2009

# Appropriate technology, human capital, and economic development

Beatrice Farkas
*Louisiana State University and Agricultural and Mechanical College*

# APPROPRIATE TECHNOLOGY, HUMAN CAPITAL, AND ECONOMIC DEVELOPMENT

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Economics

by
Beatrice Cristina Farkas
B.S., Babeş-Bolyai University, Cluj-Napoca, Romania, 2001
M.S., Louisiana State University, USA, 2004
December 2009

*This thesis is dedicated to my parents.*

# Acknowledgments

I am deeply indebted to my advisor, Dr. Areendam Chanda, who guided me through this entire process with endless patience and kindness. Working with him was (and continues to be) one of the most fortunate and exciting experiences of my life. Without his encouragement and continuous support I would have not made it, and I am very grateful for all his help and involvement.

I would also like to express my appreciation to Dr. Douglas McMillin for his support in key moments. I am grateful to Dr. Chris Papageorgiou for his guidance and constant encouragement as well as to Dr. Marios Zachariadis for initiating me in economic growth. Special thanks go to Dr. Naci Mocan and Dr. Carter Hill for their much needed and appreciated advice and help. I would also like to thank the other committee members, Dr. Robert Newman and Dr. Faik Koray for their valuable comments.

My friends made me feel like home in Baton Rouge. I am thankful to Burak, Gul, and Sandeep for their support, warm friendship and great memories. Mihaela's friendship was a solid prop these years by always being there for me in good and in bad times.

I owe everything I am today to my parents, Maria and Gavril Farkas, who surrounded me with their unconditional love and always had faith in me. Ever since I can remember they were my most enthusiastic supporters, believed in me, and made me believe in myself. I am very fortunate to have been raised by such wonderful parents.

Finally, I would like to thank my dear husband Şerban who brought a sense of balance in my life and gave me strength and confidence when I needed them most. This dissertation would not have been possible without his tireless love and support.

# Table of Contents

# Abstract

This research focuses on the role played by human capital in explaining cross-country productivity differences, and also in shaping the world allocation of capital stocks. The central question of the first essay is- what determines whether a country is better at using some technologies than others? A widely held view is that a country's ability to absorb and implement technologies is tied to its human capital. In this chapter, we construct a novel specification of technology that incorporates this idea. Countries are comprised of a range of industries with heterogeneous productivities. In high human capital countries, productivity is maximized for industries with the most sophisticated technologies, while in low human capital countries, productivity is maximized for industries with less sophisticated technologies. A key result is that both aggregate total factor productivity and the industrial structure of an economy are driven by inter-industry variations in productivity which in turn is a function of human capital. We embed this specification within a standard production function framework and undertake a development accounting exercise. Our results indicate that almost half of the variation in aggregate TFP differences can be explained by the distribution of inter-industry TFP.

The second essay models the entry of foreign multinationals within the technology-skill complementarity framework. Foreign and domestic firms engage in a Bertrand competition over each industry. The equilibrium solution of the model yields the threshold industry starting from which foreign firms edge out domestic firms. Interest rates are endogenously determined within the model and this allows us to observe the extent to which the international capital markets are globalized. Our findings suggest that financial markets are characterized by imperfect capital mobility. Therefore we carry out a hypothetical experiment by analyzing the reallocation of the world capital stock under perfect capital mobility.

The third essay evaluates the local conditions that are required for FDI to bring positive effects on growth and it consists of a unified study of absorptive capacities. We analyze the simultaneous interactions of FDI with other growth determinants and their effect on the contribution of FDI on the growth rate of GDP per capita. Our findings suggest that FDI can have significant contribution to economic growth, but its presence in developing countries must complement rather than substitute a set of other growth determinants.

# Chapter 1

# Introduction

Over the past decade, a vast part of the literature on economic growth has shown that the enormous cross-country differences in GDP per worker can be pinned down to total factor productivity (TFP) differences.

The first chapter of this dissertation is focused on explaining aggregate TFP differences through a novel formulation of technology that incorporates the concept of technology-skill complementarity. We analyze the extent to which skill abundance explains productivity differences across countries and we examine the role played by human capital in shaping the industrial structure of an economy.

The central question addressed in the first essay is: why do some countries not use all technologies that are available, especially the latest ones? To answer this question, we start from the observation that technologies differ not only across countries, but also across industries, within a country. Also, some industries require inherently more human capital than others. Therefore, poor countries that are scarce in human capital are more efficient in producing in low-tech industries that do not require high levels of skills. Rich countries that are abundant in human capital, on the other hand, favor hi-tech industries that are skill intensive. In other words, a country's human capital endowment determines which industries are "appropriate". Thus this technology-skill complementarity shapes the distribution of productivities across industries within a country.

The theoretical model presents a new formulation for technology consisting of three components: an industry specific component, a skill complementary component and finally a homogeneous, industry neutral component. A consequence of this formulation is that a country will choose to concentrate its production in certain industries and less in others depending on its human capital. We calibrate the equilibrium solution of the model and under plausible parameter values, it turns out that human capital is the engine behind TFP differences and it shapes the entire industrial structure of an economy. The exercise shows that almost half of the variation in aggregate TFP can be explained by the variation of inter-industry TFP. The results show that cross-country income gaps are driven by TFP differences and more importantly, TFP differences are explained by inter-industry variation in productivities.

The second chapter of this thesis analyzes the allocation of the world capital stock using the technology-skill complementarity framework presented in Chapter 2 but deviating from the closed economy structure. We model the entry of foreign multinationals in an economy starting from the fact that the heterogeneity of productivities across industries gives rise to foreign direct investments in domestic markets in which foreign firms have a technological advantage. The endogenous determination of interest rates allows us to observe the distribution of the world supply of capital stock and to calculate endogenously the FDI inflows for each country considered which is a function of each country's human capital endowments. Since our findings suggest that the rates of return to capital investments (or marginal product of capital) differ across countries we conclude that the international financial markets are characterized by imperfect capital mobility. We then carry out a simulation exercise by imposing equalization on MPK to see how the optimal distribution of world capital stock would look if capital was allowed to move freely across countries. As a result of MPK equalization, the capital stock would dramatically increase by 120% in the average less developed country. Also,under perfect capital mobility, the world output would increase by 3%.

The third chapter analyzes the necessary local conditions required for the existence of positive spillovers from multinationals' entry. We start from the idea that FDI is a channel through which less developed countries gain access to advanced technologies. In this sense, FDI speeds up the diffusion of technologies across countries. Yet, the question that arises is: to what extent are these advanced technologies absorbed and successfully internalized by the receiving countries such that they materialize in welfare gains? The impact of FDI depends on the country specific absorptive capacity that consists of local conditions favorable to economic growth. We first interact FDI individually with different growth determinants and we find that the contribution of FDI to economic growth is positive and significant depending on the level of human capital and development of financial markets. Then we test the robustness of the linear interaction terms relative to each other and we analyze the set of conditions that are the most beneficial for FDI.

# Chapter 2

# Technology-Skill Complementarity and International TFP Differences

## 2.1 Introduction

The standard of living in U.S. is estimated to be about 20 times higher than the standard of living in Kenya. What are the roots behind these enormous income differences across countries? As Robert Lucas eloquently put it, "Once one starts to think about [these questions], its hard to think about anything else."[1]. This key question has led to an explosion in the field of economic growth over the past two decades. Over the past decade, this body of research has increasingly shown that total factor productivity (or the "residual") differences account for most of the cross-country differences in GDP per worker.[2] While this is an important step forward, the fact remains that TFP is a proximate determinant and not a fundamental determinant of average incomes. Moreover, exercises that tend to emphasize the primacy of TFP do not always incorporate the role of human capital in shaping it.

In this chapter we pay particular attention to the role of what one might call appropriate human capital. In particular, we revisit the question - are all countries equally good at using all technologies? The trivial answer to this is no. The view of a uniform technology within an economy that diffuses instantly across all industries is hardly a depiction of reality. Agriculture does not use the same technology as the software industry. Furthermore, within each

[1]See Lucas (1988)

[2]See Hall and Jones(1999) and Klenow and Rodriguez-Clare (1997). Both papers argue that a substantial variation in GDP per worker is due to differences in TFP as opposed to factors of production (mainly physical and human capital). Subsequent research, however, has tried to reinstate the primacy of human capital. See Seshadri and Manuelli (2005).

industry, different technologies will have different skill requirements. Since each country has its own skill endowments, some industries will be more productive in one country than in another. The subsequent question is, what determines whether a country is better at using some technologies than others? Here, we model the idea that a country is best suited to produce some specific technologies that complement its human capital. To fix ideas, we can think of ranking countries in terms of their human capital. At the same time, we can also rank technologies in terms of their increasing sophistication. One can argue that more sophisticated technologies tend to be more productive when used with higher amounts of human capital. Less sophisticated technologies are not necessarily more productive when used with high levels of human capital. For instance, poor countries that are less abundant in human capital are not efficient in producing the latest IT equipment and software. Conversely, these countries might be efficient in producing textiles or agricultural products that traditionally require less human capital. While these observations are in themselves not new, we implement a novel mechanism to capture these ideas, and relate them to comparisons of aggregate TFP undertaken in the literature.

We model total factor productivity as comprising three distinct components. First, there is a sector neutral national homogeneous TFP component, a common assumption in the literature. This can reflect the overall ease with which technologies can enter an economy, or other aspects of efficiency that are not necessarily technology specific. Second, we allow for variation in technology levels across industries within a country. Thus, while we adopt a product variety framework for intermediate inputs, we allow the productivity of intermediate inputs to vary. Third, and the crucial innovation in our setup, is the introduction of a human capital driven technology component. In particular, within different varieties, there are some for which productivity is highest, given the country's current human capital level relative to the remaining varieties. Thus, the third component gives some industries within a country a productivity advantage over other industries. To get an initial idea of how the last two features interact, consider Figure 2.1.

Here industries are indexed along 0 to 1, with industry 0 using the least sophisticated technology and industry 1 using the most sophisticated technology. Thus, *ex-ante*, at any

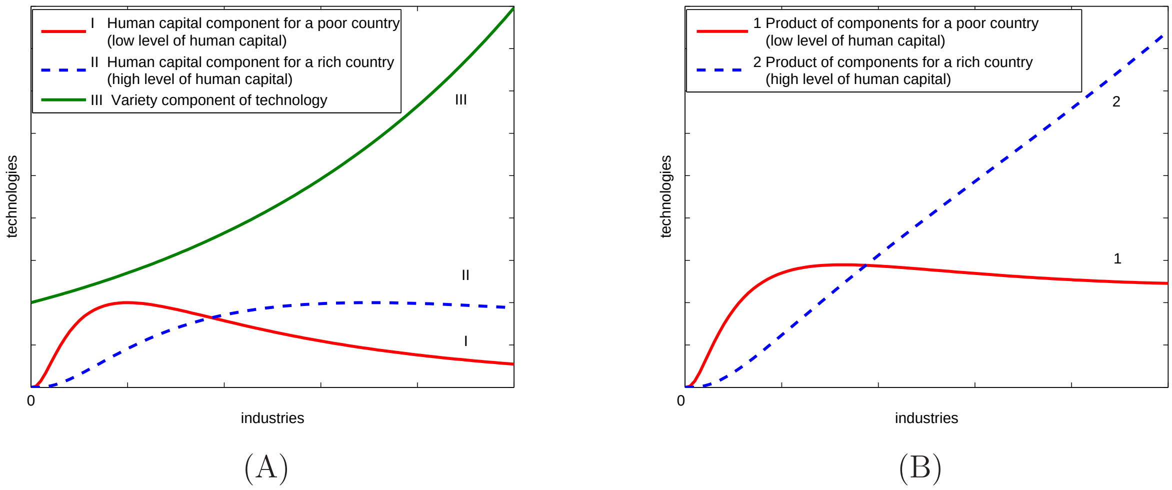



Figure 2.1: Distribution of the components of technology across industries

point in time it is feasible for a whole range of industries to exist. In Figure 2.1 Panel A, this inter-industry variation in technology which is independent of human capital is depicted by line III. Now consider two countries with different levels of human capital per worker. For the country with a low level human capital (line I), the human capital specific aspect of productivity is maximized at an industry with a low degree of sophistication and for the country with high human capital level (line II), this is maximized at an industry with a higher degree of sophistication. The human capital component of productivity is then multiplied by the industry specific productivity of each country (line III). The product of the two is depicted in Figure 2.1 Panel B. In our benchmark model, this distribution of industry specific TFP becomes a component of aggregate TFP. Finally, though not depicted, for each of the countries, this is further multiplied by the national homogeneous TFP level.

A few important inferences can be made right away. First, note that the manner in which lines I and II are drawn suggest that poor countries are really disadvantaged in producing sophisticated goods. However, rich countries are not as disadvantaged in producing less sophisticated goods. This asymmetry does appeal to one's intuition. A relatively uneducated worker in a poor country will not have the capabilities to operate hi-tech equipment which requires substantial investments of time and costs in human capital. On the other hand it is conceivable that a highly educated worker, with some training, can start working in an industry that does not require much human capital.[3] Secondly, note that for some industries (the less sophisticated ones), the poor country shown by line 1 in Figure 2.1 Panel B is actually more productive than the rich country. However, we still need to multiply these with the homogeneous TFP component and if the differences in the latter are large enough across countries then the first two components may be less relevant.

This quantitative question is addressed in the second part of the chapter. We calibrate the equilibrium solution of the model by using a standard development accounting approach in order to back out our measure for aggregate TFP (which is a product of all three components). We undertake a variance decomposition exercise and we find that differences in aggregate TFP explain 62% of variation in GDP per worker. More importantly, we also calculate the contribution of the non-homogeneous components of TFP in the variation of aggregate TFP. We infer that the former accounts for 41% of the variation in the latter. This is a fairly large number and it underscores the importance of what others have referred to as "technology-skill" complementarity.[4]

The rest of the chapter is organized as follows: Section 2.2 presents the model where we emphasize the new formulation for technology and its importance in the construction of TFP. In section 2.3 we describe the calibration methodology and we use different measures for human capital in a variance decomposition exercise similar to Klenow and Rodriguez-Clare (1997). Section 2.4 concludes.

### 2.1.1 Related Literature

Our approach constructs a link between two strands of the literature. First, we take into account the recent findings of the vast literature of appropriate technology and skill biased technological differences. The idea of a country being better at using technologies specific to its capital-labor ratios dates back to Atkinson and Stiglitz (1969). Basu and Weil (1996) further build upon this concept of "appropriate technology" in a learning-by-doing model

[3]The cliche of the "overqualified worker" comes to mind.
[4]See Goldkin and Katz (1998).

where improvements in technology are localized and tied to capital-labor ratios. While our current version of the model is a static one, it is easy to see that the distribution of technologies across inputs could ultimately be a function of localized learning by doing albeit based on human capital rather than capital-labor ratios.

Closest to this chapter, however are Caselli and Coleman (2006) and Acemoglu and Zilibotti (2001). Using a model of endogenous technological choice, Caselli and Coleman show that technologies chosen by different countries are not identical because of the existence of technological skill bias: poor countries choose technologies that complement unskilled labor, while rich countries (skilled labor abundant) favor the use of technologies that complement skilled labor. However, the structure in this chapter is more general in the sense that since technologies themselves are partly endogenous to human capital, it provides a theory for where technological differences come from without having to estimate production possibility frontiers. Further, since we allow for a continuum of goods, the model can provide some theoretical implications regarding the diversification in the structure of production. Finally, in principle, the model can allow for a joint endogenous evolution of human capital and technological change- something we explore in a separate paper. Nevertheless, the two essays should be viewed as complementary.

Acemoglu and Zilibotti (2001) point out that some technologies might be inappropriate for poorer, less skill abundant countries, since the new technologies from rich countries are meant to be used by skilled workers. They find that income disparity arises because of "technology-skill mismatch" where skill scarce countries are forced to adopt some skill biased technologies ultimately leading to lower productivity. However ex-ante this is quite different from our chapter since we do not have any such skill mismatch and skill-scarce countries choose to focus on less sophisticated technologies in equilibrium. Nevertheless, it is easy to see that one could get the same outcome if we introduced distortions in our model which would lead to an inefficient production structure. Again, this is obviously something that is true in reality (whether one thinks of urban bias or agricultural protection) and is a future extension that we plan to work on.

Finally, we connect the above conclusions to the findings of the emerging literature of inter-sectoral linkages. The view is that sectoral composition and the ties between sectors create a multiplier effect reflected in TFP differences.[5] Jones (2008) builds a model of linkages across intermediate goods starting from the premise that intermediate goods enter the final good production in a complementary fashion. The idea is that weak links, i.e., industries with low productivity will cause even lower productivities in subsequent industries. Hsieh and Klenow (2007) stress that missallocation of inputs at the firm level highly affects TFP. By using micro data they quantify this impact by constructing a measure for within industry TFP for manufacturing sectors in China, India and United States.

## 2.2 Model

We consider a discrete-time model with a representative infinitely lived consumer who maximize utility over a final homogeneous good. In addition to the final good, there is a continuum of intermediate inputs which in conjunction with capital produce the final good. The intermediate inputs are produced using skilled labor and unskilled labor. The key innovation is, of course, the construction of the technology for each of these varieties which we shall discuss in detail later. In this section we solve for equilibrium GDP which in turn depends upon the equilibrium allocation of endowments across industries. Using this equilibrium allocation, we derive expressions for aggregate TFP, and its inter-industry component.

[5]Chanda and Dalgaard (2007) also show that the allocation of inputs between agricultural and non-agricultural sector has a significant impact on TFP levels and provide evidence that the resulting relative efficiency between sectors accounts for 85% of international variation of TFP. They indicate that structural differences are as important as technological differences in explaining TFP disparity. Caselli (2005) notes that without sectorial differences, income disparity would be reduced to one third of its actual level and as long as these sectorial differences matter, it might be wiser to focus on barriers to mobility of inputs across industries rather than barriers to technology adoption.

### 2.2.1 Production

**Final Good Sector**

Perfectly competitive firms produce a homogeneous final good by combining capital and a continuum of differentiated intermediate inputs using a Cobb-Douglas production function,

$$Y_t = K_{Y_t}^{1-\alpha} \int_0^1 X_{it}^{\alpha} di, \qquad 0 < \alpha < 1, \tag{2.1}$$

where $K_{Yt}$ is the capital used in the production of final goods at time $t$, $X_{it}$ is the amount of intermediate good $i$ used in final good production at time $t$ and $\alpha$ is the share of intermediate good $i$ in total output. From here on, we eliminate the time subscripts unless otherwise noted.

Final good producers maximize their profits:

$$\pi = P_Y Y - (r + d)K_Y - \int_0^1 p_i X_i di,$$

where $r$ is the interest rate and $d$ is the depreciation rate. To simplify matters, we assume that from now on the depreciation rate is 1. Further, we set the final good as the numeraire good, with $P_Y = 1$. First order conditions imply that the conditional demand for intermediate input, $X_i$, and capital, $K_Y$ are:

$$X_i = \left[\frac{p_i}{\alpha}\right]^{\frac{1}{\alpha-1}} K_Y \tag{2.2}$$

$$1 + r = (1 - \alpha)\frac{Y}{K_Y} \tag{2.3}$$

**Intermediate Goods Sector**

The intermediate goods sector consists of a continuum of differentiated varieties $i$ that are indexed from 0 to 1.The composite intermediate good is obtained by aggregating all varieties $i \in (0, 1)$:

$$X = \int_0^1 X_i di \tag{2.4}$$

Monopolistic competition characterizes the market setting of each variety $i$. Before entering the market, a potential entrant needs to make an up-front investment to acquire the appropriate technology $A(i, h)$ for variety $i$. Each variety $i$ is produced by a single firm according to the following production function:

$$X_i = A(i, h) L_i^{\delta} H_i^{1-\delta}, \tag{2.5}$$

where $L_i$ and $H_i$ represent the amount of unskilled and skilled labor used in the production of variety $i$ and $\delta$ is the share of unskilled labor.[6]

We assume that each country faces the following resource constraints:

$$\int_0^1 H_i di = H \qquad \int_0^1 L_i di = L \tag{2.6}$$

where L and H represent the fixed supply of total unskilled and skilled labor in the economy.

**Technology**

We assume that technology is country specific, variety specific, and human capital specific. All of these can be captured using the following functional form,

$$A(i, h) = B \; e^{\mu i} \; e^{-\frac{1}{2}\left(\ln \frac{h}{i}\right)^2}, \tag{2.7}$$

- $B$ is the country-specific productivity index at time t (sector neutral homogeneous component) that grows at an exogenous rate $\phi$.
- $e^{\mu i}$ is the variety specific component of technology that reflects the sophistication of each variety (i.e. productivities are increasing exponentially at a rate $\mu$).
- $e^{-\frac{1}{2}(\ln \frac{h}{i})^2}$ is the human capital specific component of technology, where the appropriate human capital $h = \frac{H}{H+L}$ describes the country-specific human capital intensity.

[6] Labor inputs enter indirectly in the production of final goods, through the composite intermediate good $X$. Each intermediate good $i$ is used as an input in the production of final good and embodies unskilled and skilled labor. Adding labor in the production function of final goods would not change our equilibrium results. However, to eliminate this caveat, in the empirical part we calibrate the labor-income share to realistic values (i.e., 2/3).

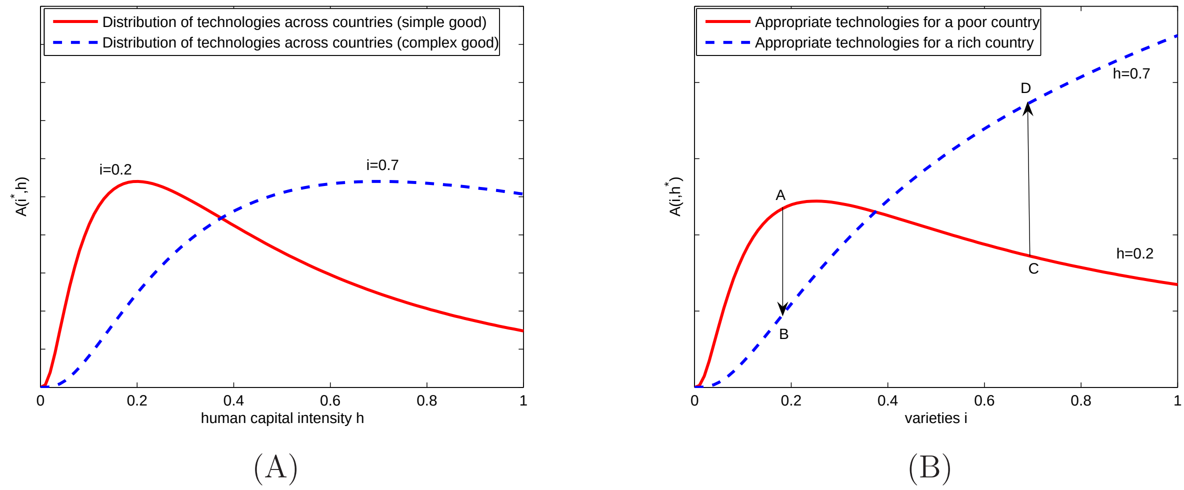



Figure 2.2: Distribution of technologies. Panel (A): across countries; Panel (B): across industries

The human capital component captures the distribution of technologies across countries and across industries. On one hand, by holding $i$ constant ($i = i^*$), $A(i, h)$ as a function of $h$ describes the *log normal distribution of technologies across countries within industry* $i^*$ (see Figure 2.2 Panel A). Thus, skill intensity $h$ shapes the appropriate technology $A(i, h)$ for a given industry $i^*$. Moreover, the highest technology for $i^*$ is developed by the country that satisfies $h = i^*$. For $h < i^*$, $A(i^*, h)$ is increasing in $h$ suggesting that technologies and skills are complements. This relationship is switched if $h > i^*$, in the sense that technology and skill endowments are substitutes ($A(i^*, h)$ is decreasing in $h$).

On the other hand, by holding $h$ constant ($h = h^*$), and letting $A(i, h)$ vary with respect to $i$ only, we get the *distribution of technologies across industries* $i \in [0, 1]$ *within a country* (see Figure 2.2 Panel B). In other words, each industry has its own appropriate technology based on the country specific human capital intensity. The substitutability/complementarity between technology and skills can be seen once again in Figure 2.2 Panel B: the same increase in $h$ has different effects on $A(i, h)$ depending on the location of $i$ within the range: for a simple variety ($i \to 0$), the A(i,h) will decline (movement from A to B) suggesting that $A(i, h)$ and $h$ are substitutes, while for a complex variety($i \to 1$) the $A(i, h)$ will rise (movement from C to D) i.e., $A(i, h)$ and $h$ are complements.

The decision to enter industry $i$ is made in two stages:

Stage 1: Free-entry condition

The up-front investment in $A(i,h)$ represents a setup cost $F_i$ to each potential entrant. Thus, $F_i$ as a barrier to entry characterizes each industry $i$. In period $t$ the potential entrant makes the investment in $A(i,h)$ and enter the market if the present value (as of $t$) of future monopoly profits exceeds the entry costs. Let $V_t = \frac{\pi_{t+1}}{1+r}$ be the present discounted value of future profits as of time $t$. If $V_t > F_{it}$ then the firm enters the market for $i$. In equilibrium, the free-entry condition has to be met:

$$\frac{\pi_{t+1}}{1+r} = F_{it} \tag{2.8}$$

Stage 2: In period $t+1$, the firm makes all pricing and output decisions that maximize its monopolistic profits.

Given (2.5), the cost function of the producer of variety $i$ is:

$$C(w_{L_i}, w_{H_i}, X_i) = \frac{1}{A(i,h)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} \; w_{L_i}^{\delta} w_{H_i}^{1-\delta} X_i$$

Each monopolist maximizes its profits each period:

$$max \quad \pi(i) = p_i X_i - C(w_{L_i}, w_{H_i}, X_i)$$

The first order conditions give the optimal price charged by the monopolist, which represents a standard markup of $\frac{1}{\alpha}$ over the marginal cost of manufacturing intermediate goods:

$$p_i = \frac{1}{\alpha} \frac{1}{A(i,h)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} \, w_{L_i}^{\delta} w_{H_i}^{1-\delta} \tag{2.9}$$

as well as the nominal wages $w_{L_i}$ and $w_{H_i}$:

$$w_{L_i} = \delta\alpha^2 \, A(i,h)^{\alpha} \, L_i^{\alpha\delta-1} \, H_i^{(1-\delta)\alpha} \tag{2.10}$$

$$w_{H_i} = (1-\delta)\alpha^2 \, A(i,h)^\alpha \, L_i^{\alpha\delta} \, H_i^{(1-\delta)\alpha-1} \tag{2.11}$$

Therefore, all pricing and output decisions of the firm are influenced by $A(i,h)$. Equations (2.2) and (2.9) yield the explicit demand $X_i$:

$$X_i = \left[\frac{1}{\alpha^2} \frac{1}{A(i,h)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta}\right]^{\frac{1}{\alpha-1}} K_Y \tag{2.12}$$

Next, using equations (2.9) and (2.12) we solve for profits $\pi_i$ in order to back out $F_i$ from the free-entry condition (2.8). Thus,

$$F_i = \frac{\pi_{t+1}(i)}{1+r} = \frac{1}{1+r} \, (1-\alpha) \, \alpha^{\frac{1+\alpha}{1-\alpha}} \, A(i,h)^{\frac{\alpha}{1-\alpha}} \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}} \tag{2.13}$$

Equation (2.13) implies that the entry costs $F_i$ are an increasing function of the appropriate technology $A(i,h)$. Summing up the setup costs from all industries $i \in [0,1]$, we get total investments in appropriate technologies:

$$K_X = \int_0^1 F_i di = \frac{1}{1+r} \, (1-\alpha) \, \alpha^{\frac{1+\alpha}{1-\alpha}} \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}} \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \tag{2.14}$$

### 2.2.2 Consumers

The economy has a large number (N) of infinitely lived consumers and zero population growth. At each moment $t$ consumers maximize the present discounted value of their lifetime CES utility function:

$$max \quad \sum_{t=0}^{\infty} \beta^t u(C_t) \, , \qquad u(C_t) = \frac{C_t^{1-\sigma} - 1}{1-\sigma} \tag{2.15}$$

where $\beta > 0$ is the discount rate, $\sigma > 0$ is the inverse of intertemporal elasticity of substitution and $u(C_t)$ is the objective function.

