Has Economic Growth in WAEMU Countries Benefited from World Technology Diffusion?

Abdoulaye Seck*
Faculté des Sciences Economiques et de Gestion
Université Cheikh Anta Diop de Dakar, Sénégal

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Abstract

In an increasingly integrated world economy, R&D efforts in one country can substantially benefit its foreign counterparts. The paper asks whether countries within WAEMU that do little, if any, R&D activity, have gained from international technology diffusion. The results based on a non-stationary panel suggest that even though they have indeed gained in terms of aggregate productivity increase, they appear to have done so less than the average African country and the rest of the developing world. Their apparent weaker technology absorption capabilities have to do with their international trade patterns, their lower accumulation of human capital, as well as the seemingly burdensome French legal tradition, all of which offering directions for public policies aiming at boosting growth in the community and ultimately improving living standards in the long run.

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1 Introduction

Economic growth profile in Sub-Saharan Africa has been very disappointing over the past three decades. In effect, GDP per capita has grown by a meager 0.83 percent on average over the period 1980-2010, and about a third of the economies in the region has actually declined.[1] Countries that make up the West African Economic and Monetary Union (WAEMU) fit very well in this whole picture, with an average growth rate of almost zero percent (0.07 percent).[2] At the same time, other parts of the developing world have enjoyed higher economic performance, with a growth rate ranging from 0.88 percent in North Africa and the Middle East, to 1.52 percent in Latin America, 2.21 percent in East Asia, and 3.38 percent in South Asia. These contrasted figures have led many authors to refer to growth in Africa as an "economic tragedy" (Artadi and Sala-i-Martin, 2003).

*Contacts: Tel.: +221.77.330.13.03; Email address: abdoulaye.seck@ucad.edu.sn.

[1] Unless otherwise specified, the data source is the online World Development Indicators.

[2] The West African Economic and Monetary Union is made up of Benin, Burkina Faso, Cote d'Ivoire, Guinea Bissau, Mali, Niger, Senegal, and Togo. Because Guinea Bissau joined in 1997, we choose to drop it from our analysis that covers the 1980-2008 period, and we hypothesize that the picture that will emerge from such an analysis is representative of the whole region.

What makes the growth experience in Africa so puzzling is that over the same time period, the world technology frontier has moved very rapidly, bringing about significant growth opportunities to not only Research and Development (R&D) performing countries, but also to foreign countries through the externalities they generate. In effect, the cumulative effort in R&D spending in the seven most industrialized countries (G7) has translated into an increase in their domestic R&D capital stock by a factor of more than three (Seck, 2011a), and an increasing number of countries have been involved in technology production. The public good nature of technology has meant that more activity in a given country has generated significant growth benefits to their foreign partners. A seminal work by Coe and Helpman (1995) has estimated the international technology spillover gains to about 30-percent-increase in foreign aggregate productivity.

Poor economic performance in WAEMU countries in particular, and in Sub-Saharan Africa in general, relative to other parts of the developing world, in the face of this historical technological development, raises the issue of their technology absorption capabilities. One might hypothesize that Africa has relatively weak capacity to fully benefit from growth opportunities brought about by foreign R&D, based on their relatively poor growth figures. Or it could be that African countries do in fact reap some spillover benefits, but other factors important to growth has prevented the full materialization of these benefits in terms of economic growth.

The paper sets out to answer the question of whether economic growth in WAEMU countries has benefitted from externalities associated with world technology frontier. More specifically, the paper asks about the extent to which these economies have absorbed foreign technology, if any, and the economic, social, and institutional determinants of their absorption capabilities, as well the policy implications for their economic growth and development.

A key concept in international technology spillover literature is foreign R&D capital stock. For a given country, it is computed as a weighted average of its foreign partners' domestic R&D capital, and the weights emphasize the diffusion channels considered. A non-stationary panel model, namely the Fully Modified Ordinary Least Squares (FMOLS), then relates countries' aggregate productivity to their foreign R&D stock and a host of other factors thought to play a role in the growth dynamics, as well as some interaction terms to allow for cross-country heterogeneity in the absorption capabilities.

The paper produces the following key results. Technology diffusion does indeed provide significant growth opportunities to developing countries. Countries within WAEMU appear nevertheless to have gained less than the rest of the developing world, even less than the average African country. Their relatively weak absorption capability originates in their international trade patterns, their lower accumulation of human capital, as well as the weak incentives to domestic innovators and inventors through the intellectual property rights systems.

The remainder of the paper is organized as follows. The next section discusses the mechanisms through which technology diffuses across countries. Section 3 presents the methodological approach. Section 4 introduces the data as well as some additional insights into the growth experience of the WAEMU countries. Section 5 discusses the econometric results. The last section concludes and draws some policy implications.

2 International Technology Diffusion

Technology refers to both the amount of techniques available to producers and the organization with which factors are used which then determines the efficiency of the production process. It has long been seen as a main source of economic growth, not only for countries that produce it, but also for their economic partners. The standard Solow growth model (1956) first suggested that technology, which progress is exogenous, is a public good, and as such, once produced in a given country, it spills over to foreign countries almost instantaneously and at virtually no cost. This idea of technology generating externalities, coupled with the assumption of decreasing marginal returns, is at the core of the growth convergence hypothesis.

