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# North-South Trade, Technology Diffusion and Productivity Growth: Are Small States Different?

Maurice Schiff\* and Yanling Wang\*\*

## Abstract

The economies of small developing states tend to be more fragile than those in large ones. This paper examines this issue in a dynamic context by focusing on the impact of education and North-South trade-related technology diffusion (NRD) on TFP growth in small and large states in the South. The main findings are: i) *TFP* growth increases with *NRD*, education and the interaction between the two; ii) the impact of *NRD*, education and their interaction on *TFP* growth in small states is over three times that for large countries; and iii) the greater *TFP* growth loss in small states has two brain drain-related causes: a substantially greater sensitivity of *TFP* growth to the brain drain, and brain drain levels that are much higher in small than in large states.

JEL: F22, J61

Keywords: Technology Diffusion, Trade, Productivity Growth, Education

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## 1. Introduction

An important literature exists on the effects of countries' human capital on their productivity growth, with most studies conducted in a closed-economy context. This paper focuses on the differential impact of human capital in facilitating trade-related North-South technology diffusion and then analyzes its implications on South-North brain drain in small and large states. It provides an empirical analysis of the impact on total factor productivity (TFP) growth in the South: i) of trade-related technology diffusion, human capital, and country size, and ii) of the interaction between all pairs of these variables, and between the three variables. The use of trade-related technology diffusion as a determinant of productivity (*TFP*) growth in the South is based on the assumption that North-South trade provides a vehicle for the diffusion to the South of technology developed in the North. Second, the South's absorption capacity—as measured by countries' average level of human capital – is hypothesized to affect *TFP* growth as well as the impact of trade-related technology diffusion on *TFP* growth.

This study relates to a large literature estimating gains from trade. Until about three decades ago, while trade theory emphasized the importance of trade liberalization, empirical estimates of the gains from trade were found to be disappointingly small. The development of endogenous growth theory in the 1980s (Romer, 1986; Lucas, 1988) allowed policy reform to generate large gains by

moving the economy to a higher growth path. Grossman and Helpman (1991) expanded the endogenous growth model by applying it to the open economy. Based on the idea that goods embody technological know-how, they showed that countries can acquire foreign knowledge through trade and increase their growth rate through trade liberalization.

Coe and Helpman (1995) provided an empirical implementation of the model in Grossman and Helpman (1991). They constructed an index of “foreign R&D”, defined as the trade-weighted sum of trading partners’ R&D stocks, and found for OECD countries that both domestic and “foreign R&D” have a large and significant impact on *TFP*, and that the latter increases with the economy’s openness. Coe et al. (1997) also examined the impact of North-South trade-related technology diffusion on *TFP* in the South and obtained similar results. This led to a number of other studies, inter alia, Engelbrecht (1997), Falvey et al. (2002), and Lumenga-Neso et al. (2005), which have tended to confirm Coe and Helpman’s (1995) findings. Other studies have extended the approach to the industry level, including Schiff and Wang (2006) who included South-South trade-related technology diffusion in their analysis and found it to have a positive impact on *TFP* in the South, though a smaller one than that obtained from North-South trade.

If the technology is to have an impact on *TFP* growth in developing countries, it is crucial that developing countries’ have certain capacity to absorb trade-related technology transfers from the North, to adapt them to the specific conditions prevailing in their own

country and to make productive use of them. That capacity has been found to be closely linked to the labor force's educational attainment level, for instance, Wang (2007), and Correa, et al. (2008). Given that brain drain has a negative impact on labor force's education level, brain drain is likely to have negative impact on a country's absorption and adaptation capacity and therefore also on the rate of growth of *TFP*.

This paper focuses on the impact of education and whether it differs in small and in large states, and then analyzes the implications of brain drain on TFP growth. The emigration rate of skilled workers in small states is much higher than in large states (Table 2), thus the implications of brain drain on TFP growth is significantly different in small states than in large ones.

The contribution of this paper to the open-economy endogenous growth literature is twofold. First, it offers an empirical analysis of the relationship between North-South trade-related technology diffusion, education, country size and productivity growth in the South. Second, it examines how the impact on productivity growth of changes in such variables as the level of education, trade-related technology diffusion, and of a change in both variables, is affected by country size.

The main findings are: i) Trade-related technology diffusion has a positive impact on productivity growth that is several times larger

for small than for large states. Thus, an increase in the degree of openness has a greater impact on productivity growth in small than in large states. ii) Similarly, education has a positive impact on productivity growth that is several times larger for small than for large states. Hence, brain drain's negative impact on productivity growth in small states is a multiple of that in large ones. iii) The impact of trade-related technology diffusion on productivity growth increases with the level of education, and this increase is also several times larger for small than for large states. Consequently, the brain drain reduces productivity growth both directly as well as through its interaction with trade-related technology diffusion, with a greater reduction for small than for large states. Finally, iv) the continuous growth of the North's R&D over time has a positive impact on the South's *long-term* productivity growth, an impact that is substantially greater for small than for large states.