Consumers' budget constraint is given by:

$$D_{t+1} = C_t + w_H H_t + w_L L_t + (1+r) D_t,$$

where $D_t$ represents total asset holdings at time t, $w_H H + w_L L$ is the wage income, and $r$ is the interest rate. $C_t$ is consumption of the final good which is the choice variable, while $D_{t+1}$ is the state variable-a stock variable that reflects assets inherited from the past.

The solution of the Bellman equation from below gives the optimal path for consumption and investment:

$$V(D_t) = [u(C_t) + V(D_{t+1})],$$

where $V(D_t)$ describes the value function that represents the objective function $u(C_t)$ maximized with respect to $C_t$ and $D_{t+1}$ from time t onwards. The Euler equation is given by;

$$\beta \frac{U'(C_{t+1})}{U'(C_t)} = \frac{1}{1+r} \tag{2.16}$$

In other words $\left[\frac{C_{t+1}}{C_t}\right]^{-\sigma} = \frac{1}{\beta(1+r)}$. Thus the growth rate of $C_t$ is

$$g_C = \frac{C_{t+1} - C_t}{C_t} = [\beta(1+r)]^{\frac{1}{\sigma}} - 1 \tag{2.17}$$

### 2.2.3 General Equilibrium

We present a decentralized equilibrium solution of the model in which firms are maximizing their profits, consumers are maximizing their utility and inputs and output markets clear. Equilibrium is defined by the following conditions:

1. $Y = C + I$
2. $\overline{K} = K_Y + K_X$
3. $L = \int_0^1 L_i di$ and $H = \int_0^1 H_i di$

The second condition explains that investments in the final goods sector, $K_Y$, and investments in appropriate technologies made in the intermediate goods sector, $K_X$, sum up to total capital in the economy $\overline{K}$. Each period $\overline{K}$ fully depreciates, thus $\overline{K}_{t+1} = I_t = Y_t - C_t$, where $I_t$ is total amount of investments and $C_t$ is consumption at time $t$. The third condition reflects labor market equilibrium implying that the labor employed by all industries add up to the total labor supply.

In equilibrium, nominal wages are equalized such that $w_{L_i} = w_L$ and $w_{H_i} = w_H$ for $i \in (0,1)$. Using (2.10) and (2.11) the variety specific demands for unskilled labor $L_i$ and human capital $H_i$ are expressed as functions of nominal wages and appropriate technologies:

$$L_i = \alpha^{\frac{2}{1-\alpha}} \, \delta^{\frac{1-\alpha(1-\delta)}{1-\alpha}} \, (1-\delta)^{\frac{\alpha(1-\delta)}{1-\alpha}} \, K_Y \, w_L^{\frac{\alpha(1-\delta)-1}{1-\alpha}} \, w_H^{\frac{-\alpha(1-\delta)}{1-\alpha}} \, A(i,h)^{\frac{\alpha}{1-\alpha}}$$

$$H_i = \alpha^{\frac{2}{1-\alpha}} \, \delta^{\frac{\alpha\delta}{1-\alpha}} \, (1-\delta)^{\frac{-\alpha\delta+1}{1-\alpha}} \, K_Y \, w_L^{\frac{-\alpha\delta}{1-\alpha}} \, w_H^{\frac{\alpha\delta-1}{1-\alpha}} \, A(i,h)^{\frac{\alpha}{1-\alpha}}$$

In order to derive $w_L$ and $w_H$ as functions of skill endowments and technologies, we substitute the above equations into the labor market equilibrium conditions. Thus equilibrium nominal wages are given by:

$$w_L = \alpha^2\delta \;\, K_Y^{1-\alpha} \, L^{\alpha\delta-1} \, H^{\alpha(1-\delta)} \left[\int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di\right]^{1-\alpha} \tag{2.18}$$

$$w_H = \alpha^2(1-\delta) \, K_Y^{1-\alpha} \, L^{\alpha\delta} \, H^{\alpha(1-\delta)-1} \left[\int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di\right]^{1-\alpha} \tag{2.19}$$

Next, we substitute the equilibrium nominal wages from (4.9) and (4.10) into the explicit demand of $X_i$ given by (2.12). We can now substitute the explicit demand for intermediates $X_i$ into the production function of the aggregate output from (2.1). Thus in equilibrium, aggregate income is:

$$Y = K_Y^{1-\alpha} \, L^{\alpha\delta} \, H^{\alpha(1-\delta)} \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} \left[\int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di\right]^{-\alpha} di \tag{2.20}$$

Equation (2.20) already suggests the causes of income disparities: part of $Y$ is determined by factors of accumulation, while the other part is governed by appropriate technologies. According to the previous literature, this other part represents TFP.

In order to get a cleaner expression for TFP, denote $g(i) = A(i,h)^{\frac{\alpha}{1-\alpha}}$. The focus is on simplifying $\int_0^1 g(i)\left[\int_0^1 g(i)di\right]^{-\alpha} di$. Since $\int_0^1 g(i) \equiv G$ is constant, we can rewrite

$$\int_0^1 g(i)\left[\int_0^1 g(i)di\right]^{-\alpha} di = \int_0^1 g(i)G^{-\alpha}di = G^{1-\alpha} = \left[\int_0^1 g(i)di\right]^{1-\alpha}$$

Thus, aggregate income can now be expressed as:

$$Y = K_Y^{1-\alpha}\, L^{\alpha\delta}\, H^{\alpha(1-\delta)}\, \left[\int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}}di\right]^{1-\alpha} \tag{2.21}$$

Next, we substitute the formula for $A(i,h)$ given by (2.7) into (4.14). Notice that:

$$\left[\int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}}di\right]^{1-\alpha} = B_t^{\alpha}\left[\int_0^1 \left[e^{\mu i}e^{\frac{-1}{2}(\ln\frac{h}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di\right]^{1-\alpha}$$

Let $Z \equiv \int_0^1 \left[e^{\mu i}e^{\frac{-1}{2}(\ln\frac{h}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di$ capture *inter-industry TFP*. Then aggregate income from (4.14) becomes[7]:

$$Y = K_Y^{1-\alpha}\, L^{\alpha\delta}\, H^{\alpha(1-\delta)} B_t^{\alpha} Z^{1-\alpha} \tag{2.22}$$

Next, we solve for $K_X$. In a similar fashion as for solving for $Y$, we substitute the nominal wage from (2.10) and (2.11) into the expression of $K_X$ given by (2.23):

$$K_X = \frac{1}{1+r}\,\alpha\,(1-\alpha)\, K_Y^{1-\alpha}L^{\alpha\delta}H^{\alpha(1-\delta)}\left[\int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}}di\right]^{1-\alpha}. \tag{2.23}$$

After substituting the interest rate from (2.25) into the above equation, we get $K_X = \alpha K_Y$ which implies that $K_Y = \frac{1}{1+\alpha}\overline{K}$.

Finally, we close the model by solving for the endogenous interest rate $r$. Along BGP, all variables grow at constant rates (i.e., $g_{\overline{K}}$, $g_Y$, and $g_C$ are constant). Therefore, the growth rate of capital-output ratio is zero on BGP, which implies that $g_{\overline{K}} = g_Y$. Since total capital

[7] Although technology does not appear in the production function of the final good, however, aggregate output $Y$ effectively comprises the country specific productivity index, since $B_t$ falls out of the integral $\int_0^1 B_t e^{\mu i}e^{\frac{-1}{2}(\ln\frac{h}{i})^2}di$.

is given by $\overline{K} = K_X(\frac{1+\alpha}{\alpha})$, we use (2.23) to solve for $g_{\overline{K}} = \frac{\overline{K}_{t+1} - \overline{K}_t}{\overline{K}_t}$ :

$$g_{\overline{K}} = \frac{\overline{K}_{t+1}}{\overline{K}_t} - 1 = \frac{\left[\int_0^1 A_{t+1}(i,h)^{\frac{\alpha}{1-\alpha}} di\right]^{1-\alpha}}{\left[\int_0^1 A_t(i,h)^{\frac{\alpha}{1-\alpha}} di\right]^{1-\alpha}} - 1 = \frac{B_{t+1}^{\alpha}\left[\int_0^1 \left[e^{\mu i} e^{\frac{-1}{2}(\ln\frac{h}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di\right]^{1-\alpha}}{B_t^{\alpha}\left[\int_0^1 \left[e^{\mu i} e^{\frac{-1}{2}(\ln\frac{h}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di\right]^{1-\alpha}} - 1$$

$$g_K = (1+\phi)^{\alpha} - 1 \tag{2.24}$$

In equilibrium, $(1 + g_{\overline{K}})\frac{\overline{K}_t}{Y_t} = 1 - \frac{C_t}{Y_t}$ therefore $g_{\overline{K}} = g_C$. Using (2.17) and (2.24) we back out the interest rate $r$:

$$r = \frac{(1+\phi)^{\alpha\sigma} - \beta}{\beta} \tag{2.25}$$

## 2.3 Empirical Assessment

The purpose of our empirical exercise is to address the following question: to what extent do differences in inter-industry TFP explain differences in aggregate TFP? If inter-industry TFP matters, then its importance should be reflected in aggregate TFP, and our goal is to quantify the contribution of the former in the variation of the latter. Moreover, if inter-industry TFP turns out to be important then the results would emphasize the role played by appropriate human capital in driving cross-country income differences.

But first, before answering the above question, we test the significance of our theoretical model by comparing its predictions to the standard results of Hall and Jones (1999). We carry out a variance decomposition exercise for output per worker similar to the one presented in Klenow and Rodriguez-Clare (1997).

In order to do so, we express GDP per worker in Hall and Jones (1999)'s style. Therefore, equation (2.22) becomes:

$$y \equiv \frac{Y}{N} = \left[\frac{K_Y}{Y}\right]^{\frac{1-\alpha}{\alpha}} \left[\frac{h}{1-h}\right]^{-\delta} \frac{H}{N}\; BZ^{\frac{1-\alpha}{\alpha}} \tag{2.26}$$

Equation (2.26) is the key equation for our calibration exercise. Notice that

$$TFP = BZ^{\frac{1-\alpha}{\alpha}} \tag{2.27}$$

where $Z^{\frac{1-\alpha}{\alpha}}$ represents the inter-industry component in per worker terms. Equation (2.26) captures the double role played by $h$: the appropriate human capital has a direct effect on income per worker (as a factor of production), and an indirect effect through TFP.

### 2.3.1 Data

Data for GDP per worker ($y$), investment shares and population are extracted from Penn World Tables 6.2 that use 2000 as the base year. Capital stocks ($\overline{K}$) are calculated by using the perpetual inventory approach.

The construction of human capital is the essential piece of our empirical exercise. In this sense, we use two sources of data. First, Barro and Lee (2001) provide data for educational attainment for population aged 15 and over. They break each country's labor force into seven categories of educational attainment: no schooling, some primary, primary completed, some secondary, secondary completed, some higher, and higher completed. Second, Caselli and Coleman (2006) report the durations of primary and secondary education as well as the private returns from schooling for each country considered. Based on these datasets, we construct different measures for human capital by using the Mincerian approach. The standard Mincerian wage regression states that there is a linear relationship between the log of wage and the returns from schooling. Specifically, $\log w_i = \beta_0 + \beta_1 \lambda_i + \epsilon_i$, where $\lambda_i$ represents average years of schooling for individual $i$. The coefficient $\beta_1$ captures the Mincerian private returns to schooling and reflects a $100\,\beta_1\%$ increase in wage coming from an additional year of schooling.

We construct the stocks of unskilled labor and skilled labor (human capital) for each country:

$$L = N\frac{S_1 e^{\beta\lambda_1} + ... + S_i e^{\beta\lambda_i}}{e^{\beta\lambda_1}}$$

$$H = N\frac{S_{i+1}e^{\beta\lambda_{i+1}} + ... + S_7 e^{\beta\lambda_7}}{e^{\beta\lambda_{i+1}}},$$

where $S_1$,$S_2$,...,$S_7$ are the fractions of labor force $N$ that have no schooling, some primary education, ...,completed higher education. $\beta$ is the country-specific private return to education and $\lambda_1$,...,$\lambda_7$ are the durations in years of each educational level for a given country.[8] Since there is a disparity across countries in terms of duration of educational levels, we rescale $L$ and $H$ based on the fact that in our set of countries, the shortest length of primary education is four years and six years for secondary education. Therefore, we multiply $H$ by $e^{\beta(\lambda_3+\lambda_5-10)}$.

The next question that arises is where to place the threshold $i$, i.e, what constitutes unskilled labor and what human capital? We choose the secondary completed level of attainment as the boundary between unskilled and skilled labor. Then, considering the workers who completed secondary education as the reference group, we express $H$ in "secondary completed equivalents", while $L$ is expressed in "no schooling equivalents"(Caselli and Coleman (2006)). Alternatively, we consider the scenario where human capital consists of workers who have completed some higher education and above.

To calibrate the model we use empirical estimates for parameters $\alpha$, $\delta$, and $\mu$. For the share of capital in aggregate output we set $(1-\alpha) = \frac{1}{3}$ (see Gollin (2002)). Following Basu (1996), the monopolist's mark-up over marginal cost is estimated to be 10%. Accordingly, we set $\delta$ - the share of unskilled labor in the composite intermediate good equal to 0.5. The sophistication of each variety - $\mu$ captures the idea that productivities are increasing exponentially with complexity (Jones (2008)). For each country, we initially set $\mu = 1$ which implies that the inter-industry TFP of the $90^{th}$ percentile relative to the inter-industry TFP of the $10^{th}$ percentile is 2.2. Later on, we undertake a sensitivity analysis and set $\mu = 0.5$ and $\mu = 1.5$ which imply a 90/10 ratio of inter-industry TFP of 1.5 and 3.3, respectively.

[8] From Caselli and Coleman (2006) we have country specific durations of primary and secondary education. For subgroups that did not complete the respective levels of study (some primary, some secondary, some higher), we use, as they did, half of the duration of that level.

### 2.3.2 Calibration

We calibrate the equilibrium solution of the model given by (2.26) using a cross-section of 51 countries for the year 2000.

Table 2.1 presents the summary statistics of the data. GDP per worker ($y$), capital output ratio ($\frac{K}{Y}$), and human capital intensity ($h = \frac{H}{H+L}$) are calculated as ratios to the U.S. values. The data reflect huge income dispersion across countries: Kenya, the country with the lowest standard of living from our sample of countries, has 4.9% of U.S.' GDP per worker. Output per worker in the richest country (Singapore) is around 24 times higher than in the least developed country. The two poorest countries (Kenya and Ghana) have also the lowest levels of human capital per worker (about 5% of the U.S.' level), which implies a 20-fold difference. Also, the group of four countries with highest levels of human capital per worker $\frac{H}{N}$ (U.S., Canada, Sweden, South Korea) are also the most intensive in appropriate human capital $h$.

Table 2.1: **Summary Statistics of the Data**

| Variable | Mean | Std.Dev | Min | Max |
|---|---|---|---|---|
| $y$ | 0.371 | 0.272 | 0.048 | 1.158 |
| $\frac{K}{Y}$ | 0.886 | 0.348 | 0.347 | 1.819 |
| $h$ | 0.409 | 0.244 | 0.035 | 1.036 |

We explore the relationship between our measure of human capital and Hall and Jones' estimates for human capital per worker. Human capital per worker ($\frac{H}{N}$) has a correlation of 0.84 (not shown here) with Hall and Jones' values that are based on a 1985 dataset.Also, Figure 2.3 suggests a strong positive correlation between our measure for appropriate human capital $h$ and Hall and Jones' estimates for human capital per worker.

To calculate inter-industry TFP ($Z$ in our calibration equation), we approximate numerically the definite integral under $Z$ by using the quadratic interpolation method (Simpson rule). After taking logs of the levels, we back out $\ln B$, the homogeneous sector neutral component of TFP:

$$\ln B = \ln y - \frac{1-\alpha}{\alpha} \ln \frac{K_Y}{Y} + \delta \ln \frac{h}{1-h} - \ln \frac{H}{N} - \frac{1-\alpha}{\alpha} \ln Z \qquad (2.28)$$

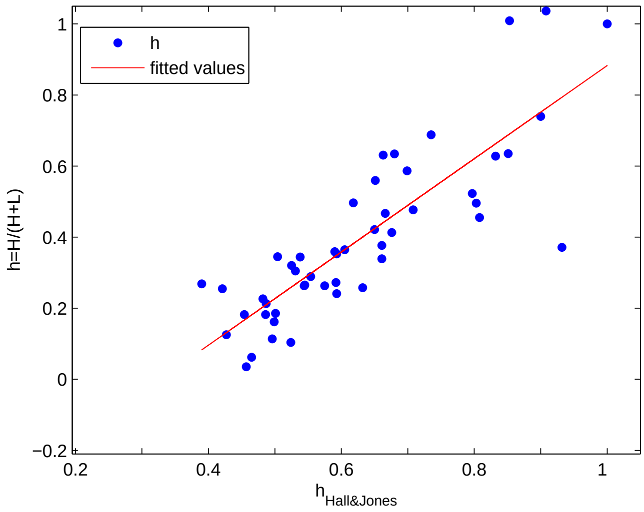



Figure 2.3: Comparison of appropriate human capital values with Hall and Jones (1999)' estimates for human capital per worker

By substituting (2.28) into $\ln(TFP) = \ln B + \frac{1-\alpha}{\alpha}\ln Z$ we construct aggregate TFP. Figure 4.1 in Appendix indicate a strong linear relationship between our values for aggregate TFP and Hall and Jones' estimates. We find a correlation of 0.92 between the values predicted by our model and Hall and Jones' values.

To decompose this 24-fold difference in income per worker between the richest and the poorest country we carry out a levels accounting exercise by decomposing the variance of GDP per worker. Equation (2.26) implies that $y = \left[\frac{K_Y}{Y}\right]^{\frac{1-\alpha}{\alpha}}\left[\frac{h}{1-h}\right]^{-\delta}\frac{H}{N}\quad TFP$. The methodology is based on the idea that the variance of $y$ is divided up between the variance of factors of accumulation and the variance of aggregate TFP:

$$\texttt{var}\left[\ln(y)\right] = \texttt{var}\left[\ln(factors)\right] + \texttt{var}\left[\ln(TFP)\right] + 2\texttt{cov}\left[\ln(factors),\ \ln(TFP)\right]$$

Specifically, we calculate the contribution of each of these elements to the cross-country income dispersion. Following Klenow and Rodriguez-Clare (1997), we allocate half of the covariance term to TFP and the other half to factors of accumulation. Thus, the contribution of aggregate TFP is given by:

$$\frac{\texttt{var}\left[\ln\left(TFP\right)\right] + \texttt{cov}\left[\ln\left(factors\right),\ \ln\left(TFP\right)\right]}{\texttt{var}\left[\ln\left(y\right)\right]} \tag{2.29}$$

The covariance matrix shown in Table 2.2 presents the results of this decomposition exercise. In accordance with the previous literature, aggregate TFP accounts for 62% in cross-country income variation, while factors of accumulation (including human capital) explain only 39%. We conclude that the direct effect of appropriate human capital on income differences is weaker than its indirect effect through TFP. Further, we quantify this indirect effect to see what is the impact of appropriate human capital on TFP differences and implicitly, on income dispersion.

Table 2.2: **Variance Decomposition of GDP/worker**

| Variable | $\ln(y)$ | $\ln(factors)$ | $\ln(TFP)$ |
|---|---|---|---|
| $\ln(y)$ | 0.632 | | |
| $\ln(factors)$ | 0.235 | 0.177 | |
| $\ln(TFP)$ | 0.387 | 0.071 | 0.321 |

Table A-2 in Appendix reports the values of TFP and its components relative to U.S. values. After ranking countries with respect to aggregate TFP, we notice that the average of the values of top five countries (Singapore, Hong Kong, U.S., Italy, and Canada) is about 6 times higher than the average TFP of the lowest five countries (Kenya, Ecuador, Peru, Honduras, Jamaica). Ghana has an aggregate TFP equal to only 28% of aggregate TFP in U.S.; moreover, Ghana's inter-industry TFP is just 4% of U.S.' inter-industry TFP. Not surprinsingly, human capital intensity in U.S. is about 16 times higher than in Ghana. The correlation between $h$ and $Z$ (not shown here) is 0.97 suggesting that inter-industry productivity is driven by human capital.

By undertaking the second decomposition exercise we try to deepen these explanations. Starting from equation (2.27), we decompose the variance of TFP in order to quantify the role played by inter-industry TFP in explaining international TFP differences. The contribution of inter-industry TFP is calculated based on the formula:

$$\texttt{var}\left[\ln\left(TFP\right)\right] = \texttt{var}\left[\ln\left(B\right)\right] + \texttt{var}\left[\ln\left(Z^{\frac{1-\alpha}{\alpha}}\right)\right] + 2\texttt{cov}\left[\ln\left(B\right),\ \ln\left(Z^{\frac{1-\alpha}{\alpha}}\right)\right]$$

Table (2.3) summarizes our findings by reporting the covariance matrix. The variance of

Table 2.3: **Variance Decomposition of TFP***

| Variable | $\ln(TFP)$ | $\ln(B)$ | $\ln(Z^{\frac{1-\alpha}{\alpha}})$ |
|---|---|---|---|
| $\ln(TFP)$ | 0.321 | | |
| $\ln(B)$ | 0.187 | 0.233 | |
| $\ln(Z^{\frac{1-\alpha}{\alpha}})$ | 0.133 | -0.004 | 0.180 |

* 90/10 ratio of inter-industry TFP is 2.2 ($\mu = 1$). H consists of secondary completed education and above.

inter-industry TFP represents 41% of the total variance in TFP and the covariance between the homogeneous part of TFP and inter-industry TFP is very low. Thus, inter-industry TFP has a major impact on total TFP. Since $h$ directly determines $Z$ (the correlation between them is 0.97), we infer that appropriate human capital drives the differences in inter-industry TFP, and indirectly the differences in aggregate TFP. Moreover, we find a very weak correlation of $-0.14$ between skill intensity $h$ and the residual $B$, the homogeneous component of aggregate TFP, suggesting that (without being necessarily a proof) some other factors, but not the appropriate human capital, determine the exogenous component of TFP. This idea is reinforced by a weak correlation of $-0.22$ between inter-industry TFP and the residual $B$.

For sensitivity purposes, we carry out the same exercise for $\mu = 0.5$, which implies a lower productivity gap between the most and the least complex industries within each country (the ratio of inter-industry TFP between the $90^{th}$ percentile and the $10^{th}$ percentile is 1.5). The

Table 2.4: **Variance Decomposition of TFP for $\mu = 0.5$ ***

| Variable | $\ln(TFP)$ | $\ln(B)$ | $\ln(Z^{\frac{1-\alpha}{\alpha}})$ |
|---|---|---|---|
| $\ln(TFP)$ | 0.321 | | |
| $\ln(B)$ | 0.213 | 0.226 | |
| $\ln(Z^{\frac{1-\alpha}{\alpha}})$ | 0.108 | -0.001 | 0.121 |

* 90/10 ratio of inter-industry TFP is 1.5. H consists of secondary completed education and above

results shown in Table 2.4 suggest that in this case inter-industry TFP, captured by $Z^{\frac{1-\alpha}{\alpha}}$, still accounts for a big fraction of 33% in total variation in TFP. Table 2.5 reports the results for $\mu = 1.5$ (i.e, the 90/10 ratio of inter-industry TFP is 3.3); in this case almost half of the variation of aggregate TFP (49%) originates from inter-industry TFP and implicitly from appropriate human capital. Therefore, the higher the discrepancy between the most

Table 2.5: **Variance Decomposition of TFP for $\mu = 1.5$ ***

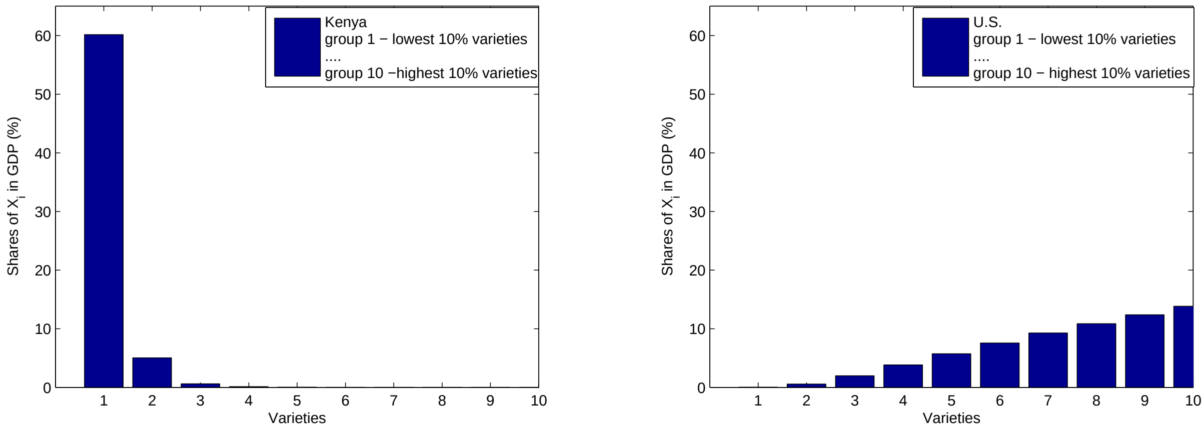
| Variable | $\ln(TFP)$ | $\ln(B)$ | $\ln(Z^{\frac{1-\alpha}{\alpha}})$ |
|---|---|---|---|
| $\ln(TFP)$ | 0.321 | | |
| $\ln(B)$ | 0.161 | 0.256 | |
| $\ln(Z^{\frac{1-\alpha}{\alpha}})$ | 0.160 | -0.009 | 0.255 |

* The 90/10 ratio of inter-industry TFP is 3.3. H consists of secondary completed education and above

productive and the least productive industries within a country, the more important is the contribution of inter-industry TFP in the variance of aggregate TFP. Since this discrepancy tends to be higher in less developed countries, the role of inter-industry TFP is even more critical to them. In other words, there is more room for less skill intensive countries to improve inter-industry TFP by increasing their stocks of human capital. Thus, policies that stimulate skill intensity and inter-industry TFP would lower cross-country differences in total factor productivity.

Overall, the results indicate a significant role for inter-industry TFP in the international variation of TFP. Since human capital is driving the productivities of different industries within a country, we expect human capital to be concentrated in the industries where technologies complement skills. We categorize industries in ten groups based on their sophistication in order to calculate each group's share in total GDP (see Appendix 1A). The representation of industries within an economy is shaped by the existent human capital intensity in the country: in a poor country, production is clustered in less skill intensive industries, while in a rich country (human capital abundant), skill intensive industries are better represented in GDP. Figure 2.4 captures exactly this trend: in Kenya's case (Figure 2.4 Panel A), almost 60% of GDP can be attributed to the lowest 10% of varieties, 5% of GDP is accounted by the next group and from here on, as we move up on the sophistication scale, the shares of more complex varieties in GDP become smaller and smaller and almost inexistent.

One can observe exactly the opposite pattern in U.S (Figure 2.4 Panel B), where the




(A) Kenya

(B) U.S.

Figure 2.4: Shares of industries in GDP (%).

shares of varieties in GDP are increasing in sophistication. The group of highest 10% of varieties accounts for 14% of GDP, followed by the second highest 10% group that produces 12% of GDP, while the least intensive human capital industries that fall in the lowest 10% group comprise only 0.02% of GDP.

Finally, as a sensitivity analysis, we carry out the same decomposition exercise of the variance of TFP for a higher threshold of human capital. We measure human capital as consisting of workers who have attained some higher education and above and we keep the 90/10 ratio of inter-industry TFP at 2.2.

Table 2.6: **Variance Decomposition of TFP for $\mu = 1$.***

| Variable | $\ln(TFP)$ | $\ln(B)$ | $\ln(Z^{\frac{1-\alpha}{\alpha}})$ |
|---|---|---|---|
| $\ln(TFP)$ | 0.304 | | |
| $\ln(B)$ | 0.214 | 0.4 | |
| $\ln(Z^{\frac{1-\alpha}{\alpha}})$ | 0.089 | -0.185 | 0.274 |

* The 90/10 ratio of inter-industry TFP is 2.2. H consists of partial higher education and above.

