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Productivity Growth and Technological Diffusion Through Foreign Direct Investment

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Abstract

Foreign direct investment (FDI) has dramatically increased worldwide and is the most important form of all private capital flows to developing countries. Yet it is an important empirical question whether FDI affects total factor productivity (TFP) positively. We investigate the effect of FDI on TFP growth in a large sample of countries in 1970-2000. Our econometric results indicate that FDI has a positive and direct effect on TFP growth. However, we do not find any evidence that the impact of FDI on TFP growth is only conditional on the recipient country's capability to absorb foreign technology. We carefully address the robustness of the empirical results.

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I. Introduction

The recent surge in cross-border financial flows has generated an intense debate among economists and policymakers on the benefits and costs of the ongoing international financial integration. In principle, financial integration can promote productivity growth by allowing a country to borrow to finance productive domestic investment and increasing access to foreign advanced technologies. However, it can be accompanied with macroeconomic volatility and even financial crises. Fuelling this debate, the empirical evidence on the effects of financial integration on growth has been mixed (see Kose et al. 2006).

Yet recent financial crises led policymakers to rethink about appropriate policies for growth. It is widely believed that the short-term debt is the most volatile source of foreign capital and can contribute most to instability of financial markets at a time of crisis, whereas foreign direct investment (FDI) is the most stable form of capital inflows. Importantly, FDI has long been regarded to be a major vehicle of technology transfer. More than ever, countries seek to leverage FDI for development. FDI represents the largest share of external capital flows to developing countries (UNCTAD 2007).[1] This seems to be driven by the belief that FDI brings positive effects to the economy, such as technology transfer, introduction of new production processes, and advanced management practices. However, it still remains to be an important empirical question whether and how FDI affects productivity growth in countries at various stages of development.

In this paper, we study total factor productivity (TFP) in relation to technology diffusion through FDI for a couple of important reasons. First, debates over the relative importance

[1] Lane and Milesi-Ferretti (2006) find that the increase in the relative importance of equity liabilities has continued for developing countries, which accounted for half of total external liabilities and that the share of FDI accounted for about 75 percent of developing countries' equity liabilities in 2004.

between factor accumulation and TFP in raising income per capita took a dramatic turn. Recent studies found that more than half of the cross-country variation in both income per capita and its growth results from differences in TFP and its growth, respectively (Caselli 2005, Parente and Prescott 2001, Easterly and Levine 2001, Hall and Jones 1999, Klenow and Rodriguez-Clare 1997).[2] This finding suggests that, in order to understand the growth of nations, it is important to develop a better understanding of the forces that shape TFP.

Technological change is an important determinant of TFP. This was Robert Solow (1957)'s original view, as well as the view of many economists in the literature (Helpman 2004). Endogenous growth models provide rigorous theoretical frameworks for understanding the economic forces underlying technological change. The models have focused on two important types of technological change: (i) innovation through R&D, and (ii) technology diffusion through assimilating and adapting advanced foreign technology (see Grossman and Helpman 1991, Romer 1990, 1992, Coe et al. 1997, Barro and Sala-i-Martin 2003 among others). Many of the earlier empirical studies focused on the effects on growth of innovation (measured by R&D expenditure or the number of scientists). The evidence on the positive impact on growth of innovation, especially at the micro-level, is substantial (Helpman 2004).

The other channel of technological change, technology diffusion, has received relatively less attention in the empirics. In a typical model of technology diffusion, technological change of a less-developed country depends on the extent of adoption and implementation of new technologies that are in use in the advanced countries (technology diffusion). That is, technological change largely consists of assimilating and adapting foreign technology. FDI is

[2] This finding is in sharp contrast with Mankiw et al. (1992) who argue that differences in physical and human capital account for most of the observed international differences in income per capita.

an important way to access advanced foreign technology. Beyond adding more capital to a receiving country, FDI can be the conduit to the production technology, cutting edge of R&D, and management expert. International technology diffusion can also take place through import of capital goods embodied with high technology (Eaton and Kortum 2001).

However, empirical research on the role of FDI in economic growth is still in its infancy (albeit growing rapidly), and has focused on growth of income per capita (Borensztein et al. 1998, Alfaro et al. 2004, Blonigen and Wang 2005, for example), not the TFP growth that is of our interest in this paper. Given the striking evidence on the importance of TFP in explaining the cross-country income differences and the preeminence of the technology development and diffusion as a key determinant of TFP in endogenous growth theory, it is surprising that there is no cross-country empirical study on the effect of FDI on TFP growth.[3] In a comprehensive review of the literature on financial globalization, Kose et al. (2006) also conclude that how different types of capital flows including FDI affect TFP growth is one of the important future research topics. Our paper fills this important gap in the literature.[4]

The goal of this paper is to provide a comprehensive econometric analysis on the effect of FDI on TFP growth in a large sample of countries (developed and developing) for the 1970-2000 period. While exploiting both cross-sectional and time-series dimensions of data, we also carefully address the robustness and consistency of the results in terms of data, samples (developed versus developing countries), estimation methods (cross-country and

[3] Among the notable partial exceptions, Edwards (1998) finds that various measures of openness to trade are positively associated with TFP growth in the 1980-1990 period. Also, Coe et al. (1997) study the effects of imported machinery and equipment on TFP level for 77 countries in the period of 1971-1990. In a panel of 19 OECD countries, Scarpetta et al. (2002) report evidence that stringent regulatory settings in the product markets and strong employment protection have negative effects on TFP growth at the industry level.

There are some empirical studies on FDI and TFP at the micro-level within a nation. Aitken and Harrison (1999) examine the relationship of FDI and TFP of Venezuelan plants in 1976-89. The micro-level studies typically examine the effect of FDI on labor productivity, not TFP. See Keller (2002).

[4] In the working paper version, we also examine the other channel of technology diffusion, import of capital goods. The results are available upon request.

panel regressions), and outlier problem (robust estimation), which often plague the standard OLS (ordinary least squares) regression analysis.

Our results indicate that FDI has a significantly positive direct effect on TFP growth. Various estimation methods and robustness check yield largely the same result. To our best knowledge, our paper is the first one that presents the evidence of positive direct effect on TFP growth from FDI in a cross-country study.[5]

Yet it is interesting to compare our finding with the existing empirical studies on FDI and international financial integration. As noted earlier, the existing empirical papers on FDI have focused on growth of income per capita, rather than TFP growth. Despite the distinct difference between income per capita and TFP, theoretical implications for *direct* effects of FDI on both per capita income growth and TFP growth are rather straightforward. However, earlier studies on FDI and per capita income growth failed to find a statistically significant positive effect of FDI on income growth. Instead, some of the studies (but not all) reported the positive effect of FDI on income growth is only conditional on other factors such as human capital (Borensztein et al. 1998) and financial development (Alfaro et al. 2004).[6] Thus, it became a popular view that the effect of FDI on income growth is *only* contingent on the recipient country's capability to absorb foreign technology.

Contrary to this popular perception and some of the studies on FDI and per capita income growth, however, we do not find any significant evidence that the contribution of FDI to TFP growth is *only* contingent on the recipient country's capability to absorb foreign technology, regardless of how the absorptive capability is measured (human capital, financial market

[5] We also find a strong positive direct effect of imported capital goods on TFP growth (not reported). Available upon request.

[6] However, Carkovic and Levine (2005) do not find strong evidence for such conditional nature of FDI's effects on income growth in a larger sample of 72 countries and for a longer time period that includes more recent years, 1960-95, than those in Borensztein et al. (1998) and Alfaro et al. (2004).

development, or institutional quality).[7] It seems that technology diffusion process through FDI flows affects the TFP growth differently.[8]

Our finding of positive effect of FDI on TFP growth is also in contrast with the empirical studies on the effect on income growth of international financial integration that often yield only ambiguous results. For example, Edison et al. (2004) examined various measures of international financial integration (such as volume of capital flows including FDI, equity and debt), and confirmed lack of a robust relationship between financial integration and per capita income growth (see Kose et al. 2006 and references therein).[9]

The plan of the paper is as follows. In Section 2, we discuss the concept of TFP and our new data set on TFP. In Section 3 we briefly discuss the empirical literature on FDI and economic growth, and data on FDI. In Section 4, we present our econometric analysis of FDI's effects on TFP growth. In Section 5, we address the robustness and consistency of the results in terms of reversed causality, outliers, and unobserved omitted variables, and then conclude in Section 6. Additional information on data is provided in the appendix.

