFP besides international trade. It is found that international trade remains an important conduit for technology transfer as characterized in the literature. In addition, there is evidence pointing out that student flows effectively facilitate international technology diffusion from industrialized countries to less developed countries in Africa. The results imply that further liberalization of trade and more open education policy should be of the top priority on development agenda for those African countries in particular, and developing countries in general, that want to reap more benefits from the foreign R&D spillovers and thus enhance their TFP. The results shed important insights regarding the new way through which knowledge spreads across countries.

The paper also extends its analysis to the role of institutions in affecting R&D spillovers. It finds that there is not enough evidence to conclude that the ease of doing business, legal origins, and religious factor make significant impact on the way foreign R&D affecting TFP of African countries. These results cast doubt on the role of these institutional measures in the R&D spillover process as the coefficients of these variables are insignificant throughout all the regressions.

In short, this paper is just the first step in tackling a rather complicated issue. To confirm the result of this paper, further studies based on micro-level data should be undertaken as soon as these data are made available. In addition, other measures of institutional quality should also be considered to give a more comprehensive view on the matter. This surely suggests a fruitful research program in the future.

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Appendix – List of African countries included in the analysis

Algeria	Kenya
Angola	Lesotho
Benin	Liberia
Botswana	Madagascar
Burkina Faso	Malawi
Burundi	Mali
Cameroon	Namibia
Cape Verde	Niger
Chad	Nigeria
Comoro Island	Rwanda
Congo	Senegal
Cote d'Ivoire	Sierra Leon
Democratic Republic of Congo	South Africa
Egypt	Sudan
Eritrea	Swaziland
Ethiopia	Tanzania
Gabon	Togo
Gambia	Tunisia
Ghana	Uganda
Guinea	Zambia
Guinea-Bissau	

[1] The only exception is the specification including $\log(TFP)$ and $m.\log(SF^{m})$ where the test results are somewhat inconclusive. Here, the panel t-statistic indicates a cointegrating relationship but the group t-statistic does not. However, when other variables are also added to the specification, there is cointegration. As a result, this paper is inclined to treat these two variables as cointegrated.

[2] Pedroni (2000) suggests an alternative estimation procedure named Fully Modified OLS (FMOLS). However, using Monte Carlo experiments to compare the small sample properties of particular forms of panel FMOLS and DOLS estimators, Kao and Chiang (2000) indicate that DOLS estimator has superior small sample properties.

[3] The result is generally in line with that of Park (2004). However, Park's (2004) study is put within OECD countries' context while this paper looks at the knowledge diffusion from advanced countries to less developed countries.

[4] This paper also recognizes other variables that can potentially be used as proxies for institutions such as the quality of tertiary education, the strength of intellectual property rights, etc. as used in Coe *et al.* (2008). However, the unavailability of data for African countries prevents this paper from using these variables.