Prior to the advent of the new growth theories in the late 1980s, many authors have suggested a more realistic view of technology development and diffusion. A seminal work by Griliches (1957) showed that even with the presumption that technology and know-how may be freely available and can be adopted relatively easily, there may be considerable differences in productivity even under similar economic conditions. In effect, he showed that a new technology diffuses slowly, with the famous S-shape curve: first it spreads slowly; then after reaching a critical level, it starts spreading more rapidly; and once it is adopted by a large proportion of its targeted population, the rate of adoption declines. A consequence of this diffusion scheme is that even in the face of a dynamic world technology production, absorbing nations may get different benefits over time, which then translate into different level of economic development.

Adding to the slow international diffusion of new technologies is the existence of barriers to adoption. Parente and Prescott (1994) show that the rate of diffusion depends crucially on the institutional and policy settings, especially the extent of intellectual property rights protection. Well designed, the property rights regime has the potential to provide strong reward to inventors and innovators, whose activities crucially depend upon the amount of existing technology, which in many cases originated from foreign R&D activities. It is indeed accurate to assert that "knowledge builds on knowledge." Countries that succeed in developing a dynamic domestic R&D sector, by the means of a sound reward structure, are therefore more likely to adopt or adapt foreign techniques and organization of the production process.

Another factor that acts more like a "natural" barrier is the stock of human capital. It unable countries to make the most out of foreign technologies. This view of human capital defers from the traditional approach by Becker, Schultz and Mincer who suggested that its role is to enhance workers' productivity on existing tasks. The alternative perspective on human capital, put forth by Nelson and Phelps (1966), insist on its role in enabling workers to adapt to new changes and disruptions associated with new technologies. In this new setting, countries that accumulate the most human capital also tend to absorb and benefit more from foreign innovation.

A key issue in the diffusion mechanism is how technology developed in one country actually spills over to its foreign partners. Two main channels can be identified: trade and foreign direct investment (FDI) (Keller, 2004). International trade makes available new products that embody foreign technologies, either higher-quality inputs or final products, (Aghion and Howitt, 1991) or horizontally-differentiated goods (Romer, 1990). International trade also provides a platform for learning, copying, and imitating foreign innovation. In effect, the many interactions with foreign partners provide strong incentives for domestic producers to use improved technologies in order to gain from both foreign and domestic competition.

As for the FDI diffusion channel, it enables a host country to develop a contact with more technologically advanced partners. By so doing, it provides a platform for learning opportunities through which the economy gets access to more efficient production know-how. One way the technology gains could occur is through the increased competition that comes with the arrival of foreign firms. In this new intense competition environment, domestic firms will then have to come up with a response strategy to the technology differential, which could be either to imitate the foreign firms' production processes, or to acquire the technology-embodied inputs they use (Holmes and Schmidt, 2001). In addition, FDI can contribute to direct technology diffusion when affiliates of technologically-advanced firms operating in the South use Northern technology, thus increasing TFP in the South. Furthermore, FDI can generate technology spillover through labor turnover. Former domestic workers in technology-advanced foreign firms bring with them their new skills and know-how to the domestic firms. In the context of relatively strong mobility in the domestic labor market, these gains can quickly spread to a significant part of the economy, hence benefiting to a large extent the economy as a whole in terms of increased productivity.

The literature has also suggested other channels through which technology diffuses from world frontier to lagging countries. As far as North-South R&D spillover is concerned, knowledge transmission can occur via temporary migration from developing to developed countries. It is expected that a country in the South can greatly benefit from workers or students they send to the North. This could be the case when for instance those workers or students return and actively participate in the economic development process. A perfect illustration is Meiji Japan between 1868 and 1912 when the country embarked in an international search for knowledge and later became a modern economic power. Other possible knowledge transmission channels are scientific exchanges (professional conferences, academic exchange program, etc.), and patent documents.[3] However, due to the formidable difficulties to measuring knowledge spillover gains through these channels (availability of reliable data on returning skilled migrants, the workforce involvement in scientific exchanges, etc.), the focus will solely be on trade, namely imports of technology-embodied machinery and equipment, and inbound FDI as diffusion channels.

3 Econometric Modeling

This section first outlines the variables to be used in the modeling exercise. Then, some details on the double-indexed integrated processes are offered, namely panel unit root and cointegration testings, as well as estimation and inference strategies.

3.1 Model Specifications

Empirical analyses of international technology diffusion are based on the concept of foreign R&D capital stock. The latter is defined as the weighted average of the domestic R&D capital stocks of the trading or investment partners. The weighting scheme reflects the diffusion channel considered. In Coe and Helpman (1995), the weights are the bilateral import ratios, and they allow capturing trade-related R&D spillovers. As for the FDI-related spillovers, Van Pottelsberghe de la Potterie and Lichtenberg (2001) suggest using FDI ratio as weights.