II. Total Factor Productivity (TFP)

Consider a standard aggregate production function where aggregate output (Y) depends on physical capital (K), labor (L), human capital (H), and TFP or stock of knowledge (A):

$$Y = Af(K, H \cdot L), \tag{1}$$

[7] This is similar to Carkovic and Levine (2005) that do not find robust evidence for the absorptive capability hypothesis in per capita income growth regression.

[8] In sharp contrast to the case of income per capita growth that does not exhibit any evidence of unconditional convergence process, we do find a strong *unconditional convergence* process for TFP (i.e., countries with initially low levels of TFP tend to experience faster TFP growth) in our sample countries (not reported to save space). Available upon request.

[9] But there is stronger evidence on positive effects on per capita income growth from a narrower aspect of capital liberalization, equity liberalization. See Bekaert et al. (2005) and Henry (2000, 2007).

where $H \cdot L$ is human-capital augmented labor (i.e., labor in efficiency units). Growth of aggregate output will depend on the rate of change of those four factors. The growth rate of TFP, which is obtained as a residual in the growth accounting, is often ascribed to technological progress. TFP can change for many reasons. First of all, an increase in stock of knowledge about production methods. The endogenous growth theory focuses on technological progress that results from intentional industrial innovation through R&D activities in response to their expected profits such as monopoly rents (for seminal papers, see Romer 1990, Grossman and Helpman 1991). Both the costs of R&D and the rewards that innovators gain are influenced by conditions in product (including market size), factor (such as skilled labor) and capital markets, and government policies and institutions that govern these market conditions.

In the context of less-developed countries, technological change is related to the extent of adoption and implementation of new technologies that are in use in the advanced countries (technology diffusion). That is, technological change largely consists of assimilating and adapting foreign technology. FDI can provide an access to advanced foreign technology, such as production technology, cutting edge of R&D, and management expert, while boosting market competition and generating spillovers and externalities to local firms in the host economy. Thus, we expect a positive direct effect of FDI on TFP growth.

Data on Total Factor Productivity

We construct TFP growth rates and exploit both their cross-country and panel dimensions for 92 developed and developing countries in the period of 1970-2000.[10] National income and

[10] The sample of countries is dictated by the availability of data, PWT 6.2 and international education data. Ninety two is the largest number of countries for which we can compute the TFP.

product account data and labor force data are obtained from the Penn World Table (PWT) version 6.2 of Heston et al. (2006). Taking a standard neoclassical approach, we assume a Cobb-Douglas production function,

$$Y = A(K)^{\alpha}(HL)^{1-\alpha}, \tag{2}$$

where $1-\alpha$ is labor income share.[11]

To construct the labor quality index for human capital (H), we take average years of schooling in the population over 15 years old from an international data on educational attainment of Barro-Lee (2000). We follow Hall and Jones (1999), and Klenow and Rodriguez-Clare (1997) to give larger weight to more-educated workers as follows:

$$H = e^{\phi(E)}, \tag{3}$$

where E is average years of schooling, and the function $\phi(E)$ is piece linear with slope of 0.134 for $E \leq 4$, 0.101 for $4 < E \leq 8$, and 0.068 for $8 < E$.[12] The rational behind this functional form for human capital is as follows. The wage of a worker with E years of education is proportional to his human capital. Since the wage-schooling relationship is widely believed to be log-linear, this would imply that human capital (H) and education (E) would have a log-linear relation as well, such as H=exp($const \cdot E$). However, international data on education-

[11] Growth accounting is consistent with a wide range of alternative production functional forms linking the factor inputs and output. It is only necessary to assume a degree of competition sufficient so that the earnings of the factors are proportionate to their factor productivity. Then we can measure TFP growth rates, using the shares of income paid to the factors to measure their importance in the production process (see Caselli 2005, Bosworth and Collins 2003, Hulten 2000 for details). Since consistent measures of factor income shares are often difficult to obtain for individual countries, most studies assume that income shares are identical across time and space. Gollin (2002) provides strong evidence in support of such an assumption of constant income shares across time and space. Bernanke and Gürkaynak (2001) also find no systematic tendency for labor shares to vary with real GDP per capita or the capital-labor ratio nor systematic tendency to rise or fall over time, and most estimated labor income shares lie between 0.6 and 0.8, the average being 0.65. In our paper, we tried both a fixed labor share of 0.65 and actual income shares from Gollin (2002) and Bernanke and Gürkaynak (2001). The results using alternative income share measures are very similar, suggesting that using a fixed labor income share is indeed not a serious problem. One advantage of using a fixed labor share is a large sample size (compared to only 50 countries that have actual shares available).

[12] To be precise, $\phi(E)=0.135 \cdot E$ if $E \leq 4$, $\phi(E)=0.135 \cdot 4 + 0.101 \cdot (E-4)$ if $4<E\leq 8$, $\phi(E)=0.135 \cdot 4 + 0.101 \cdot 4 + 0.068 \cdot (E-8)$ if $E>8$.

wage profiles (Psacharopulos 1994) suggests that in Sub-Saharan Africa (which has the lowest levels of education) the return to one extra year of education is about 13.4 percent, the world average is 10.1 percent, and the OECD average is 6.8 percent. Thus, Hall and Jones's specification above reconciles the log-linearity at a country level with the convexity across countries.[13] We also calculated the TFP growth using an alternative data on educational attainment from Cohen and Soto (2001).[14]

We estimate the capital stock, K, using the perpetual inventory method:

$$K_t = I_t + (1-\delta)K_{t-1}, \qquad (4)$$

where I_t is the investment and δ is the depreciation rate. Data on I_t are from PWT 6.2 as real aggregate investment in PPP.[15] We further adjust these capital stocks for the portion of residential capital stock that is not directly related to production activity.[16]

Two batteries of consistency checks suggest that our estimates of TFP growth are reasonable. First, the correlation coefficients between the TFP growth estimate based on Barro-Lee (2000) human capital data and TFP growth estimate based on Cohen and Soto (2001) human capital data is 0.98 for the 1970-2000 period. For our ten-year decade panel

[13] Also, we tried an alternative specification for human capital, assuming an average social return to education of 7% per year of schooling: $H=(1.07)^E$. Again, the results are very similar.

[14] Cohen and Soto (2001) construct a new data set on human capital for 95 countries at the beginning of each decade of the period 1960-2000. They try to improve upon Barro-Lee data (2000) by addressing some inconsistency in Barro-Lee data, and notably use age-specific data in the available census to construct estimates of educational attainment for each age-cohort in other years for which direct observations are missing. However, the regression results using Cohen-Soto data are similar to those using Barro-Lee data. Moreover, initial human capital variable (for example, average years of schooling of the total population aged 15 or over in 1970) is available only for 77 countries in our sample. Thus, we report regression results, using Barro-Lee data in order to maintain the largest number of observations possible.

[15] For many countries in our sample, investment data go back to as early as 1950-1955. We estimate the initial value of the capital stock, say, in year 1950 as $I_{1950}/(g+\delta)$ where g is the average compound growth rate between 1950 and 1960, and δ is the depreciation rate (δ=0.06 is assumed).

[16] PWT 5.6 provides data on residential capital per worker as a fraction of non-residential capital per worker for 63 countries. For these countries we use the average ratio of non-residential capital to total capital to impute the non-residential capital stock in our data set. For the remaining countries, we assume that non-residential capital is two-thirds of the total capital, which is about the average value of 0.69 for the countries for which we have data in our country sample.

data, the correlation between them is 0.97. Not surprisingly, the regression results are very similar, regardless of which human capital data we use to compute TFP. Thus, we mainly report regression results based on the largest sample in which we use Barro-Lee (2000). In our sample of 92 countries, Cohen and Soto (2001) have data points for 77 countries only. Second, the correlations between our TFP growth estimate and that from Bosworth and Collins (2003) are 0.89 (no. of obs.=78) for the 1970-2000 period, and 0.80 for the ten-year decade panel data.[17]

III. Foreign Direct Investment (FDI)

The Empirical Literature

Recently economists have begun to examine whether FDI, a factor largely ignored in the empirical growth literature, has an independent direct impact on per capita income growth (see Blonigen and Wang 2005, Melitz 2005, and Kose et al. 2006 for example). As noted earlier, there is no cross-country study that examines the effect on TFP growth of FDI yet.