Table 2.6 reports a decrease of the variance of inter-industry TFP falls to 29% of total variance of TFP while the covariance term increases significantly. These results suggest that the new threshold for skilled labor is set too high and the new measure of human capital is too exclusive.

## 2.4 Conclusions

Cross-country income differences have been pinned down to TFP differences, which are captured by differences in technologies. Nonetheless, technologies differ not only across countries, but also across industries within a country. Countries are not similarly equipped to adopt technologies, therefore they are not equally efficient in using them. This heterogeneity arises from the relative role given to human capital by each country. A rich country, abundant in human capital, favors more sophisticated industries that use human capital intensively. However, the same industries are poorly represented in a less developed economy that lacks the necessary skills to use complex technologies. Thus, each country's human capital intensity is *appropriate* for an industry with a particular level of sophistication, where technologies complement skills.

We capture this role of appropriate human capital in shaping each country's map of industries. Specifically, we develop a theoretical endogenous model with a novel formulation of the industry-level technology as a function of appropriate human capital. This new specification allows us to decompose aggregate TFP into inter-industry TFP (the non-homogeneous component of TFP driven by human capital) and an exogenous productivity residual. In accordance with previous studies, aggregate TFP explains 62% of the variance of output per worker. Moreover, after undertaking a variance decomposition exercise, we find that inter-industry TFP accounts for 41% of the variation of aggregate TFP, suggesting that appropriate human capital explains indirectly, through inter-industry TFP, a substantial part of income differences.

Finally, appropriate human capital models the distribution of shares of industries into GDP. The results of our levels accounting exercise show that in rich countries where technologies complement skills, a higher fraction of GDP is attributed to complex industries, while the opposite holds for poor countries where GDP consists mainly of unsophisticated industries.

# Chapter 3

# Multinationals Entry in a Model of Appropriate Human Capital and Economic Growth

## 3.1 Introduction

The objective of this chapter is to analyze to what extent the world capital stock is optimally allocated. The key question that we address is - do differences in returns to capital investments impede the efficient allocation of the world capital stock ? In other words, what is the impact of cross-country differences in returns to investments on capital flows from rich to poor countries?

If capital flows freely from one country to another, then the global financial market should be characterized by perfect capital mobility and the returns to investments or marginal product of capital (MPK) are equalized across countries. On the other hand, significant MPK differentials across countries would serve as evidence of an inefficient cross-country distribution of capital stocks, implying that an optimal reallocation of the world supply of capital could lead to welfare gains for less developed countries.

We use the technology-skill complementarity framework presented in Chapter 2 as a tool to answer the key questions from above. Deviating from the closed economy structure, we model the entry of foreign multinationals. The starting point is based on our previous result that the appropriate human capital determines whether the market concentration of domestic firms occurs in simple or complex industries. The fact that productivity is assumed to be heterogeneous across industries and a function of human capital gives rise to multinationals entry in domestic markets, since in poor countries foreign firms have a distinct advantage in sophisticated industries. Foreign and domestic firms engage in a Bertrand competition over each variety. The model allows for an endogenous determination of interest rates and yields the threshold industry starting from which foreign firms will edge out domestic firms. This endogenous threshold depends directly on the country specific human capital. The appropriate human capital generates endogenous shares of FDI in GDP and our results indicate that multinationals' entry does not crowd out domestic investments and overall it leads to welfare gains from FDI.

The central idea of the model is that human capital abundance not only shapes each country's distribution of shares of industries in GDP but also endogenously determines the amount of FDI. We analyze the implications of this model on credit market imperfections, FDI and capital flows. Our results take into account the idea that FDI is a channel through which less developed countries are able to import advanced technologies. In the absence of foreign investments, a high fraction of a less developed country's GDP is attributed to low-tech industries, since less developed countries lack the necessary skills to use complex technologies. Therefore multinationals' entry allow poor countries to have access to complex technologies used in hi-tech industries, which otherwise are very poorly represented on their map of industries. Based on our calibration results, these gains from FDI translate into an average increase of 38% in TFP. Moreover, using real world data we find that the calibrated FDI inflows in poor contries account for more than 2/3 of world FDI.

The simulated model suggests that international credit markets are characterized by imperfect capital mobility that prevents capital from moving freely across countries. The average MPK in developing countries is almost twice as large as the average MPK in developed countries. Consequently, the natural question that arises is: how would the distribution of world capital look if capital was allowed to move freely across countries? Would FDI boost the standard of living of emerging market economies if the world stock of capital was optimally allocated? A switch from imperfect to perfect capital mobility such that MPK would be equalized across countries would present new incentives for foreign firms to invest in emerging markets in less developed countries. Therefore we impose an equalization on

MPK, and we simulate the model again. Our results indicate that the shares of FDI in GDP would increase on average by 10% in less developed countries. Based on our calculations of counterfactual capital stocks and output, we conclude that developing economies would clearly benefit from financial integration, since the average GDP per worker would increase by 28%. On account of imperfect capital mobility, the world misses the opportunity to raise the global output by 3%, representing the deadweight loss caused by the inefficient capital allocation.

The previous literature pointed out the impact of international credit frictions as well as the impact of differences in skill endowments and TFP on the world allocation of capital stock. Lucas (1990) famously brought to attention the dilemma of neoclassical growth theory that fails to find a rationale why capital does not flow from rich to poor countries.

Caselli and Feyrer (2007) use three different measures for MPK (the first one based on the neoclassical model, another one that assumes a broader definition of capital that includes land and natural resources, and the last one based on a multisector model) and find that returns to capital investments are similar across countries. They show that the huge variation in capital labor ratios is brought about by cross-country differences in human capital and TFP and also by differences in the prices of capital and capital shares. Gourinchas and Jeanne (2006) estimate the welfare gains from financial integration using two versions of the neoclassical model. Their findings suggest that although some countries gain significantly when they switch from a closed economy setting to perfect capital mobility, on average though, these benefits are not very large for poor countries. Prasad, Rogoff, Wei, and Kose (2003) show that the benefits of financial integration might manifest through indirect channels: perfect capital mobility could raise the productivity of developing countries. In the same line, Borenzstein, de Gregorio and Lee (1998) indicate that FDI may speed up growth through technology diffusion rather than capital accumulation.

The rest of the chapter is organized as follows: Section 3.2 presents the endogenous theoretical model where multinationals' entry change the industrial structure of economies. In section 3.3 we describe the calibration methodology, then we observe the current distribution of world capital stock under imperfect capital mobility and the counterfactual distribution of world supply of capital under MPK equalization. Section 3.4 concludes.

## 3.2 Model

We examine a world economy that consists of a subset of less developed countries and another subset of developed countries. Each country is assigned to one of these two categories based on its skill abundance (or human capital intensity). The structure of each economy is defined by the model laid out in Chapter 2, where the country specific human capital drives technologies, shapes each country's industrial structure and leads to cross-country differences in standard of living. Given this setting, we focus on the entry of foreign direct investors in intermediate goods sectors.

In this section we determine the equilibrium capital stocks and we calculate endogenously the amount of FDI of each country. Our model allows for an endogenous determination of interest rates, which are used to calculate each country's MPK.

### 3.2.1 Bertrand Competition

Each economy comprises two sectors: a final good sector and an intermediate good sector, as described in Chapter 2. The intermediate good sector is shaped by a product variety framework that allows for variation in the productivities of intermediate inputs. Each intermediate good $i$ can be produced with different technologies, thus with different cost schedules. Therefore, foreign potential entrants with different technologies, invest in domestic industries in order to take over the domestic market. As a consequence, the domestic and foreign firm engage in a Bertrand competition and the outcome of this duopoly is ultimately decided by technology differences. In other words, given industry $i$, the firm that has a more advanced technology edges out successfully the other firm and takes over the market.

Considering that both the domestic and foreign economy follow the same specification, we simplify the notations by indexing variables with $d$ and $f$, respectively.

Therefore, the domestic technology used for variety $i$ is driven by the country specific human capital intensity, $h_d$:

$$A_d(i, h_d) = B_d\, e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h_d}{i})^2} \tag{3.1}$$

Similarly, the foreign technology used in industry $i$ is determined by the foreign human capital $h_f$, but its productivity in the host country depends on the ease with which it can be absorbed by the domestic economy. Therefore, the particular environment of the host country shapes the productivity of the foreign firm in the host country. Consequently, the foreign technology adopts the exogenous, sector neutral component of technology from the domestic economy:

$$A_{f,d}(i, h_f) = B_d\, e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h_f}{i})^2} \tag{3.2}$$

The foreign human capital $h_f$ is measured by the average of human capital intensities of all countries $h_{avg}$.

Each industry $i$ is characterized by its barriers to entry, i.e., the setup costs paid by the two competitors, $F_i^d$ and $F_i^f$, that can be interpreted as license fees paid to acquire technologies. The sum of all setup costs $F_i^d$ represents investments in domestic technologies, while the sum of all entry costs $F_i^f$ paid by MNC's represents the FDI inflows in the host country. Based on equation (2.13), the cost of entering the market is an increasing function of technology. After the setup costs have been incurred, the firms compete against each other and each firm's strategy space is represented by prices. The duopolists set their prices simultaneously without observing the other's choice. In this sense, this is a one-shot game. The firm with lower marginal cost eventually takes over the market and charges a price equal to the other firm's higher marginal cost. The marginal costs are derived from equation (2.5):

$$MC_d = \frac{\partial C_{di}}{\partial X_i} = \frac{1}{A_d(i, h_d)} \left[ \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} \right] w_L^{\delta} w_H^{1-\delta} \tag{3.3}$$

$$MC_f = \frac{\partial C_{fi}}{\partial X_i} = \frac{1}{A_{f,d}(i, h_f)} \left[ \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} \right] w_L^{\delta} w_H^{1-\delta} \tag{3.4}$$

We first present *the case of a less developed country.* A less developed country is characterized by a relatively low level of human capital intensity. Thus, $h_d < h_f$, where $h_f = h_{avg}$ represents the average of human capital intensities of all countries considered.

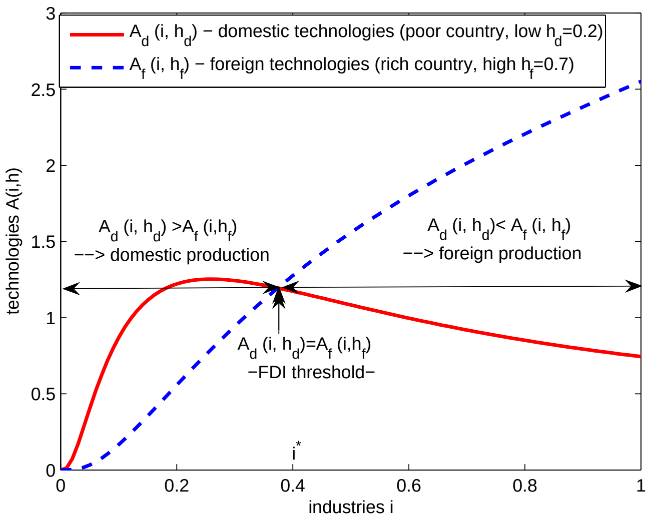



Figure 3.1: Interaction between foreign and domestic technologies in a less developed country

Figure 3.1 depicts the domestic and foreign technologies simultaneously and their interaction as a result of Bertrand competition. We analyze the three possible scenarios a foreign firm could be in after paying the setup costs to enter industry $i$:

1. $A_d(i, h_d) = A_{f,d}(i, h_f)$

   In this case industry productivities are equalized. This implies that variety $i$ can be produced with either foreign or domestic technology. Both firms have the same marginal cost. Therefore, in equilibrium the firms share the market and both of them charge the perfectly competitive price and earn zero profits:

$$p_d = p_f == \frac{1}{A_{f,d}(i, h_f)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_L^{\delta} w_H^{1-\delta}$$

   This case allows us to determine the threshold industry $i*$ for which domestic and foreign technologies are identical:

$$e^{\frac{-1}{2}(\ln \frac{h_d}{i})^2} = e^{\frac{-1}{2}(\ln \frac{h_f}{i})^2}$$

This implies that $(\ln \frac{h_f}{i} - \ln \frac{h_d}{i})(\ln \frac{h_d}{i} + \ln \frac{h_f}{i}) = 0$. Since for a less developed country $h_d < h_f$, it follows that the threshold industry $i^*$ (or the FDI threshold) is given by:

$$i^* = \sqrt{h_f h_d} \tag{3.5}$$

The equation from above implies that the threshold industry is an increasing function of domestic human capital $h_d$ and average human capital.

2. $A_d(i, h_d) > A_{f,d}(i, h_f)$

   Based on (3.3) and (3.4), if the foreign technology used in industry $i$ is inferior to the domestic one, then the domestic firm has the advantage of being the low cost firm and it has three possible options:

   - Suppose the domestic firm sets $p_d > MC_f$. This situation cannot lead to equilibrium since the foreign firm would set a price between $p_d$ and $MC_f$. Thus, the profits of the domestic firm would drop to zero and the foreign firm would earn positive profits.
   - If the domestic firm sets $p_d < MC_f$, then this is a situation in which the domestic firm "leaves money on the table" since it can do better by charging a slightly higher price to increase its profits.
   - The only possible equilibrium is when $p_d = MC_f$, which is the Nash equilibrium of this game. The domestic firm becomes the sole producer of variety $i$ and the foreign producer is edged out of the market.

   Thus the price set by the firm is given by:

$$p_d = \frac{1}{A_{f,d}(i, h_f)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_L^{\delta} w_H^{1-\delta}$$

   Next, we locate industry $i$ in the range of industries from 0 to 1. Since in this case $A_d(i, h_d) > A_{f,d}(i, h_f)$, it follows that $(\ln h_f - \ln h_d)(\ln h_d + \ln h_f - 2 \ln i) > 0$. In other words, given that $h_d < h_f$, a foreign firm will not be able to produce in the domestic market for varieties $i < i^*$. Thus, in a less developed country any low tech industry $i \in (0, \sqrt{h_d h_f})$ is dominated by domestic producers. This result is consistent with our previous findings from Chapter 2 that the industrial structure of a less developed country is concentrated in low tech industries as a result of its relatively scarce human capital, .

3. $A_{f,d}(i, h_f) > A_d(i, h_d)$

   In this case, since the foreign technology is superior to the domestic technology, the foreign firm is the low cost producer.

   The only possible Nash equilibrium is when $p_f = MC_d$ and thus, the foreign firm fully controls industry $i$ while the domestic firm is driven out of the market.

   Thus the prevailing market price is

$$p_f = \frac{1}{A_d(i, h_d)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_L^{\delta} w_H^{1-\delta} \tag{3.6}$$

   We determine the position of industry $i$ in the range of industries. $A_{f,d}(i, h_f) > A_d(i, h_d)$ implies that $(\ln h_d - \ln h_f)(\ln h_d + \ln h_f - 2\ln i) > 0$. Thus, for $i > i^*$ the foreign firm takes over industry $i$ in a less developed country. In other words,$i \in (\sqrt{h_d h_f}, 1)$, i.e., foreign direct investments are made in hi-tech industries, at the end of the range of technological sophistication.

Therefore, in a less developed country, the range of intermediate inputs $i \in (0, 1)$ is divided in two parts: domestic firms supply $X_{id}$ units of low-tech intermediate goods over $(0, i^*)$, while foreign firms supply $X_{if}$ units of hi-tech goods over $(i^*, 1)$.

### 3.2.2 Production in a Less Developed Country

#### Final Good Sector

Under perfect competition, final good producers of country $j$ combine capital $K_Y$, domestically owned intermediate goods $X_{id}$ and foreign owned intermediate goods $X_{if}$:

$$Y_j = K_{Y_j}^{1-\alpha} \left[ \int_0^{i_j^*} X_{id_j}^{\alpha} di + \int_{i_j^*}^{1} X_{if_j}^{\alpha} di \right], \qquad 0 < \alpha < 1 \tag{3.7}$$

The final good is considered the numeraire good. The maximization problem of final good producers is given by:

$$\pi_j = Y_j - \left[ \int_0^{i_j^*} p_{d_j} X_{id_j} + \int_{i_j^*}^{1} p_{f_j} X_{if_j} \right] - (r_j + d) K_{Y_j}$$

where $r_j$ is the country specific interest rate and $d$ represents the depreciation rate of capital, $d < 1$. From here on, for the simplicity of the exposure, we omit the country index $j$ unless otherwise noted.

First order conditions ( $\frac{\partial \pi}{\partial K_Y} = \frac{\partial \pi}{\partial X_{id}} = \frac{\partial \pi}{\partial X_{if}} = 0$) yield the conditional demands for inputs $X_{id}$ and $X_{if}$:

$$MPK = r + d = (1 - \alpha) \frac{Y}{K_Y} \tag{3.8}$$

$$X_{id} = \left[ \frac{p_d}{\alpha} \right]^{\frac{1}{\alpha - 1}} K_Y \tag{3.9}$$

$$X_{if} = \left[ \frac{p_f}{\alpha} \right]^{\frac{1}{\alpha - 1}} K_Y \tag{3.10}$$

#### Intermediate goods sector

Both domestic and foreign intermediate producers combine their technologies with domestic unskilled and skilled labor. Therefore they follow the same specification:

$X_{id} = A_d(i, h_d) L_{id}^{\delta} H_{id}^{1-\delta}$ and $X_{if} = A_f(i, h_f) L_{if}^{\delta} H_{if}^{1-\delta}$, respectively.

- Domestic intermediate goods producers

  Domestic firms supply $X_{id}$ over the range $(0, i^*)$ and charge a price $p_d = MC_f$. They maximize profits by choosing the optimum amount of inputs $L_{id}$ and $H_{id}$, and the optimum level of output $X_{id}$.

$$\pi_d = p_d X_{id} - C(w_{Ld}, w_{Hd}, X_{id})$$

The first order conditions ($\frac{\partial \pi}{\partial L_{id}} = \frac{\partial \pi}{\partial H_{id}} = \frac{\partial \pi}{\partial X_{id}} = 0$) yield the nominal wages $w_{Ld}$ and $w_{Hd}$ and the explicit demand for $X_{id}$:

$$\frac{\partial \pi}{\partial L_{id}} = p_d \frac{\partial X_i d}{\partial L_{id}} - w_{Ld} = 0$$

$$\frac{\partial \pi}{\partial H_{id}} = p_d \frac{\partial X_i d}{\partial H_{id}} - w_{Hd} = 0$$

$$w_{Ld} = \delta \alpha K_Y^{1-\alpha} \, A_d(i, h_d)^{\alpha} \, {L_{id}}^{\alpha\delta - 1} \, {H_{id}}^{(1-\delta)\alpha} \tag{3.11}$$

$$w_{Hd} = (1-\delta) \alpha K_Y^{1-\alpha} \, A_d(i, h_d)^{\alpha} \, {L_{id}}^{\alpha\delta} \, {H_{id}}^{(1-\delta)\alpha - 1} \tag{3.12}$$

Since $p_d = MC_f$, the explicit demand for $X_{id}$ is determined by substituting (3.3) into (3.9):

$$X_{id} = \left[ \frac{1}{\alpha} \frac{1}{A_{f,d}(i, h_f)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Ld}^{\delta} w_{Hd}^{1-\delta} \right]^{\frac{1}{\alpha - 1}} K_Y \tag{3.13}$$

Also,

$$\frac{\partial \pi}{\partial X_{id}} = p_d + \frac{\partial p_d(X_{id})}{\partial X_{id}} X_{id} - MC_d = 0$$

The conditional demand for $X_{id}$ from (3.9) is used in the equation from above to calculate profits per unit:

$$p_d - MC_d = MC_f - MC_d = -\frac{\partial p_d(X_{id})}{\partial X_{id}} X_{id}$$

$$= \alpha(1-\alpha) K_Y^{1-\alpha} X_{id}^{\alpha - 1}$$

Thus, the profits earned by the domestic duopolist are:

$$\pi_d = (MC_f - MC_d) X_{id} = \alpha(1-\alpha) K_Y^{1-\alpha} X_{id}^{\alpha}$$

$$= (1-\alpha)\alpha^{\frac{1}{1-\alpha}} A_f(i,h_f)^{\frac{\alpha}{1-\alpha}} K_Y \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Ld}^{\delta} w_{Hd}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}}$$

We back out the setup cost $F_i^d$ by using the free-entry condition ($F_i^d = \frac{\pi_d}{1+r}$), :

$$F_i^d = \frac{1}{1+r}(1-\alpha)\alpha^{\frac{1}{1-\alpha}} K_Y A_f(i,h_f)^{\frac{\alpha}{1-\alpha}} \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Ld}^{\delta} w_{Hd}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}} \tag{3.14}$$

By summing up the setup costs from all industries $i \in (0, i^*)$, we get capital investments in domestic technologies:

$$K_X = \int_0^{i^*} F_i di = \frac{1}{1+r}(1-\alpha)\,\alpha^{\frac{1}{1-\alpha}} K_Y \int_0^{i^*} \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di \tag{3.15}$$

- Foreign intermediate goods producers

Foreign firms supply $X_{if}$ over the range $(i^*, 1)$ and charge a price $p_f = MC_d$. Their profits are maximized with respect to inputs $L_{if}$ and $H_{if}$, and output $X_{if}$.

$$\pi_f = p_f X_{if} - C(w_{Lf}, w_{Hf}, X_{if})$$

The first order conditions($\frac{\partial \pi}{\partial L_{if}} = \frac{\partial \pi}{\partial H_{if}} = \frac{\partial \pi}{\partial X_{if}} = 0$) yield the nominal wages $w_{Lf}$ and $w_{Hf}$ and the explicit demand for $X_{if}$:

$$w_{Lf} = \delta\alpha K_Y^{1-\alpha} A_{f,d}(i,h_f)^{\alpha} {L_{if}}^{\alpha\delta-1} {H_{if}}^{(1-\delta)\alpha} \tag{3.16}$$

$$w_{Hd} = (1-\delta)\alpha K_Y^{1-\alpha} A_{f,d}(i,h_f)^{\alpha} {L_{if}}^{\alpha\delta} {H_{if}}^{(1-\delta)\alpha-1} \tag{3.17}$$

Since $p_f = MC_d$, we derive the explicit demand for $X_{if}$ by substituting (3.4) into (3.10):

$$X_{if} = \left[\frac{1}{\alpha}\frac{1}{A_d(i,h_d)}\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Lf}^{\delta} w_{Hf}^{1-\delta}\right]^{\frac{1}{\alpha-1}} K_Y \tag{3.18}$$

Also,

$$\frac{\partial \pi}{\partial X_{if}} = p_f + \frac{\partial p_f(X_{if})}{\partial X_{if}} X_{if} - MC_f = 0$$

Next we calculate profits per unit by inserting the conditional demand for $X_{if}$ from (3.10) into the first order condition from above:

$$p_f - MC_f = MC_d - MC_d = -\frac{\partial p_f(X_{if})}{\partial X_{if}} X_{if}$$

$$= \alpha(1-\alpha) K_Y^{1-\alpha} X_{if}^{\alpha-1}$$

Therefore the foreign profits are given by:

$$\pi_f = (MC_d - MC_f) X_{if} = \alpha(1-\alpha) K_Y^{1-\alpha} X_{if}^{\alpha}$$

$$= (1-\alpha)\alpha^{\frac{1}{1-\alpha}} A_d(i, h_d)^{\frac{\alpha}{1-\alpha}} K_Y \left[ \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Lf}^{\delta} w_{Hf}^{1-\delta} \right]^{\frac{\alpha}{\alpha-1}}$$

We back out the setup cost $F_i^f$ from the free-entry condition ($F_i^f = \frac{\pi_f}{1+r}$):

$$F_i^f = \frac{1}{1+r}(1-\alpha)\alpha^{\frac{1}{1-\alpha}} K_Y A_d(i, h_d)^{\frac{\alpha}{1-\alpha}} \left[ \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Lf}^{\delta} w_{Hf}^{1-\delta} \right]^{\frac{\alpha}{\alpha-1}} \tag{3.19}$$

Foreign direct investments in appropriate technologies consist of the sum of setup costs from all industries $i \in (i^*, 1)$ in which foreign firms produce:

$$FDI = \int_{i^*}^{1} F_i f i = \frac{1}{1+r} (1-\alpha) \alpha^{\frac{1}{1-\alpha}} K_Y \int_{i^*}^{1} \left[ \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta} \right]^{\frac{\alpha}{\alpha-1}} A_d(i, h_d)^{\frac{\alpha}{1-\alpha}} di \tag{3.20}$$

### 3.2.3 General Equilibrium in a Less Developed Country

The decentralized equilibrium of the model is described by the following conditions:

1. $Y = C + I$
2. Capital allocation: $\overline{K} = K_Y + K_X + FDI$
3. Labor market equilibrium: $L = \int_0^{i^*} L_{id} di + \int_{i^*}^1 L_{if} di$ and $H = \int_0^{i^*} H_{id} di + \int_{i^*}^1 H_{if} di$

The capital allocation condition suggests that total capital stock $\overline{K}$ consists of capital investments in final good sector, $K_Y$, domestic capital investments in technologies, $K_X$, and FDI in technologies in the intermediate good sector. Capital depreciates at rate $d < 1$, thus $\overline{K}_{t+1} - \overline{K}_t(1+d) = I_t = Y_t - C_t$. The labor market equilibrium condition implies that the unskilled and skilled labor employed by domestic and foreign firms in all industries $i \in (0,1)$ add up to total labor supply.

The industry specific demands for unskilled and skilled labor ($L_i$ and $H_i$) are calculated based on (3.11), (3.12), (3.16), and (3.17):

$$L_{id} = \alpha^{\frac{1}{1-\alpha}} \delta^{\frac{1-\alpha(1-\delta)}{1-\alpha}} (1-\delta)^{\frac{\alpha(1-\delta)}{1-\alpha}} w_{Ld}^{\frac{(1-\delta)\alpha-1}{1-\alpha}} w_{Hd}^{\frac{\alpha(\delta-1)}{1-\alpha}} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} K_Y \quad (3.21)$$

$$H_{id} = \alpha^{\frac{1}{1-\alpha}} \delta^{\frac{\alpha\delta}{1-\alpha}} (1-\delta)^{\frac{-\alpha\delta+1}{1-\alpha}} w_{Ld}^{\frac{-\alpha\delta}{1-\alpha}} w_{Hd}^{\frac{\alpha\delta-1}{1-\alpha}} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} K_Y \quad (3.22)$$

$$L_{if} = \alpha^{\frac{1}{1-\alpha}} \delta^{\frac{1-\alpha(1-\delta)}{1-\alpha}} (1-\delta)^{\frac{\alpha(1-\delta)}{1-\alpha}} w_{Lf}^{\frac{(1-\delta)\alpha-1}{1-\alpha}} w_{Hf}^{\frac{\alpha(\delta-1)}{1-\alpha}} A_{f,d}(i,h_d)^{\frac{\alpha}{1-\alpha}} K_Y \quad (3.23)$$

$$H_{if} = \alpha^{\frac{1}{1-\alpha}} \delta^{\frac{\alpha\delta}{1-\alpha}} (1-\delta)^{\frac{-\alpha\delta+1}{1-\alpha}} w_{Lf}^{\frac{-\alpha\delta}{1-\alpha}} w_{Hf}^{\frac{\alpha\delta-1}{1-\alpha}} A_{f,d}(i,h_d)^{\frac{\alpha}{1-\alpha}} K_Y \quad (3.24)$$

In equilibrium nominal wages are equalized, therefore $w_{Ld} = w_{Lf} = w_L$ and $w_{Hd} = w_{Hf} = w_H$. Next, we express the equilibrium nominal wages as functions of technologies and skills. In order to do so, we plug in the equations from above into the labor market equilibrium condition:

$$w_L = \alpha\delta L^{\alpha\delta-1} H^{\alpha(1-\delta)} K_Y^{1-\alpha} \left[ \int_0^{i^*} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^1 A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di \right]^{1-\alpha} \quad (3.25)$$

$$w_H = \alpha(1-\delta) L^{\alpha\delta} H^{\alpha(1-\delta)-1} K_Y^{1-\alpha} \left[ \int_0^{i^*} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^1 A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di \right]^{1-\alpha} \quad (3.26)$$

Next, we derive the equilibrium expressions for $K_X$ and $FDI$. In this sense, we substitute the equilibrium nominal wages from (3.25) and (3.26) into the expressions of $K_X$ and $FDI$ given by (3.15) and (3.20). Therefore:

$$K_X = \frac{1}{1+r} (1-\alpha) \alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di$$

$$\left[\int_0^{i^*} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}di + \int_{i^*}^1 A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di\right]^{-\alpha} \tag{3.27}$$

$$FDI = \frac{1}{1+r}(1-\alpha)\,\alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \int_{i^*}^1 A_d(i,h)^{\frac{\alpha}{1-\alpha}}di$$

$$\left[\int_0^{i^*} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}di + \int_{i^*}^1 A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di\right]^{-\alpha} \tag{3.28}$$

We substitute the equilibrium nominal wages given by (3.25) and (3.26) into the explicit demand for intermediates $X_{id}$ and $X_{if}$ given by (3.13) and (3.18) in order to determine the aggregate income. Thus, in equilibrium $Y$ is given by:

$$Y = K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di + \int_{i^*}^1 A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}di\right]$$

$$\left[\int_0^{i^*} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}di + \int_{i^*}^1 A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di\right]^{-\alpha} \tag{3.29}$$

### 3.2.4 The Case of a Developed Country

A developed economy is characterized by a relatively high human capital intensity, $h_d > h_f$. Following a reasoning similar to the case of a less developed country, we find that in a developed economy, the outcome of Bertrand competition splits the spectrum of industries in an opposite way than in a less developed economy: foreign firms supply $X_{if}$ units of low tech goods when $i \in (0, i^*)$, while domestic producers supply $X_{id}$ units of hi-tech goods over the range $(i^*, 1)$.