The remainder of the paper is organized as follows. Section 2 presents the empirical framework. Section 3 describes the data and Section 4 provides the empirical results. Section 5 concludes.

## **2. The Empirical Implementation**

Coe and Helpman (1995) developed an empirical model to estimate the impact on *TFP* of North-North trade-related technology

diffusion. The estimation equation is:

$$\log TFP_{ct} = \alpha + \lambda_c + \lambda_t + \beta^d \log RD_{ct}^d + \beta^f \log RD_{ct}^f + \varepsilon_{ct}, \quad (1)$$

Where  $\lambda_c$  ( $\lambda_t$ ) is country (time) fixed effects,  $RD_{ct}^d$  ( $RD_{ct}^f$ ) is the domestic (foreign) R&D stocks,  $\varepsilon$  is an error term, and subscript  $c$  ( $t$ ) denotes country (year).

Coe, et al. (1997) use a similar model to explain North-South trade-related technology diffusion. However, due to lack of data for most developing countries, the equations they estimate do not include domestic R&D. They only use the foreign R&D stock  $RD^f$ , which is referred to in this paper as “North foreign R&D” and is denoted by “ $NRD$ ” in our study. Abstracting from domestic R&D is unlikely to be a major problem because most of the world’s R&D is performed in developed countries. For instance, in 1995, 95% of the world’s R&D expenditures took place in industrial countries (calculated from the World Bank database). Moreover, recent empirical work has shown that much of the technical change in individual OECD countries is based on the international diffusion of technology among the various OECD countries. A case in point is Eaton and Kortum (1999) where they estimate that 87% of French growth is based on foreign R&D. Since developing countries invest much fewer resources in R&D than OECD countries, foreign R&D must be even more important for developing countries as a source of growth.

In our paper, we divide the manufacturing sector into high- and low- R&D intensity industries, trying to tackle the industry heterogeneity issues related to different R&D intensity in their production process. Following Coe and Helpman (1995) and Coe, et al. (1997), we define the variable “North-foreign R&D” of developing country  $c$  for industry  $j$  at year  $t$ ,  $NRD_{ct}$  as:

$$NRD_{cjt} = \sum_k \frac{M_{cjk}}{GDP_{cjt}} RD_{jkt}, \quad (2)$$

where  $c$  indexes developing countries and  $k$  indexes OECD countries. For year  $t$ ,  $GDP_{cj}$  is the value added of industry  $j$  in country  $c$ ,  $M_{cjk}$  is the value of imports of industry  $j$  in country  $c$  from OECD country  $k$ , and  $RD_{jk}$  denotes the R&D stock in industry  $j$  in OECD country  $k$ . Equation (2) says that, for industry  $j$  in any country  $c$ ,  $NRD$  is the sum, over all OECD countries  $k$ , of the R&D stock of industry  $j$  in country  $k$ , weighted by country  $c$ 's imports from OECD country  $k$  for industry  $j$  divided by country  $cj$ 's value-added.

We estimate  $TFP$  equations as a function of  $NRD$ , human capital  $YE$ , defined as the average years of education for the population aged 25 and above, and a dummy variable for small states,  $S3$ . The number of countries with a population of 1.5 million or less (on average over the period) in our sample of fifty developing countries is too small to be of much relevance. We use instead a population of 3 million or less as our definition of “small state”, with twelve countries or close to one fourth (24%) of the sample fitting the



definition.<sup>1</sup>

In the empirical estimation, we also introduce several interaction terms. Two of them are interactions between each of the two explanatory variables and *S3*, i.e., *NRD\*S3* and *YE\*S3*. The other two are interactions between the two explanatory variables both for small and large states, i.e., *NRD\*YE* and *NRD\*YE\*S3*. A positive sign for the first two interaction variables would imply that the productivity-growth impact of *NRD* and *YE* is larger for small states, and similarly, a positive sign for *NRD\*YE\*S3* would imply that the impact of *NRD\*YE* is larger for small states.

Given that changes in openness, foreign R&D and education are unlikely to have an immediate impact on productivity growth, the estimation equation is specified in terms of five-year changes in the log of *TFP* ( $\Delta \log TFP$ ), in the log of *NRD* ( $\Delta \log NRD$ ) and in *YE* ( $\Delta YE$ ), i.e.:

$$\begin{aligned} \Delta \log TFP_{cjt} = & \alpha + \beta_N \Delta \log NRD_{cjt} + \beta_Y \Delta YE_{ct} + \beta_S S3 + \beta_{NS} \Delta \log NRD_{cjt} * S3 \\ & + \beta_{YS} \Delta YE * S3 + \beta_{NY} \Delta \log NRD_{cjt} * \Delta YE_{ct} + \beta_{NYS} \Delta \log NRD_{cjt} * \Delta YE_{ct} * S3 \end{aligned}$$

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<sup>1</sup> We use the average size of the population over the first half of our sample period to determine which states are small. If the average population were taken over the entire period, the population in nine countries would be smaller than three million and would be slightly above three million in three countries: 3.11 million for Uruguay, 3.15 million for Singapore and 3.40 million for Jordan.

$$+ \gamma_{ind} Ind + \sum_{c=2} \gamma_c D_c + \sum_{t=2} \gamma_t D_t + \varepsilon_{ct} \quad (3)$$

where  $D_c$  ( $D_t$ ) indicates country (year) dummies, capturing country- (year-) specific fixed effects, and  $Ind$  is industry dummy with  $Ind=1$  for high R&D intensity industries, and 0 for R&D low intensity industries. The equations estimated in Section 4 include equation (3) and variants thereof.