Despite the straightforward theoretical implication for direct effect of FDI on per capita income growth, however, earlier empirical studies on FDI and income growth have failed to find statistically significant positive impact of FDI on income per capita growth. Instead, some of the studies, but not all, have reported the positive effect of FDI on income growth is only conditional on other factors such as human capital and financial development. That is, these studies argue that FDI boosts income growth only in economies that have the right

[17] Bosworth and Collins (2003) cover 84 countries, among which only 78 countries are also included in our sample of 92 countries. They also assume a labor share of 0.65 in estimating TFP growth. Aside from the fact that our data set is bigger, a notable difference is that their investment data are obtained from World Bank and updated by themselves, whereas our investment data are from PWT 6.2. Moreover, we adjust further for residential capital stock that is not directly related to production.

initial conditions (so-called absorptive capacity), such as human capital and financial market development. Borensztein et al. (1998) find that the coefficient of interaction term between FDI and human capital (proxied by average years of schooling in population) is significant in income growth regression, whereas the coefficient of FDI itself is not significant in a sample of 69 developing countries for the 1970-89 period. Similarly, Alfaro et al. (2004) on financial market development (proxied by private credit as a share of GDP) in 71 countries during 1975-95, and Balasubramanyan et al. (1996) on outward-looking trade policy (dummy variable) in 46 developing countries during 1970-85. On the other hand, Blonigen and Wang (2005) argue that inappropriate pooling of developed countries with developing countries is responsible for estimation of insignificant effects of FDI with respect to per capita GDP growth in some of the earlier studies.

In an analysis of the per capita income growth and FDI in a larger sample of 72 countries for a longer period of 1960-95, however, Carkovic and Levine (2005) conclude that after controlling for the joint determination of FDI and economic growth, FDI has no robust causal effect on growth. Moreover, they show that the lack of a significant positive impact of FDI on income growth does not depend on the measures of absorptive capability either. That is, unlike the aforementioned studies, they do not find robust evidence of absorptive capability hypothesis for various measures including human capital, financial market development and institutional quality.[18]

Data on FDI

[18] However, Melitz (2005) interprets their results as suggesting a positive association between FDI and growth, and argues that strong linkage between trade and FDI causes the positive link to vanish. Then he concludes that their results imply that an expansion of FDI flows accompanied by an increase in trade can enhance growth.

We consider three different measures of foreign direct investment (FDI).[19] The International Financial Statistics (IFS) published by the International Monetary Fund (IMF) is the standard data source of international capital flows including FDI. It provides the most comprehensive and comparable data on international capital flows. The main categories of capital inflows are FDI, portfolio equity investment, and debt inflows. The FDI categories include controlling stakes in acquired foreign firms and greenfield investments (construction of new production facilities).[20] Since we are interested in technology diffusion from foreign countries, we first consider FDI inflows to a country from abroad (as a share of the recipient country's GDP), which is denoted by "inward FDI (IMF)".

However, outward FDI as well as inward FDI may lead to a transfer of technology into the country. For example, the acquisition of a foreign firm (in advanced countries) can bring with it some knowledge or technology that cannot be obtained by simply buying the products of that foreign firm (Feenstra 1999). The World Development Indicators 2006 by World Bank reports annual data for gross FDI flow (sum of inward and outward FDI capital flows as a share of GDP), using IFS as the primary source data. Thus, we also consider gross FDI flow, which is denoted by "gross FDI (WB)".

Given our primary interest in investigating the technology diffusion from technology frontier nations, we can focus on the FDI flows from the industrial countries only. FDI taking place between countries with similar technological levels may reflect factors other than technological diffusion process, such as market penetration, circumventing trade restrictions, and offsetting other advantages given to domestic firms. If this is the case, we expect to find

[19] FDI is usually defined as an investment involving a long-term relationship and reflecting a lasting interest in and control by a resident entity in one economy (foreign direct investor or parent enterprise) of an enterprise resident in a different economy (FDI enterprise or affiliated enterprise or foreign affiliate).
[20] Once an FDI investment is established, all subsequent financial transactions between the parent and affiliate are classified under FDI, including intrafirm debt assets and liabilities.

stronger positive effects on TFP growth from FDI inflows from industrial countries to developing countries. The OECD International Development Statistics provides annual data on FDI from the OECD countries to developing countries. We compute the share of this FDI inflow as a share of GDP, which is denoted by "inward FDI from OECD".[21]

IV. Econometric Analysis of TFP Growth

Our baseline cross-country regression specification is as follows:

$$\text{TFPgrowth}_i = \text{constant} + \alpha\ln(\text{initial TFP relative to US})_i + \beta\ln(\text{human capital})_i + \gamma\ln(\text{population})_i + \lambda(\text{government share})_i + \delta(\text{FDI})_i + \phi X_i + \varepsilon_i, \quad (5)$$

where i denotes the country, and ε_i is an unobserved error term. TFP growth is the average TFP growth over the 1970-2000 period. First, we expect the catching-up process to occur in the TFP growth. Countries with a lower level of initial TFP will imitate more quickly than those with a higher initial level of TFP because these countries are farther away from the technology frontier, and hence the absorption of low technology will be relatively easier (Barro and Sala-i-Martin 2003).[22] The catching-up term, representing the distance from the technological frontier, is proxied by log of TFP in 1970 relative to the U.S. value (i.e.,

[21] Regarding the IFS capital flow data, the recent literature has drawn attention to the importance of valuation effects due to capital gains and losses, price and exchange rate fluctuations. For example, Lane and Milesi-Ferretti (2006) construct estimates of foreign assets and liabilities and their subcomponents for up to 145 countries in the period of 1970-2004. In order to estimate FDI stocks, the authors cumulate flows and adjust for the effects of exchange rate changes. For our purpose in this paper, however, this valuation effect may not be so important as in a study that examines a country's external position and the international financial adjustment. We tried the FDI inflow measure based on Lane and Milesi-Ferretti data (not shown). The results are statistically weaker in general, although the coefficients of the measure retain the correct sign (+).

[22] In a panel of 19 OECD countries at industry level in 1984-1998, Scarpetta et al. (2002) report such evidence.

$\ln(TFP_i/TFP_{US})$ in 1970).[23] When the initial TFP level is used instead of the initial per capita income, the catching-up term enters the regression with much stronger and statistically significant coefficients, and the goodness of fit (R^2) also improves.

We also include initial human capital and population size in the regression. Countries with an abundance of human capital and large country size (capturing potentially large market extents and aggregate scale effects) have a greater ability and incentive to engage in innovation activities (Grossman and Helpman 1991).[24] We proxy initial human capital by the log of average years of secondary schooling in the population over age 15 in 1970 from Barro and Lee (2000), and as a proxy for country size the log of initial population in 1970 from PWT 6.2. Inclusion of country size has multi-purposes. It is originally intended to capture the potential market extents or aggregate scale effects that provide an incentive for innovation or adoption of better technologies. But recent studies have shown there are some interactions among country size, trade openness, and government size. For instance, Alesina and Wacziarg (1998) find that the country size determines the degree of trade openness and the size of government. We also control for the initial government size measured by government consumption share of GDP in 1970, taken from PWT 6.2. Sala-i-Martin et al. (2004) use Bayesian averaging of classical regression estimates to identify economic variables: initial income per capita, initial level of human capital, and initial government size, for which the posterior inclusion probability increases relative to the prior. We expect the initial government size to enter the regression with a negative coefficient. Finally, X_i

[23] With data on output, capital, human capital and labor force, we can calculate the level of TFP (A) directly from the production function: $y = A\left(\frac{K}{L}\right)^{\alpha} H^{1-\alpha}$, where y=Y/L is output per worker.

[24] Endogenous growth theory typically predicts that population size (scale effect) or population growth is positively related to technological progress and hence economic growth. See Jones (1999) for a comparison of variants of endogenous growth theory.

represents other variables which we specify later.[25] Because heteroskedasticity may be more important in a cross-country sample, the standard errors of the coefficients are based on White heteroskedasticity-consistent covariance matrix, which reduces the sensitivity of inference and hypothesis test using OLS estimator to general form of heteroskedasticity. As a more complete way of robustness check, we also present the robust estimation and fixed-effects panel regression results later.

Table 1 shows the OLS results. The estimated coefficients of the initial TFP level are significant at the 1 percent level, and have the expected sign (—). In fact, the initial TFP level is strongly negatively correlated with TFP growth in subsequent years even when TFP growth is regressed on the initial TFP level only (not reported to save space), which indicates unconditional convergence in contrast to the case of per capita income growth that only exhibits conditional convergence. Human capital enters regressions with positive coefficients that are significant at the 1-5 percent level. However, the coefficients of initial population are largely insignificant, although they have the expected positive sign (+). The coefficients of initial government share are largely insignificant at the conventional level, while having the expected negative sign (—).