Some important empirical contributions that build on Coe et al. (1997) include Engelbrecht (1997) who points to the crucial role of human capital both as a source of productivity growth (directly affecting aggregate productivity), in the line of the human capital literature, and as a determinant of countries' absorption capacity, as suggested by Nelson and Phelps (1966).

Following these empirical developments, a series of specifications are considered. The first, dubbed the baseline specification, is as follows:

[3] The well-known survey by Levin et al. (1987) identifies some seven sources of knowledge diffusion.

$$\log TFP_{it} = \alpha + \theta_t + \alpha^M \log S_{it}^M + \alpha^F \log S_{it}^F + \alpha^H \log H_{it} + \varepsilon_{it}, \tag{1}$$

where TFP_{it} stands for the total factor productivity of country i at time t, obtained through the growth accounting method which was first suggested by Abramovitz (1956) and then popularized by Solow (1957), θ_t is a parameter that captures time-specific effects (common to all countries), S_{it}^M and S_{it}^F are the stocks of foreign R&D available through the import channel and the FDI channel, respectively, H_{it} is human capital (average years of schooling), and ε_{it} is an error term. The functional form of the model (logarithmic) allows one to interpret the coefficients as elasticities, and it is derived from the non-linear Cobb-Douglas production function.

Foreign R&D capital stocks available through each channel are constructed in a way that tells how much technology developed abroad is embodied in the goods a country imports or in the direct investment it hosts. They are constructed as follows:

$$S_{it}^M = \sum_{j=1}^{J} ME_{ijt} * \frac{S_{jt}^d}{Y_{jt}} \quad \text{and } S_{it}^F = \sum_{j=1}^{J} FDI_{ijt} * \frac{S_{jt}^d}{Y_{jt}},$$

where S_{jt}^D is the domestic R&D capital of developed country j, ME_{ijt} are bilateral imports of machinery and equipment, FDI_{ijt} is bilateral inbound FDI, and Y_{jt} country j's GDP. The ratio S_{jt}^d / Y_{jt} is the R&D intensity, or the "amount" of foreign technology contained in a unit of GDP. The more machinery and equipment a country imports, or the more foreign activity it hosts, the more technology it gets from its partners.

The domestic R&D stock of developed country j, S_{jt}^D, is constructed using the perpetual inventory procedure and allowing for depreciation:

$$S_{jt}^D = (1-d) S_{jt-1}^D + I_{jt}^{RD},$$

with d the R&D depreciation rate (set to five percent), and I_{jt}^{RD} the R&D expenditures in country j.[4] The benchmark for S^D is calculated as $S_{j1980}^D = I_{1980}^{RD}/(g+d)$, where g is the average annual growth of R&D spending over the sample period. This procedure follows Griliches (1991). The rationale behind this process of knowledge accumulation stems from the idea that newly developed knowledge improves our understanding of the economic process as well as our ability to stretch the aggregate production domain. But the inclusion of the depreciation recognizes that over the course of technology development, new ideas can make prior ones obsolete or less valuable, or simply that the research process can sometimes lead to a duplication of ideas, especially when the intellectual property right system generates a high level of artificial excludability of knowledge. Consequently, the resulting effect is a lower marginal gain.

To allow for heterogeneity in the absorption capabilities, the baseline model is extended in a number of ways, all of which adding some interaction terms. The literature has suggested different routes. Nelson and Phelps (1966) has suggested an alternative view of human capital, which primary role is no longer to increase workers productivity in existing tasks, but to enable them to adapt to new changes, like the ones associated with the advent of new technologies that often times change significantly the production process. In addition, Parente and Prescott (1994) argue that one of the main reasons why there might be significant productivity differences among countries even in

[4] It is customary to choose a depreciation rate under 15 percent, and evidence suggests that the empirical results are not sensitive to the changes in these values (see Helpman, 2004).

the face of freely available world technology is the existence of barriers to technology diffusion. A chief institutional and policy barrier has to do with the property rights system. It has been shown that a sound system not only provide sufficiently strong incentives to develop boost domestic R&D activities, but also allow countries to benefit significantly from foreign technology advances (see Coe et al., 2008, for advanced countries, and Seck, 2011a, for developing countries). Furthermore, LaPorta et al. (2007) suggest that the historical origin of the legal system might explain cross-country difference in economic outcomes, in particular foreign technology absorption. In effect, the legal institutions broadly defines the economic incentives that shape countries' ability to benefits from growth opportunities, in particular those brought about by foreign technology. The Legal Origins Theory often compares the French Civil Law and the British common Law systems, and more often, the latter tends to be associated with more favorable economic outcomes. It has been shown that such legal differences can also play a role in shaping a country's technology absorption capabilities.