### 3. Data Description

The data cover 50 developing (and transition) countries and 15 industrialized OECD trading partners over the period 1976 to 2002. The 50 developing countries – with the twelve small states in italics – are: Bangladesh, Bolivia, Bulgaria, Cameroon, Chile, Colombia, *Cyprus*, Ecuador, Egypt, El Salvador, Ethiopia, Greece, Guatemala, Hong Kong (China), Hungary, India, Indonesia, Iran, I.R. of, Israel, *Jordan*, Kenya, Korea, *Kuwait*, *Latvia*, *Macao (China)*, Malawi, Malaysia, *Malta*, Mexico, Morocco, Myanmar (Burma), Nepal, Nigeria, *Oman*, Pakistan, *Panama*, Peru, Philippines, Poland, Romania, Senegal, *Singapore*, *Slovenia*, Sri Lanka, Tanzania, *Trinidad & Tobago*, Tunisia, Turkey, *Uruguay* and Venezuela. We aggregate industry level data into two composite industries with high- and low-R&D intensities. The industries fall in high- and low R&D intensities are adapted from Schiff and Wang (2006), with more documented in the appendix.

The log *TFP* index is calculated as the difference between the logs of value-added and primary factor use, with the inputs weighted by their income shares, i.e.,  $\ln TFP = \ln Y - \alpha \ln L - (1 - \alpha) \ln K$ , where  $\alpha$  is the mean labor share over the available time period. The labor share is derived as the ratio of the wage bill over value added.<sup>2</sup> Fixed capital formation used to construct capital stocks, value added, labor and wages, is from the World Bank data set described in Nicita and Olarreaga (2007), all reported in current US dollars at the 3-digit ISIC codes (Revision 2). Value-added and fixed capital formation are deflated by the US GDP deflator (1991=100), and capital stocks are derived from the deflated fixed capital formation series using the perpetual inventory method with a 5% depreciation rate.<sup>3</sup>

R&D expenditure for the 15 OECD countries is taken from OECD ANBERD with ISIC Revision 2 (2002) covering data from 1973 to 1998, and ANBERD with ISIC Revision 3 (2006) covering data from 1987 on. Since ANBERD ISIC 2 and ISIC 3 have 12 years of overlapping data, we are able to match the different specifications. The R&D stock in each country is constructed from R&D expenditures using the perpetual inventory method with a 10% depreciation rate.

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<sup>2</sup> For labor income share, if self-employed workers fail to report their wages, and if the under-reporting causes is substantial, then the labor income share would be under-understated. The under-reporting problem might cause some concern at the micro-level studies, but for the industry-level data, the under-reporting problem is unlikely to be major, as the industry-level data have already passed the edit by each country's statistics bureau.

<sup>3</sup> Given that the data reported in Nicita and Olarreaga (2007) are in current US dollars, we use the US GDP deflator. In the empirical analysis, country-specific as well as year dummies are used in order to control for some of the distortions possibly introduced by the conversion.

Bilateral trade data of the 50 developing countries with the 15 industrialized OECD countries at the 4-digit ISIC 2 level are taken from Nicita and Olarreaga (2007). We construct bilateral trade shares for each year and each composite industry and each of the 50 developing countries with respect to each of the 15 OECD countries, which are then used to construct *NRD*, defined in equation (2).

Average years of education for the population aged 25 and above are obtained by annualizing the five-year averages in Barro and Lee (2000), and extrapolated to year 2002, which is at the country level. There are several countries included in the sample that are not included in the Barro and Lee dataset. We matched each of these countries with the countries included in Barro and Lee, using indicators such as real GDP per capita and government expenditure on education as a share of GDP per capita.

Due to missing observations for production and trade data, our sample is unbalanced. Our sample has 100 panels (50 countries, each with a composite high and low R&D intensity industry). Taking five-year first difference will leave each panel with 4 data points. However, due to missing data on production and bilateral trade, some countries have only two five-year first difference data points.

#### **4. Empirical Findings**

#### *4.1. Some concerns for unit root and endogeneity*

We proceed by first testing whether the data contain unit root and whether *NRD* is endogeneous in order to choose a proper econometric model for the estimation. For the unit root test, all the test techniques for panel data are developed in the context of balanced panels. Thus, if we were to test unit root for our data, we have to exclude those data points which are missing in some panels. Doing so leaves us with two data points for each of the remaining panels, which makes it impossible to employ any of the unit root techniques. Thus, essentially, our data can be treated as panel data (100 panels), with not long enough period to be considered as time series data (maximum 4).