Columns (2)-(4) include Gross FDI (WB). The coefficient of gross FDI is significant at the 10 percent level (except column 4 in which it becomes insignificant) and of the expected sign (+). In columns (3) and (4), we also add a measure of institutional constraints facing policymakers as a proxy for institutional quality (executive constraints). The indicator refers to the extent of institutionalized constraints on the decision-making power of chief executives, which is from Polity IV data of Marshall and Jaggers (2003). Common measures of

[25] We consider a small "core set" of variables that have been identified as having significant explanatory power in the growth regression. The sensitivity of OLS coefficients of growth regressors to inclusion of other conditioning variables is now well-known (see Durlauf et al. 2005 and references therein).

institutions used in the empirical growth literature are mostly based on subjective assessments of risk for international investors along such dimensions as law and order, bureaucratic quality, corruption, risk of expropriation by the government, and risk of government contract repudiation, which tend to rise with per capita income, rather than on durable institutional constraints on government. Thus, Glaeser et al. (2004) argue that a measure of constraints on the executives is probably the best of the available measures of the institutional quality, although even these seem to be based on political outcomes (see Glaeser et al. 2004 for more details).[26] The coefficients of executive constraints are significant at the 10 percent, and of the positive sign (+). Finally, column (4) adds regional dummy variables for Latin America and the Caribbean, and sub-Saharan Africa. Regional dummies are intended to control for structural characteristics related to geographical location. Reflecting the economic stagnation or slow growth of these two developing regions during the past decades, the coefficients are both negative, and that of Latin America is significant at the 5 percent.

The next columns (5)-(7) show the regression results using inward FDI flows from IFS data (see Figure 1 for a scatter plot). Its estimated coefficients are all significant at the 5-10 percent, and again of the expected positive sign. Overall, the initial level of TFP and initial human capital are statistically strongly associated with TFP growth, and the institutional quality proxied by executive constraints is positively associated with TFP growth at various significance levels. The coefficients of initial population and initial government size are all of their expected signs, and occasionally significant at the conventional level.

[26] Nonetheless, this executive constraint measure is highly correlated with the aforementioned subjective measures, such as expropriation risk or corruption. For example, the correlation between executive constraint indicator and expropriation risk from ICRG (inter-country risk guide)—which is a popular measure in growth literature—is 0.72.

Columns (8)-(12) re-run the same regressions using the developing country sample only. Blonigen and Wang (2005) examine the question of whether less-developed countries' experiences with FDI are systematically different from those of developed countries. They find the significant effect of FDI on economic growth only for developing countries in the aggregate data, but not for developed countries for the period of 1970-1989. Thus, they conclude that inappropriate pooling of developed countries with developing countries is responsible for estimation of insignificant effects of FDI with respect to per capita GDP growth in some of the earlier studies. Unlike the case of per capita income growth, we already found significant effects of FDI on the TFP growth in the entire sample of developed and developing countries. Yet we still want to see whether the positive effect on TFP growth of FDI is stronger in the developing country sample. Columns (8)-(12) show that the magnitude and statistical significance of estimated effects from FDI are largely similar to those in the entire sample.

Finally, the remaining columns (10)-(12) show the regression results using Inward FDI from OECD (see Figure 2 for a scatter plot). The estimated coefficients are all significant at the 5 percent, and the magnitude of its positive effect on TFP growth is about 3.2 times as large as that of the entire inward FDI based on the measure of Inward FDI (IMF).

In Table 2, we show the regression results using data averaged over ten years during the 1970-2000 period-that is, three observations (1970-80, 1980-90, 1990-2000) for each country if data permit. Although there is no consensus on frequency of the data, we do not expect annual flows (or one year-lagged values) to have a discernible effect on the year's growth rate. By considering the FDI flows aggregated over the 10-year period, we still focus on the long-term relationship between FDI and TFP growth and take advantage of more data points.

The regression includes initial TFP level, years of secondary schooling, population, and government size that are all measured in the first year of each decade. Additionally, we include decade dummies (Dum70, Dum80, Dum90), and regional dummies for Latin America and the Caribbean and sub-Saharan Africa.

The results are largely the same as those from the cross-country regression in Table 1. First of all, the FDI measures remain statistically significant at various significance levels. The estimated coefficients of FDI tend to be slightly bigger than in the case of cross-country regression. The initial TFP and initial human capital are strongly associated with TFP growth. Now the coefficients of initial government size are all significant at the 1-10 percent for different measures of FDI and different samples (full and developing countries only). But the coefficients of executive constraints are mostly insignificant.

To get an idea about the magnitude of inward FDI effect on TFP growth, we can compare Ireland with Korea using column (3). In 1970-2000, Ireland received FDI at an average 3.52 percent of GDP per year (ranked 7th out of 90 countries in our sample), compared to Korea's meager 0.45 percent of GDP per year (ranked 73rd). If Korea had attracted inward FDI up to the Irish level, the estimated coefficient suggests that it would have added an extra growth rate of 0.63, other things being equal. During the same period, the TFP growth rate in Korea was 0.93 percent per year, whereas it was 2.06 percent in Ireland.

FDI and Absorptive Capacity of the Recipient Country

Next we further examine whether the contribution of FDI to TFP growth becomes particularly stronger depending on certain aspects of "absorptive capacity" of the recipient country, such as human capital, developed financial markets, and quality institutions.

Following the previous studies on FDI and absorptive capacity, we introduce an interaction term with the FDI indicator for each of the absorptive capacity indicators: human capital (measured by log of years of secondary schooling in population of age 15 and above, as in Borensztein et al. 1998), financial development (proxied by private credit as percent of GDP, as in Alfaro et al. 2004, which is taken from financial structure data, 2007 update of Beck et al. 2000), and institutional quality (as proxied by executive constraints).

Table 3 shows the regression results. It is quite striking to see that none of the interaction terms between FDI measures and indicators of absorptive capacity are significant at the conventional level! A couple of these interaction terms even take the wrong sign (—). Regarding the human capital case, FDI measures and human capital continue to be individually significant for both entire and developing country samples. As for the financial development, even individual terms of FDI and private credit are insignificant (except for the private credit term in the case of inward FDI from OECD).[27] Much the same result is obtained for the case of institution quality.

V. Robustness Checks

In this section, we further address the robustness and consistency of the results in terms of reversed causality, outliers and unobserved omitted variables. As the empirical growth literature has explosively grown, some shortcomings of growth regressions have become apparent (see Durlauf et al. 2005 for a critical survey). A dominant concern has been the robustness. Many growth studies have regressed output growth on a vast array of potential

[27] We also tried another measure of financial depth, LLY (liquid liabilities as a share of GDP), which has been found to be important in the growth regression. But it yields the same result – the interaction term between LLY and FDI remains insignificant.

determinants. But this approach has been called into question, largely because the resulting parameter estimates are often sensitive to other conditional variables. Recent studies such as Bosworth and Collins (2003) suggest that we focus on a core set of explanatory variables that have been shown to be consistently associated with growth and evaluate the importance of other variables conditional on inclusion of the core set. That is why we have focused on a "core set" of TFP growth determinants that are mostly initial conditions.[28]

Reversed Causality

One might be concerned with reversed causality that rapidly growing economy may induce direct investment from abroad. Although we have focused on a small core set of growth determinants that are mostly initial conditions which can be viewed as predetermined, FDI flows are measured during the same time period in which the dependent variable, TFP growth, is measured. In order to address the potential reversed causality from TFP growth to FDI, we re-estimate the regression using the one-decade lagged values of FDI flows.

Table 4 displays the regression results. Since one-decade lagged values are used, there are two observations (1980-90, 1990-2000) for each country, if data permit. Overall, the results are very similar to those reported in Table 2. The lagged values of FDI (except inward FDI from OECD) enter the regression with significant coefficients. Interestingly, the estimated coefficients of executive constraint term are all significant at the 1-5 percent.

The results suggest that the FDI flows tend to have long-term positive effects on the TFP growth (possibly even with time lags). Not only adding more capital to the host economy, FDI can bring new kinds of activities such as new production methods and managerial

[28] However, it is very difficult to establish a causal relationship between FDI and TFP growth either conceptually and empirically, as the empirical growth literature shows (see Kose et al. 2006 on the difficulty in establishing a causality between financial globalization and growth, for example).

expertise already in use in foreign countries, changing the production possibility frontier, boosting market competition and generating spillovers and externalities to local firms in the host economy. It would be not hard to think that these types of benefits can be realized only in a long-term period.