In light with these theoretical and empirical developments, two empirical strategies are followed. First, the baseline model is enriched with additional explanatory variables, one at a time. More specifically, let Z be such a variable (human capital, patent protection, or legal origin), the model specification then becomes:

$$\begin{aligned}\log TFP_{it} = {} & \alpha + \theta_t + \alpha^M \log S_{it}^M + \alpha^F \log S_{it}^F + \alpha^H \log H_{it} \\ & + \alpha^{MZ} \left(Z_{it} * \log S_{it}^M\right) + \alpha^{FZ} \left(Z_{it} * \log S_{it}^F\right) + \alpha^Z Z_{it} + \varepsilon_{it}.\end{aligned} \tag{2}$$

The interaction terms will allow the effect of foreign technology on TFP, namely technology absorption capacity, to differ from one country to another, and one could test whether this heterogeneity is explained by the variable Z. For instance, α^M would tell how much of trade-related technology is translated into productivity growth in the average country i, and α^{MZ} would tell how much a unit-difference in Z between two countries shows in their TFP difference or, equivalently, in their absorption capability differences.

Second, a richer analytical approach should put the growth experience of WAEMU countries in the general context of the growth experience of the developing world. There are two rationale to such an approach. On econometric ground, the is little, even no variability along one dimension of the growth story across countries in the grouping. For instance, the property right system appears quite identical, and all of them, have their legal tradition in the French Civil Law. In addition, any meaningful appreciation of the dynamics of these economies and the strength of their absorption capability would command using a framework that allows a comparison with other parts of the developing word.

Therefore, the general strategy will be to first estimate the baseline model for a large set of developing countries, including WAEMU countries, and then reestimate the model by adding an interaction dummy that accounts for these countries. The significance of the associated coefficient will tell whether these countries have benefitted more or less than the average developing country, if any. In case one finds some cross-regional heterogeneity in the gains, then the extended specification which comprises the modifying variable Z would inform about the sources of heterogeneity (whether it has to do with differences in human capital accumulation or the quality of domestic institutions).

3.2 Non-Stationary Panel Modeling

Economic growth is in essence a long run phenomenon. As such, studying it in the context of a group of countries makes suitable an approach such as non-stationary panel. The merit of panel cointegration models lies on the fact that they "are directed at studying questions that surround long-run economic relationships typically encountered in macroeconomic and financial data" (Baltagi, 2008, p. 298).

The econometrics of panel cointegration involves first testing for unit root process and cointegrating relationships, and then estimating the model. Recent developments in the cointegration literature have led to what is known as the second generation panel unit root tests. By far the most commonly used test procedures are Levin, Lin, and Chu (2002, LLC henceforth), and Im, Pesaran, and Shin (2003, IPS henceforth). These tests generalize the times series ADF equation to panel data. Both LLC and IPS tests assume that all series are non stationary under the null hypothesis. They differ in how they define the alternative hypothesis: while LLC imposes the same dynamics across the units, the IPS procedure allows for heterogeneity in the short run dynamics. Because of these different treatments of the cross sectional units, LLC is known as a homogeneous test, and IPS a heterogeneous test.

If the data-generating process of the variables turns out to be a panel unit root, then the next step is testing for panel cointegration. If the variables have a long run relationship, the residuals from the estimation of this relationship have to be stationary. Running a regression based on non-cointegrating relationships leads to spurious estimations. In such a case, the correlation generated by the regression is due to other variables (confounding or lurking variables) that influence those in the model, instead of a real causal relationship. Various panel cointegration tests have been suggested, and they are based on their time series counterparts. Pedroni (1999, 2004), Kao (1999), and Larsson et al. (2001) extended the Engle and Granger (1987) time series framework to panel data. They are residual-based tests.

Comparison among the panel cointegration tests is often based on the time length of the data. For example, Gutierrez (2003) has demonstrated that, in the case of small (high) time dimension, Kao test has higher (lower) power than the Pedroni test, and both tests show higher power than the Larsson et al. test. In addition, the Kao test procedure is able to handle larger number of variables than the Pedroni tests. In that sense, the Kao test is more general. It also assumes individual specific intercept terms and homogenous coefficients in the first stage. Under the null of no cointegration, the test statistic is shown to converge asymptotically to the standard normal distribution. Results from both panel unit root and cointegration tests determine the variables to be considered in the model; that is, the cointegrating relationship.

When developing an estimator for a panel cointegration model, two issues generally arise: a potential endogeneity of the regressors, and a heterogeneity of the variance-covariance matrix (e.g., serial correlation). As a consequence, the regular OLS method tends to generate biased coefficient estimates, and the standard test statistics (e.g. t-statistics or F-statistic) become irrelevant. One of the estimators that have been suggested as an alternative is known as the Fully Modified Ordinary Least Squares (FMOLS). It was first developed, as it is often the case, in the times series context. Pedroni (1996) first generalized it to panel data framework.[5] The central theme of the FMOLS estimation strategy was to “pool only the information concerning the long run relationship”, and

[5] The time series counterpart was proposed by Phillips and Hansen (1990) as a way to deal with the same issues of inefficiency and inconsistency. The former is brought about by serial correlation, while the latter is a consequence of endogeneity.

"allow the short run dynamics to be potentially heterogeneous." Three versions of this estimator have been developed: residual-FM, adjusted-FM, and group-FM. While the first two pool the data along the within dimension, the latter does so along the between dimension. Based on their performance in finite samples, the group-FMOLS has more desirable properties, and it is associated with lower size distortion. Phillips and Moon (1999) have proposed a version which asymptotic properties are derived from joint limits, in contrast to the previous estimators that are based on sequential limits.