Consequently, the firm that dominates technologically the other sets its price equal to the marginal cost of its competitor. Therefore:

$$p_d = \frac{1}{A_{f,d}(i,h_f)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_L^{\delta} w_H^{1-\delta}$$

$$p_f = \frac{1}{A_d(i,h_d)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_L^{\delta} w_H^{1-\delta}$$

We present the equilibrium results for a developed economy. The derivation of these results can be found in the Appendix. We calculate the investments in domestic technologies

$K_X$ by summing up the setup costs $F_i^d$ corresponding to industries $i \in (i^*, 1)$. In equilibrium $K_X$ is given by:

$$K_X = \frac{1}{1+r}(1-\alpha)\alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \int_{i^*}^{1} A_{f,d}(i, h_f)^{\frac{\alpha}{1-\alpha}} di$$

$$\left[\int_0^{i^*} A_{f,d}(i, h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^{1} A_d(i, h_d)^{\frac{\alpha}{1-\alpha}} di\right]^{-\alpha} \quad (3.30)$$

Similarly, foreign direct investments in low tech industries are determined by summing up the entry costs $F_i^f$ paid by foreign firms in industries $i \in (0, i^*)$. The equilibrium expression for $FDI$ is given by:

$$FDI = \frac{1}{1+r}(1-\alpha)\alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \int_0^{i^*} A_d(i, h)^{\frac{\alpha}{1-\alpha}} di$$

$$\left[\int_0^{i^*} A_{f,d}(i, h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^{1} A_d(i, h_d)^{\frac{\alpha}{1-\alpha}} di\right]^{-\alpha} \quad (3.31)$$

In equilibrium, the aggregate income is:

$$Y = K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \left[\int_0^{i^*} A_d(i, h_d)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^{1} A_{f,d}(i, h_f)^{\frac{\alpha}{1-\alpha}} di\right]$$

$$\left[\int_0^{i^*} A_{f,d}(i, h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^{1} A_d(i, h_d)^{\frac{\alpha}{1-\alpha}} di\right]^{-\alpha} \quad (3.32)$$

## 3.3 Simulation

One channel through which FDI raises the income level of a country is TFP. By allowing inflows of FDI in their complex industries, developing countries gain access to those advanced technologies that make foreign firms more productive. Thus, as a result of multinationals' presence, developing countries enjoy an increase in their productivity, which ultimately is reflected on income levels. In order to measure the TFP of a less developed country, we rearrange equation (3.36) to express GDP per worker in Hall and Jones (1999)'s manner:

$$y = \left[\frac{K_Y}{Y}\right]^{\frac{1-\alpha}{\alpha}} \frac{L^{\delta}H^{(1-\delta)}}{N} B_d \left[W1 + Z2\right]^{\frac{1}{\alpha}} \left[Z1 + W2\right]^{-1} \tag{3.33}$$

where $Z1 = \int_0^{i^*} \left[e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h_d}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di$ , $Z2 = \int_{i^*}^1 \left[e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h_d}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di$,
$W1 = \int_0^{i^*} \left[e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h_f}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di$, and $W2 = \int_{i^*}^1 \left[e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h_f}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di$.

The previous equation points out the expression for TFP for a less developed country:

$$TFP = B_d \left[W1 + Z2\right]^{\frac{1}{\alpha}} \left[Z1 + W2\right]^{-1} \tag{3.34}$$

We compare the our model's prediction on TFP with the standard results of Hall and Jones (1999). We use the same data for a cross-section of 51 countries for the year 2000 as in Chapter 2. We approximate numerically the definite integrals under $Z1$, $Z2$, $W1$, and $W2$ by using the quadratic interpolation method. Then, we back out $B_d$, the exogenous component of TFP, from (3.33) and substitute it back in (3.34) in order to obtain the estimates for aggregate TFP. Figure 3.2 suggests a strong linear relationship between our

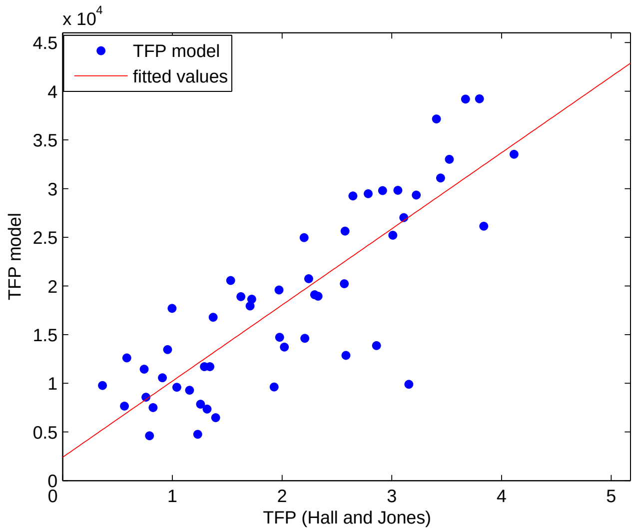



Figure 3.2: Comparison of TFP values with Hall and Jones (1999)' estimates

estimates for TFP and Hall and Jones' values. We find a correlation of 0.83 between the values predicted by our model and Hall and Jones' values.

Based on our results from Chapter 2, in a closed less developed economy, a high fraction of its GDP is concentrated in low tech industries, where the technologies complemented the country's low skills. The premise of this chapter is that FDI is a channel through which a less developed country has access to better technologies brought by foreign producers.

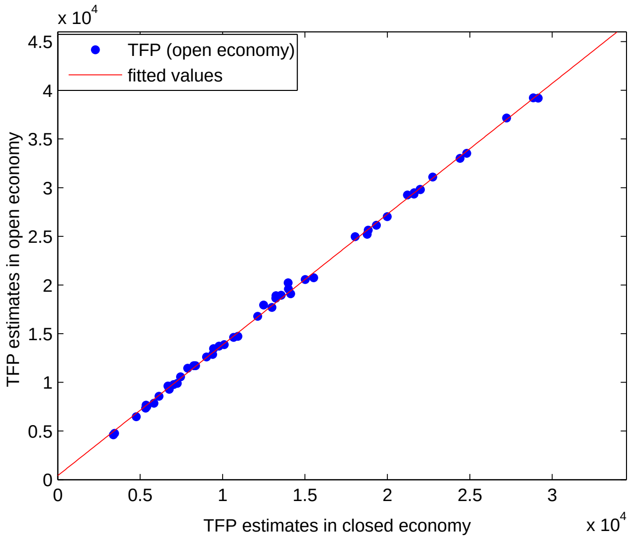



Figure 3.3: Comparison of TFP estimates in closed vs. open economy

In other words, multinationals' entry gives less developed countries the opportunity to increase their TFP by taking advantage of foreign firms' higher productivities in complex industries. Therefore, we compare the estimates for TFP with the previous estimates presented in Chapter 2, corresponding to the case of a closed economy. Figure 3.3 plots the the previous estimates for TFP against the current ones. Indeed, as a result of multinationals' entry, TFP estimates increase on average by 38% .

### 3.3.1 Marginal Product of Capital Differentials

The objective of our exercise is to analyze the effect of foreign direct investments on domestic output and to observe the current world allocation of capital stocks across countries. In this sense, we determine endogenously the equilibrium interest rates implied by our theoretical model. In order to do so, we start from the capital allocation condition and from MPK condition given by (3.8). Therefore:

$$\overline{K} = \frac{1-\alpha}{r+d}\,Y + \frac{\alpha(1-\alpha)}{1+r}\,Y \tag{3.35}$$

After plugging in the estimates for GDP given by (3.36), we get a quadratic equation in $r$ that gives us the estimates for $MPK = r + d$ (the depreciation rate of capital is $d = 0.03$).

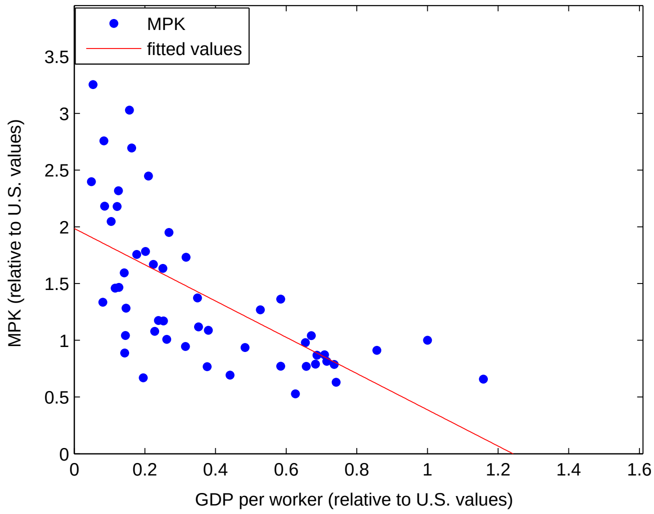



Figure 3.4: MPK estimates

Table 3.1: **Summary Statistics** relative to U.S. values

| Variable | Mean | Std.Dev | Min | Max |
|---|---|---|---|---|
| $k$ | 0.393 | 0.384 | 0.018 | 1.713 |
| $MPK$ | 1.391 | 0.676 | 0.527 | 3.253 |
| $TFP$ | 0.497 | 0.257 | 0.124 | 1.055 |

Table 3.1 presents the summary statistics for $k$, $MPK$ and $TFP$ calculated in relative to U.S. values. The values reflect enormous variation across countries in capital per worker and rates of return to capital investments. Capital per worker in Kenya, the country with the lowest GDP per worker from the sample, is only 2.21% of capital per worker in U.S. while MPK in the richest country (Singapore) is 3.64 times lower than in the least developed country.

Our estimates suggest that there are large MPK differentials across countries. Figure 3.4 indicates a clearly negative relationship between MPK and GDP per worker. The average MPK in less developed countries sample is 1.83 times higher than the average MPK in developed countries. As a result of these significant differences in rates of return to investments, the world financial market is characterized by imperfect capital mobility. Thus the equilibrium world output is not efficiently allocated across countries. Instead, developing economies might have a better chance to increase their GDP if the world capital stock would be optimally distributed, which would result in higher capital flows from low to high interest rates countries.

Next we calculate each country's allocation of total capital stock across domestic investments ($K_Y$ and $K_X$) and foreign capital inflows ($FDI$).

Aggregate income, domestic investments, and FDI can be rewritten as:

$$Y = K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} B_d^{\alpha} \left[W1 + Z2\right] \left[Z1 + W2\right]^{-\alpha} \tag{3.36}$$

$$K_Y = \left[\frac{1-\alpha}{r+d}\right]^{\frac{1}{\alpha}} L^{\delta} H^{(1-\delta)} B_d \left[W1 + Z2\right]^{\frac{1}{\alpha}} \left[Z1 + W2\right]^{-1} \tag{3.37}$$

$$K_X = \frac{1}{1+r}(1-\alpha)\alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} B_d^{\alpha} W1 \left[Z1 + W2\right]^{-\alpha} \tag{3.38}$$

$$FDI = \frac{1}{1+r}(1-\alpha)\alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} B_d^{\alpha} Z2 \left[Z1 + W2\right]^{-\alpha} \tag{3.39}$$

Table 3.4 reports the estimates for domestic and foreign capital per worker ($K_Y$, $K_X$, and $FDI$) for all 51 countries in the sample. FDI inflows in less developed countries represent 69% of world FDI. Out of the set of less developed countries, China is the biggest recipient of FDI: foreign investments in Chinese markets account for 27% of world FDI flows. In per worker terms, however, the situation is different: Portugal has the highest FDI per worker, while China's FDI per worker represents only 21% of Portugal's. The average FDI per worker in less developed countries sample represents 8.1% of capital per worker.

Using the equilibrium expressions for FDI and GDP given by (3.39) and (3.36), we calculate the share of FDI in GDP for a less developed country as:

$$\frac{FDI}{Y} = \frac{\alpha(1-\alpha)}{1+r} \frac{Z2}{Z2 + W1}$$

while for a developed country the formula is:

$$\frac{FDI}{Y} = \frac{\alpha(1-\alpha)}{1+r} \frac{Z1}{Z1+W2}$$

Table 3.3 reports the estimates for $MPK$, the shares of FDI in GDP, and the shares of FDI in $\overline{K}$ for all 51 countries from our sample. The shares of FDI in GFP are consistently higher in less developed countries than in rich countries. In the former sample, FDI accounts on average for 14.44 % of GDP, while only 3.48% in the latter sample. Thus the average share of FDI in GDP is 4.14 times higher in less developed countries than in developed countries.

Next, we rank countries with respect to MPK's. We notice that the average FDI per worker in the top five countries with highest MPK's (Japan, Switzerland, Singapore, Thailand, and South Korea) is 3.61 larger than in the countries with lowest five values for MPK (Ghana, Guatemala, Pakistan, El Salvador, and Kenya). For instance, Ghana's FDI per worker represents only 13% of U.S.' value for FDI per worker. One possible explanation for this result relies on our previous outcome that the the industrial structure of an economy and its TFP are shaped by the appropriate human capital. As mentioned in Chapter 2, human capital intensity in Ghana in 16 times lower than in U.S..

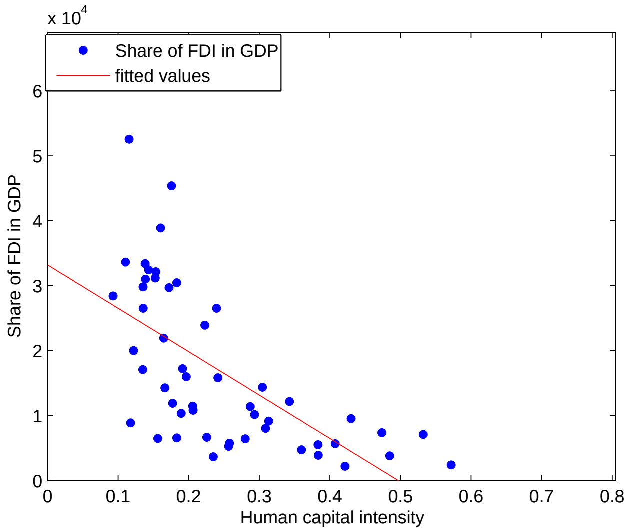



Figure 3.5: Share of FDI in GDP vs. human capital intensity

However, Figure 3.5 indicates a negative linear relationship between human capital intensity and the share of FDI in GDP (the correlation between them, not shown here, is -0.70).

Therefore, even though foreign investments are relatively low in very poor countries, multinationals raise significantly these countries' income levels, making a notable difference in their standard of living.

### 3.3.2 Perfect Capital Mobility

The MPK differentials previously shown support the view that financial markets are not integrated and consequently, the distribution of world capital stock is not efficient. Therefore we carry out the following experiment: we observe how the efficient world allocation of capital would look under perfect capital mobility, or in other words if capital would be allowed to move freely across countries. The premise of this reallocation of world supply of capital is based on perfect capital mobility, i.e., MPK equalization. We are interested in finding out how the reallocation of world capital stock would affect income levels, FDI inflows and the ranking of countries.

In order to proceed with this exercise, we calculate the world interest rate $r_w$ that would ensure perfect capital mobility. First, we construct the ratio $\frac{K_{Y_i}}{\overline{K}_i}$ for country $i$ by using the formula for total capital stock given by (3.35) and the equilibrium expression for $K_{Y_i}$ given by (3.37):

$$\frac{K_{Y_i}}{\overline{K}_i} = \frac{1 + r_i}{1 + r_i + \alpha(r_i + d)}$$

Under MPK equalization, the interest rate $r$ is uniform across countries, i.e.,$r_i = r_w$. By summing up for all countries, we calculate the world supply of capital, $\overline{K}_w$, as a function of $r_w$ and counterfactual $K_{Y_{ci}}$:

$$\overline{K}_w = \sum \overline{K}_{ci} = \frac{1 + r_w + \alpha(r_w + d)}{1 + r_w} \sum K_{Y_{ci}}$$

where counterfactual $K_{Y_{ci}}$ is calculated based on equation (3.37):

$$K_{Y_{ci}} = \left[\frac{1-\alpha}{r_w + d}\right]^{\frac{1}{\alpha}} L_i^{\delta} H_i^{(1-\delta)} TFP_i$$

We substitute this expression into the equation for worls supply of capital stock. Therefore, the world interest rate is given by:

$$\frac{1+r_w}{1+r_w+\alpha(r_w+d)}(r_w+d)^{\frac{1}{\alpha}} = \overline{K}_w^{\,-1}(1-\alpha)^{\frac{1}{\alpha}} \sum L_i^{\delta} H_i^{(1-\delta)} TFP_i$$

We solve numerically the nonlinear equation from above and we find that the world interest rate is $r_w = 0.14$. This implies that the average of actual interest rates is 1.37 times higher than $r_w$. Once we determined $r_w$, the next step is to back out the counterfactual output and capital when interest rates are equalized. We substitute in the capital allocation condition the equilibrium expressions for $K_Y$, $K_X$, and $FDI$ given by (3.37), (3.38), and (3.39). Thus, under perfect capital mobility, the counterfactual capital stock for country $i$ is:

$$\overline{K}_{ci} = \left[\frac{1-\alpha}{r_w + d}\right]^{\frac{1}{\alpha}} \left[1 + \frac{\alpha(r_w+d)}{1+r_w}\right] L_i^{\delta} H_i^{(1-\delta)} TFP_i \tag{3.40}$$

Next, we plug in $\overline{K}_{ci}$ from above into (3.3.2) to determine the domestic investments in final good sector $K_{Y_{ci}}$.

$$K_{Y_{ci}} = \overline{K}_{ci}\frac{1+r_w}{1+r_w+\alpha(r_w+d)}$$

Then we substitute $K_f$ and $r_w$ into the equilibrium expressions for $K_{X_i}$ and $FDI$.

$$K_{X_{ci}} = \frac{1}{1+r_w}(1-\alpha)\alpha K_{Y_{ci}}^{1-\alpha} L_i^{\alpha\delta} H_i^{\alpha(1-\delta)} B_{di}^{\alpha} W1_i \left[Z1_i + W2_i\right]^{-\alpha}$$

$$FDI_{ci} = \frac{1}{1+r_w}(1-\alpha)\alpha K_{Y_{c1}}^{1-\alpha} L_i^{\alpha\delta} H_i^{\alpha(1-\delta)} B_{di}^{\alpha} Z2_i \left[Z1_i + W2_i\right]^{-\alpha}$$

Table 3.5 reports the counterfactual values for domestic capital and FDI in per worker terms when the world supply of capital is optimally allocated. We observe a huge increase of 120% in capital stock in the average less developed country. The average developed country experiences a 9% decrease in its capital stock due to the reallocation of worls capital stock. The major recipients of FDI would be still the less developed countries, where under MPK equalization, FDI would increase on average by 45%. The most remarkable change is observed in Ghana's case, where FDI rises by 145%. In the developed countries sample, FDI decreases on average by 6% as a result of capital reallocation.

As a consequence of specialization in industries where domestic technologies complement human capital, domestic investments in technologies follow the same pattern as FDI, increasing by 45% in the average less developed country and decreasing by 6% in the average rich country. This implies that overall foreign investments do not crowd out domestic investments.

Table 3.2: **Average changes under perfect capital mobility**

| Sample | $K_Y$ | $K_X$ | $FDI$ | $K$ | $y$ |
|---|---|---|---|---|---|
| Less developed countries | +135% | +45% | +45% | 120% | 28% |
| Developed countries | -9% | -6% | -6% | -9% | -5% |

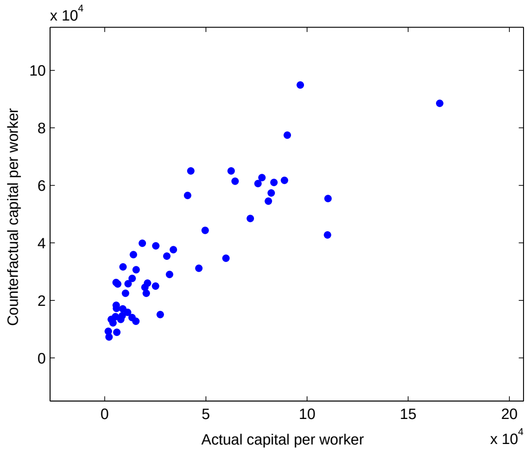
Table 3.2 summarizes these findings by presenting the average changes in equilibrium capital and output as a result of perfect capital mobility in less developed and developed countries.

Figure 4.4 plots the optimal allocation of capital per worker and GDP per worker against the actual allocation. We find a strong positive correlation between the actual and counterfactual estimates for GDP per worker is 0.97, while in the case of capital per worker, this correlation is 0.86.

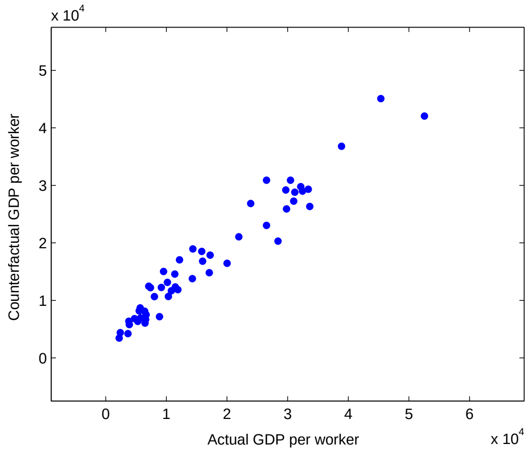
The only outliers in the sample whose GDP per worker would fall as a results of MPK equalization are Thailand, Singapore, Switzerland, Japan and South Korea.

As a result of MPK equalization, less developed countries experience a huge increase in GDP per worker; the average less developed country would increase its output per worker by 28% as a result of free movement of capital, while rich countries would lose 5% of their GDP per worker after MPK equalization. At the global level, the world misses the opportunity to increase the world output by 3% because of the existence of MPK differentials.

Table 3.6 reports the percentage changes in GDP per worker and capital per worker

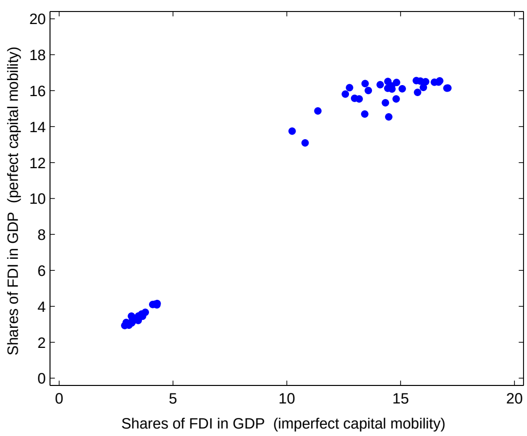



(A) Capital per worker

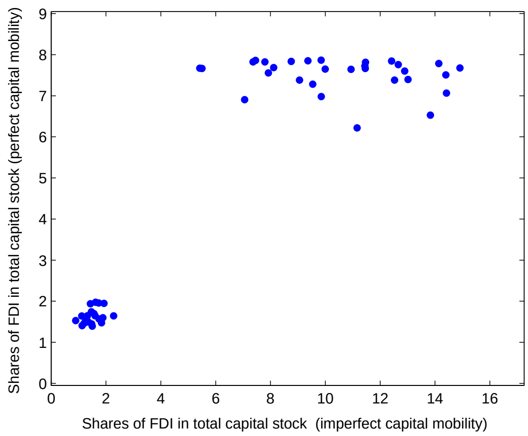



(B) Output per worker

Figure 3.6: Counterfactual capital and output per worker under perfect capital mobility




(A) $\frac{FDI}{Y}$




(B) $\frac{FDI}{\overline{K}}$

Figure 3.7: Shares of FDI in GDP and $\overline{K}$ under imperfect and perfect capital mobility

as financial markets switch from imperfect to perfect capital mobility. The table reports the new shares of FDI in counterfactual GDP's. Figure 3.7 plots the distribution of FDI shares under MPK equalizations against the distribution of these shares in imperfect capital mobility. We notice a clear split: the shares of FDI in GDP (as well as the shares of FDI in K) are very high and variable in the poor countries, and significantly lower and constant in rich countries. Overall, the shares of FDI in GDP increase by 10% in poor countries and fall by 1% in rich countries when capital moves freely across countries. On the other hand, the shares of FDI in K fall by 22% in less deveoped countries and increase by 12% in developed countries.

## 3.4 Conclusions

This chapter analyzes the current allocation world of capital stock and the effect of foreign direct investments on domestic output. Our first finding is that less developed countries increase significantly their total factor productivity and thus, their standard of living by allowing multinationals to invest in their most advanced industries. The premise of this chapter is based on the concept that FDI is a channel through which less developed countries gain access to complex technologies. Therefore, TFP increases as foreign investments flow in industries where multinationals have a technological advantage. Our estimates for TFP are 38% higher in the open economy case than in the closed economy case. These results suggest that FDI may boost the standard of living of developing countries primarily through technology diffusion.

The theoretical model that we use builds on the technology-skill complementarity framework developed in Chapter 2 in which foreign firms engage in a Bertrand competition with domestic firms over each industry. The FDI threshold industry starting from which multinationals overthrow the domestic producers is an increasing function of host country's appropriate human capital. Our focus is to observe the current allocation of world capital stock across countries by deriving endogenously the interest rates. The results indicate that there are significant MPK differences across countries that prevent a free movement of capital.

Therefore, financial markets are characterized by imperfect capital mobility that leads to an inefficient allocation of world supply of capital stock. In this setting, FDI inflows in poor countries represent 69% of world FDI. The shares of FDI in GDP are more than four times higher in less developed countries than in developed countries.

The second finding is based on a hypothetical experiment of reallocating the world capital stock such that it would be optimally distributed across countries and MPK would be equalized. We determine the world interest rate and the counterfactual output and capital stock of each country. As a result of MPK equalization, the capital stock would dramatically increase by 120% in the average less developed country and would fall by 9% in the average developed country. Also, the deadweight loss of failing to equalize interest rates represents 3% of the actual global output.