However, we still might face endogeneity problem as more productive countries might imports more goods from overseas. We tested for the possible endogeneity problem using the methodology proposed by Wooldridge (2002), and the test results suggest that the endogeneity hypothesis is rejected. In what follows, the results are estimated using panel data fixed effects.

#### *4.2. The results*

<Table 1 Here>

Table 1 reports the main regression results. It shows that the coefficient  $\beta_N$  on  $\Delta \log NRD$  is positive and significant in all nine regressions. Denote the coefficient  $\beta_N$  for small states—i.e., for  $\Delta \log NRD * S3$ —by  $\beta_{NS}$  (see equation (3)). The value of  $\beta_N$  ranges from 0.269 to 0.615 and falls to a range of 0.269 to 0.397 when the variable  $\Delta \log NRD * S3$  is included in the regression. For instance, in equation (1),  $\beta_N = 0.490$  (significant at the 1% level) and falls to 0.269 (significant at the 10% level) in equation (2), with  $\beta_{NS} = 0.964$  (significant at the 1% level). The impact  $\phi_{NS}$  of  $\Delta \log NRD$  on  $\Delta \log TFP$  in small states is  $\phi_{NS} \equiv \beta_N + \beta_{NS} = 1.233$ . Thus, the impact of  $\Delta \log NRD$  in small states is well over 4 times the impact in large countries ( $\phi_{NS} > 4\beta_N$ ). The same result obtains for equations (6) and (9), while  $\phi_{NS} > 3\beta_N$  for equations (5) and (8).

The coefficient  $\beta_Y$  of the education variable  $\Delta YE$  for the full sample ranges from 0.721 to 0.807, with significance of 1% or 5% in equations (1), (2), (3) and (5). It falls to between 0.194 and 0.310 and is

no longer significant when the small states variable,  $\Delta YE*S3$ , is included in the regression. For instance, in equation (1),  $\beta_Y = 0.766$  (significant at the 5% level) for the full sample. Adding  $\Delta YE*S3$  in equation (4) results in a value  $\beta_Y = 0.242$  (not significant), with the coefficient for small states  $\beta_{YS} = 1.075$  (significant at the 10% level). The impact of  $\Delta YE$  for small states is equal to  $\phi_{YS} \equiv \beta_Y + \beta_{YS} = 1.317$ , or over five times the impact in large countries ( $\phi_{YS} > 5\beta_Y$ ). Similar results are obtained in equations (6) to (9), with  $\phi_{YS} > 6\beta_Y$  in equation (7),  $\phi_{YS} > 5\beta_Y$  in equation (8), and  $\phi_{YS} > 4\beta_Y$  in equations (6) and (9).

The coefficient  $\beta_{NY}$  of the interaction effect  $\Delta \log NRD * \Delta YE$  for the full sample ranges from 1.618 to 1.701, with significance level of 5% or 10%, in regressions (3), (5), (7) and (8).

We introduce the variable  $\Delta \log NRD * \Delta YE * S3$  in equation (9), in which case  $\beta_{NY}$  falls to 0.726 and is no longer significant.

On the other hand,  $\beta_{NYS} = 2.966$  (significant at the 10% level), with the impact of  $\Delta \log NRD * \Delta YE$  in small states equal to  $\phi_{NYS} \equiv \beta_{NY} + \beta_{NYS} = 3.792 \cdot 5\beta_{NY}$ .

The results provided in Table 3 imply that the impact of  $\Delta \log NRD$ ,  $\Delta YE$  and  $\Delta \log NRD * \Delta YE$  on  $\Delta \log TFP$  is systematically greater in small states than in large ones. Equation (9) – which includes all seven explanatory variables and is our preferred equation – shows that the impact of these three variables in small states is at least four times the impact in large ones, and the impact of  $\Delta YE$  and of  $\Delta \log NRD * \Delta YE$  is more than 5 times greater.

By construction, the increase in  $NRD$  either comes from the increase in the trade share, or the increase in North's R&D, or both. Our regression results indicate that the continuous growth in North's R&D over time has a positive impact on the South's *long-term* productivity growth, an impact that is substantially greater for small than for large states.

#### *4.3. Implications of brain drain*

Emigration of skilled workers has long been a problem for developing, especially small developing countries. Table 2 (taken from Docquier and Schiff, 2008) presents skilled and overall emigration rates in 2000, as well as the ratio of the former to the latter (the



schooling gap), for 46 small developing states – defined by the UN as states with population below 1.5 million – and for other categories of interest. Skilled workers are defined as those with university education. Row 1 of Table 2 shows that small developing states experience an extremely high level of brain drain (43.2%).<sup>4</sup> In other words, 3 out of every 7 individuals with university education live outside their country of origin. This rate is 2.8 times as large as the 15.3% overall migration rate.

<Insert Table 2 here>

The table also shows a brain drain for small (all) high-income states of 23% (3.5%) or a ratio of 6.5 for small versus all states. The same ratio for developing countries is close to 6 (43.2% versus 7.4%). In other words, the impact of country size on the brain drain seems robust across a wide range of incomes. Moreover, the brain drain for all developing countries (7.4%) is over twice that of high-income countries (3.5%) and the schooling gap is close to four times as high (4.9% versus 1.3% or 3.8 times).