Robust Regression Estimation

Next, we check the robustness of our results in terms of the observations by using a robust estimation method. The OLS estimates tend to be sensitive to outliers, either observations with unusually large errors or influential observations with unusual values of explanatory variables (often called leverage points). In a recent evaluation of growth regressions in relation to policy variables, Easterly (2005) argues that some of the large effects of a policy variable(s) are often caused by outliers. Thus, it is important to make sure that some of our results are not unduly driven by outlier observations. One of the most common ways to deal with outliers is to drop observations one at a time or to use single-case diagnostics such as Cook's distance measure, the studentized residual, or DFIT. But this is often inadequate because it may miss a group of outliers due to the masking effect.

Instead, we employ robust estimation to obtain estimates that are not sensitive to outliers, and hence to characterize the most coherent part of the data set. This estimation involves a reweighted least squares (RWLS) procedure. We first use the least median of squares (LMS) estimator due to Rousseeuw and Leroy (1987), which is given by

$$\underset{\hat{\beta}}{Minimize}\ \underset{i}{Median}\ \hat{\varepsilon}_i^2 \qquad (6)$$

where $\hat{\varepsilon}_i$ is the residual of the ith observation with respect to the LMS fit. This LMS estimator, typically computed by approximate algorithms, can resist the effect of nearly 50%

of contamination in the data. A disadvantage of the LMS method is its lack of efficiency because of its unusually slow convergence, making it unsuitable for inference. To deal with this problem, we use the LMS estimates to identify outliers, and then carry out a simple reweighted least squares (RWLS) procedure by assigning zero weight to outliers and full weight to the rest of the observations, as recommended by Rousseeuw and Leroy (1987).[29]

Table 5 displays the robust estimation results. They are largely similar to the OLS results. But it is remarkable that statistical significance of the estimated coefficients of FDI measures rises further (except for inward FDI from OECD which is significant at the 10 percent). In addition, the initial level of TFP and years of schooling remain to be significant at the 1-10 percent. Also, the coefficients of government share of GDP are mostly negatively significantly associated with the TFP growth. But the coefficients of executive constraints are largely insignificant. To sum up, controlling for outliers tend to produce stronger results regarding positive effects of inward FDI on TFP growth.

Fixed-Effect Panel Regression and Time-Invariant Country Specific Omitted Variables

Finally, we try to control for unobservable country-specific omitted variables by using the fixed-effects (within) panel regression. The unobservable country-specific aspect (say, of technology, resource endowments or institutions) may be correlated with the included explanatory variables, and this would create omitted variables bias. Of course, other variables

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[29] A weight for each observation is as follows: $w_i = \begin{cases} 1 & if \;\; \hat{\varepsilon}_i^2 \le (2.5\hat{\sigma})^2 \\ 0 & otherwise, \end{cases}$

where the robust standard error, $\hat{\sigma}$, is given (after running the LMS) by $\hat{\sigma} = 1.4826[1 + 5/(n-k)]\sqrt{\underset{i}{median}\ \hat{\varepsilon}_i^2}$; $\hat{\varepsilon}_i$ is the residual of the *i*th observation with respect to the LMS result; n = number of observations; and k = number of explanatory variables.

on the right-hand side of the regressions that we consider are intended to account for the differences in those underlying factors across countries. Yet differences in such factors may still have dimensions that are not directly measurable or observable. The fixed-effects model allows for the potential correlation and still obtains a consistent estimator (under the standard assumption).[30]

The results are broadly in line with the OLS and robust regression outcomes. The coefficients of initial TFP, human capital, and initial government share of GDP are mostly significant at the conventional level. The coefficients of initial population are now statistically significant at the 1 percent level, but of the negative sign. However, executive constraint term is rather imprecisely estimated and often wrongly signed.

As we noted earlier, the estimated relationship between FDI and TFP growth tend to become more stronger once the outliers are removed. This is largely true of the fixed-effects panel regression results. In the second and fourth columns, we run fixed-effects panel regressions after removing the outliers that were identified by the LMS as in Table 5. Again, controlling for the outliers tends to yield stronger results. However, the coefficients of inward FDI from the OECD remain insignificant.

VI. Concluding Remarks

We have examined the question of whether and how technology diffusion process through FDI affects TFP growth for the period of 1970-2000, using new estimates of TFP based on the latest Penn World Table 6.2 (2006) and employing various estimation methods. Our

[30] Hausman (1978) test strongly rejects the hypothesis of no correlation between the unobserved country-specific effect and the explanatory variables at the 1 percent level (p-value=0.0000), favoring the fixed-effects model over the random-effects model.

results indicate that FDI has a statistically significant and positive effect on TFP growth. Various estimation methods and robustness check yield largely the same result. This is consistent with endogenous growth theory that emphasizes technology diffusion through assimilating and adapting foreign technology as an important source of technological change in a (less-developed) country. FDI has long been considered a major vehicle of technology diffusion from advanced countries to less-developed countries. Our result sharply contrasts with the empirical studies that failed to find a significant direct impact of FDI on per capita income growth as well as the studies of financial integration on economic growth that often yielded ambiguous results.

Interestingly, we do not find any significant evidence for the absorptive capability hypothesis that FDI can boost growth *only* when a country has a certain level of initial conditions such human capital and financial development. Technology diffusion process through FDI flows seems to affect TFP and per capita income growth differently. Given that TFP reflects technological change, this contrasting result may not be so surprising. Yet more work on this would be needed in the future.

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Table 1. Cross-Country Regression of TFP Growth and FDI

Dependent Variable: TFP growth rate (in percent) in 1970-2000[a b]

Explanatory Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Full sample	Full sample	Full sample	Full sample	Full sample	Full sample	Full sample	Developing countries	Developing countries	Developing countries	Developing countries	Developing countries
Log of initial TFP	-1.541*	-1.474*	-1.525*	-1.548*	-1.444*	-1.451*	-1.453*	-1.492*	-1.471*	-1.537*	-1.559*	-1.54*
relative to US	(0.227)	(0.224)	(0.214)	(0.204)	(0.229)	(0.226)	(0.209)	(0.236)	(0.24)	(0.243)	(0.242)	(0.243)
Log of initial years	0.643*	0.586*	0.379*	0.331**	0.580*	0.373*	0.321**	0.401**	0.403**	0.52*	0.478*	0.428**
of schooling	(0.103)	(0.105)	(0.118)	(0.135)	(0.104)	(0.114)	(0.132)	(0.172)	(0.169)	(0.133)	(0.149)	(0.175)
Log of initial	0.087	0.103	0.172***	0.095	0.113	0.193**	0.122	0.111	0.108	0.153***	0.146	0.063
population	(0.071)	(0.075)	(0.093)	(0.091)	(0.079)	(0.095)	(0.088)	(0.116)	(0.112)	(0.088)	(0.093)	(0.095)
Initial government	-0.019	-0.018	-0.013	-0.017	-0.019	-0.012	-0.017	-0.020	-0.02	-0.008	-0.007	-0.015
consumption	(0.012)	(0.012)	(0.011)	(0.012)	(0.012)	(0.011)	(0.011)	(0.013)	(0.013)	(0.013)	(0.012)	(0.014)
Gross FDI (WB)		2.734***	10.931***	8.433				12.198**				
		(1.449)	(5.619)	(5.398)				(5.267)				
Inward FDI (IMF)					5.72***	16.622**	15.217**		14.744**			
					(3.029)	(7.172)	(6.017)		(6.047)			
Inward FDI from										53.336*	53.192**	46.925**
OECD countries										(18.837)	(20.617)	(20.927)
Executive			0.133***	0.1202***		0.156**	0.140**	0.152***	0.149***		0.078	0.107
Constraints			(0.073)	(0.070)		(0.071)	(0.068)	(0.089)	(0.087)		(0.082)	(0.082)
Latin America				-0.482**			-0.541**	-0.64***	-0.628***			-0.629***
				(0.235)			(0.226)	(0.352)	(0.354)			(0.353)
Sub-Saharan				-0.490			-0.451	-0.418	-0.413			-0.569***
Africa				(0.349)			(0.347)	(0.337)	(0.334)			(0.334)
No. Obs.	82	81	78	78	80	77	77	58	58	60	58	58
Adj. R^2	0.47	0.48	0.52	0.53	0.48	0.52	0.54	0.54	0.54	0.55	0.53	0.55

Note: Levels of significance are indicated by asterisks: * 1 percent, ** 5 percent, *** 10 percent. White heteroskedasticity-consistent standard errors are reported in parentheses. An intercept term is included in each regression, but not reported to save space. See data appendix for definitions and sources of variables.

a. TFP growth rates (compound average) are computed based on the Penn World Table 6.2 (2006) and human capital data from Barro-Lee (2000).

b. The OLS regressions use one observation for each country with data over the 1970-2000 period.