Table 3.3: **Imperfect capital mobility.** Estimates for $MPK$= marginal product of capital, shares of FDI in GDP, and shares of FDI in $\overline{K}$.

| Country | Country code | $MPK$ | $\frac{FDI}{Y}$ | $\frac{FDI}{\overline{K}}$ |
|---|---|---|---|---|
| Argentina | ARG | 0.20 | 2.88 | 1.50 |
| Australia | AUS | 0.14 | 3.78 | 1.47 |
| Bolivia | BOL | 0.36 | 14.10 | 12.66 |
| Botswana | BWA | 0.29 | 13.42 | 9.85 |
| Brazil | BRA | 0.19 | 15.75 | 7.92 |
| Canada | CAN | 0.14 | 4.31 | 1.62 |
| Chile | CHL | 0.24 | 15.69 | 9.85 |
| China | CHN | 0.26 | 15.07 | 9.99 |
| Colombia | COL | 0.31 | 14.43 | 11.46 |
| Costa Rica | CRI | 0.34 | 14.44 | 12.42 |
| Cyprus | CYP | 0.24 | 2.95 | 1.84 |
| Dominican Republic | DOM | 0.43 | 13.44 | 14.14 |
| Ecuador | ECU | 0.23 | 15.87 | 9.36 |
| El Salvador | SLV | 0.47 | 12.57 | 14.39 |
| France | FRA | 0.14 | 3.19 | 1.20 |
| Germany | GER | 0.14 | 3.43 | 1.26 |
| Ghana | GHA | 0.57 | 10.24 | 13.83 |
| Greece | GRC | 0.13 | 3.60 | 1.32 |
| Guatemala | GTM | 0.53 | 11.37 | 14.42 |
| Honduras | HND | 0.23 | 14.81 | 9.06 |
| Hong Kong | HKG | 0.16 | 3.63 | 1.56 |
| Hungary | HUN | 0.17 | 16.72 | 7.46 |
| India | IND | 0.38 | 13.18 | 12.53 |
| Indonesia | IDN | 0.26 | 14.33 | 9.54 |
| Israel | ISR | 0.17 | 3.48 | 1.60 |
| Italy | ITA | 0.14 | 3.07 | 1.13 |
| Jamaica | JAM | 0.18 | 14.48 | 7.06 |
| Japan | JPN | 0.09 | 3.47 | 0.90 |
| Kenya | KEN | 0.42 | 10.80 | 11.16 |
| Malaysia | MYS | 0.19 | 16.00 | 8.12 |
| Mexico | MEX | 0.18 | 16.48 | 7.80 |
| Netherlands | NLD | 0.15 | 3.22 | 1.33 |
| Nicaragua | NIC | 0.41 | 12.98 | 13.01 |
| Pakistan | PAK | 0.48 | 12.76 | 14.91 |
| Panama | PAN | 0.21 | 3.22 | 1.75 |
| Paraguay | PRY | 0.31 | 14.60 | 11.44 |
| Peru | PER | 0.16 | 3.21 | 1.35 |
| Philippines | PHL | 0.28 | 3.17 | 2.28 |
| Portugal | PRT | 0.16 | 16.67 | 7.36 |
| South Korea | KOR | 0.12 | 4.29 | 1.43 |
| Singapore | SGP | 0.12 | 17.08 | 5.42 |
| Sri Lanka | LKA | 0.38 | 13.58 | 12.89 |
| Sweden | SWE | 0.15 | 4.21 | 1.73 |
| Switzerland | CHE | 0.11 | 3.66 | 1.12 |
| Taiwan | TWN | 0.22 | 3.24 | 1.89 |
| Thailand | THA | 0.12 | 17.03 | 5.50 |
| Tunisia | TUN | 0.29 | 14.62 | 10.94 |
| UK | GBR | 0.18 | 3.03 | 1.48 |
| Uruguay | URY | 0.30 | 14.82 | 11.46 |
| USA | USA | 0.18 | 4.11 | 1.93 |
| Venezuela | VEN | 0.21 | 16.10 | 8.76 |

Table 3.4: **Imperfect capital mobility.** Estimates for $k_Y$= domestic investments in final good sector per worker; $k_X$= domestic investments in appropriate technologies per worker; $fdi$= foreign direct investments in appropriate technologies per worker; $\bar{k}$= capital per worker.

| Country | Country code | $k_Y$ | $k_X$ | $fdi$ | $\bar{k}$ |
|---|---|---|---|---|---|
| Argentina | ARG | 27643 | 2613 | 460 | 30717 |
| Australia | AUS | 77104 | 5315 | 1227 | 83646 |
| Bolivia | BOL | 4488 | 132 | 670 | 5289 |
| Botswana | BWA | 13489 | 504 | 1529 | 15522 |
| Brazil | BRA | 18547 | 373 | 1628 | 20547 |
| Canada | CAN | 82103 | 5324 | 1438 | 88865 |
| Chile | CHL | 22292 | 448 | 2484 | 25224 |
| China | CHN | 6982 | 170 | 794 | 7946 |
| Colombia | COL | 9942 | 280 | 1323 | 11544 |
| Costa Rica | CRI | 12081 | 323 | 1759 | 14162 |
| Cyprus | CYP | 37644 | 4139 | 781 | 42564 |
| Dominican Republic | DOM | 7544 | 247 | 1283 | 9073 |
| Ecuador | ECU | 10043 | 193 | 1057 | 11293 |
| El Salvador | SLV | 5297 | 220 | 928 | 6444 |
| France | FRA | 75997 | 5287 | 988 | 82272 |
| Germany | GER | 74861 | 5031 | 1022 | 80914 |
| Ghana | GHA | 1432 | 104 | 246 | 1782 |
| Greece | GRC | 43068 | 2855 | 615 | 46538 |
| Guatemala | GTM | 4532 | 253 | 806 | 5591 |
| Honduras | HND | 5317 | 140 | 544 | 6001 |
| Hong Kong | HKG | 82551 | 6310 | 1410 | 90271 |
| Hungary | HUN | 29204 | 433 | 2388 | 32025 |
| India | IND | 3456 | 132 | 514 | 4103 |
| Indonesia | IDN | 7580 | 227 | 823 | 8630 |
| Israel | ISR | 58623 | 4800 | 1034 | 64457 |
| Italy | ITA | 66553 | 4570 | 813 | 71937 |
| Jamaica | JAM | 12221 | 328 | 953 | 13502 |
| Japan | JPN | 104120 | 5013 | 987 | 110120 |
| Kenya | KEN | 1787 | 118 | 239 | 2144 |
| Malaysia | MYS | 30630 | 573 | 2756 | 33959 |
| Mexico | MEX | 22812 | 366 | 1960 | 25138 |
| Netherlands | NLD | 71270 | 5388 | 1035 | 77692 |
| Nicaragua | NIC | 4739 | 188 | 737 | 5664 |
| Pakistan | PAK | 2666 | 101 | 485 | 3252 |
| Panama | PAN | 18953 | 1819 | 370 | 21141 |
| Paraguay | PRY | 8845 | 237 | 1173 | 10255 |
| Peru | PER | 14105 | 1082 | 208 | 15395 |
| Philippines | PHL | 7797 | 949 | 204 | 8950 |
| Portugal | PRT | 45332 | 682 | 3657 | 49672 |
| South Korea | KOR | 55820 | 3254 | 859 | 59932 |
| Singapore | SGP | 154730 | 1890 | 8975 | 165590 |
| Sri Lanka | LKA | 4894 | 166 | 749 | 5808 |
| Sweden | SWE | 69520 | 4923 | 1313 | 75755 |
| Switzerland | CHE | 103380 | 5753 | 1233 | 110370 |
| Taiwan | TWN | 36463 | 3724 | 774 | 40961 |
| Thailand | THA | 25645 | 319 | 1511 | 27476 |
| Tunisia | TUN | 11780 | 319 | 1486 | 13585 |
| UK | GBR | 56586 | 5004 | 924 | 62514 |
| Uruguay | URY | 16049 | 400 | 2130 | 18579 |
| USA | USA | 87770 | 7023 | 1865 | 96657 |
| Venezuela | VEN | 17820 | 322 | 1741 | 19883 |

Table 3.5: **Perfect capital mobility.** Estimates for $k_Y$= domestic investments in final good sector per worker; $k_X$= domestic investments in appropriate technologies per worker; $fdi$= foreign direct investments in appropriate technologies per worker; $\bar{k}$= capital per worker.

| Country | Country code | $k_Y$ | $k_X$ | $fdi$ | $\bar{k}$ |
|---|---|---|---|---|---|
| Argentina | ARG | 32098 | 2793 | 492 | 35384 |
| Australia | AUS | 55373 | 4605 | 1063 | 61041 |
| Bolivia | BOL | 13028 | 219 | 1114 | 14362 |
| Botswana | BWA | 27828 | 707 | 2142 | 30676 |
| Brazil | BRA | 20388 | 389 | 1698 | 22475 |
| Canada | CAN | 56003 | 4513 | 1219 | 61735 |
| Chile | CHL | 35366 | 553 | 3067 | 38986 |
| China | CHN | 12144 | 219 | 1024 | 13386 |
| Colombia | COL | 23412 | 418 | 1978 | 25808 |
| Costa Rica | CRI | 32581 | 517 | 2817 | 35915 |
| Cyprus | CYP | 59003 | 5081 | 959 | 65043 |
| Dominican Republic | DOM | 28710 | 474 | 2464 | 31648 |
| Ecuador | ECU | 14369 | 227 | 1244 | 15839 |
| El Salvador | SLV | 23330 | 457 | 1931 | 25717 |
| France | FRA | 52052 | 4489 | 839 | 57379 |
| Germany | GER | 49456 | 4207 | 855 | 54518 |
| Ghana | GHA | 8388 | 255 | 604 | 9247 |
| Greece | GRC | 28278 | 2382 | 513 | 31173 |
| Guatemala | GTM | 23814 | 583 | 1855 | 26251 |
| Honduras | HND | 8084 | 170 | 658 | 8912 |
| Hong Kong | HKG | 70293 | 5881 | 1314 | 77488 |
| Hungary | HUN | 26330 | 414 | 2281 | 29025 |
| India | IND | 11053 | 232 | 899 | 12184 |
| Indonesia | IDN | 13273 | 293 | 1065 | 14631 |
| Israel | ISR | 55747 | 4695 | 1011 | 61453 |
| Italy | ITA | 44005 | 3824 | 681 | 48509 |
| Jamaica | JAM | 12753 | 334 | 971 | 14058 |
| Japan | JPN | 38793 | 3317 | 653 | 42764 |
| Kenya | KEN | 6591 | 223 | 452 | 7265 |
| Malaysia | MYS | 34129 | 601 | 2892 | 37623 |
| Mexico | MEX | 22656 | 365 | 1954 | 24975 |
| Netherlands | NLD | 56865 | 4882 | 938 | 62685 |
| Nicaragua | NIC | 16616 | 346 | 1355 | 18317 |
| Pakistan | PAK | 12160 | 215 | 1029 | 13405 |
| Panama | PAN | 23583 | 2006 | 408 | 25997 |
| Paraguay | PRY | 20378 | 350 | 1736 | 22464 |
| Peru | PER | 11557 | 992 | 191 | 12740 |
| Philippines | PHL | 15494 | 1306 | 280 | 17080 |
| Portugal | PRT | 40235 | 648 | 3471 | 44353 |
| South Korea | KOR | 31436 | 2546 | 672 | 34654 |
| Singapore | SGP | 80312 | 1430 | 6790 | 88533 |
| Sri Lanka | LKA | 15628 | 290 | 1310 | 17227 |
| Sweden | SWE | 55009 | 4445 | 1185 | 60640 |
| Switzerland | CHE | 50275 | 4238 | 908 | 55421 |
| Taiwan | TWN | 51268 | 4345 | 903 | 56516 |
| Thailand | THA | 13685 | 244 | 1156 | 15086 |
| Tunisia | TUN | 25091 | 454 | 2114 | 27659 |
| UK | GBR | 59003 | 5098 | 941 | 65043 |
| Uruguay | URY | 36171 | 586 | 3117 | 39874 |
| USA | USA | 86085 | 6963 | 1849 | 94897 |
| Venezuela | VEN | 22279 | 356 | 1925 | 24560 |

Table 3.6: **Perfect capital mobility.** Estimates for: $\%\Delta y$ =change in GDP per worker after MPK equalization; $\%\Delta k$ =% change in capital per worker after MPK equalization ; $y_f$ =counterfactual GDP per worker; $\frac{FDI_f}{Y_f}$ =share of FDI in GDP under MPK equalization; $\frac{FDI_f}{K_f}$ =share of FDI in K under MPK equalization.

| Country | Country code | $\%\Delta y$ | $\%\Delta k$ | $y_f$ | $\frac{FDI_f}{Y_f}$ | $\frac{FDI_f}{K_f}$ |
|---|---|---|---|---|---|---|
| Argentina | ARG | 0.05 | 0.15 | 16808 | 2.93 | 1.39 |
| Australia | AUS | -0.11 | -0.27 | 28996 | 3.67 | 1.74 |
| Bolivia | BOL | 0.44 | 1.72 | 6822 | 16.33 | 7.76 |
| Botswana | BWA | 0.28 | 0.98 | 14572 | 14.70 | 6.98 |
| Brazil | BRA | 0.03 | 0.09 | 10676 | 15.91 | 7.56 |
| Canada | CAN | -0.12 | -0.31 | 29326 | 4.16 | 1.97 |
| Chile | CHL | 0.17 | 0.55 | 18519 | 16.56 | 7.87 |
| China | CHN | 0.21 | 0.68 | 6359 | 16.10 | 7.65 |
| Colombia | COL | 0.34 | 1.24 | 12260 | 16.13 | 7.66 |
| Costa Rica | CRI | 0.40 | 1.54 | 17061 | 16.51 | 7.84 |
| Cyprus | CYP | 0.17 | 0.53 | 30897 | 3.10 | 1.47 |
| Dominican Republic | DOM | 0.58 | 2.49 | 15034 | 16.39 | 7.79 |
| Ecuador | ECU | 0.13 | 0.40 | 7524 | 16.53 | 7.85 |
| El Salvador | SLV | 0.66 | 2.99 | 12217 | 15.81 | 7.51 |
| France | FRA | -0.12 | -0.30 | 27257 | 3.08 | 1.46 |
| Germany | GER | -0.13 | -0.33 | 25898 | 3.30 | 1.57 |
| Ghana | GHA | 0.82 | 4.19 | 4393 | 13.75 | 6.53 |
| Greece | GRC | -0.13 | -0.33 | 14808 | 3.46 | 1.64 |
| Guatemala | GTM | 0.76 | 3.69 | 12470 | 14.87 | 7.06 |
| Honduras | HND | 0.15 | 0.49 | 4233 | 15.54 | 7.38 |
| Hong Kong | HKG | -0.05 | -0.14 | 36809 | 3.57 | 1.70 |
| Hungary | HUN | -0.03 | -0.09 | 13788 | 16.55 | 7.86 |
| India | IND | 0.48 | 1.97 | 5788 | 15.54 | 7.38 |
| Indonesia | IDN | 0.21 | 0.70 | 6950 | 15.33 | 7.28 |
| Israel | ISR | -0.02 | -0.05 | 29192 | 3.46 | 1.65 |
| Italy | ITA | -0.13 | -0.33 | 23043 | 2.95 | 1.40 |
| Jamaica | JAM | 0.01 | 0.04 | 6678 | 14.54 | 6.91 |
| Japan | JPN | -0.29 | -0.61 | 20314 | 3.22 | 1.53 |
| Kenya | KEN | 0.56 | 2.39 | 3451 | 13.09 | 6.22 |
| Malaysia | MYS | 0.04 | 0.11 | 17872 | 16.18 | 7.69 |
| Mexico | MEX | 0.00 | -0.01 | 11864 | 16.47 | 7.82 |
| Netherlands | NLD | -0.07 | -0.19 | 29777 | 3.15 | 1.50 |
| Nicaragua | NIC | 0.53 | 2.23 | 8701 | 15.57 | 7.40 |
| Pakistan | PAK | 0.68 | 3.12 | 6368 | 16.16 | 7.68 |
| Panama | PAN | 0.08 | 0.23 | 12349 | 3.30 | 1.57 |
| Paraguay | PRY | 0.33 | 1.19 | 10671 | 16.26 | 7.73 |
| Peru | PER | -0.07 | -0.17 | 6052 | 3.15 | 1.50 |
| Philippines | PHL | 0.26 | 0.91 | 8114 | 3.46 | 1.64 |
| Portugal | PRT | -0.04 | -0.11 | 21069 | 16.47 | 7.83 |
| South Korea | KOR | -0.18 | -0.42 | 16462 | 4.08 | 1.94 |
| Singapore | SGP | -0.20 | -0.47 | 42056 | 16.15 | 7.67 |
| Sri Lanka | LKA | 0.48 | 1.97 | 8184 | 16.01 | 7.60 |
| Sweden | SWE | -0.08 | -0.20 | 28806 | 4.11 | 1.95 |
| Switzerland | CHE | -0.22 | -0.50 | 26327 | 3.45 | 1.64 |
| Taiwan | TWN | 0.12 | 0.38 | 26847 | 3.36 | 1.60 |
| Thailand | THA | -0.19 | -0.45 | 7166 | 16.14 | 7.67 |
| Tunisia | TUN | 0.29 | 1.04 | 13139 | 16.09 | 7.64 |
| UK | GBR | 0.01 | 0.04 | 30897 | 3.05 | 1.45 |
| Uruguay | URY | 0.32 | 1.15 | 18941 | 16.46 | 7.82 |
| USA | USA | -0.01 | -0.02 | 45079 | 4.10 | 1.95 |
| Venezuela | VEN | 0.08 | 0.24 | 11667 | 16.50 | 7.84 |

# Chapter 4

# Absorptive Capacities and the Impact of FDI on Economic Growth

## 4.1 Introduction

Over the last two decades the world has experienced an unprecedented upsurge of FDI flows. World FDI more than tripled since 1990 and currently, more than 50% of the private capital flows of developing countries are represented by foreign investments. These stylized facts suggest that FDI is now very much a global affair and its increasing importance as a catalyst that boosts the growth of developing countries is just another feature of globalization.

However, the experience has shown that some countries experienced higher growth rates as a result of increased FDI, while others did not. Previous studies analyzed the required conditions for FDI to have a positive impact on growth. One of the proposed explanations in the literature consists of the idea that positive spillovers from FDI depend on the absorptive capacity of a country, i.e., on the existence of various local conditions favorable to economic growth. This explanation is based on the concept that FDI is a channel through which developing countries gain access to advanced technologies and increase their TFP. But in order to absorb these advanced technologies, host economies need to meet certain conditions that define the absorptive capacity of a country.

This chapter analyzes the optimal mix of such conditions that allows FDI to speed up growth. We evaluate different combinations of measures for absorptive capacity that could generate the most favorable economic environment for positive spillovers from FDI. Therefore, we carry out a unified study of absorptive capacities by analyzing the simultaneous interactions of FDI with other growth determinants and their effect on economic growth. The set of these growth determinants consists of various measures for absorptive capacity that were individually and separately taken into account by the previous literature (development of financial markets, level of human capital, trade openness, natural resource abundance).

The contribution of this chapter lies in our empirical approach. We construct linear interaction terms between FDI and each proxy for absorptive capacity and then we evaluate the robustness of these interaction terms relative to each other. Thus we analyze all possible combinations of favorable conditions that are the most beneficial for FDI and their outcome on the impact of FDI on growth. We find that countries with well developed financial markets that have either low agricultural exports or low oil exports constitute the optimum setting for welfare gains from FDI to exist. Our results indicate that positive spillovers from FDI may coexist with low human capital only if the financial markets of the host country are well developed. Also, the results suggest that oil abundant countries that trade intensively have lower growth rates as a result of FDI.

As an exercise, we then employ the empirical approach of the previous literature by regressing FDI and individual interaction terms on growth rates. We find that gains from FDI exist only when FDI interacts with well developed financial markets and relatively high levels of human capital that induce growth. We then analyze the extent to which these requirements differ across various regions of the world.

Previous studies have shown that even though the first and immediate benefit from FDI comes from the direct capital financing carried out by foreign investors, nevertheless the contribution of FDI to growth consists mainly of diffusion of technologies from rich to poor countries. As Romer (1990) first pointed out, cross-country differences in GDP per worker are accounted for by the huge gaps of ideas across counties (i.e., gaps between technologies and productivities with which rival inputs are used or TFP). Since multinational corporations (MNC) have undertaken a major part of world's R&D, their presence in developing countries eases the transfer of technologies. This process can take the form of imitation/adoption of technologies, formation of forward and backward linkages between industries, and a higher productivity of using the existing technologies.

The common intuition is that FDI should have only positive effects on the development of host economies by giving rise to technology diffusion, productivity gains, access to emerging markets, transfer of business know-how, and employee training. As a consequence, over the last decade developing countries eased the restrictions on FDI by offering tax incentives and subsidies in order to attract foreign capital. However, the empirical evidence has shown that the causality between FDI and growth is ambiguous, in the sense that it is still not clear whether FDI determines growth or vice versa. More often than not studies based on micro level data did not find significant positive effects of FDI on growth, whereas the consensus among macroeconomic studies (that use FDI flows for cross sections of countries) is that FDI may speed up growth conditional on the absorptive capacity of the host country. In other words, these studies suggest that the extent to which foreign technologies are internalized by developing countries is dependent on the absorptive capacity.

The rest of the chapter is organized as follows: the next subsection presents the findings of the previous literature; Section 4.2 presents the empirical methodology and the results. Section 4.3 concludes.

### 4.1.1 Related Literature

A recurring idea in the previous literature is the condition for a developing country to have reached a certain threshold of development for positive spillovers from FDI to exist. The magnitude of spillovers or, in other words, the impact of FDI on economic growth varies with the absorptive capacity of the host economy. Previous studies have shown that the absorptive capacity depends on a minimum threshold level of human capital, well developed financial markets, trade openness, levels of income, and technological gap.

Borensztein, De Gregorio and Lee (1998) have shown that is takes an educated labor force to spread the benefits of new technologies across all industries. Foreign investments are able to speed up growth only when there is a minimum threshold level of human capital in the host economy. Their findings indicate that the gains from FDI come through technology diffusion rather than through capital accumulation.

Alfaro, Chanda, Kalemli-Ozcan, and Sayek (2004) point out that economies with well developed financial markets gain significantly from FDI. The level of development of financial market is a deciding factor whether MNC's operate isolated in enclaves or they become catalysts for technology transfers. Blomstrom, Lypsey, and Zejan (1994) show that FDI has a significant impact on growth and positive spillovers from FDI depend on the income level of the host economy, but not on education. According to Balusubramayam, Salisu, and Sapsford (1999), trade openness is another component of a country's absorptive capacity that increases the contribution of FDI to economic growth.

Carkovic and Levine (2002) show that the benefits from FDI are conditional on other growth determinants, while the exogenous component of FDI does not have a robust positive effect on growth. Therefore they show that FDI per se does not have a direct influence on growth.

A vast part of the literature addressed the issue of the relationship between FDI spillovers and absorptive capacities. According to the first strand of the literature, this relationship is a positive and linear one. The idea dates back to the "relative backwardness" hypothesis of Findlay (1978) that states that the rate of technological progress of a relatively backward country is an increasing function of the technological gap. Therefore the absorptive capacity is measured as the size of the technological gap and technology diffusion from FDI takes place through a "contagion effect". As a result, FDI increases the rate of technological progress in the host country. The other view considers a quadratic relationship between FDI and absorptive capacity. Girma (2005) uses firm level data from UK and finds that the effect of FDI on TFP growth depends on the absorptive capacity that is defined as the distance of a firm from the technological leader in the industry. He shows that there is a non-linear relationship between absorptive capacities and spillovers from FDI. In Girma and Gorg (2005), FDI is interacted with absorptive capacity. They show that there is a U-shaped relationship between this interaction term and TFP growth suggesting that improvements in absorptive capacity at the firm level allow the firm to enhance the spillovers from FDI.

## 4.2 Empirical Analysis

### 4.2.1 Data

Our dataset consists of a cross-section of 69 countries and comprises measures for FDI and for other determinants of economic growth between 1975 and 2000. Several sources were used to construct the final data. We begin with a short description of the measures used in our analysis.

Data for growth rates, real GDP per capita, investment rates, and trade are extracted from Penn World Tables 6.1. The average of annual growth rates of real GDP per capita represents the dependent variable in our regression analysis. The initial GDP enters as the log of real PPP GDP per capita, while the investment rate is measured as the log of average of investment shares in real GDP per capita. Openness to trade is calculated as the log of total trade as a percentage of current GDP i.e., $\log\left(\frac{X+M}{PPP\ GDP}\right)$, where $X$ and $M$ denotes exports and imports in real prices.

Data for FDI are obtained from World Development Indicators. FDI represents the sum of equity capital, reinvestments and other types of capital and it is measured as average of net inflows of foreign investment as percentage of GDP.

As a financial market indicator we use the log of private credit (credit by deposit money banks to GDP) provided by Easterly (2001). Data for educational attainment is provided by Barro and Lee (2001) that reports the average years of secondary schooling in total population over the age of 25.

Data for other explanatory variables, such as agriculture and oil exports are obtained from World Development Indicators. We use the log of average of agricultural raw materials exports in total merchandise exports and the log of average fuel exports in total merchandise exports in current US$ as controls for natural resources abundance.

Finally, we add fixed factors in our analysis in order to control for region and income levels. The data [1] are provided by Easterly (2001).

[1] http://www.nyu.edu/fas/institute/dri/globaldevelopmentnetworkgrowthdatabase.html

### 4.2.2 Methodology

The purpose of our empirical exercise is estimate the impact of FDI on growth and to examine the channels through which FDI can bring welfare gains to the recipient country.

Table 4.1 presents the summary statistics of the data. The data reflects a high cross country variation in the shares of FDI in GDP; FDI inflows in Singapore are 47 times that of South Africa, while on average, FDI represents 1.76 percent of GDP. The highest growth rate over the 1975-2000 period was attained by South Korea (6.081), while Nicaragua experienced the lowest negative growth rate (-3.052). China's spectacular development is reflected in its growth rate (5.835% -the second highest in the sample) while its initial GDP takes the second to last position in the ranking. Regarding human capital, the educational attainment level in Malawi represent 3% of the U.S. level. Table 4.2 presents the correlation matrix for the data averaged over the 1975-2000 period.

Table 4.1: **Summary Statistics.** Based on a sample of 69 countries using the average over the 1975-2000 period. Variables $GDP_{1975}$, I rate, PC, Trade, Oil, and Agriculture are included in regressions as logarithms.

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Growth | 1.890 | 1.683 | -3.052 | 6.081 |
| GDP $_{1975}$ | 8.532 | 0.885 | 6.435 | 9.922 |
| School | 1.827 | 1.042 | 0.167 | 4.576 |
| I rate | 2.795 | 0.411 | 1.907 | 3.789 |
| Private credit | -1.150 | 0.703 | -3.314 | 0.311 |
| Trade | 3.506 | 0.735 | 1.536 | 5.646 |
| Oil | -0.867 | 2.059 | -8.726 | 3.050 |
| Agriculture | 1.123 | 1.373 | -3.428 | 3.548 |
| FDI | 1.764 | 1.637 | 0.042 | 10.107 |

We estimate the effects of FDI on economic growth after controlling for other growth determinants. Thus the regression equation for the cross section data of 69 countries is given by:

$$GROWTH_i = \beta_0 + \beta_1 \log GDP_{1975_i} + \beta_2 CONTROLS_i + \beta_3 FDI_i + \epsilon_i \qquad (4.1)$$

The set of control variables consists of investment rate, human capital, financial devel-

Table 4.2: **Correlation matrix.** Based on a sample of 69 countries using the average over the 1975-2000 period. Variables $GDP_{1975}$, I rate, PC, Trade, Oil, and Agriculture are included in regressions as logarithms.

| Variable | Growth | GDP1975 | School | I rate | PC | Trade | Oil | Agric | FDI |
|---|---|---|---|---|---|---|---|---|---|
| Growth | 1.00 | | | | | | | | |
| GDP1975 | -0.02 | 1.00 | | | | | | | |
| School | 0.26 | 0.75 | 1.00 | | | | | | |
| I rate | 0.46 | 0.63 | 0.63 | 1.00 | | | | | |
| PC | 0.41 | 0.54 | 0.58 | 0.68 | 1.00 | | | | |
| Trade | 0.16 | 0.56 | 0.51 | 0.49 | 0.49 | 1.00 | | | |
| Oil | 0.06 | 0.23 | 0.19 | 0.17 | 0.11 | 0.26 | 1.00 | | |
| Agric | -0.09 | -0.18 | -0.11 | -0.18 | -0.17 | -0.18 | -0.16 | 1.00 | |
| FDI | 0.24 | 0.25 | 0.17 | 0.29 | 0.26 | 0.58 | 0.32 | -0.06 | 1.00 |

opment indicator, openness to trade, agricultural exports, and natural resource abundance (oil exports) of the host country.