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<sup>4</sup> For the brain drain data, the primary data source is from Caglar and Schiff (2007) and Docquier and Schiff (2008). Since it is hard to track all emigrants, there might be measurement problems on brain drain data. Regarding the potential measurement problems on the implications, there are small, mainly because we are not doing quantitative analysis, but some general discussions. Regardless of the magnitudes of the measurements errors on brain drain, it is a general consensus that brain drain problems in small states are much more severe than for large countries.

<Insert Table 3 here>

The region with the highest small-state brain drain (74.9%) is the Caribbean (in “Latin America and the Caribbean”), and Table 3 shows that several states’ brain drain is well above 80%. The East Asia and Pacific region (mainly the South Pacific islands) follows, with a brain drain of 50.8%, with several countries over 70% (Table 3). Sub-Saharan Africa is next with 41.7%, with several countries over 60% (Table 3).<sup>5</sup>

Thus, as far as small states are concerned, three out of four skilled Caribbean individuals live outside their country of origin, two out of four in East Asia and Pacific, and two out of five in Sub-Saharan Africa. Though Sub-Saharan Africa (SSA) has the lowest brain drain among these three regions, its schooling gap is more than double that in the other two developing regions. The main reason is the smaller share of skilled individuals in the population.

As shown in Table 2, the share of migrants who are skilled is two times the share among residents (Docquier and Schiff, 2008), implying that the brain drain reduces the average level of education *YE* and reduces the absorption capacity of

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<sup>5</sup> Table 3 also shows countries in Central America (Belize) and the Mediterranean (Malta) with brain drain above 50% and Cyprus with brain drain above 30%.

developing source countries. The reduction is much larger for small than for large states. The interaction effect of  $\Delta YE$  and  $\Delta \log NRD$  is positive, so that brain drain reduces the impact that the diffusion of technology from the North has on productivity growth, and this reduction is greater for small than for large states.<sup>6</sup>

Small states also tend to suffer from significantly higher brain drain rates. The brain drain in 2000 was 43.2% for small states or well over five times the brain drain for all developing countries (7.4%), with the former equal to over five times the latter. Thus, the negative impact of the brain drain is greater in small states both because *TFP* growth is more sensitive to the brain drain and because the brain drain is substantially greater than in large countries.

The results are subject to an important caveat, though it may increase rather than reduce the difference between the small and the large states impact on *TFP* growth. A recent literature has argued that the loss in human capital is smaller than the brain drain because of a

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<sup>6</sup> A hypothesis for the greater impact on *TFP* growth in small than in large states of  $\Delta \log NRD$ ,  $\Delta YE$  and their interaction relates to economies of scale. These would hold in the case of education if subject to a threshold effect, with a minimum education level needed to absorb the North's new technologies and adapt them to the South's circumstances. They might also hold in the case of *NRD* if new technologies that firms obtain through trade were adopted by other firms through a logistic process, with adoption proceeding at an increasing rate once a threshold level had been reached, a pattern that was later found to hold for a wide range of phenomena. Small states are much more open to trade than large ones and have therefore a greater *NRD*. **With increasing returns, the impact of  $\Delta \log NRD$ ,  $\Delta YE$  and their interaction on *TFP* growth would be greater for small states than for large ones (as, for instance, ).** The empirical findings in Table 1 show that this condition is satisfied in the case of small states but not large ones.

brain drain, a concept unrelated to return migration by some of the skilled migrants. Rather, this literature argues that a brain drain obtains because the positive probability of emigration and of earning a higher salary abroad raises the expected return to education and provides an incentive to acquire more of it. The change in the stock of human capital or net brain drain is the difference between the brain gain and the brain drain.

Several studies argue that under certain conditions, the net brain gain might actually be positive, with the incentive effect of the brain drain on human capital accumulation larger than the brain drain itself. For instance, a recent study by Beine et al. (2008) finds that the net brain gain is negative for most developing countries, particularly in the case of small states, though it tends to be positive in the very large countries where the brain drain is small such as Brazil, China, India, and others. Thus, the brain drain would be expected to result in a reduction in TFP growth in most developing countries. This is particularly true for small states, and for four reasons. First, as shown in tables 2 and 3, the brain drain in small states is close to six times that in large ones. Second, the large states may experience a net brain gain rather than a brain drain, which is certainly not the case for small states (Beine et al., 2008). Third, TFP growth is more sensitive to the brain drain in small than in large states; and fourth, small states are more open to trade which implies, *ceteris paribus*, a higher level of technology diffusion.

Thus, the difference in the impact of the brain drain on TFP growth between small states and the larger states may be even *greater* than in the absence of a brain gain because the *net* brain gain remains highly negative for small states while that for large states tends to be positive (Beine, et al., 2008).