Table 2. Regression of TFP Growth and FDI

Dependent Variable: TFP growth rate (decadal average, percent)[a b]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Explanatory Variables	**Full sample**	**Full sample**	**Full sample**	**Developing countries**	**Developing countries**	**Developing countries**	**Developing countries**
Log of initial TFP level relative to US	-1.644*	-1.77*	-1.657*	-1.73*	-1.849*	-1.799*	-1.846*
	(0.269)	(0.274)	(0.274)	(0.309)	(0.313)	(0.317)	(0.331)
Log of initial years of schooling	0.445*	0.468*	0.484*	0.556*	0.551*	0.546*	0.482**
	(0.168)	(0.156)	(0.152)	(0.185)	(0.182)	(0.177)	(0.192)
Log of initial population	-0.058	0.077	0.098	-0.085	0.078	0.081	-0.071
	(0.087)	(0.089)	(0.088)	(0.107)	(0.112)	(0.107)	(0.109)
Initial government consumption	-0.029**	-0.027**	-0.028**	-0.032**	-0.028**	-0.029**	-0.025***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.013)
Gross FDI (WB)		10.992**			12.096***		
		(4.625)			(6.628)		
Inward FDI (IMF)			20.598*			20.318*	
			(6.151)			(6.859)	
Inward FDI from OECD							43.354**
							(19.35)
Executive Constraints	0.118	0.0801	0.084	0.146***	0.092	0.090	0.13
	(0.073)	(0.062)	(0.062)	(0.085)	(0.074)	(0.073)	(0.090)
Latin America	-0.746*	-0.546**	-0.624**	-0.851**	-0.566***	-0.583***	-0.738**
	(0.282)	(0.276)	(0.268)	(0.340)	(0.34)	(0.331)	(0.354)
Sub-Saharan Africa	-0.934**	-0.576	-0.479	-0.893***	-0.498	-0.431	-1.011**
	(0.438)	(0.416)	(0.419)	(0.457)	(0.442)	(0.445)	(0.497)
Dum70	0.400	-0.999	-1.169	0.842	-0.925	-0.95	0.305
	(0.925)	(0.971)	(0.973)	(1.106)	(1.219)	(1.174)	(1.179)
Dum80	0.001	-1.505	-1.669***	0.163	-1.707	-1.703	-0.268
	(0.954)	(1.005)	(0.996)	(1.134)	(1.251)	(1.194)	(1.203)
Dum90	0.289	-1.388	-1.581	0.401	-1.525	-1.604	-0.193
	(0.993)	(1.094)	(1.079)	(1.170)	(1.335)	(1.278)	(1.277)
No. Obs.	257	244	242	195	184	184	187
Adj. R^2	0.22	0.27	0.28	0.22	0.26	0.28	0.24

Note: Levels of significance are indicated by asterisks: * 1 percent, ** 5 percent, *** 10 percent. Heteroskedastic-panel-corrected standard errors are reported in parentheses. See data appendix for definitions and sources of variables.

a. TFP growth rates are computed based on the Penn World Table 6.2 (2006) and human capital data from Barro-Lee (2000).

b. A pooled regression is employed, which uses data averaged over ten-year periods during 1970-2000. Thus, data permitting, there are three observations (1970-80, 1980-90, 1990-2000) for each country.

Table 3. Regression of TFP Growth: FDI and Initial Conditions

Dependent Variable: TFP growth rate (decadal average, percent)[a b]

FDI measures	Full Sample			Developing countries		
	FDI	FDI*Initial School	Initial School	FDI	FDI*Initial School	Initial School
Gross FDI (WB)	10.407*** (5.518)	1.566 (5.014)	0.444* (0.172)	12.353*** (6.635)	5.248 (7.076)	0.477** (0.211)
Inward FDI (IMF)	20.559* (5.141)	8.933 (6.045)	0.397** (0.165)	22.031* (5.453)	11.51 (6.996)	0.429** (0.197)
Inward FDI from OECD				41.865** (19.312)	9.594 (19.178)	0.446** (0.220)

FDI measures	Full Sample			Developing countries		
	FDI	FDI*Private Credit	Private Credit	FDI	FDI*Private Credit	Private Credit
Gross FDI (WB)	11.097 (9.89)	-3.296 (9.845)	0.518 (0.556)	4.119 (12.284)	6.772 (13.535)	1.076 (0.881)
Inward FDI (IMF)	12.984 (10.596)	10.031 (12.421)	0.292 (0.472)	10.059 (11.194)	11.899 (14.933)	0.766 (0.834)
Inward FDI from OECD				40.092 (42.770)	-10.646 (49.809)	1.606*** (0.954)

FDI measures	Full Sample			Developing countries		
	FDI	FDI*Executive Constraints	Executive Constraints	FDI	FDI*Executive Constraints	Executive Constraints
Gross FDI (WB)	14.753***(8.493)	-0.73 (1.6)	0.093 (0.070)	12.720 (14.236)	-0.155 (4.226)	0.094 (0.1)
Inward FDI (IMF)	16.401 (12.937)	0.96 (3.001)	0.073 (0.075)	16.261 (16.307)	1.005 (4.233)	0.079 (0.09)
Inward FDI from OECD				63.462*** (37.656)	-4.433 (9.79)	0.148 (0.101)

Note: Levels of significance are indicated by asterisks: * 1 percent, ** 5 percent, *** 10 percent. Heteroskedastic-panel-corrected standard errors are reported in parentheses. See data appendix for definitions and sources of variables.

a. TFP growth rates are computed based on the Penn World Table 6.2 (2006) and the human capital dataset from Barro-Lee (2000).

b. A pooled regression is employed, which uses data averaged over ten-year periods during 1970-2000. Thus, data permitting, there are three observations (1970-80, 1980-90, 1990-2000) for each country. The regression also includes log of initial TFP relative to USA level, log of initial years of schooling, log of initial population, initial government consumption share of output, executive constraints, regional dummies (Latin America, sub-Saharan Africa), decade dummies (1970s, 1980s, 1990s), but they are not reported to save space. The table summarizes the findings from 15 separate regressions.

Table 4. Regressions with Lagged Values of FDI Measures: Check on Reversed Causality

Dependent Variable: TFP growth rate (decadal average, percent)[a b]

	(1)	(2)	(3)	(4)	(5)
Explanatory Variables	**Full sample**	**Full sample**	**Developing countries**	**Developing countries**	**Developing countries**
Log of initial TFP relative to US	-1.773*	-1.775*	-1.827*	-1.915*	-2.066*
	(0.351)	(0.356)	(0.394)	(0.417)	(0.436)
Log of initial years of schooling	0.363***	0.4**	0.374***	0.377***	0.383
	(0.192)	(0.188)	(0.226)	(0.22)	(0.253)
Log of initial population	0.041	0.081	0.048	0.090	-0.095
	(0.101)	(0.104)	(0.122)	(0.124)	(0.128)
Initial government consumption	-0.03**	-0.028***	-0.032**	-0.029***	-0.036**
	(0.015)	(0.015)	(0.016)	(0.016)	(0.015)
Lagged Gross FDI (WB)	10.623***		12.760**		
	(5.908)		(5.841)		
Lagged Inward FDI (IMF)		26.048**		32.668*	
		(11.151)		(12.491)	
Lagged Inward FDI from OECD					7.454
					(23.162)
Executive constraints	0.201**	0.222*	0.192**	0.204**	0.264**
	(0.078)	(0.077)	(0.091)	(0.086)	(0.122)
Latin America	-1.122*	-1.056*	-1.104*	-0.921**	-1.390*
	(0.312)	(0.319)	(0.382)	(0.398)	(0.430)
Sub-Saharan Africa	-0.818**	-0.57	-0.849***	-0.586	-1.316**
	(0.452)	(0.451)	(0.479)	(0.479)	(0.619)
Dum80	-1.524	-2.190	-1.621	-2.433	-0.119
	(1.177)	(1.337)	(1.37)	(1.539)	(1.443)
Dum90	-1.157	-1.841	-1.168	-2.017	0.038
	(1.254)	(1.431)	(1.45)	(1.640)	(1.503)
No. of Observations	165	164	125	125	129
Adj. R^2	0.32	0.33	0.30	0.32	0.26

Note: Levels of significance are indicated by asterisks: * 1 percent, ** 5 percent, *** 10 percent.
Heteroskedastic-panel-corrected standard errors are reported in parentheses.
See data appendix for definitions and sources of variables.
a. TFP growth rates are computed based on the Penn World Table 6.2 (2006) and the human capital dataset from Barro-Lee (2000).
b. A pooled regression is employed, which uses data averaged over ten-year periods during 1980-2000.
Thus, data permitting, there are two observations (1980-90, 1990-2000) for each country.