This estimator has been opposed in the econometric literature to the Dynamic OLS (DOLS) estimator. While FMOLS uses a non-parametric technique, the DOLS estimator is essentially a parametric approach, and the model specification basically adds lags and leads of the independent variables. Furthermore, both FMOLS and DOLS estimators have the same limiting distribution, but they perform differently in finite samples. The DOLS estimator appears to improve the properties of the simple OLS more so than the FMOLS does. But a main drawback is its higher sensitivity to the leads and lags of the regressors. More importantly, in a panel setting with relatively small time dimension and many regressors, a large number of lags and leads is synonymous to significant loss of degrees of freedom. In that sense, the use of the DOLS estimator appears to be more conditional on the length of the data.

4 Data and Variables

The first set of data shows how growth has evolve over the last three decades in WAEMU countries. The disappointing experience for the region as a whole is materialized by a decline in GDP per capita by a average annual rate of -0.19 percent. This overall picture exhibits the following discernible patterns. First, there is a large heterogeneity in national growth profile. These countries appears to be dragging down the overall growth rate: Cote d'Ivoire (-1.38 percent), Niger (-1.17 percent), and Togo (-0.76 percent). Second, the year 1994, in which the common currency (Franc CFA) was devaluated by 50 percent against the then-French Franc, appears to mark a structural breaking point in the growth dynamics: growth before 1994 was actually negative for five of the seven accounted countries setting the regional average at -1.59 percent. From that year on, all countries have positive growth rate, which averaged 1.09 percent.

The jury is still out on whether the devaluation of their currency has played a significant role in WAEMU's economic growth. Fueling the debate is this return to growth has coincided with the end of the growth slowdown in the major advanced economies, which started to reap the benefits from their cumulative efforts in technology investment. In effect, for the group of seven (G7) countries, which happen to be the world technology frontier, domestic R&D capital stock has more than tripled (a factor of 3.1), on average over the period 1980-2008, and the business sector has accounted for more that two-third (Seck, 2011a).

The ever-increasing economic ties among countries may constitute a sign that this investment effort in technology development in advanced countries have benefitted their foreign counterparts. This shows first in the trade and capital flows. For the developing countries as a whole, the imports of knowledge-embodied goods have increased by a factor of almost seven, and the accumulated foreign capital by a factor of more than 190. The combination of the R&D investment effort in world technology frontier and the strengthening of trade ties with developing countries is translated into an increase in the latter's foreign R&D capital, which has almost doubled from 1980 to 2008. Adding to that the overall positive trend of education and the quality of domestic institutions, one might reasonably hypothesize that there is indeed significant technology diffusion between the North and the South.

Differences along the many factors at play when it comes to technology diffusion represent an indication that developing countries may not have benefitted equally. Africa appears to show be lagging behind. It's lower productivity growth (2 percent over the whole period of 1980-2008) is accompanied with smaller performance when it comes to foreign technology acquisition: the relatively small increase in foreign capital and the actual decline in imports of machinery and equipment are synonymous to smaller increase in the foreign R&D capital available through both import and FDI channel.

Once again, WAEMU countries appear to fit very well the African picture. These countries appear to have devote more effort to benefit FDI-related technology, both in percentage increase as well as in level, relative to the African average. As for trade-related technology, it is quite the opposite, with WAEMU countries' performance below the African average. As a results, and coupled with the facts that African countries tend to share similar trade patterns when it comes for instance to foreign partners, the differences in the FDI and trade performance are also translated into similar difference in the both their accumulated foreign R&D stock.

Table 1. Summary statistics

	WAEMU		Africa		Latin America		Asia & Pacific		Sample	
	Ratio	Level	Ratio	Level	Ratio	Level	Ratio	Level	Ratio	Level
TFP	1.019	—	1.021	—	1.058	—	1.542	—	1.166	—
S^M	3.32	0.29*	3.36	0.34*	10.02	0.91*	38.69	5.01*	14.38	1.71*
S^F	2.22	0.23*	2.18	0.17*	3.05	2.73*	2.09	3.21*	2.41	1.70*
ME	0.73	5.06	0.83	5.21	1.72	8.87	1.32	6.18	1.17	6.54
FDISR	11.46	164.42	8.23	152.58	19.28	201.04	10.87	204.63	12.17	180.22
Education	2.09	3.39	1.96	5.24	1.48	7.94	1.52	7.36	1.71	6.58
IPP	2.95	2.91	1.52	2.37	2.93	3.54	1.62	3.01	1.96	2.88
LEGALBR	—	0.00	—	48.57	—	4.35	—	20.00	—	29.49
Count	6**		35		23		20		78	

Notes: Ratios are the value in 2008 to that in 1980, and levels are for 2008. ME represents the ratio of imports of machinery and equipment to GDP, $FDISR$ the ratio of FDI stock to GDP, IPP the index of patent protection, and $LEGALBR$ the percentage of countries within each region with British legal tradition. More details on the variables and data sources are provided in the Appendix. * indicates values in constant US$ billions.
** Burkina Faso is dropped, in addition to Guinea Bissau, from the WAEMU group due to lack of data on education.