Previous studies explored the channels through which FDI may speed up growth by analyzing the interaction between FDI and other determinants of economic growth. Thus, we first linearly interact FDI with five different measures for absorptive capacity. We estimate five additional regression equations corresponding to the interaction terms that are added as explanatory variables: FDI x Financial markets, FDI x Trade, FDI x Schooling, FDI x Oil, and FDI x Agriculture. The interaction terms are the regressors used for testing the significance of those local conditions that ease the absorption of foreign technologies and thus, complement FDI in creating welfare gains in the receiving country. Both FDI and the measure for absorptive capacity are included as well in the new regressions, to avoid the omitted variables problem. Thus, the regressions that estimate the effect of absorptive capacity (ABSCAP) on FDI spillovers and implicitly, on growth are given by:

$$GROWTH_i = \beta_0 + \beta_1 FDI_i + \beta_2 (FDI_i * ABSCAP_i) + \beta_3 ABSCAP_i + \beta_4 CONTROLS + \epsilon_i \tag{4.2}$$

We then account for continent and level of development by adding fixed factors for region and income levels to the regressions. In this sense, dummy variables for Sub-Saharan and Latin American countries are added to control for region, while dummy variables for developing and high income OECD countries are used to control for levels of development.

Finally, we carry out a unified study of absorptive capacities to evaluate the mix of necessary conditions that are required for FDI to increase the growth rate. We test the robustness of the five measures for absorptive capacity relative to each other. Thus we estimate ten regression equations that contain two interaction terms at a time:

$$GROWTH_i = \beta_0 + \beta_1 FDI_i + \beta_2(FDI_i * ABSCAP1_i) + \beta_3(FDI_i * ABSCAP2_i)$$

$$+\beta_4 ABSCAP1_i + \beta_5 ABSCAP2_i + \beta_6 CONTROLS + \epsilon_i \qquad (4.3)$$

The purpose of this exercise is to analyze the combinations of factors that would generate the highest payoffs from FDI for a receiving country. The previous literature has showed that a threshold level of human capital or well developed financial markets are essential for FDI to bring beneficial effects on the host economy. Yet, in this study, we are interested in finding out how a simultaneous interaction of this factors with FDI might change the impact of foreign investments on growth.

### 4.2.3 Results

The results confirm without exception the significant impact of initial levels of income, human capital and investment rates on economic growth. The coefficients of these regressors are all positive and strongly significant at 5% level.

FDI has a positive and significant effect on growth rate of GDP per capita even when absorptive capacities are not taken into consideration. Our estimates of the regression equation (4.1) are presented in column (1) of Table 4.3. The results indicate that the regression coefficient for FDI (0.224) is significant at 10% level, suggesting that a 1 % increase in the share of FDI in GDP is associated with 0.224 % increase in the growth rate of GDP per capita. The coefficient for financial development indicator (private credit) is positive and statistically significant at 10% level, such that a 1% increase in private credit increases the growth rate by 0.05%.

The estimation results of equation (4.2) are reported in columns (2), (3), (4), and (5) of Table 4.3. The estimates highlight the positive effect of FDI on the growth rates of recipient countries when absorptive capacities are taken into consideration. After adding the interaction term between FDI and financial development indicator, the contribution of FDI to growth more than doubles at 5% significance level. The interaction term FDI x Fin enters positively (0.334) and it is statistically significant at 5% level, confirming that well developed financial markets are vital for FDI to enhance growth. When FDI x Agric is added in the regression, the coefficient for FDI increases (0.305) and remains significant at 5%, but the coefficient of the interaction term, although not significant, is negative, suggesting that FDI is growth enhancing in economies where the share of agricultural exports in GDP is low. Although not significant, the coefficients for FDI remain positive when FDI is interacted with oil exports and human capital, while the interaction with trade brings a negative (but insignificant) impact of FDI on the convergence rate of the host country.

Fixed factors that control for region and level of income are added in regression equation (4.2) along with linear interaction terms . The results are presented in Tables 4.4 and 4.5. The coefficient estimates of dummy variables for developing and high income OECD countries are negative and insignificant. However, after adding dummy variables for income levels in regressions, the coefficient for FDI becomes significant not only when FDI is interacted with private credit and agriculture, but also when the the absorptive capacity is proxied by human capital endowment and trade openness. Moreover, after we regress FDI x School on growth rate, both the coefficient of FDI (0.044) and the coefficient on the interaction term (0.071) are significant at 5% level and positive. These results confirm the findings of the previous literature that FDI induces growth in countries that have sufficiently high endowments of human capital.

We then add continental dummies for Sub-Saharan and Latin American countries in the regression equation (4.2). The regression results are presented in Table 4.5. The coefficients for both dummy variables suggest that location brings a penalty to the growth rates of African and Latin American countries. We then add continental dummies for Sub-Saharan and Latin American countries in the regression equation (4.2). The regression results are presented in Table 4.5. The coefficients for both dummy variables suggest that location

brings a penalty to the growth rates of African and Latin American countries. The growth rates of Latin American countries are 0.96% lower than of the rest of the world when FDI is interacted with financial development. Adding the interaction term between FDI and Agriculture brings down the growth rates of Latin American countries even lower (they are 1.11% lower than the growth rates of the rest of the sample).

In both of these two cases, the coefficients for Latin America dummies are significant at 5% level.

Since agriculture accounts for an important fraction of GDP in Sub-Saharan countries, we analyze the way in which the volume of agricultural exports affects the relationship between FDI and growth in African countries. Column (2) in Table 4.5 shows that the interaction term FDI x Agriculture enters negatively, while the coefficient for FDI (0.362) is positive and significant at 5% level. This result suggests that the lower the agricultural intensity in Sub-Saharan countries, the higher the contribution of FDI to growth. In this case, the dummy coefficient for Sub-Saharan countries (-0.901) indicates that their growth rates are 90% lower than of the reference group.

Our results suggests that natural resource abundance does not influence significantly FDI's effect on growth. When absorptive capacity is proxied by the volume of oil exports, the coefficients of both FDI and interaction term become insignificant whether we add continental and income dummy variables or not.

Finally, we test the robustness of these five measures of absorptive capacity relative to each other. We construct pairs of absorptive capacities and we regress their simultaneous interaction with FDI on the growth rate of GDP per capita. The regression equation is given by (4.3). Table 4.6 reports the estimated coefficients for FDI and for the pair of interaction terms considered in each regression. The first column presents the regression coefficients for FDI and interaction terms when FDI x Fin is regressed successively with FDI x Schooling, FDI x Oil, FDI x Agriculture, and FDI x Trade, respectively. In the second column, FDI x Schooling is regressed together with FDI x Oil, FDI x Agriculture and FDI x Trade- one at a time. The third column reports the interaction of FDI x Oil with FDI x Agric and FDI x Trade.

Table 4.3: **FDI and per capita GDP growth: effects of different measures of absorptive capacity on growth** The dependent variables are the average of per capita GDP growth rates from 1975 to 2000. Control variables: $GDP_{1975}$=initial GDP per capita; Schooling=educational attainment; I rate=investment rate, PC=private credit as % in GDP; Trade=total trade as % of GDP; Oil=oil exports as % of GDP; Agriculture=agricultural exports as % in GDP; FDI=share of FDI in GDP. Variables $GDP_{1975}$, I rate, PC, Trade, Oil, and Agriculture are included in regressions as log(variable). P-values are in parentheses below coefficient estimates.

| Independent variable | (1) | FDI x Fin (PC) (2) | FDI x Agriculture (3) | FDI x Oil (4) | FDI x Schooling (5) | FDI x Trade (6) |
|---|---|---|---|---|---|---|
| $GDP_{1975}$ | -1.420 | $-1.296^{***}$ | $-1.440^{***}$ | $-1.403^{***}$ | $-1.423^{***}$ | $-1.391^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Schooling | $0.606^{**}$ | $0.642^{**}$ | $0.542^{**}$ | $0.612^{**}$ | 0.524 | $0.629^{**}$ |
| | (0.019) | (0.013) | (0.038) | (0.018) | (0.181) | (0.016) |
| I rate | $2.123^{***}$ | $1.820^{***}$ | $2.400^{***}$ | $2.052^{***}$ | $2.158^{***}$ | $1.976^{***}$ |
| | (0.001) | (0.005) | (0.000) | (0.001) | (0.001) | (0.002) |
| PC | $0.540^{*}$ | 0.158 | $0.559^{*}$ | $0.552^{*}$ | $0.547^{*}$ | $0.571^{*}$ |
| | (0.100) | (0.704) | (0.088) | (0.095) | (0.099) | (0.086) |
| Trade | -0.265 | -0.358 | -0.235 | -0.247 | -0.273 | -0.399 |
| | (0.412) | (0.274) | (0.465) | (0.449) | (0.403) | (0.278) |
| Oil | 0.001 | -0.014 | 0.005 | -0.053 | -0.000 | -0.000 |
| | (0.987) | (0.859) | (0.950) | (0.670) | (0.997) | (0.995) |
| Agriculture | -0.067 | -0.118 | 0.122 | -0.069 | -0.066 | -0.076 |
| | (0.575) | (0.340) | (0.546) | (0.563) | (0.584) | (0.527) |
| FDI | $0.224^{*}$ | $0.468^{**}$ | $0.305^{**}$ | 0.179 | 0.110 | -0.196 |
| | (0.077) | (0.029) | (0.036) | (0.227) | (0.796) | (0.722) |
| FDI x absorptive capacity | | $0.334^{**}$ | -0.098 | 0.031 | 0.055 | 0.088 |
| | | (0.045) | (0.249) | (0.557) | (0.782) | (0.436) |
| $R^2$ -adjusted | 0.409 | 0.420 | 0.413 | 0.403 | 0.400 | 0.406 |
| Observations | 69 | 69 | 69 | 69 | 69 | 69 |

$^{***}$ represents significant at 1% level;$^{**}$ represents significant at 5% level; $^{*}$ represents significant at 10% level

Table 4.4: **FDI and per capita GDP growth: effects of different measures of absorptive capacity on growth. Fixed factor added: dummy for high income OECD countries** The dependent variables are the average of per capita GDP growth rates from 1975 to 2000; P-values are in parentheses below coefficient estimates.

| Independent variable | FDI x FIN (1) | FDI x AGRIC (2) | FDI x OIL (3) | FDI x SCHOOL (4) | FDI x TRADE (5) |
|---|---|---|---|---|---|
| $GDP_{1975}$ | 0.340*** | 0.326*** | 0.331*** | 0.331*** | 0.334*** |
| | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) |
| Schooling | 0.683** | 0.595** | 0.659** | 0.560*** | 0.678** |
| | (0.012) | (0.029) | (0.016) | (0.009) | (0.014) |
| I rate | 1.770*** | 2.238*** | 1.933*** | 2.007*** | 1.871*** |
| | (0.007) | (0.001) | (0.003) | (0.003) | (0.005) |
| PC | 0.251 | 0.595* | 0.579* | 0.590* | 0.608* |
| | (0.571) | (0.086) | (0.098) | (0.096) | (0.087) |
| Trade | -0.360 | -0.287 | -0.302 | -0.321 | −0.406* |
| | (0.293) | (0.400) | (0.386) | (0.351) | (0.079) |
| Oil | -0.007 | 0.012 | -0.022 | 0.007 | 0.007 |
| | (0.935) | (0.883) | (0.865) | (0.937) | (0.936) |
| Agriculture | -0.098 | 0.133* | -0.061 | -0.055 | -0.062 |
| | (0.459) | (0.057) | (0.636) | (0.674) | (0.630) |
| FDI | 0.412* | 0.272* | 0.168 | 0.044** | −0.141** |
| | (0.052) | (0.069) | (0.269) | (0.019) | (0.010) |
| FDI x absorptive capacity | 0.291 | -0.100 | 0.018 | 0.071** | 0.070 |
| | (0.257) | (0.246) | (0.759) | (0.043) | (0.563) |
| Developing countries dummy | -0.411 | -0.851 | -0.775 | -0.810 | -0.670 |
| | (0.700) | (0.392) | (0.460) | (0.427) | (0.527) |
| High income OECD dummy | -0.674 | -1.051 | -0.958 | -1.054 | -0.924 |
| | (0.495) | (0.263) | (0.329) | (0.268) | (0.339) |
| $R^2$ -adjusted | 0.405 | 0.406 | 0.392 | 0.393 | 0.395 |
| Observations | 69 | 69 | 69 | 69 | 69 |

*** represents significant at 1% level;** represents significant at 5% level; * represents significant at 10% level

Table 4.5: **FDI and per capita GDP growth: effects of different measures of absorptive capacity on growth. Fixed factors added: dummies for Sub-Saharan and Latin American countries** The dependent variables are the average of per capita GDP growth rates from 1975 to 2000. Control variables: $GDP_{1975}$=initial GDP per capita; Schooling=educational attainment; I rate=investment rate, PC=private credit as % in GDP; Trade=total trade as % of GDP; Oil=oil exports as % of GDP; Agriculture=agricultural exports as % in GDP; FDI=share of FDI in GDP. Variables $GDP_{1975}$, I rate, PC, Trade, Oil, and Agriculture are included in regressions as log(variable). P-values are in parentheses below coefficient estimates.

| Independent variable | FDI x FIN (1) | FDI x Agriculture (2) | FDI x Oil (3) | FDI x Schooling (4) | FDI x Trade (5) |
|---|---|---|---|---|---|
| $GDP_{1975}$ | $-1.152^{***}$ | $-1.217^{***}$ | $-1.203^{***}$ | $-1.189^{***}$ | $0.310^{***}$ |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Schooling | $0.514^{**}$ | $0.412^{*}$ | $0.483^{*}$ | 0.569 | $0.490^{*}$ |
| | (0.045) | (0.100) | (0.059) | (0.147) | (0.059) |
| I rate | $1.331^{*}$ | $1.883^{***}$ | $1.465^{**}$ | $1.534^{**}$ | $1.503^{**}$ |
| | (0.057) | (0.009) | (0.034) | (0.025) | (0.034) |
| PC | 0.030 | 0.293 | 0.309 | 0.261 | 0.315 |
| | (0.942) | (0.389) | (0.372) | (0.458) | (0.379) |
| Trade | -0.392 | -0.348 | -0.322 | -0.367 | -0.401 |
| | (0.250) | (0.304) | (0.354) | (0.285) | (0.272) |
| Oil | -0.019 | -0.007 | -0.067 | -0.010 | -0.009 |
| | (0.816) | (0.922) | (0.581) | (0.906) | (0.908) |
| Agriculture | -0.161 | 0.061 | -0.131 | -0.136 | -0.130 |
| | (0.193) | (0.756) | (0.280) | (0.269) | (0.282) |
| FDI | $0.448^{**}$ | $0.362^{**}$ | 0.219 | 0.411 | $0.085^{*}$ |
| | (0.033) | (0.017) | (0.166) | (0.376) | (0.089) |
| FDI x absorptive capacity | $0.260^{*}$ | -0.101 | 0.034 | -0.064 | 0.038 |
| | (0.097) | (0.225) | (0.529) | (0.758) | (0.753) |
| Sub-Saharan dummy | -1.030 | -0.901 | -1.055 | -0.952 | -1.003 |
| | (0.125) | (0.177) | (0.125) | (0.159) | (0.143) |
| Latin America dummy | $-0.967^{**}$ | $-1.110^{**}$ | $-1.073^{**}$ | $-1.138^{**}$ | $-1.042^{**}$ |
| | (0.048) | (0.020) | (0.026) | (0.025) | (0.039) |
| $R^2$ -adjusted | 0.447 | 0.450 | 0.439 | 0.436 | 0.436 |
| Observations | 69 | 69 | 69 | 69 | 69 |

$^{***}$ implies significant at 1% level;$^{**}$ implies significant at 5% level; $^{*}$ implies significant at 10% level

The coefficient for FDI is positive (0.571) and significant at 5% level when FDI is interacted simultaneously with both the financial market indicator and human capital. While FDI x Fin enters positively in the regression and is statistically significant at 5%, the coefficient for FDI x Schooling although insignificant, is negative. This surprising result suggest that well developed finacial market might make up for a low endowment of human capital, such that overall, FDI might have a positive and significant impact on growth. Thus, positive spillovers from FDI may coexist with a lower human capital endownment if the condition for well developed financial markets is met in the host country.

We then analyze simultaneously the conditions on natural resource abundance and development of financial markets that are required for generating positive effects of FDI on growth. The coefficient estimate for FDI is positive (0.491) and significant when FDI x Fin and FDI x Oil enter the regression. However, even though both interaction terms are insignificant, the coefficient for FDI x Oil is negative, suggesting that natural resources abundance might inhibit the benefits from FDI. Thus gains from FDI materialize in a country that is relatively scarce in natural resources but has well developed financial markets

A similar situation is found when FDI x Fin is interacted with FDI x Agriculture. The coefficient for FDI is strongly significant at 1% level and positive (0.685). While the coefficient for FDI x Fin is significant and positive, the coefficient for FDI x Agriculture is also significant but negative (-0.150). Thus, countries with well developed financial markets and low shares of agricultural exports in GDP increase their welfare through FDI from FDI.

When FDI x Trade enters the regressions, the coefficients for FDI become negative with one exception: when FDI x Trade is combined with FDI x Fin, the coefficient for FDI is positive but insignificant. However, when FDI x Trade is regressed together with FDI x Oil, FDI is significant at 1% level and negative. This suggests that the growth of oil abundant countries that trade intensively might slow down when MNC's invest in their markets.

Table 4.6: **Robustness of absorptive capacities relative to each other: growth effects of simultaneous interactions between absorptive capacities and FDI** The dependent variable is the average of per capita GDP growth rates from 1975 to 2000. Control variables: $GDP_{1975}$=initial GDP per capita; Schooling=educational attainment; I rate=investment rate, PC=private credit as % in GDP; Trade=total trade as % of GDP; Oil=oil exports as % of GDP; Agriculture=agricultural exports as % in GDP; FDI=share of FDI in GDP. P-values are in parentheses near coefficient estimates.

| ABSCAP | | FDIxFin | FDIxSchool | FDIxOil | FDIxAgric | FDIxTrade |
|---|---|---|---|---|---|---|
| FDI*Fin | FDI | $0.468^{**}$ (0.029) | | | | |
| | FDIxFin | $0.334^{**}$ (0.045) | | | | |
| FDIxSchool | FDI | $0.571^{**}$ (0.018) | 0.110 (0.796) | | | |
| | FDIxFin | $0.352^{**}$ (0.012) | | | | |
| | FDIxSchool | -0.043 (0.834) | $0.055^{***}$ (0.009) | | | |
| FDI x Oil | FDI | $0.491^{*}$ (0.085) | 0.068 (0.875) | 0.179 (0.227) | | |
| | FDIxFin | 0.351 (0.197) | | | | |
| | FDIxSchool | | 0.053 (0.789) | | | |
| | FDIxOil | -0.007 (0.901) | 0.031 (0.562) | 0.031 (0.557) | | |
| FDIxAgric | FDI | $0.685^{***}$ (0.006) | 0.255 (0.567) | 0.262 (0.115) | $0.305^{**}$ (0.036) | |
| | FDIxFin | $0.463^{**}$ (0.059) | | | | |
| | FDIxSchool | | 0.023 (0.908) | | | |
| | FDIxOil | | | 0.028 (0.594) | | |
| | FDIxAgric | $-0.150^{*}$ (0.089) | -0.097 (0.265) | -0.096 (0.263) | -0.098 (0.249) | |
| FDIxTrade | FDI | 0.713 (0.443) | -0.210 (0.734) | $-0.173^{***}$ (0.006) | -0.228 (0.667) | -0.196 (0.722) |
| | FDIxFin | 0.395 (0.226) | | | | |
| | FDIxSchool | | 0.010 (0.959) | | | |
| | FDIxOil | | | $0.004^{***}$ (0.008) | | |
| | FDIxAgric | | | | $-0.113^{**}$ (0.011) | |
| | FDIx Trade | -0.042 (0.787) | 0.086 (0.469) | 0.082 (0.609) | $-0.115^{***}$ (0.004) | 0.088 (0.436) |

*** implies significant at 1% level;** implies significant at 5% level; * implies significant at 10% level

## 4.3 Conclusions

This chapter analyzes the necessary local conditions that enable FDI to generate welfare gains in host countries. The mix of these local conditions defines the absorptive capacity.

The relationship between FDI and economic growth is shaped by absorptive capacities that consist of development of financial markets, endowment of human capital, trade openness, agricultural intensity and natural resources abundance.

We first focus on the relationship between FDI and other growth determinants by constructing linear interaction terms between FDI and different measures for absorptive capacity. Using a cross section of 69 countries we regress FDI and these individual interaction terms on the growth rate of GDP per capita after controlling for other growth determinants. We find that the contribution of FDI to economic growth is positive and significant Our results indicate that a minimum level of human capital and well developed financial markets are essential for positive spillovers from FDI to exist.

The second exercise consists of a unified study of absorptive capacities that tests the robustness of the linear interaction terms previously constructed relative to each other. The results suggest that the most favorable economic environments for FDI are represented by countries with well developed financial markets that are either relatively scarce in natural resources or have low shares of agricultural exports in GDP. The condition of having well developed financial markets dominates in importance the condition for a threshold level of human capital.

# Bibliography


Acemoglu, D. 1998. Why Do New Technologies Complement Skills? Directed Technical Change and Wage Inequality. Quarterly Journal of Economics. 113(4): 1055-89.

Acemoglu, D. 2002. Directed Technical Change. Review of Economic Studies. 69(4): 781-809.

Acemoglu, D. and Zilibotti, F. 2001. Productivity Differences. Quarterly Journal of Economics. 116(2): 563-606.

Acemoglu, D. and Zilibotti, F. 1997. Was Prometheus Unbound by Chance? Risk, Diversification, and Growth. Journal of Political Economy, University of Chicago Press, vol. 105(4), pages 709-51, August.

Aghion, P. and Howitt, P. 1990. A Model of Growth Through Creative Destruction EconometricaMarch 1992, 60 (2)

Alfaro, L., Chanda, A., Kalemli-Ozcan, S., and Sayek, S. 2004. FDI and economic growth: the role of local financial markets Journal of International Economics, Elsevier, vol. 64(1), pages 89-112, October.

Atkinson, A. and Stiglitz, J. 1969. A New View of Technological Change. Economic Journal. Royal Economic Society, vol. 79(315):573-78.

Aiyar, S. and Dalgaard,C. 2004. Total Factor Productivity Revisited: A Dual Approach to Development Accounting EPRU Working Paper Series 04-07, Economic Policy Research Unit (EPRU), University of Copenhagen. Department of Economics.

Barro, R. and Lee, J. 2001. International Data on Educational Attainment: Updates and Implications, Oxford University Press. vol. 53(3):541-63.

Barro, R., Mankiw, N., and Sala-i-Martin, X. 1995. Capital Mobility in Neoclassical Models of Growth. American Economic Review, American Economic Association, vol. 85(1), pages 103-15, March.

Basu, S. and Weil, D. 1998. Appropriate Technology and Growth. Quarterly Journal of Economics. 113(4): 1025-54.

Bekaert, G., Harvey, C., and Lundblad, C. 2005. Does financial liberalization spur growth? Journal of Financial Economics, Elsevier, vol. 77(1), pages 3-55, July.

Benhabib, J. and Spiegel, M. 2002. Human Capital And Technology Diffusion. FRB of San Francisco Working Paper No. 2003-02.

Bernanke, B. and Gurkaynak, R. 2002. Is Growth Exogenous? Taking Mankiw, Romer, and Weil Seriously. Cambridge, MA: MIT Press. 11-57.

Bils, M.and Klenow, P. 2000. Does Schooling Cause Growth? American Economic Review. 90(5): 1160-83.

Borensztein, E., De Gregorio, J. and Lee, J-W. 1998. How does foreign direct investment affect economic growth? Journal of International Economics. Elsevier, vol. 45(1), pages 115-135, June.

Bosworth, B., Collins, S.M. and Chen, Y.C. 1995. Accounting for Differences in Economic Growth Papers 115, Brookings Institution - Working Papers.

Boyd, J. and Smith, B. 1997. Capital Market Imperfections, International Credit Markets, and Nonconvergence Journal of Economic Theory, Elsevier, vol. 73(2), pages 335-364, April.

Card, D. 1999. The causal effect of education on earnings. Handbook of Labor Economics. in: O. Ashenfelter and D. Card (ed.), Handbook of Labor Economics, edition 1, volume 3, chapter 30, pages 1801-1863 Elsevier.

Caselli, F. 2005. Accounting for Cross-Country Income Differences. in: Philippe Aghion and Steven Durlauf (ed.), Handbook of Economic Growth,Elsevier. edition 1, volume 1: pages 679-741.

Caselli, F. and Coleman, W.J. 2001. Cross-Country Technology Diffusion: The Case of Computers American Economic Review vol. 91(2): 328-35.

Caselli, F. and Coleman, W.J. 2006. The World Technology Frontier. American Economic Review. vol. 96(3):499-522.

Caselli, F. and Feyrer, J. 2007. The Marginal Product of Capital. The Quarterly Journal of Economics.

Chakrabarty, D., Chanda, A. and Ghate, C. 2006. Education, Growth, and Redistribution in the Presence of Capital Flight. *Topics in Macroeconomics*, Berkeley Electronic Press. vol. 6(2).

Chanda, A. and Putterman, L. 2004. The Quest for Development. World Economics, World Economics, NTC Economic and Financial Publishing, PO Box 69, Henley-on-Thames, Oxfordshire, United Kingdom, RG9 1GB. vol. 5(2): 1-31.

Chanda, A. and Dalgaard, C-J. 2007. Dual Economies and International Total Factor Productivity Differences: Channelling the Impact from Institutions, Trade, and Geography. Economica. forthcoming.

Cordoba, J.C. and Ripoll, M. 2005. Endogenous TFP and Cross-Country Income Differences. Development and Comp Systems 0512018, EconWPA.

Duffy, J., Papageorgiou, C., and Perez-Sebastian, F. 2004. Capital-Skill complementarity? Evidence from a Panel of Countries. The Review of Economics and Statistics. MIT Press, vol. 86(1): 327-44.

Easterly, W. and Levine,R. 2002. It's Not Factor Accumulation: Stylized Facts and Growth Models. Working Papers Central Bank of Chile 164, Central Bank of Chile.

Eaton, J. and Kortum, S. 2001. Trade in Capital Goods. NBER Working Papers. 8070, National Bureau of Economic Research, Inc.

Gertler, M. and Rogoff, K. 1990. North-South lending and endogenous domestic capital market inefficiencies Journal of Monetary Economics, Elsevier, vol. 26(2), pages 245-266, October.

Graham, B. and Temple, J. 2006. Rich Nations, Poor Nations: How Much Can Multiple Equilibria Explain? Journal of Economic Growth. Springer, vol. 11(1): 5-41.

Grossman, G., and Helpman, E. 1993. Innovation and Growth in the Global Economy MIT Press Books, The MIT Press, edition 1, volume 1, number 0262570971

Goldin, C. and Katz, L.1998. The Origins Of Technology-Skill Complementarity. The Quarterly Journal of Economics. MIT Press, vol. 113(3): pages 693-732.

Gollin, D. 2002. Getting Income Shares Right. Journal of Political Economy University of Chicago Press, vol. 110(2), pages 458-474, April.

Gourinchas, P. and Jeanne, O. 2006. The Elusive Gains from International Financial Integration. Review of Economic Studies. 73, 715-741

Greenwood, J., Hercowitz, Z., and Krusell, P. 1995. Long-Run Implications of Investment-Specific Technological Change. American Economic Review. Vol. 87 (3). p.342-62. June 1997

Hall, R.E. and Jones, C.I. 1999. Why Do Some Countries Produce So Much More Output Per Worker Than Others? Quarterly Journal Of Economics. 114: 83-116.