Table 5. Robust Estimation: FDI and TFP Growth

Dependent Variable: TFP growth rate (decadal average, percent)[a b]

	(1)	(2)	(3)	(4)	(5)
Explanatory Variables	**Full sample**	**Full sample**	**Developing countries**	**Developing countries**	**Developing countries**
Log of initial TFP level relative to US	-1.831*	-1.382*	-1.766*	-1.417*	-1.749*
	(0.242)	(0.254)	(0.304)	(0.288)	(0.318)
Log of initial years of schooling	0.343*	0.293**	0.388**	0.635*	0.574*
	(0.13)	(0.14)	(0.154)	(0.173)	(0.177)
Log of initial population	0.174**	0.043	-0.197**	0.084	-0.127
	(0.078)	(0.082)	(0.097)	(0.106)	(0.100)
Initial government consumption	-0.031*	-0.024**	-0.047*	-0.039*	-0.036*
	(0.011)	(0.011)	(0.010)	(0.011)	(0.012)
Gross FDI (WB)	15.375*		10.808**		
	(3.249)		(4.703)		
Inward FDI (IMF)		18.297*		19.121*	
		(5.972)		(5.997)	
Inward FDI from OECD					31.145***
					(16.939)
Executive Constraints	-0.027	0.027	0.164*	0.072	0.087
	(0.058)	(0.056)	(0.062)	(0.066)	(0.072)
No. outliers	19	13	11	7	6
No. Obs.	225	229	173	177	181
Adj. R^2	0.39	0.32	0.35	0.32	0.32

Note: Levels of significance are indicated by asterisks: * 1 percent, ** 5 percent, *** 10 percent. Heteroskedastic-panel-corrected standard errors are reported in parentheses. See data appendix for definitions and sources of variables.

a. TFP growth rates are computed based on the Penn World Table 6.2 (2006) and the human capital dataset from Barro-Lee (2000). A pooled regression is employed, which uses data averaged over ten-year periods during 1970-2000. Thus, data permitting, there are three observations (1970-80, 1980-90, 1990-2000) for each country. Each regression includes regional dummies (Latin America, sub-Saharan Africa) and decade dummies (1970s, 1980s, 1990s), but they are not reported to save space.

b. A reweighted least squares (RWLS) procedure was used to obtain the robust estimates. The least median of squares (LMS) was first used to detect outliers, and then weighted least squares (WLS) was performed, assigning a weight for each observation as follows: $w_i = \begin{cases} 1 & if \;\; \hat{\varepsilon}_i^2 \le (2.5\hat{\sigma})^2 \\ 0 & otherwise, \end{cases}$

where the robust standard error, $\hat{\sigma}$, is given (after running the LMS) by $\hat{\sigma} = 1.4826[1 + 5/(n-k)]\sqrt{\underset{i}{median}\ \hat{\varepsilon}_i^2}$; $\hat{\varepsilon}_i$ is the residual of the *i*th observation with respect to the LMS result; n = number of observations; and k = number of explanatory variables.

Table 6. Fixed-Effects Panel Regressions: FDI and TFP Growth

Dependent Variable: TFP growth rate (decadal average, percent)[a b]

Regression	Variables	Full Sample		Full Sample		Developing Countries		Developing Countries	
		No control for outliers		Control for outliers based on Robust Estimation[c]		No control for outliers		Control for outliers based on Robust Estimation	
		Coefficient		Coefficient		Coefficient		Coefficient	
(1)	Gross FDI (WB)	9.785***	No. obs=244	14.253*	No. obs=225	11.688	No. obs=184	11.544**	No. obs=173
		(5.200)	R^2=0.48	(4.714)	R^2=0.45	(7.805)	R^2=0.50	(4.842)	R^2=0.54
(2)	Inward FDI (IMF)	15.225**	No. obs=242	18.882*	No. obs=229	11.826***	No. obs=184	13.664**	No. obs=177
		(6.297)	R^2=0.49	(6.791)	R^2=0.45	(6.904)	R^2=0.49	(6.342)	R^2=0.48
(3)	Inward FDI from OECD					3.039	No. obs=187	-3.425	No. obs=181
						(30.238)	R^2=0.35	(30.103)	R^2=0.45

Note: Levels of significance are indicated by asterisks: * 1 percent, ** 5 percent, *** 10 percent. Heteroskedastic-consistent standard errors are reported in parentheses. See data appendix for definitions and sources of variables.

a. TFP growth rates are computed based on the Penn World Table 6.2 (2006) and the human capital dataset from Barro-Lee (2000).

b. Fixed-effects (within) panel regression is employed, which uses data averaged over ten-year in the 1970-2000 period, so data permitting there are three observations for each country (1970-80, 1980-80, 1990-2000). Initial TFP level, years of schooling, population, government share, executive constraints, decade dummies are included in each regression, but not reported to save space. Hausman (1978) test rejects the hypothesis of no correlation between the unobserved (fixed) country-specific effect and the explanatory variables (at the 1 percent level (p-value=0.0000)), favoring the fixed-effects regression model over the random-effects regression model.

c. Fixed-effects (within) panel regression is employed after removing the outliers that were identified by the least median of squares (LMS), as reported in Table 5.

Figure 1. Scatter Plot between Inward FDI (IMF) and TFP growth 1970-2000

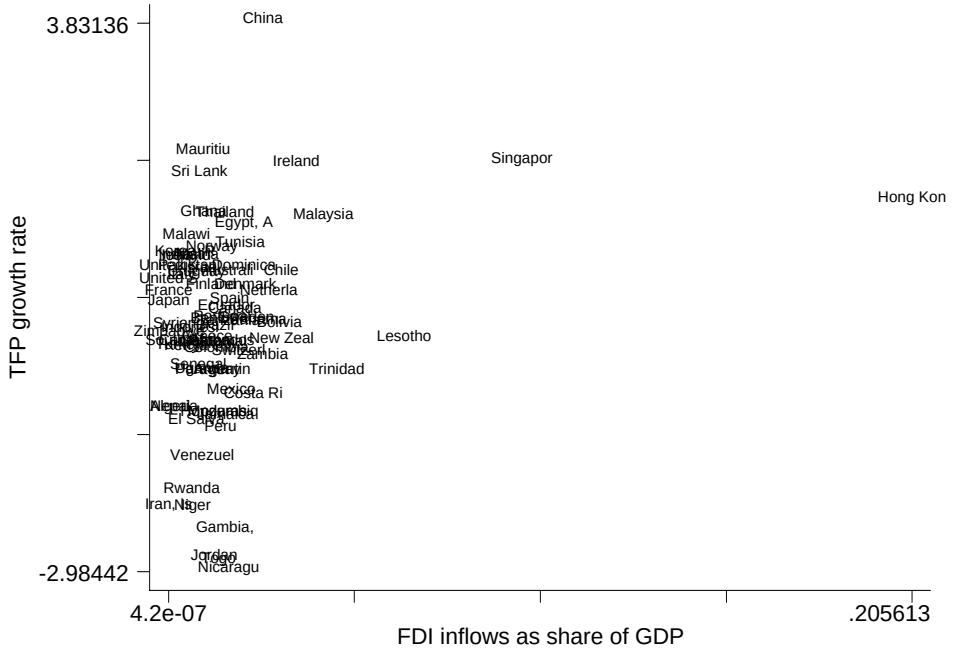
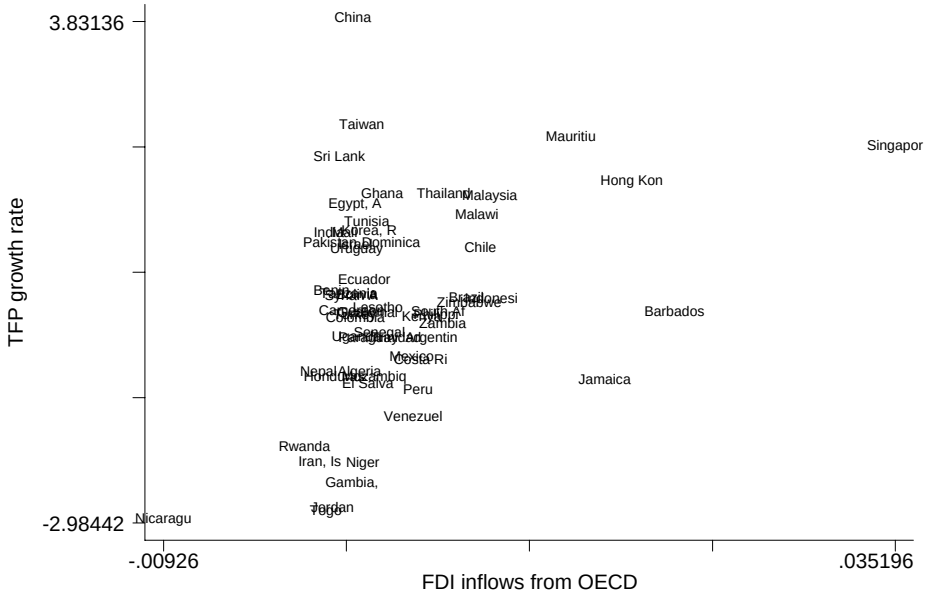