As for cross-country heterogeneity in any gains associated with technology spillover, in light of the different dynamics of both aggregate productivity on the one hand and the R&D capital stocks and other country specifics, one could hypothesize that African countries (WAEMU included) may have gained less than the other developing countries. Whether WAEMU countries have gained more or less than other African countries may not be that clear. Although TFP appear to have grown relatively slower in WAEMU countries, they seem to face less institutional barriers to technology diffusion, as shown in the protection or property rights, with both larger increase and higher level of the index of patent protection. However, when it comes to education, which can be viewed as one of the main components of countries' ability to absorb new technology, WAEMU countries' performance is below the African average level, which seems to matter more than the percentage change. Overall, whether WAEMU countries have benefitted from world technology diffusion, and whether these benefits, if any, have been larger than those for other African countries or other developing countries, are in the end a mater of a rigorous empirical investigation, which is the task of the next section.

5 Estimation Results

The test results for panel unit roots and cointegration are shown in Tables A1 and A2 in the Appendix. They indicate non-stationary data generating processes for the variables as well as the existence of long run relationships. These test results pave the way for the use of FMOLS as an estimation and inference method.

Two series of estimation results are shown below. The first tell how much foreign technology spillover to developing countries and how African and WAEMU countries fare compared to other developing countries. The second set of results shows the sources of heterogeneity in the spillover gains.

5.1 Baseline Model

Table 2 clearly indicates that developing countries gains significantly from world technology frontier. As shown in Column (I), a ten-percent rise in their foreign R&D capital, which a result of either an increase in G7 R&D effort or an increase in international economic ties, is associated with a rise in two percent in aggregate that accrues through the import channel, and an additional half-a-percentage-point increase through the FDI channel. These figures are close to those found in the North-South R&D literature, as in Seck (2011a). The fact that FDI turns out to be less conducive to knowledge spillover is also empirically grounded in most of the mentioned literature, and one of the hypothesized reasons has to do with one mechanism technology diffusion seems to rely on, that is labor turnover. The result may be interpreted as a relatively weak phenomenon in developing countries' labor markets.

The results also indicate that Africa countries seem to be trailing other developing countries. In so far the trade-related R&D spillover is concerned, the gain differential associated with a ten-percent rise in foreign R&D capital amounts to close to half-a-percentage increase in TFP, as shown in Column (II). This result is a combination of at least two phenomenons. The first has to do with the way the foreign R&D capital is constructed. For relatively the same partners, the average African country has consistently devoted less effort to acquire technology-embodied goods. In effect, while other developing countries on average have strengthened their trade ties along those goods, African countries appear to have actually reduced the share of such goods in their total trade, as shown in Table 1.

The second reason is related to the second dimension of the broader concept technology. In addition to the techniques used in the production process, technology also involves the organization of such a process which contributes to the efficiency with which those techniques are used. So, even with the same sources of foreign technology and similar trade patterns, two countries are very likely to end up with different efficiency gains, namely aggregate productivity increase. The lower gains for African countries can then be interpreted in part as an indication of lower aggregate production efficiency.

Results in Column (III) show that African countries within WAEMU are those that have benefitted the less from foreign technology. In effect, the average country in this grouping trailed the average developing country almost twice as much as does the average African country, with a gap of 0.7-percentage point differential in the TFP increase relative to the average developing country when one considers a ten-percent rise in foreign R&D capital.

Again, the worst performance of WAEMU countries is a perfect translation of their weaker trade performance. In effect, these countries appear have seen the share of technology-embodied goods in total trade decrease more than it does for the average African country. As a result, both the level of and increase in foreign technology stock available through the import channel have been below the African average.

Table 2. Estimation results of the baseline model

	(I)	(II)	(III)
$\log S^M$	0.2018***	0.1877***	0.1903***
	(0.016)	(0.011)	(0.042)
$\log S^F$	0.0504***	0.0553***	0.0681*
	(0.017)	(0.020)	(0.041)
$\log H$	0.0241**	0.0248*	0.0362**
	(0.011)	(0.013)	(0.018)
$\log S^M * AFR$		-0.0403***	
		(0.014)	
$\log S^F * AFR$		-0.0247	
		(0.038)	
$\log S^M * WM$			-0.0715***
			(0.022)
$\log S^F * WM$			-0.0041
			(0.025)
$Intercept$	3.0485	4.1167	3.1760
	(0.403)	(0.347)	(0.349)
N	2262	2262	2262
Fstat	297.53	246.21	239.84

Notes: The dependent variable is $logTFP$. Column (I) considers the full sample of developing countries; (II) introduces a modifying dummy AFR for Africa countries, including WAEMU; and (III) represents the model with a modifying dummy WM for only WAEMU countries. The standard errors are between parentheses, and significance at 1, 5, and 10 percent is indicated by ***,**, and *.