## **5. Conclusion**

This paper examined the impact of North-South trade-related technology diffusion on *TFP* growth in the South. It contributes to the open-economy endogenous growth literature by offering an empirical analysis of the impact of the brain drain, education and country size on *TFP* growth, and of a combination of these variables. The main findings are the following. First, *TFP* growth increases with growth in trade-related technology diffusion, and the increase is substantially larger for small states than for large ones. Second, education has a positive impact on TFP growth, and the increase is substantially larger for small states than for large ones. Third, the share of migrants who are skilled is larger than the share of residents who are skilled, implying that the brain drain has a negative impact on the stock of human capital and thus on *TFP* growth; and that the impact is larger (in absolute value) for small than for large states. Fourth, the impact of the interaction of trade-related technology diffusion and education on TFP growth is positive, and this impact is greater for small than for large states. Thus, TFP growth in small states is more sensitive to changes in the brain drain, to

changes in North-South trade-related technology diffusion, and to the interaction between the two. Moreover, small states are more open to trade and thus have higher levels of North-South trade-related technology diffusion. This is another reason why TFP growth in small states would react more strongly to changes in trade-related technology diffusion. Brain Drain levels are also substantially larger in small than in large states, causing greater losses in TFP growth in the former than in the latter. Hence, there are two reasons for the greater negative impact of the brain drain in small than in large states: i) the former's TFP growth is more sensitive to the brain drain, and ii) their brain drain is substantially larger. Finally, the continuous growth of the North's R&D over time has a positive impact on the South's *long-term* productivity growth, an impact that is substantially greater for small than for large states.

One needs to be cautious regarding the implications on the impact of brain drain on TFP growth, as these implications are subject to a caveat, which is related to what has been referred to as the brain gain. The idea is that the brain drain might lead people to acquire more education because this would raise their probability of migrating and because the education premium is higher in the North than in the South. In other words, the increase in the (expected) return to education would provide an incentive to invest in education. Since only a small share of people acquiring more education will be able to migrate while the bulk will not, the brain drain would be expected to generate a brain gain. Hence, the loss of human capital associated with the brain drain would be expected to be smaller than the brain drain itself.

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**Table 1: TFP Growth and Small States**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta \log NRD$	<b>0.49</b>	<b>0.269</b>	<b>0.595</b>	<b>0.509</b>	<b>0.375</b>	<b>0.291</b>	<b>0.615</b>	<b>0.397</b>	<b>0.337</b>
	(3.71)***	(1.83)*	(4.18)***	(3.87)***	(2.42)**	(1.98)**	(4.33)***	(2.57)***	(2.14)**
$\Delta YE$	<b>0.766</b>	<b>0.807</b>	<b>0.721</b>	<b>0.242</b>	<b>0.761</b>	<b>0.31</b>	<b>0.194</b>	<b>0.261</b>	<b>0.296</b>
	(2.47)**	(2.66)***	(2.33)**	(0.56)	(2.52)**	(0.73)	(0.45)	(0.62)	(0.71)
$S3$	<b>-0.117</b>	<b>0.338</b>	<b>0.048</b>	<b>-0.559</b>	<b>0.519</b>	<b>-0.087</b>	<b>-0.396</b>	<b>0.092</b>	<b>0.206</b>
	(-0.09)	(0.27)	(0.04)	(-0.44)	(0.42)	(-0.07)	(-0.31)	(0.07)	(0.16)
$\Delta \log NRD * S3$		<b>0.964</b>			<b>0.982</b>	<b>0.949</b>		<b>0.966</b>	<b>1.158</b>
		(3.12)***			(3.21)***	(3.09)***		(3.17)***	(3.59)***
$\Delta \log NRD * \Delta YE$			<b>1.618</b>		<b>1.694</b>		<b>1.627</b>	<b>1.701</b>	<b>0.726</b>
			(1.89)*		(2.03)**		(1.91)*	(2.05)*	((0.73)
$\Delta YE * S3$				<b>1.075</b>		<b>1.019</b>	<b>1.082</b>	<b>1.025</b>	<b>0.97</b>
				(1.74)*		(1.69)*	(1.77)*	(1.71)*	(1.63)*
$\Delta \log NRD * \Delta YE * S$									<b>2.966</b>
<b>3</b>									(1.75)*
<b>Adj. R2</b>	<b>0.25</b>	<b>0.28</b>	<b>0.26</b>	<b>0.26</b>	<b>0.3</b>	<b>0.29</b>	<b>0.27</b>	<b>0.3</b>	<b>0.31</b>
<b>obs</b>	<b>230</b>	<b>230</b>	<b>230</b>	<b>230</b>	<b>230</b>	<b>230</b>	<b>230</b>	<b>230</b>	<b>230</b>

Note: Figures in parentheses are robust t-statistics. \*\*\*(\*\*) (\*) indicates 1(5) (10) % significance level. The sample includes 50 developing countries covering the period of 1976 to 2000. *NRD* is trade-related North foreign R&D, defined in Section 2. *YE* is the average years of schooling of the population aged 25 and above. *S3* is the dummy variable capturing small states.