Figure 2. Scatter Plot between Inward FDI from OECD and TFP growth 1970-2000



Appendix Table 1. List of 92 Countries in the Sample

The sample of countries is dictated by the availability of data in Penn World Table 6.2 (2006) and international data on educational attainment, which would be needed to compute TFP (total factor productivity). The classification of countries in terms of developed and developing country group follows the convention in the literature. In particular, the developed country group includes 22 traditional OECD member countries, which excludes Korea and Mexico.

22 Developed Countries (traditional OECD member nations)

	Country		Country		Country
1	Australia	9	Greece	17	Portugal
2	Austria	10	Iceland	18	Spain
3	Belgium	11	Ireland	19	Sweden
4	Canada	12	Italy	20	Switzerland
5	Denmark	13	Japan	21	United Kingdom
6	Finland	14	Netherlands	22	United States
7	France	15	New Zealand		
8	Germany	16	Norway		

70 Developing countries

	Country		Country		Country
1	Algeria	25	Guinea-Bissau	49	Paraguay
2	Argentina	26	Honduras	50	Peru
3	Bangladesh	27	Hong Kong	51	Philippines
4	Barbados	28	India	52	Rwanda
5	Benin	29	Indonesia	53	Senegal
6	Bolivia	30	Iran	54	Sierra Leone
7	Botswana	31	Israel	55	Singapore
8	Brazil	32	Jamaica	56	South Africa
9	Cameroon	33	Jordan	57	Sri Lanka
10	Central African Republic	34	Kenya	58	Syria
11	Chile	35	Korea, Republic of	59	Taiwan
12	China	36	Lesotho	60	Tanzania
13	Colombia	37	Malawi	61	Thailand
14	Congo, Dem. Rep.	38	Malaysia	62	Togo
15	Costa Rica	39	Mali	63	Trinidad &Tobago
16	Cyprus	40	Mauritius	64	Tunisia
17	Dominican Republic	41	Mexico	65	Turkey
18	Ecuador	42	Mozambique	66	Uganda
19	Egypt	43	Nepal	67	Uruguay
20	El Salvador	44	Nicaragua	68	Venezuela
21	Fiji	45	Niger	69	Zambia
22	Gambia, The	46	Pakistan	70	Zimbabwe
23	Ghana	47	Panama		
24	Guatemala	48	Papua New Guinea		

Appendix Table 2. TFP Growth Rates (per annum) for 1970–2000

Country	TFP growth rates			
	Labor share =0.65		Actual labor share	
	Barro-Lee human capital data	Cohen-Soto human capital data	Barro-Lee human capital data	Cohen-Soto human capital data
Algeria	-0.99	-1.15	-0.92	-1.07
Argentina	-0.52	-0.32		
Australia	0.70	0.49	0.74	0.53
Austria	0.90	0.78	1.05	0.92
Bangladesh*				
Barbados	-0.17			
Belgium	1.03	0.73	1.24	0.90
Benin	0.11	0.15		
Bolivia	0.05	-0.51	0.04	-0.54
Botswana*				
Brazil	0.01	-0.45		
Cameroon	-0.16	-0.46		
Canada	0.22	0.20	0.26	0.24
Central African Republic*				
Chile	0.70	0.62	0.72	0.65
China	3.83	3.66		
Colombia	-0.25	-0.32	-0.25	-0.32
Congo, Dem. Rep.*				
Costa Rica	-0.83	-0.99	-0.72	-0.89
Cyprus*				
Denmark	0.53	0.34	0.63	0.42
Dominican Republic	0.77	0.60		
Ecuador	0.26	0.27	0.45	0.45
Egypt	1.30	1.26	1.13	1.08
El Salvador	-1.15	-1.19	-1.17	-1.21
Fiji*				
Finland	0.52	0.68	0.59	0.76
France	0.45	0.53	0.63	0.72
Gambia, The	-2.49			
Germany*				
Ghana	1.44	1.11		
Greece	-0.12	-0.01	0.04	0.18
Guatemala	-0.18	-0.44		
Guinea-Bissau*				
Honduras	-1.05	-0.82		
Hong Kong	1.61		1.31	
Iceland	0.88			
India	0.90	0.96		
Indonesia	0.00	-0.50		
Iran	-2.21	-2.30		
Ireland	2.06	2.21	2.26	2.43
Israel	0.74		0.84	
Italy	0.65	0.40	0.75	0.48
Jamaica	-1.09	-1.16	-1.01	-1.08
Japan	0.33	0.34	0.46	0.47
Jordan	-2.84	-2.93	-2.86	-2.95
Kenya	-0.23	-0.46		
Korea, Republic of	0.93	1.13	0.93	1.13

(Continued)

Country	TFP growth rates			
	Labor share =0.65		Actual labor share	
	Barro-Lee human capital data	Cohen-Soto human capital data	Barro-Lee human capital data	Cohen-Soto human capital data
Lesotho	-0.12			
Malawi	1.15	0.94		
Malaysia	1.40	1.10	1.46	1.15
Mali	0.90	0.82		
Mauritius	2.21	1.85	2.13	1.81
Mexico	-0.78	-0.65	-0.77	-0.66
Mozambique	-1.06	-1.38		
Nepal	-0.99	-1.17		
Netherlands	0.46	0.42	0.47	0.43
New Zealand	-0.14	-0.17	-0.14	-0.17
Nicaragua	-2.98	-3.45		
Niger	-2.23	-2.28		
Norway	1.00	1.43	0.98	1.38
Pakistan	0.77			
Panama	0.10	0.19	0.19	0.30
Papua New Guinea*				
Paraguay	-0.53	-0.54	-1.16	-1.17
Peru	-1.24	-1.23	-1.02	-1.01
Philippines	-0.21	-0.05	-0.25	-0.10
Portugal	0.13	0.26	0.29	0.43
Rwanda	-2.00			
Senegal	-0.47	-0.79		
Sierra Leone*				
Singapore	2.10	1.79	1.72	1.47
South Africa	-0.17	-0.40	-0.18	-0.39
Spain	0.35	0.36	0.40	0.40
Sri Lanka	1.94		2.18	
Sweden	0.12	0.37	0.18	0.47
Switzerland	-0.29	-0.13	-0.15	0.04
Syria	0.04	0.00		
Taiwan	2.37			
Tanzania	0.08	-0.38		
Thailand	1.43	0.93		
Togo	-2.88			
Trinidad &Tobago	-0.53	-0.39	-0.48	-0.34
Tunisia	1.04	1.20	1.07	1.22
Turkey	-0.21	-0.29		
Uganda	-0.51	-0.35		
United Kingdom	0.77	0.64	0.97	0.82
United States	0.60	0.77	0.74	0.93
Uruguay	0.69	0.62	0.69	0.63
Venezuela	-1.60	-1.00	-1.25	-0.76
Zambia	-0.34	-0.19	-0.71	-0.54
Zimbabwe	-0.05	-0.03		

Source: Author's calculation using data from Penn World Table 6.2 (2006) and human capital data from Barro-Lee (2000) or Cohen-Soto (2001). Note: * indicates that we do not have TFP growth rate for 1970-2000, but have data on TFP growth rate for sub-periods, 1980-90, and 1990-2000, for the country.