Howitt, P. and Mayer-Foulkes, D. 2005. R&D, Implementation, and Stagnation: A Schumpeterian Theory of Convergence Clubs. Journal of Money, Credit and Banking. Blackwell Publishing, vol. 37(1): 147-77.

Hsieh, C. and Klenow, P. 2007. Misallocation and Manufacturing TFP in China and India. NBER Working Papers 13290, National Bureau of Economic Research, Inc.

Islam, N. 1995. Growth Empirics: A Panel Data Approach. The Quarterly Journal of Economics. MIT Press, vol. 110(4), pages 1127-70, November.

Jones, C. 2008. Intermediate Goods, Weak Links, and Superstars: A Theory of Economic Development. NBER Working Papers 13834, National Bureau of Economic Research, Inc.

Jovanovic, B. and Rob, R. 1997. Solow vs. Solow: Machine Prices and Development NBER Working Papers. 5871, National Bureau of Economic Research, Inc.

Klenow, P. and Rodriguez-Clare, A. 1997. The Neoclassical Revival in Growth Economics: Has It Gone Too Far? in Bernanke, B. and Rotemberg, J. (eds). *NBER Macroeconomics Annual*, Cambridge, MA: MIT Press. 73-103.

Koren, M. and Tenreyro, S. 2003. Diversification and development. Working Papers 03-3, Federal Reserve Bank of Boston.

Kugler, M. 2006.Spillovers From Foreign Direct Investment:Within Or Between Industries? Borradores de Economia.003523, Banco de la Republica.

Levine, R., Loayza, N., and Beck, T 1999. Financial intermediation and growth : Causality and causes. Policy Research Working Paper Series. 2059, The World Bank.

Lucas, R.Jr. 1988. On the mechanics of economic development. Journal of Monetary Economics, Elsevier. vol. 22(1): 3-42.

Mankiw, G., Romer, D. and Weil, D. 1992. A Contribution to the Empirics of Economic Growth. The Quarterly Journal of Economics, MIT Press. vol. 107(2); 407-37.

Markusen, J. and Venables, A.J. 1999. Foreign direct investment as a catalyst for industrial development. European Economic Review. Elsevier vol. 43(2), pages 335-356, February.

Matsuyama,K. 2004. Financial Market Globalization, Symmetry-Breaking, and Endogenous Inequality of Nations Econometrica, Econometric Society, vol. 72(3), pages 853-884, 05.

Nelson, R. and Phelps, E. 1965. Investment in Humans, Technological Diffusion and Economic Growth. American Economic Review. 1966, 56, 69-75

Papageorgiou, C., Lall, S. and Jaumotte, F. 2008. Rising Income Inequality: Technology, or Trade and Financial Globalization? IMF Working Papers 08/185, International Monetary Fund.

Parente, S. and Prescott, E. 2000. Barriers to Riches. Walras-Pareto lectures. Vol. 3 Cambridge, MA: MIT Press.

Prasad, E., Rogoff, K., Wei, S., and KoseM. 2007. Financial Globalization, Growth and Volatility in Developing Countries NBER Chapters, in: Globalization and Poverty, pages 457-516 National Bureau of Economic Research, Inc.

Prescott, E. 1998. Needed: a Theory of Total Factor Productivity. International Economic Review. 39: 525-51.

Pritchett, L. 2006. Does Learning to Add up Add up? The Returns to Schooling in Aggregate Data. Handbook of the Economics of Education. Elsevier.

Rajan, R. and Zingales, L. 2001. The Great Reversals: The Politics of Financial Development in the 20th Century CRSP working papers 526, University of Chicago.

Restuccia, D. 2004. Barriers to Capital Accumulation and Aggregate Total Factor Productivity. International Economic Review. Department of Economics, University of Pennsylvania and Osaka University Institute of Social and Economic Research Association, vol. 45(1):225-238.

Seshadri, A. and Manuelli, R. 2005. Human Capital and the Wealth of Nations. 2005 Meeting Papers 56, Society for Economic Dynamics.

Tornell, A. and Velasco, A. 1992. The Tragedy of the Commons and Economic Growth: Why Does Capital Flow from Poor to Rich Countries? Journal of Political Economy, University of Chicago Press, vol. 100(6), pages 1208-31, December.

Ventura, J. 1997. Growth and Interdependence. The Quarterly Journal of Economics. MIT Press, vol. 112(1), pages 57-84, February.

Wozniak, G. 1984. The Adoption of Interrelated Innovations: A Human Capital Approach. The Review of Economics and Statistics MIT Press, vol. 66(1), pages 70-79, February.

Young,A. 1993. Lessons from the East Asian NICs: A Contrarian View. 1994 European Economic Review 38.

Xu, B. 2000. Multinational enterprises, technology diffusion, and host country productivity growth. Journal of Development Economics. Elsevier, vol. 62(2), pages 477-493, August.

# Appendix 1. Supplementary Derivations for Chapter 2: Labor Market Equilibrium

In equilibrium, nominal wages are equalized such that $w_{L_i} = w_L$ and $w_{H_i} = w_H$ for $i \in (0,1)$.

**Step 1: Get $L_i$, $H_i$ as functions of $(w_L, w_H, \int_0^1 A(i,h), K_Y)$**

Using (2.10) and (2.11) the variety specific demands for unskilled labor $L_i$ and human capital $H_i$ are expressed as functions of nominal wages and appropriate technologies:

We back out $H_{id}$ from (2.11) and insert it in (2.10):

$$H_i = \left[\frac{w_H}{(1-\delta)\alpha^2 A(i,h)^\alpha L_i^{\alpha\delta} K_Y^{1-\alpha}}\right]^{\frac{1}{\alpha(1-\delta)-1}}$$

Thus,

$$w_L = \delta(1-\delta)^{\frac{\alpha(\delta-1)}{\alpha(1-\delta)-1}} A(i,h)^{\frac{-\alpha}{\alpha(1-\delta)-1}} \alpha^{\frac{-2}{\alpha(1-\delta)-1}} w_H^{\frac{\alpha(1-\delta)}{\alpha(1-\delta)-1}} L_i^{\frac{1-\alpha}{\alpha(1-\delta)-1}} K_Y^{\frac{\alpha-1}{\alpha(1-\delta)-1}}$$

In order to express $L_i$ and $H_i$ as functions of nominal wages and technologies, we use the equation from above. First, we determine the variety specific demand for unskilled labor $L_i$;

$$L_i = \alpha^{\frac{2}{1-\alpha}} \delta^{\frac{1-\alpha(1-\delta)}{1-\alpha}} (1-\delta)^{\frac{\alpha(1-\delta)}{1-\alpha}} K_Y\, w_L^{\frac{\alpha(1-\delta)-1}{1-\alpha}}\, w_H^{\frac{-\alpha(1-\delta)}{1-\alpha}}\, A(i,h)^{\frac{\alpha}{1-\alpha}} \tag{4.4}$$

Next, we derive the variety specific demand for skilled labor $H_i$ by substituting (4.4) into the expression for $H_i$:

$$H_i = \alpha^{\frac{2}{1-\alpha}} \delta^{\frac{\alpha\delta}{1-\alpha}} (1-\delta)^{\frac{-\alpha\delta+1}{1-\alpha}} K_Y\, w_L^{\frac{-\alpha\delta}{1-\alpha}}\, w_H^{\frac{\alpha\delta-1}{1-\alpha}}\, A(i,h)^{\frac{\alpha}{1-\alpha}} \tag{4.5}$$

**Step 2: Use the labor market resource constraints $L = \int_0^1 L_i di$ and $L = \int_0^1 L_i di$**

**to get** $w_L = w_L(L, H, \int_0^1 A(i,h), K_Y)$ **and** $w_H = w_H(L, H, \int_0^1 A(i,h), K_Y)$:

Use (4.4) and (4.5) to calculate $L$ and $H$:

$$L = \alpha^{\frac{2}{1-\alpha}} \, \delta^{\frac{1-\alpha(1-\delta)}{1-\alpha}} \, (1-\delta)^{\frac{\alpha(1-\delta)}{1-\alpha}} \, K_Y \, w_L^{\frac{\alpha(1-\delta)-1}{1-\alpha}} \, w_H^{\frac{-\alpha(1-\delta)}{1-\alpha}} \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \tag{4.6}$$

$$H = \alpha^{\frac{2}{1-\alpha}} \, \delta^{\frac{\alpha\delta}{1-\alpha}} \, (1-\delta)^{\frac{-\alpha\delta+1}{1-\alpha}} \, K_Y \, w_L^{\frac{-\alpha\delta}{1-\alpha}} \, w_H^{\frac{\alpha\delta-1}{1-\alpha}} \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \tag{4.7}$$

We back out $w_H$ from (4.6) to substitute it into formula for $H$ given by (4.7):

$$w_H = \alpha^{\frac{-2}{\alpha(\delta-1)}} (1-\delta) \delta^{\frac{(1-\delta)\alpha-1}{(\delta-1)\alpha}} \, w_L^{\frac{1-(1-\delta)\alpha}{(\delta-1)\alpha}} \, L^{\frac{1-\alpha}{(\delta-1)\alpha}} K_Y^{\frac{1-\alpha}{\alpha(1-\delta)}} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \right]^{\frac{1-\alpha}{(1-\delta)\alpha}} \tag{4.8}$$

Substituting the formula from above into (4.7), we get:

$$H = \alpha^{\frac{2}{\alpha(1-\delta)}} \delta^{\frac{1}{\alpha(1-\delta)}} w_L^{\frac{1}{\alpha(1-\delta)}} L^{\frac{\alpha\delta-1}{\alpha(\delta-1)}} K_Y^{\frac{\alpha-1}{\alpha(1-\delta)}} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \right]^{\frac{\alpha-1}{(1-\delta)\alpha}}$$

From the previous equation we back out the equilibrium nominal wage $w_L$:

$$w_L = \alpha^2 \delta \;\, K_Y^{1-\alpha} \, L^{\alpha\delta-1} \, H^{\alpha(1-\delta)} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \right]^{1-\alpha} \tag{4.9}$$

Substitute $w_L$ from (4.9)into (4.8) to get the equilibrium nominal wage $w_H$.

Thus,

$$w_H = \alpha^2 (1-\delta) \, K_Y^{1-\alpha} \, L^{\alpha\delta} \, H^{\alpha(1-\delta)-1} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \right]^{1-\alpha} \tag{4.10}$$

**Step 3: Get $K_X$ as a function of $(H, L, \int_0^1 A(i,h), K_Y)$**

Next, we substitute the equilibrium nominal wages from (4.9) and (4.10) into the expression of $K_X$ given by (2.23).

First, we calculate $S = \left[ \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta} \right]$ by substituting (4.9) and (4.10):

$$S = \left[ \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta} \right] = \alpha^2 L^{\delta(\alpha-1)} H^{(1-\delta)(\alpha-1)} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \right]^{1-\alpha} K_Y^{1-\alpha}$$

Thus

$$S^{\frac{\alpha}{\alpha-1}} = \alpha^{\frac{2\alpha}{\alpha-1}} L^{\alpha\delta} H^{\alpha(1-\delta)} K_Y^{-\alpha} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{-\alpha}} di \right]^{1-\alpha}$$

Substitute (4.3) into the formula for $K_X$ given by (2.23):

$$K_X = \frac{1}{1+r} \alpha (1-\alpha) K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \right]^{-\alpha} di. \tag{4.11}$$

Denote $g(i) = A(i,h)^{\frac{\alpha}{1-\alpha}}$. The focus is on simplifying $\int_0^1 g(i) \left[\int_0^1 g(i)di\right]^{-\alpha} di$. Since $\int_0^1 g(i) \equiv G$ is constant, we can rewrite

$$\int_0^1 g(i) \left[ \int_0^1 g(i) di \right]^{-\alpha} di = \int_0^1 g(i) G^{-\alpha} di = G^{1-\alpha} = \left[ \int_0^1 g(i) di \right]^{1-\alpha} \tag{4.12}$$

Substitute (4.12) into formula for $K_X$ given by (4.11):

$$K_X = \frac{1}{1+r} \alpha (1-\alpha) K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \right]^{1-\alpha}. \tag{4.13}$$

**Step 4: Get $Y$ as a function of $(H, L, \int_0^1 A(i,h), K_Y)$**

Next, we substitute the equilibrium nominal wages from (4.9) and (4.10) into the explicit demand of $X_i$ given by (2.12):

$$X_i = \left[ \frac{1}{\alpha^2} \frac{1}{A(i,h)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta} \right]^{\frac{1}{\alpha-1}} K_Y$$

Thus

$$X_i^{\alpha} = \left[ \frac{1}{\alpha^2} \frac{1}{A(i,h)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta} \right]^{\frac{\alpha}{\alpha-1}} K_Y^{\frac{\alpha}{\alpha-1}}$$

$$= \alpha^{\frac{2\alpha}{1-\alpha}} A(i,h)^{\frac{\alpha}{1-\alpha}} \alpha^{\frac{2\alpha}{\alpha-1}} L^{\alpha\delta} H^{\alpha(1-\delta)} K_Y^{-\alpha} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{-\alpha}} di \right]^{1-\alpha} K_Y^{\alpha}$$

$$X_i^{\alpha} = L^{\alpha\delta} H^{\alpha(1-\delta)} A(i,h)^{\frac{\alpha}{1-\alpha}} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \right]^{-\alpha}$$

$$\int_0^1 X_i^{\alpha} = L^{\alpha\delta} H^{\alpha(1-\delta)} \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \right]^{-\alpha} di$$

In a similar manner as for $K_X$, the above formula becomes:

$$\int_0^1 X_i^\alpha = L^{\alpha\delta} H^{\alpha(1-\delta)} \left[ \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \right]^{1-\alpha}$$

Therefore, in equilibrium, the aggregate income $Y$ is expressed as:

$$Y = K_Y^{1-\alpha}\, L^{\alpha\delta}\, H^{\alpha(1-\delta)} \, \left[ \int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di \right]^{1-\alpha} \tag{4.14}$$

# Appendix 2. Supplementary Derivations for Chapter 2: Share of Industry $i$ in GDP

From (2.1) and (2.2) we calculate the share of variety $i$ in GDP:

$$\frac{p_i X_i}{Y} = \alpha \frac{p_i X_i}{\int_0^1 p_i X_i di} = \alpha \frac{X_i^\alpha}{\int_0^1 X_i^\alpha di} \tag{4.15}$$

$X_i$ is given by the first order condition from the intermediate goods sector:

$$X_i = \left[\frac{1}{\alpha^2} \frac{1}{A(i,h)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta}\right]^{\frac{1}{\alpha-1}} K_Y$$

After substituting for $\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta}$ , we get:

$$X_i^\alpha = L^{\alpha\delta} H^{\alpha(1-\delta)} A(i,h)^{\frac{\alpha}{1-\alpha}} \left[\int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di\right]^{-\alpha} = L^{\alpha\delta} H^{\alpha(1-\delta)} \left[\int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di\right]^{1-\alpha} \tag{4.16}$$

Substituting (4.16) into (4.15), we have:

$$\alpha \frac{p_i X_i}{\int_0^1 p_i X_i di} = \alpha \frac{A(i,h)^{\frac{\alpha}{1-\alpha}}}{\int_0^1 A(i,h)^{\frac{\alpha}{1-\alpha}} di} \tag{4.17}$$

$$= \alpha \frac{A(i,h)^{\frac{\alpha}{1-\alpha}}}{B^{\frac{\alpha}{1-\alpha}} Z} = \alpha \frac{B^{\frac{\alpha}{1-\alpha}} \left[e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h}{i})^2}\right]^{\frac{\alpha}{1-\alpha}}}{B^{\frac{\alpha}{1-\alpha}} Z} = \alpha \frac{\left[e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h}{i})^2}\right]^{\frac{\alpha}{1-\alpha}}}{Z}$$

Thus, the share of variety $i$ in GDP is given by:

$$\frac{p_i X_i}{Y} = \alpha \frac{\left[e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h}{i})^2}\right]^{\frac{\alpha}{1-\alpha}}}{Z} \tag{4.18}$$

Next, we calculate the share of the lowest 10% of varieties in GDP:

$$\frac{\int_0^{0.1} p_i X_i di}{Y} = \alpha \frac{\int_0^{0.1} \left[e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di}{\int_0^1 \left[e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di}$$

.....

The share of the highest 10% of varieties in GDP is given by:

$$\frac{\int_{0.9}^{1} p_i X_i di}{Y} = \alpha \frac{\int_{0.9}^{1} \left[e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di}{\int_0^1 \left[e^{\mu i} e^{\frac{-1}{2}(\ln \frac{h}{i})^2}\right]^{\frac{\alpha}{1-\alpha}} di}$$

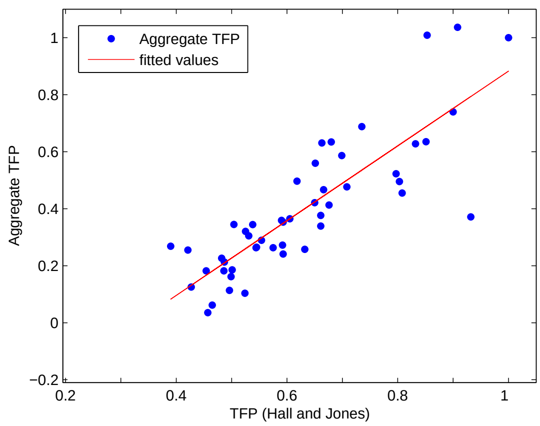



Figure 4.1: Comparison of TFP values with Hall and Jones (1999)' estimates -case of a closed economy

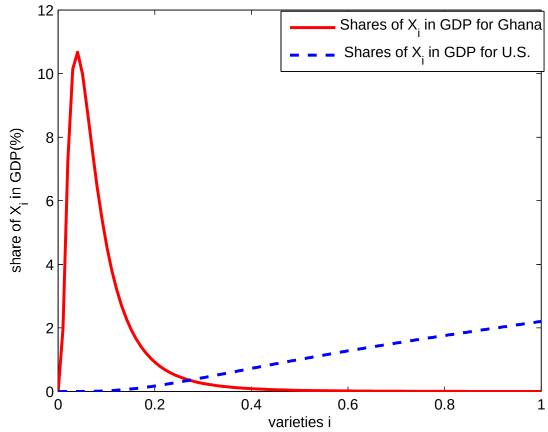



Figure 4.2: Shares of industries in GDP (%)for Ghana and for U.S.

# Appendix 3. Supplementary Derivations for Chapter 3: Solution of the Model for a Developed Country

The outcome of Bertrand competition in a developed country is summarized in Figure 4.3. A foreign competitor faces three possible options:

1. $A_d(i, h_d) = A_{f,d}(i, h_f)$

   In the case of a technological match, both firms use an identical technology. Using the expressions for technologies and given that $h_d > h_f$, we derive the threshold industry $i^*$ starting from which foreign firms take over the market. Thus, $i^* = \sqrt{h_d h_f}$.

2. $A_d(i, h_d) > A_{f,d}(i, h_f)$

   In this case, the foreign technology is inferior to the domestic technology. This implies that $MC_d < MC_f$. In other words, the domestic competitor has the advantage of being the low cost firm and sets its price equal to the marginal cost of the foreign firm:

$$p_d = \frac{1}{A_{f,d}(i, h_f)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_L^{\delta} w_H^{1-\delta}$$

   Since a developed country is abundant in human capital, the foreign competition will be edged out from complex industries $i \in (i^*, 1)$.

3. $A_d(i, h_d) < A_{f,d}(i, h_f)$ In low tech industries $i \in (0, i^*)$, a foreign firm might dominate technologically a domestic firm. In this situation, the foreign producer chooses to set its price equal to the marginal cost of the domestic firm which ensures its full control

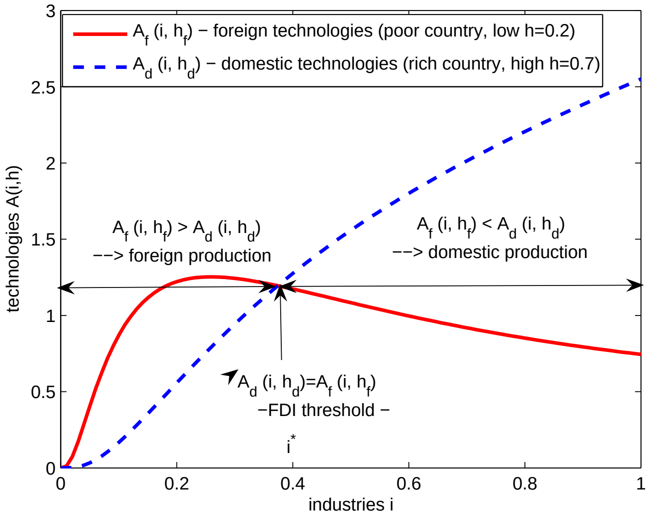



Figure 4.3: Interaction of domestic and foreign technologies in a developed country

over the market and leads to the only possible Nash equilibrium:

$$p_f = \frac{1}{A_d(i, h_d)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_L^{\delta} w_H^{1-\delta}$$

.

Therefore, the range of industries that form the intermediate goods sector is divided into two regions: on $(0, i^*)$ foreign firms supply $X_{if}$ units of low tech intermediate goods, while on $(i^*, 1)$ domestic producers supply the market with $X_{id}$ units of hi-tech goods.

**Final good sector**

Final goods producers combine capital $K_Y$, low-tech intermediate goods $X_{if}$ and hi-tech intermediate goods $X_{id}$:

$$Y = K_Y^{1-\alpha} \left[ \int_0^{i^*} X_{if}^{\alpha} di + \int_{i^*}^{1} X_{id}^{\alpha} di \right] \tag{4.19}$$

Final goods producers's maximization problem is given by:

$$\pi = Y - \left[ \int_0^{i^*} p_f X_{if} + \int_{i^*}^{1} p_d X_{id} \right] - (r + d) K_Y$$

First order conditions ( $\frac{\partial \pi}{\partial K_Y} = \frac{\partial \pi}{\partial X_{id}} = \frac{\partial \pi}{\partial X_{if}} = 0$) yield the conditional demands for inputs $X_{id}$ and $X_{if}$:

$$(1-\alpha)\frac{Y}{K_Y} = r + d$$

$$X_{id} = \left[\frac{p_d}{\alpha}\right]^{\frac{1}{\alpha-1}} K_Y \tag{4.20}$$

$$X_{if} = \left[\frac{p_f}{\alpha}\right]^{\frac{1}{\alpha-1}} K_Y \tag{4.21}$$

**Intermediate good sector**

- Domestic intermediate goods producers

  The domestic firm's maximization problem is given by:

$$\pi_d = p_d X_{id} - C(w_{Ld}, w_{Hd}, X_{id})$$

  The first order conditions ( $\frac{\partial \pi}{\partial L_{id}} = \frac{\partial \pi}{\partial H_{id}} = \frac{\partial \pi}{\partial X_{id}} = 0$) yield the nominal wages $w_{Ld}$ and $w_{Hd}$ and the explicit demand for $X_{id}$:

$$\frac{\partial \pi}{\partial L_{id}} = p_d \frac{\partial X_i d}{\partial L_{id}} - w_{Ld} = 0$$

$$\frac{\partial \pi}{\partial H_{id}} = p_d \frac{\partial X_i d}{\partial H_{id}} - w_{Hd} = 0$$

$$w_{Ld} = \delta \alpha K_Y^{1-\alpha} \, A_d(i, h_d)^{\alpha} \, L_{id}{}^{\alpha\delta - 1} \, H_{id}{}^{(1-\delta)\alpha} \tag{4.22}$$

$$w_{Hd} = (1-\delta) \alpha K_Y^{1-\alpha} \, A_d(i, h_d)^{\alpha} \, L_{id}{}^{\alpha\delta} \, H_{id}{}^{(1-\delta)\alpha - 1} \tag{4.23}$$

  Since $p_d = MC_f$, the explicit demand for $X_{id}$ is determined by substituting (3.3) into (3.9):

$$X_{id} = \left[\frac{1}{\alpha} \frac{1}{A_{f,d}(i, h_f)} \frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Ld}^{\delta} w_{Hd}^{1-\delta}\right]^{\frac{1}{\alpha-1}} K_Y \tag{4.24}$$

$$\frac{\partial \pi}{\partial X_{id}} = p_d + \frac{\partial p_d(X_{id})}{\partial X_{id}} X_{id} - MC_d = 0$$

  The conditional demand for $X_{id}$ from (4.20) is used in the equation from above to calculate profits per unit:

$$p_d - MC_d = MC_f - MC_d = -\frac{\partial p_d(X_{id})}{\partial X_{id}} X_{id}$$

$$= \alpha(1-\alpha)K_Y^{1-\alpha} X_{id}^{\alpha-1}$$

We calculate the profits earned by the domestic producer as $\pi_d = (MC_f - MC_d)X_{id}$:

$$\pi_d = \alpha(1-\alpha)K_Y^{1-\alpha} X_{id}^{\alpha} = (1-\alpha)\alpha^{\frac{1}{1-\alpha}} A_f(i, h_f)^{\frac{\alpha}{1-\alpha}} K_Y \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Ld}^{\delta} w_{Hd}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}}$$

We calculate the setup cost $F_i^d$ by using the free-entry condition ($F_i^d = \frac{\pi_d}{1+r}$):

$$F_i^d = \frac{1}{1+r}(1-\alpha)\alpha^{\frac{1}{1-\alpha}} K_Y A_{f,d}(i, h_f)^{\frac{\alpha}{1-\alpha}} \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Ld}^{\delta} w_{Hd}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}} \tag{4.25}$$

Domestic capital investments in appropriate technologies are derived by summing up the entry costs from all industries $i \in (i^*, 1)$:

$$K_X = \int_{i^*}^{1} F_i^d di = \frac{1}{1+r}(1-\alpha)\,\alpha^{\frac{1}{1-\alpha}} K_Y \int_{i^*}^{1} \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}} A_{f,d}(i, h_f)^{\frac{\alpha}{1-\alpha}} di \tag{4.26}$$

- Foreign intermediate producers

Foreign producers supply $X_{if}$ over the range $(0, i^*)$ and charge a price $p_f = MC_d$. They maximize their profits with respect to inputs $L_{if}$ and $H_{if}$, and output $X_{if}$

$$\pi_f = p_f X_{if} - C(w_{Lf}, w_{Hf}, X_{if})$$

First order conditions ($\frac{\partial \pi}{\partial L_{if}} = \frac{\partial \pi}{\partial H_{if}} = \frac{\partial \pi}{\partial X_{if}} = 0$) yield the nominal wages $w_{Lf}$ and $w_{Hf}$ and the explicit demand for $X_{if}$:

$$w_{Lf} = \delta\alpha K_Y^{1-\alpha} A_{f,d}(i, h_f)^{\alpha} {L_{if}}^{\alpha\delta-1} {H_{if}}^{(1-\delta)\alpha} \tag{4.27}$$

$$w_{Hf} = (1-\delta)\alpha K_Y^{1-\alpha}\, A_{f,d}(i,h_f)^{\alpha}\, {L_{if}}^{\alpha\delta}\, {H_{if}}^{(1-\delta)\alpha-1} \tag{4.28}$$

Since $p_f = MC_d$, the explicit demand for $X_{if}$ is derived by inserting (3.4) in (4.21):

$$X_{if} = \left[\frac{1}{\alpha}\frac{1}{A_d(i,h_d)}\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Lf}^{\delta} w_{Hf}^{1-\delta}\right]^{\frac{1}{\alpha-1}} K_Y \tag{4.29}$$

Also,

$$\frac{\partial\pi}{\partial X_{if}} = p_f + \frac{\partial p_f(X_{if})}{\partial X_{if}} X_{if} - MC_f = 0$$

Since the profits of the domestic producer are $\pi_f = (MC_d - MC_f)X_{if}$, then:

$$\pi_f = \alpha(1-\alpha)K_Y^{1-\alpha}X_{if}^{\alpha} = (1-\alpha)\alpha^{\frac{1}{1-\alpha}} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} K_Y \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Lf}^{\delta} w_{Hf}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}}$$

We use the calculated expression for foreign profits to back out the setup cost $F_i^f$ from the free-entry condition ($F_i^f = \frac{\pi_f}{1+r}$):

$$F_i^f = \frac{1}{1+r}(1-\alpha)\alpha^{\frac{1}{1-\alpha}} K_Y A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{Lf}^{\delta} w_{Hf}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}} \tag{4.30}$$

Foreign direct investments in appropriate technologies are determined by summing up the setup costs from all industries $i \in (0, i^*)$, we get

$$FDI = \int_0^{i^*} F_i^f di = \frac{1}{1+r}\,(1-\alpha)\,\alpha^{\frac{1}{1-\alpha}} K_Y \int_0^{i^*} \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di \tag{4.31}$$

### General equilibrium

General equilibrium requires that both the capital allocation condition and the labor market equilibrium condition have to be met.