**Table 2. Emigration Rates in 2000 by Country Group (%)**

	N	(1) Skilled Emigration Rate	(2) Average Emigration Rate	(3) Schooling Gap
<b>Small States (pop&lt;1.5million)</b>	<b>46</b>	<b>43.2</b>	<b>15.3</b>	<b>2.81</b>
<i>by population size</i>				
<i>population from 0 to 0.5 million</i>	32	41.7	21	2
<i>population from 0.5 to 1 million</i>	8	47.2	15.7	3
<i>population from 1 to 1.5 million</i>	6	40.9	9.8	4.2
<i>by region/income</i>				
<i>East Asia and Pacific</i>	12	50.8	17	3
<i>Latin America and Caribbean</i>	10	74.9	35	2.1
<i>Sub-Saharan Africa</i>	10	41.7	6	6.9
<i>High-income Countries</i>	12	23	10.7	2.1
<b>Other Groups of Interest</b>				
<i>Small Islands Developing States</i>	37	42.4	13.8	3.1

<i>Population from 1.5 to 3 million</i>	15	20.9	7.1	3
<i>Population from 3 to 4 million</i>	13	18.5	10	1.8
<i>World Average</i>	192	5.3	1.8	3
<i>Total High-income Countries</i>	41	3.5	2.8	1.3
<i>Total Developing Countries</i>	151	7.4	1.5	4.9

Note: Skilled (average) emigration rates are defined as number of skilled (all) migrants divided by the sum of skilled (all) migrants. Schooling gap=Skilled emigration rate / average emigration rate. The table is from Docquier and Schiff (2008).

**Table 3. Highest Brain Drain (%) in a Sample of Small States in 2000 (By Region)**

<u>Region / Country</u>	<u>Brain Drain (%)</u>
<u>1. Sub-Saharan Africa</u>	
Cape Verde	67.4
Gambia	63.2
Mauritius	56.1
Seychelles	55.8
<u>2. Caribbean</u>	
Guyana	89.0
Grenada	85.1
St Vincent and the Grenadines	84.5
St Kitts and Nevis	78.5
<u>3. Central America</u>	
Belize	65.5
<u>4. South Pacific</u>	
Samoa	76.4
Tonga	75.2
Fiji	62.2
Micronesia, Federated States	37.8
<u>5. Mediterranean</u>	
Malta	57.6
Cyprus	33.2



## Appendix

### I: R&D-Intensive Industries

The industry-level data were aggregated in two industry groups: R&D-intensive aggregate industry and low R&D-intensity aggregate industry in order to examine whether there were significant differences between the two. The R&D-intensity measure used (R&D expenditures divided by sales) is based on the US, the technologically more advanced country. The regressions were estimated by adding a dummy variable for R&D-intensive industries for all countries. The results are shown in Table A1 below for all the sample countries (with no differentiation between small and large states).

The preferred specification is equation (5) which includes all the variables. It shows that the differential impact of North–South trade–related technology diffusion (i.e., of  $\Delta \log NRD * Dr$ ) on *TFP* growth in R&D–intensive industries relative to non–intensive industries is small and not significant. Second, the differential impact of the interaction of  $\Delta \log NRD$  and education *YE* (i.e., of  $\Delta \log NRD * YE * Dr$ ) on *TFP* growth in R&D-intensive industries relative to non-intensive industries is not significant either. The regressions were also estimated with small state dummies, with similar results: variables interacted with the dummy *Dr* were not

significant. Consequently, we decided to estimate the model without differentiating the impacts according to their R&D intensity.



**Table A1. TFP Growth and R&D Intensity**

	(1)	(2)	(3)	(4)	(5)
$\Delta \log \text{NRD}$	<b>0.348</b>	<b>0.289</b>	<b>0.366</b>	<b>0.373</b>	<b>0.295</b>
	(7.05)***	(5.27)***	(7.38)***	(7.46)***	(5.54)***
$\Delta \text{YE}$	<b>0.292</b>	<b>0.289</b>	<b>0.319</b>	<b>0.318</b>	<b>0.328</b>
	(5.99)***	(5.97)***	(6.45)***	(6.47)***	(6.82)***
$\Delta \log \text{NRD} * \text{Dr}$		<b>0.043</b>			<b>0.03</b>
		(1.30)			(1.53)
$\Delta \log \text{NRD} * \Delta \text{YE}$			<b>0.326</b>	<b>0.217</b>	<b>0.148</b>
			(3.33)***	(2.45)**	(1.69)*
$\Delta \log \text{NRD} * \Delta \text{YE} * \text{D}$					
<b>r</b>				<b>0.068</b>	<b>0.049</b>
				(1.60)	(1.50)
<b>obs</b>	<b>230</b>	<b>230</b>	<b>230</b>	<b>230</b>	<b>230</b>
<b>Adj. R2</b>	<b>0.23</b>	<b>0.23</b>	<b>0.24</b>	<b>0.24</b>	<b>0.24</b>

Note: \*\*\* (\*\*) (\*) indicates 1 (5) (10) percent significance level. Figures in parentheses are robust t-statistics. The sample includes 50 developing countries covering the period of 1976 to 2002. *NRD* is trade-related North foreign R&D, defined in Section 2. *YE* is the average number of years of schooling of the population aged 25 and above. *Dr* is the dummy for R&D-intensive industries, and *S3* is a dummy variable capturing small states.