There seems to be no significant difference in the spillover gains associated with the FDI-related technology. It has been shown that when it comes to the such gains, the econometric literature has documented some threshold effect. As shown in Seck (2011a) for instance, a critical amount of FDI is necessary to bring and spread foreign technology to the domestic economy and make it available to the domestic producers. Once such level is attained, additional foreign capital does neither bring new knowledge nor significantly contribute to the spreading of the existing foreign knowledge. The fact that there is no significant difference in the FDI-related technology spillover gains between African countries and the rest of the developing world on one hand, and between WAEMU countries and other African and developing countries, is an indication that the typical country in each group have made sufficient effort to propel the FDI stock above that threshold.

Another important determinant of aggregate productivity is human capital. The positive significant effect is in line with the traditional view of human capital which role is to enhance workers' productivity in existing tasks. To test the alternative view of Nelson and Phelps (1966) that puts human capital in the heart of countries' technology absorption capability, the baseline model is extended to include an interaction term between human capital and the foreign R&D capital. The next subsection presents the estimation results such an extension, as well as others that explore other sources of heterogeneity in the spillover gains.

5.2 Determinants of World Technology Absorption Capabilities

Table 3 explores three potential determinants of developing countries' ability to benefit from world technology. Three directions are considered, namely human capital accumulation, the index of patent protection, and the historical origin of the legal system.

Results in Column (IV) clearly support the two views of human capital. First, the significant coefficient estimate on the variable $logH$ suggests that countries that invest more in education are able to increase the productivity of their workforce in the existing tasks. Second, the estimation results for the interaction variables indicate that those countries are also able to translate world technology into larger productivity productivity. In effect, adopting or adapting new foreign technology more often requires a well educated labor force, and cross-country differences among developing countries with respect to education also show in differences in their absorption capabilities, whatever diffusion channel one considers, and ultimately in aggregate productivity.

Column (V) shows that the extent of intellectual property rights protection also a significant component in countries' technology absorption capabilities. A sound property rights system appears to impact aggregate productivity both directly and indirectly. By providing innovators and inventors with strong incentives, mostly in terms of monopoly power, a country is more likely to enjoy a dynamic domestic R&D sector with benefits directly domestic activities. On the other hand, given that knowledge feeds on knowledge, foreign technology advances are more likely to benefit a country already involved in technology production.

An important issue in the technology literature is how far should the patent protection go. Some form of market power is necessary for a thriving innovation sector: the legal excludability associated with the intellectual property system provides innovators and investors with some market power necessary to get returns on their often large investment. But too much a protection could easily end up stifling innovation, by preventing other knowledge producers from using as an input domestic or foreign knowledge. The empirical literature provides some evidence of that threshold effect. For example, Seck (2011b), using the same index of patent protection (IPP), suggests as some protection is necessary for a country to start producing technology, but once the R&D sector is sufficiently developed, further strengthening of the property rights protection brings no additional gains to the innovation activity. Given that most developing countries have either inexistent or weak property rights protection, effort to develop a sound system can still benefit both their domestic innovation activity and foreign technology absorption capabilities.

The last Column in Table 3 explores whether the legal heritage is a significant discriminant among countries when it comes to technology absorption. As far as FDI-related technology spillover is concerned, countries with the British Common Law appear to enjoy stronger absorption capabilities than countries with the French Civil Law. This results seems consistent with much of the findings of the burgeoning literature on the Legal Origins Theory, which often associates the French Civil Law as being associated with a "heavier hand of government ownership and regulation" than British common law, therefore more prone to generate "adverse effects on markets" (La Porta et al., 2008). The British common law is often described as offering relatively better investor protection, with lighter government ownership and regulation, and less formalized and more independent judicial system. All of these features are in turn associated with more favorable economic outcomes, in particular technology-related economic gains. The positive result for the common law could be an indication that it influences more favorably the mechanisms that underlie technology diffusion and adoption, such as factor mobility, than the civil law does.

Table 3. Estimation results of the extended models.

	(IV)	(V)	(VI)
$\log S^M$	0.1937***	0.1802***	0.1827***
	(0.026)	(0.018)	(0.015)
$\log S^F$	0.0471**	0.0417**	0.0302*
	(0.023)	(0.021)	(0.017)
$\log H$	0.0313*	0.0231*	0.0311**
	(0.018)	(0.013)	(0.014)
$\log S^M * Z$	0.0188*	0.0242*	0.0182
	(0.010)	(0.013)	(0.013)
$\log S^F * Z$	0.0199*	0.0025	0.0198*
	(0.012)	(0.016)	(0.011)
IPP		0.0371**	
		(0.018)	
$Intercept$	6.2734	6.5582	5.7846
	(0.282)	0.271	(0.253)
N	2262	2262	2262
Fstat	263.21	257.08	241.36

Notes: The dependent variable is $logTFP$. All results are based on the full sample of developing countries. The modifying variable Z represents $logH$ in Column (IV), IPP in Column (V) and $LEGALBR$ in Column (VI). The standard errors are between parentheses, and significance at 1, 5, and 10 percent is indicated by ***, **, and *.

6 Summary and Concluding Remarks

Technology diffusion offers economic growth opportunities to developing countries to the extent that they develop a relatively strong absorption capabilities. The paper has shown that weaker growth performance in African economies, in particular those within WAEMU, has been associated with their weaker foreign technology absorption capabilities than the rest of the developing world.

The paper suggested that cross-country differences in absorption capabilities have to do with countries' international trade patterns, their overall effort to develop a viable domestic R&D sector, and the quality of domestic institutions. More specifically, the reasons why WAEMU countries appeared to have gain less than the rest of the developing world have to do with the reduction in their effort to import technology-embodied goods, lower accumulation of human capital, weaker institutional setting that would otherwise provide sufficient incentives to inventors and innovators in the form of intellectual property rights, and the apparent legal burden of the French Civil Law legacy.

Any public effort to bridge the gap between WAEMU and African countries, on the one hand, and other developing countries, on the other, can be based on these empirical grounds. For instance, at a community level, these countries could explore the possibility to develop a joint viable intellectual property rights system, which would have a direct effect on aggregate productivity growth, but also an indirect effect by contributing to a strengthening or their world technology absorption capabilities.

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Appendix

A. Panel unit root and cointegration test results

Table A1 shows the unit root test results of Im, Pesaran, and Shin (2003) and Levin, Lin, and Chu (2002), and Table A2 the results for the cointegration test results of Pedroni (1999, 2004) and Kao (1999).

Table A1. IPS and LLC panel unit root tests.

	IPS (2003)		LLC (2002)	
	W[t-bar]	p-value	t-star	p-value
$\log TFP$	2.970	0.99	-0.634	0.26
$\log S^M$	0.934	0.82	2.398	0.99
$\log S^F$	0.332	0.63	0.194	0.57
$\log H$	-1.759**	0.04	-0.871	0.19
IPP	-1.306*	0.09	-1.258	0.11

Notes: Under the null hypothesis, the series are non-stationary in both test procedures. Significance at 5 and 10 percent are denoted by ** and *.

Table A2: Pedroni and Kao panel cointegration tests.

Models	(I)	(II)	(III)	(IV)	(V)	(VI)
Panel v-Stat.	-0.383	7.962***	2.723***	6.93***	4.073***	-0.01
Panel rho-Stat.	0.578	-1.140	2.269**	1.080	-4.201***	2.281**
Panel PP-Stat.	5.051***	0.304	-0.996	-1.67*	3.271***	0.934
Panel ADF-Stat.	-0.529	9.185***	2.241**	8.52***	-0.374	3.932***
Group rho-Stat.	16.930***	5.872***	4.967***	3.86***	8.263***	6.290***
Group PP-Stat.	2.615**	2.442**	17.446***	0.503	7.392***	7.240***
Group ADF-Stat.	-0.554	0.328	3.475***	4.847***	5.135***	-0458
Kao ADF t-Stat.	-6.247***	-4.812***	-0.709	-1.230	-1.017	-0.826

Notes: All test procedures consider, under the null hypothesis, that there is no long run relationship, that is, no cointegration, between the variables. Significance at 1, 5, and 10 percent are denoted by ***, **, and *.

B. Data Sources

Various sources are used for the data. Total R&D spending for the G7 countries and their bilateral exports of machinery and equipment and FDI to developing countries are from OECD. Data on education attainment (average years of schooling for the population age more than 15) are compiled by Barro and Lee (2010).[6] The index of patent protection is from Park (2008).[7] It is a scale from 0 to 5 that shows the strength of the property rights system, higher index values being synonymous with stronger protection. Macroeconomic data on GDP, GDP per capita, labor force, physical investment, and total inward FDI are from the World Bank (World Development Indicators). LaPorta et al. (2008) contains data on the legal origins, and the corresponding dummy variable *LEGALBR* takes the value of 1 if the country has a British common law system, and 0

[6] http://www.nber.org/pub/barro.lee/

[7] http://www.american.edu/cas/econ/faculty/park.htm

otherwise. Given that more than 96 percent of countries in the sample has either French or British system, the variable broadly compares between these two legal traditions.

C. Country List

AFRICA	Sierra Leone	Taiwan
Algeria	South Africa	Thailand
Benin	Sudan	Viet Nam
Botswana	Togo	LATIN AMERICA
Burundi	Tunisia	Argentina
Cameroon	Uganda	Barbados
Central African Republic	Un. Rep. of Tanzania	Bolivia
Congo	Zambia	Brazil
Cote d'Ivoire	Zimbabwe	Chile
D.R. of the Congo	ASIA-PACIFIC	Colombia
Egypt	Bangladesh	Costa Rica
Gabon	Cambodia	Cuba
Gambia	China	Dominican Rep.
Ghana	Hong Kong	Ecuador
Kenya	India	El Salvador
Liberia	Indonesia	Guatemala
Malawi	Lao People's D.R.	Guyana
Mali	Malaysia	Honduras
Mauritania	Maldives	Jamaica
Mauritius	Mongolia	Mexico
Morocco	Nepal	Nicaragua
Mozambique	Pakistan	Panama
Namibia	Papua New Guinea	Paraguay
Niger	Philippines	Peru
Reunion	Republic of Korea	Trinidad and Tobago
Rwanda	Singapore	Uruguay
Senegal	Sri Lanka	Venezuela