## II: Country Size in Term of GDP, Trade-related Technology Diffusion and TFP Growth

This subsection explores another direction in measuring the size of the states directly by their size of gross domestic product

(GDP), rather than the one used in the main text with a small states dummy variable. Quite often, in the group of developing and transition economies covered in the study, a country's GDP is closely related to population size, as countries with small population usually have smaller size of GDP if GDP per capita in each country is about the same. The two measurements will differ if GDP per capita is significantly different among the countries included in the sample. Nonetheless, this subsection uses GDP as country size to study how country's GDP affects trade-related technology diffusion, and on TFP growth. Note that smaller GDP implies smaller country size in general, but not necessarily a smaller population, and thus a small state as outlined by the criteria by the United Nation.

Table A2 provides the estimation results. The difference between Table 1 and Table A2 is that Table 1 contains small states dummy (S3), while Table 2 replaces it with  $\Delta \ln \text{GDP}$ . Thus, the estimated results in Table A2 here reflect the change of GDP on NRD and on YE and thus on their estimated effects on TFP, not necessarily a differentiation between large and small states, as estimated in Table 1. Summarizing the results lead to the following conclusions:

First, increases in trade-related technology diffusion generate substantial effects on TFP growth in the South. That is consistent with the findings in Table 1. Second, increase in a country's GDP directly affects its TFP growth. For developing countries, the larger the

increase is in its economy size, the faster is its TFP growth rate. Third, the increase of the economic size of GDP in developing countries increases their TFP growth not only through its direct effects, but also through NRD, i.e., a larger increase in GDP leads to increased effects of trade-related technology diffusion on TFP growth. Fourth, although educational attainment fails to obtain any direct significant effects on TFP growth in the presence of GDP, it enhances the effects of trade-related technology diffusion on TFP growth. That is, for developing countries, the higher is the educational level, the larger of the effects of trade-related technology diffusion on TFP growth. This finding is also consistent with those reported in Table 1.

**Table A2: TFP Growth and Small States in Term of GDP Size**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta \log NRD$	<b>0.247</b>	<b>0.173</b>	<b>0.339</b>	<b>0.247</b>	<b>0.252</b>	<b>0.170</b>	<b>0.342</b>	<b>0.215</b>	<b>0.374</b>
	(2.27)**	(1.55)	(2.92)***	(2.27)**	(1.99)**	(1.51)	(2.93)***	(1.99)**	(2.73)***
$\Delta YE$	<b>0.120</b>	<b>0.170</b>	<b>0.105</b>	<b>0.109</b>	<b>0.149</b>	<b>0.038</b>	<b>0.003</b>	<b>-0.022</b>	<b>-0.033</b>
	(0.46)	(0.66)	(0.40)	(0.28)	(0.57)	(0.10)	(0.00)	(0.06)	(0.09)
$\Delta \log GDP$	<b>1.061</b>	<b>0.698</b>	<b>0.992</b>	<b>1.051</b>	<b>0.733</b>	<b>0.560</b>	<b>0.894</b>	<b>0.557</b>	<b>0.425</b>
	(3.98)***	(2.28)**	(3.72)***	(2.82)***	(2.39)**	(1.33)	(2.38)**	(1.33)	(1.01)
$\Delta \log NRD * \Delta \log GDP$		<b>0.649</b>			<b>0.504</b>	<b>0.674</b>		<b>0.529</b>	<b>1.190</b>
		(2.36)**			(1.70)*	(2.40)**		(1.77)*	(2.82)***
$\Delta \log NRD * \Delta YE$			<b>1.423</b>		<b>0.963</b>		<b>1.465</b>	<b>1.007</b>	<b>1.236</b>
			(2.09)**		(1.32)		(2.12)**	(1.37)	(1.69)*
$\Delta YE * \Delta \log GDP$				<b>0.024</b>		<b>0.292</b>	<b>0.227</b>	<b>0.373</b>	<b>0.818</b>
				(0.04)		(0.48)	(0.37)	(0.61)	(1.29)
$\Delta \log NRD * \Delta YE * \Delta \log GDP$									<b>-2.268</b>
									(2.20)**
<b>Adj. R2</b>	<b>0.35</b>	<b>0.37</b>	<b>0.36</b>	<b>0.35</b>	<b>0.37</b>	<b>0.36</b>	<b>0.36</b>	<b>0.37</b>	<b>0.38</b>
<b>obs</b>	<b>218</b>	<b>218</b>	<b>218</b>	<b>218</b>	<b>218</b>	<b>218</b>	<b>218</b>	<b>218</b>	<b>218</b>

Note: Figures in parentheses are robust t-statistics. \*\*\*(\*\*) (\*) indicates 1(5) (10) % significance level. The sample includes 50 developing countries covering the period of 1976 to 2000. *NRD* is trade-related North foreign R&D, defined in Section 2. *YE* is the average years of schooling of the population aged 25 and above. *GDP* is the gross domestic product, a measure for country size.