*Labor market equilibrium:*

**Step 1:** Express $L_{id}$ , $L_{if}$, $H_{id}$ and $H_{if}$ as functions of $(w_L, w_H, \int A, K_Y)$

We back out $H_{id}$ from (4.23) to substitute its expression in (4.22):

$$H_{id} = \left[\frac{w_{Hd}}{(1-\delta)\alpha K_Y^{1-\alpha} A_d(i,h_d)^\alpha L_{id}^{\alpha\delta}}\right]^{\frac{1}{\alpha(1-\delta)-1}}$$

Thus,

$$w_{Ld} = \delta(1-\delta)^{\frac{\alpha(\delta-1)}{\alpha(1-\delta)-1}} A_d(i,h_d)^{\frac{-\alpha}{\alpha(1-\delta)-1}} \alpha^{\frac{-1}{\alpha(1-\delta)-1}} w_{Hd}^{\frac{\alpha(1-\delta)}{\alpha(1-\delta)-1}} L_{id}^{\frac{1-\alpha}{\alpha(1-\delta)-1}} K_Y^{\frac{\alpha-1}{\alpha(1-\delta)-1}}$$

We use the equation from above to express $L_{id}$ and $H_{id}$ as functions of nominal wages and technologies. First, we determine the variety specific demand for unskilled labor $L_{id}$;

$$L_{id} = w_{Ld}^{\frac{(1-\delta)\alpha-1}{1-\alpha}} w_{Hd}^{\frac{\alpha(\delta-1)}{1-\alpha}} \delta^{\frac{1-\alpha(1-\delta)}{1-\alpha}} (1-\delta)^{\frac{\alpha(1-\delta)}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} K_Y \tag{4.32}$$

Next, we derive the variety specific demand for skilled labor by substituting (4.32) into the expression for $H_{id}$:

$$H_{id} = w_{Ld}^{\frac{-\alpha\delta}{1-\alpha}} w_{Hd}^{\frac{\alpha\delta-1}{1-\alpha}} \delta^{\frac{\alpha\delta}{1-\alpha}} (1-\delta)^{\frac{-\alpha\delta+1}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} K_Y \tag{4.33}$$

Similarly, we get the equivalent equations for $L_{if}$ and $H_{if}$: Given (4.28) we calculate $H_{if}$ as:

$$H_{if} = \left[\frac{w_{Hf}}{(1-\delta)\alpha K_Y^{1-\alpha} A_{f,d}(i,h_f)^\alpha L_{if}^{\alpha\delta}}\right]^{\frac{1}{\alpha(1-\delta)-1}}$$

Next, $H_{if}$ is substituted into (4.27):

$$w_{Lf} = \delta(1-\delta)^{\frac{\alpha(\delta-1)}{\alpha(1-\delta)-1}} A_{f,d}(i,h_f)^{\frac{-\alpha}{\alpha(1-\delta)-1}} \alpha^{\frac{-1}{\alpha(1-\delta)-1}} w_{Hf}^{\frac{\alpha(1-\delta)}{\alpha(1-\delta)-1}} L_{if}^{\frac{1-\alpha}{\alpha(1-\delta)-1}} K_Y^{\frac{\alpha-1}{\alpha(1-\delta)-1}}$$

We use the equation from above to express $L_{if}$ and $H_{if}$ as functions of nominal wages and technologies. First, we determine the variety specific demand for unskilled labor $L_{if}$;

$$L_{if} = w_{Lf}^{\frac{(1-\delta)\alpha-1}{1-\alpha}} w_{Hf}^{\frac{\alpha(\delta-1)}{1-\alpha}} \delta^{\frac{1-\alpha(1-\delta)}{1-\alpha}} (1-\delta)^{\frac{\alpha(1-\delta)}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} K_Y \tag{4.34}$$

Thus, the variety specific demand for skilled labor is given by:

$$H_{if} = w_{Lf}^{\frac{-\alpha\delta}{1-\alpha}} w_{Hf}^{\frac{\alpha\delta-1}{1-\alpha}} \delta^{\frac{\alpha\delta}{1-\alpha}} (1-\delta)^{\frac{-\alpha\delta+1}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} K_Y \tag{4.35}$$

**Step 2**: Use the labor market resource constraints to get $w_L = w_L(L, H, \int A_d, \int A_f, K_Y$ and $w_H = w_H(L, H, \int A_d, \int A_f, K_Y$

In equilibrium, nominal wages are equalized, therefore $w_{Ld} = w_{Lf}$ and $w_{Hd} = w_{Hf}$. Labor market equilibrium implies that the unskilled respectively, skilled labor employed by all industries add up to the total labor supply:

$$L = \int_0^{i^*} L_{if} di + \int_{i^*}^1 L_{id} di \tag{4.36}$$

$$H = \int_0^{i^*} H_{if} di + \int_{i^*}^1 H_{id} di \tag{4.37}$$

$$L = w_L^{\frac{(1-\delta)\alpha-1}{1-\alpha}} w_H^{\frac{(\delta-1)\alpha}{1-\alpha}} \delta^{\frac{1-(1-\delta)\alpha}{1-\alpha}} (1-\delta)^{\frac{(1-\delta)\alpha}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} K_Y \left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^1 A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di\right]$$

$$H = w_L^{\frac{-\alpha\delta}{1-\alpha}} w_H^{\frac{\alpha\delta-1}{1-\alpha}} \delta^{\frac{\alpha\delta}{1-\alpha}} (1-\delta)^{\frac{-\alpha\delta+1}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} K_Y \left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^1 A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di\right]$$

Thus, equilibrium nominal wages are given by:

$$w_L = \delta\alpha L^{\alpha\delta-1} H^{\alpha(1-\delta)} K_Y^{1-\alpha} \left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^1 A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di\right]^{1-\alpha} \tag{4.38}$$

$$w_H = (1-\delta)\alpha L^{\alpha\delta} H^{\alpha(1-\delta)-1} K_Y^{1-\alpha} \left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^1 A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di\right]^{1-\alpha} \tag{4.39}$$

Capital allocation condition implies that $\overline{K} = K_Y + K_X + FDI$ where

$$K_X = \int_{i^*}^1 F_i^d di = \frac{1}{1+r} (1-\alpha) \alpha^{\frac{1}{1-\alpha}} K_Y \int_{i^*}^1 \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di$$

$$FDI = \int_0^{i^*} F_i^f di = \frac{1}{1+r} (1-\alpha) \alpha^{\frac{1}{1-\alpha}} K_Y \int_0^{i^*} \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_{L_i}^{\delta} w_{H_i}^{1-\delta}\right]^{\frac{\alpha}{\alpha-1}} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di$$

In order to determine the domestic investments in appropriate technologies and FDI, we substitute (4.38) and (4.39) into the formulas (4.26) and (4.31) for $K_X$ and $FDI$. First, we calculate $S = \left[\frac{\delta^{-\delta}}{(1-\delta)^{1-\delta}} w_L^{\delta} w_H^{1-\delta}\right]$ by substituting (4.38) and (4.39):

$$S = \alpha L^{\delta(\alpha-1)} H^{(1-\delta)(\alpha-1)} K_Y^{1-\alpha} \left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^{1} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di\right]^{1-\alpha}$$

Thus

$$S^{\frac{\alpha}{\alpha-1}} = \alpha^{\frac{\alpha}{\alpha-1}} L^{\alpha\delta} H^{\alpha(1-\delta)} K_Y^{-\alpha} \left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^{1} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di\right]^{-\alpha} \tag{4.40}$$

Substitute (4.40) into the formula for $K_X$ given by (4.26):

$$K_X = \frac{1}{1+r}(1-\alpha)\,\alpha^{\frac{1}{1-\alpha}} K_Y \alpha^{\frac{\alpha}{\alpha-1}} L^{\alpha\delta} H^{\alpha(1-\delta)} K_Y^{-\alpha} \int_{i^*}^{1} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}$$

$$\left[\int_0^{i^*} A_f(i,h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^{1} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di\right]^{-\alpha} di$$

Therefore in equilibrium, domestic investments in appropriate technologies are

$$K_X = \frac{1}{1+r}(1-\alpha)\,\alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \int_{i^*}^{1} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}$$

$$\left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^{1} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di\right]^{-\alpha} di \tag{4.41}$$

We plug in (4.40) into the formula for $FDI$ that is given by (4.31):

$$FDI = \frac{1}{1+r}(1-\alpha)\,\alpha^{\frac{1}{1-\alpha}} K_Y \alpha^{\frac{\alpha}{\alpha-1}} L^{\alpha\delta} H^{\alpha(1-\delta)} K_Y^{-\alpha} \int_0^{i^*} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}$$

$$\left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^{1} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} di\right]^{-\alpha} di$$

Thus in equilibrium, foreign direct investments are given by:

$$FDI = \frac{1}{1+r}(1-\alpha)\,\alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \int_0^{i^*} A_d(i,h)^{\frac{\alpha}{1-\alpha}}$$

$$\left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di + \int_{i^*}^1 A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}di\right]^{-\alpha} di \tag{4.42}$$

Denote $A_d(i,h_d)^{\frac{\alpha}{1-\alpha}} = f(i)$ and $A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} = g(i)$. Since $\int_0^{i^*} f(i)di = F$ and $\int_{i*}^1 g(i) = G$, and $\int_0^{i^*} g(i) = J$ are constant, we can rewrite:

$$\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}} \left[\int_0^{i^*} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}di + \int_{i^*}^1 A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di\right]^{-\alpha} di$$

$$= \int_0^{i^*} g(i)\left[\int_0^{i^*} f(i)di + \int_{i^*}^1 g(i)di\right]^{-\alpha} di$$

$$= \int_0^{i^*} g(i)\left[F+G\right]^{-\alpha} di = \left[F+G\right]^{-\alpha} J$$

This implies that

$$K_X = \frac{1}{1+r}\left(1-\alpha\right)\alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \int_{i^*}^1 A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di$$

$$\left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di + \int_{i^*}^1 A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}di\right]^{-\alpha} \tag{4.43}$$

$$FDI = \frac{1}{1+r}\left(1-\alpha\right)\alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \int_0^{i^*} A_d(i,h)^{\frac{\alpha}{1-\alpha}}di$$

$$\left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di + \int_{i^*}^1 A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}di\right]^{-\alpha} \tag{4.44}$$

The final step is to solve for Y. We substitute the equilibrium nominal wages $w_L$ and $w_H$ from (4.38) and (4.39) into (4.24) and we get:

$$\int_{i^*}^1 X_{id}^{\alpha} = L^{\alpha\delta} H^{\alpha(1-\delta)} \int_{i^*}^1 A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di \left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di + \int_{i^*}^1 A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}di\right]^{-\alpha}$$

Similarly,

$$\int_0^{i^*} X_i f^{\alpha} = L^{\alpha\delta} H^{\alpha(1-\delta)} \int_0^{i^*} A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}di \left[\int_0^{i^*} A_{f,d}(i,h_f)^{\frac{\alpha}{1-\alpha}}di + \int_{i^*}^1 A_d(i,h_d)^{\frac{\alpha}{1-\alpha}}di\right]^{-\alpha}$$

Hence in equilibrium, the aggregate income is given by:

$$Y = K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} \left[ \int_0^{i^*} A_d(i, h_d)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^1 A_{f,d}(i, h_f)^{\frac{\alpha}{1-\alpha}} di \right]$$

$$\left[ \int_0^{i^*} A_{f,d}(i, h_f)^{\frac{\alpha}{1-\alpha}} di + \int_{i^*}^1 A_d(i, h_d)^{\frac{\alpha}{1-\alpha}} di \right]^{-\alpha} \tag{4.45}$$

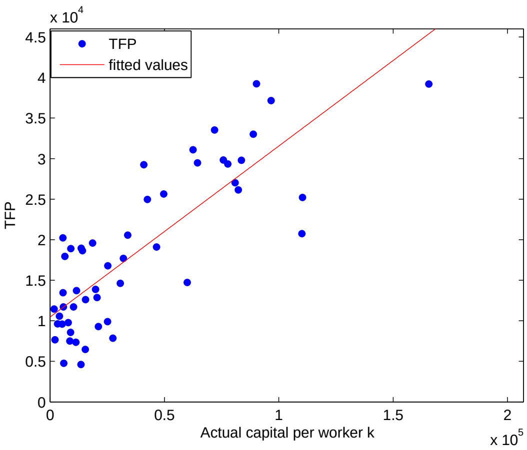
We rewrite the expressions fro aggregate income, domestic investments, and FDI as:

$$Y = K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} B_d^{\alpha} \left[Z1 + W2\right] \left[W1 + Z2\right]^{-\alpha} \tag{4.46}$$

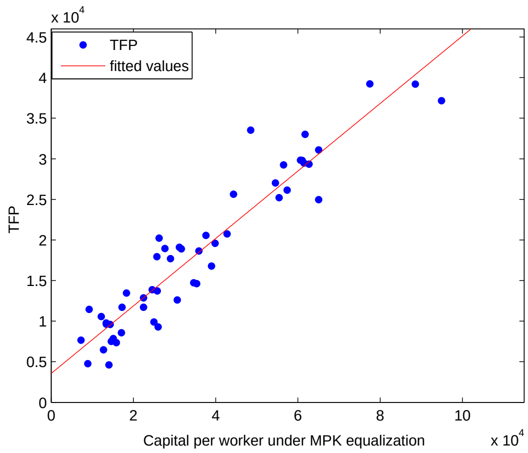
$$K_Y = \left[\frac{1-\alpha}{r+d}\right]^{\frac{1}{\alpha}} L^{\delta} H^{(1-\delta)} B_d \left[Z1 + W2\right]^{\frac{1}{\alpha}} \left[W1 + Z2\right]^{-1} \tag{4.47}$$

$$K_X = \frac{1}{1+r}(1-\alpha)\alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} B_d^{\alpha} W2 \left[W1 + Z2\right]^{-\alpha} \tag{4.48}$$

$$FDI = \frac{1}{1+r}(1-\alpha)\alpha K_Y^{1-\alpha} L^{\alpha\delta} H^{\alpha(1-\delta)} B_d^{\alpha} Z1 \left[W1 + Z2\right]^{-\alpha} \tag{4.49}$$




(A) Imperfect capital mobility




(B) Perfect capital mobilty

Figure 4.4: TFP and capital per worker

# Appendix 4. Supplementary Tables for Chapter 2 and Chapter 4

Table A-1: **Data for Chapter 2:** $y$= GDP per worker; $\frac{K_Y}{Y}$= capital output ratio; $\frac{H}{N}$= human capital per worker; $h$= human capital intensity or appropriate human capital. $(1-\alpha)$= share of capital in GDP. All variables are relative to U.S.

| Country | Country code | $y$ | $\left[\frac{K_Y}{Y}\right]^{\frac{1-\alpha}{\alpha}}$ | $\frac{H}{N}$ | $h=\frac{H}{H+N}$ |
|---|---|---|---|---|---|
| Argentina | ARG | 0.352 | 0.950 | 0.438 | 0.413 |
| Australia | AUS | 0.715 | 1.100 | 0.580 | 0.740 |
| Bolivia | BOL | 0.105 | 0.723 | 0.223 | 0.305 |
| Botswana | BWA | 0.251 | 0.800 | 0.207 | 0.114 |
| Brazil | BRA | 0.228 | 0.966 | 0.218 | 0.226 |
| Canada | CAN | 0.736 | 1.118 | 0.768 | 1.037 |
| Chile | CHL | 0.349 | 0.865 | 0.396 | 0.377 |
| China | CHN | 0.116 | 0.841 | 0.184 | 0.257 |
| Colombia | COL | 0.202 | 0.769 | 0.256 | 0.263 |
| Costa Rica | CRI | 0.268 | 0.739 | 0.318 | 0.359 |
| Cyprus | CYP | 0.584 | 0.868 | 0.520 | 0.477 |
| Dominican Republic | DOM | 0.210 | 0.668 | 0.257 | 0.320 |
| Ecuador | ECU | 0.147 | 0.892 | 0.359 | 0.365 |
| El Salvador | SLV | 0.163 | 0.640 | 0.173 | 0.213 |
| France | FRA | 0.683 | 1.116 | 0.432 | 0.467 |
| Germany | GER | 0.657 | 1.129 | 0.453 | 0.559 |
| Ghana | GHA | 0.053 | 0.589 | 0.050 | 0.062 |
| Greece | GRC | 0.377 | 1.131 | 0.405 | 0.634 |
| Guatemala | GTM | 0.156 | 0.608 | 0.116 | 0.125 |
| Honduras | HND | 0.081 | 0.876 | 0.206 | 0.182 |
| Hong Kong | HKG | 0.857 | 1.044 | 0.525 | 0.688 |
| Hungary | HUN | 0.315 | 1.026 | 0.277 | 0.371 |

| Country | Country code | $y$ | $\left[\frac{K_Y}{Y}\right]^{\frac{1-\alpha}{\alpha}}$ | $\frac{H}{N}$ | $h = \frac{H}{H+N}$ |
|---|---|---|---|---|---|
| India | IND | 0.086 | 0.703 | 0.127 | 0.182 |
| Indonesia | IDN | 0.127 | 0.840 | 0.201 | 0.162 |
| Israel | ISR | 0.654 | 1.010 | 0.517 | 0.635 |
| Italy | ITA | 0.585 | 1.128 | 0.265 | 0.421 |
| Jamaica | JAM | 0.145 | 0.981 | 0.247 | 0.104 |
| Japan | JPN | 0.626 | 1.349 | 0.440 | 0.522 |
| Kenya | KEN | 0.049 | 0.674 | 0.044 | 0.035 |
| Malaysia | MYS | 0.380 | 0.962 | 0.254 | 0.272 |
| Mexico | MEX | 0.262 | 0.996 | 0.405 | 0.344 |
| Netherlands | NLD | 0.709 | 1.065 | 0.439 | 0.495 |
| Nicaragua | NIC | 0.125 | 0.684 | 0.152 | 0.186 |
| Pakistan | PAK | 0.084 | 0.634 | 0.192 | 0.268 |
| Panama | PAN | 0.253 | 0.930 | 0.628 | 0.559 |
| Paraguay | PRY | 0.177 | 0.774 | 0.277 | 0.289 |
| Peru | PER | 0.143 | 1.056 | 0.405 | 0.497 |
| Philippines | PHL | 0.142 | 0.809 | 0.492 | 0.631 |
| Portugal | PRT | 0.484 | 1.031 | 0.278 | 0.345 |
| South Korea | KOR | 0.441 | 1.186 | 0.907 | 0.988 |
| Singapore | SGP | 1.158 | 1.216 | 0.309 | 0.265 |
| Sri Lanka | LKA | 0.122 | 0.703 | 0.190 | 0.241 |
| Sweden | SWE | 0.687 | 1.068 | 0.805 | 1.009 |
| Switzerland | CHE | 0.741 | 1.241 | 0.540 | 0.628 |
| Taiwan | TWN | 0.527 | 0.897 | 0.450 | 0.587 |
| Thailand | THA | 0.196 | 1.206 | 0.262 | 0.263 |
| Tunisia | TUN | 0.224 | 0.792 | 0.195 | 0.255 |
| UK | GBR | 0.671 | 0.982 | 0.404 | 0.455 |
| Uruguay | URY | 0.317 | 0.779 | 0.324 | 0.339 |
| USA | USA | 1.000 | 1.000 | 1.000 | 1.000 |
| Venezuela | VEN | 0.238 | 0.929 | 0.289 | 0.353 |

Table A-2: Chapter 2: **TFP and its components** $B$=exogenous part of TFP, $Z$=inter-industry TFP. $(1-\alpha)$= share of capital in GDP. All variables are relative to U.S.

| Country | Country code | $B$ | $Z^{\frac{1-\alpha}{\alpha}}$ | $TFP = BZ^{\frac{1-\alpha}{\alpha}}$ |
|---|---|---|---|---|
| Argentina | ARG | 0.545 | 0.718 | 0.392 |
| Australia | AUS | 0.856 | 0.943 | 0.808 |
| Bolivia | BOL | 0.424 | 0.588 | 0.249 |
| Botswana | BWA | 1.152 | 0.288 | 0.332 |
| Brazil | BRA | 0.729 | 0.473 | 0.345 |
| Canada | CAN | 0.894 | 1.003 | 0.896 |
| Chile | CHL | 0.657 | 0.678 | 0.445 |
| China | CHN | 0.497 | 0.520 | 0.258 |
| Colombia | COL | 0.680 | 0.529 | 0.359 |
| Costa Rica | CRI | 0.739 | 0.657 | 0.486 |
| Cyprus | CYP | 0.849 | 0.781 | 0.663 |
| Dominican Republic | DOM | 0.799 | 0.608 | 0.486 |
| Ecuador | ECU | 0.295 | 0.664 | 0.196 |
| El Salvador | SLV | 1.014 | 0.452 | 0.459 |
| France | FRA | 0.920 | 0.772 | 0.710 |
| Germany | GER | 0.867 | 0.847 | 0.734 |
| Ghana | GHA | 1.487 | 0.195 | 0.289 |
| Greece | GRC | 0.580 | 0.894 | 0.519 |
| Guatemala | GTM | 1.665 | 0.308 | 0.513 |
| Honduras | HND | 0.315 | 0.403 | 0.127 |
| Hong Kong | HKG | 1.150 | 0.922 | 1.059 |
| Hungary | HUN | 0.711 | 0.671 | 0.477 |
| India | IND | 0.678 | 0.403 | 0.273 |
| Indonesia | IDN | 0.537 | 0.369 | 0.198 |
| Israel | ISR | 0.887 | 0.895 | 0.794 |
| Italy | ITA | 1.253 | 0.727 | 0.911 |
| Jamaica | JAM | 0.458 | 0.271 | 0.124 |
| Japan | JPN | 0.696 | 0.819 | 0.570 |
| Kenya | KEN | 1.405 | 0.140 | 0.197 |
| Malaysia | MYS | 1.018 | 0.542 | 0.551 |

| Country | Country code | $B$ | $Z^{\frac{1-\alpha}{\alpha}}$ | $TFP = BZ^{\frac{1-\alpha}{\alpha}}$ |
|---|---|---|---|---|
| Mexico | MEX | 0.417 | 0.639 | 0.266 |
| Netherlands | NLD | 0.996 | 0.797 | 0.794 |
| Nicaragua | NIC | 0.849 | 0.409 | 0.347 |
| Pakistan | PAK | 0.458 | 0.536 | 0.246 |
| Panama | PAN | 0.293 | 0.847 | 0.248 |
| Paraguay | PRY | 0.543 | 0.566 | 0.307 |
| Peru | PER | 0.219 | 0.798 | 0.175 |
| Philippines | PHL | 0.253 | 0.892 | 0.226 |
| Portugal | PRT | 1.082 | 0.639 | 0.692 |
| South Korea | KOR | 0.402 | 0.999 | 0.401 |
| Singapore | SGP | 2.013 | 0.532 | 1.070 |
| Sri Lanka | LKA | 0.611 | 0.496 | 0.303 |
| Sweden | SWE | 0.807 | 1.001 | 0.807 |
| Switzerland | CHE | 0.774 | 0.891 | 0.689 |
| Taiwan | TWN | 0.900 | 0.865 | 0.779 |
| Thailand | THA | 0.405 | 0.529 | 0.214 |
| Tunisia | TUN | 0.964 | 0.517 | 0.498 |
| UK | GBR | 1.098 | 0.761 | 0.835 |
| Uruguay | URY | 0.813 | 0.632 | 0.514 |
| USA | USA | 1.000 | 1.000 | 1.000 |
| Venezuela | VEN | 0.571 | 0.649 | 0.371 |

Table A-3: **Data for Chapter 4.** Growth=average annual per capita growth rate; Schooling=educational attainment; I rate=investment rate; PC=private credit as % in GDP; Oil=oil exports as % of GDP; FDI=share of FDI in GDP. Variables I rate, PC, and Oil are reported as log(variable).

| Country | Growth | Schooling | I rate | PC | Oil | FDI |
|---|---|---|---|---|---|---|
| Algeria | 1.258 | 1.127 | 2.940 | -1.128 | 2.420 | 0.316 |
| Argentina | 0.528 | 1.607 | 2.821 | -1.842 | -1.122 | 1.448 |
| Australia | 1.928 | 3.197 | 3.147 | -0.754 | 0.850 | 1.665 |
| Austria | 2.227 | 3.889 | 3.237 | -0.231 | -1.045 | 0.748 |
| Barbados | 3.252 | 3.084 | 2.586 | -1.073 | -1.223 | 2.652 |
| Belgium | 1.960 | 2.290 | 3.113 | -0.898 | 1.064 | 8.496 |
| Bolivia | -0.134 | 1.119 | 2.202 | -1.501 | 0.547 | 3.078 |
| Brazil | 1.434 | 0.690 | 2.985 | -1.642 | -2.228 | 1.275 |
| Cameroon | 0.868 | 0.606 | 2.071 | -1.630 | 0.577 | 0.671 |
| Canada | 1.901 | 4.123 | 3.156 | -0.733 | 1.050 | 1.756 |
| Chile | 2.886 | 1.582 | 2.765 | -0.909 | -2.410 | 3.116 |
| China | 5.835 | 1.610 | 2.919 | -0.133 | -1.519 | 1.911 |
| Colombia | 1.473 | 1.485 | 2.453 | -1.947 | -0.078 | 1.497 |
| Costa Rica | 0.831 | 1.193 | 2.733 | -1.809 | -2.240 | 2.394 |
| Cyprus | 5.278 | 2.461 | 3.177 | -0.451 | -0.628 | 3.448 |
| Denmark | 1.740 | 3.301 | 3.089 | -0.892 | 0.112 | 1.958 |
| Dominican Rep | 2.870 | 1.014 | 2.625 | -1.868 | -1.138 | 1.933 |
| Ecuador | 0.221 | 1.525 | 2.896 | -1.517 | 1.523 | 1.611 |
| Egypt | 3.395 | 1.204 | 2.098 | -1.358 | 0.237 | 1.940 |
| El Salvador | 0.112 | 0.495 | 1.996 | -2.744 | -1.910 | 0.760 |
| Fiji | 1.243 | 1.153 | 2.636 | -1.316 | -8.726 | 2.278 |
| Finland | 2.205 | 2.724 | 3.220 | -0.529 | -0.202 | 1.175 |
| France | 1.749 | 2.472 | 3.175 | -0.287 | -0.569 | 1.051 |
| Ghana | 0.112 | 1.203 | 1.914 | -3.314 | -0.628 | 0.968 |
| Greece | 1.534 | 2.078 | 3.113 | -1.066 | -0.493 | 1.035 |
| Guatemala | 0.567 | 0.524 | 2.079 | -1.977 | -2.162 | 1.251 |
| Honduras | 0.345 | 0.722 | 2.564 | -1.506 | -2.897 | 1.302 |
| Hungary | 1.732 | 1.426 | 2.952 | -1.250 | -0.602 | 2.006 |

| Country | Growth | Schooling | I rate | PC | Oil | FDI |
|---|---|---|---|---|---|---|
| India | 3.512 | 0.888 | 2.477 | -1.497 | -3.012 | 0.195 |
| Indonesia | 3.985 | 0.856 | 2.761 | -1.165 | 1.480 | 0.577 |
| Ireland | 4.640 | 2.600 | 2.963 | -0.675 | -1.225 | 3.636 |
| Israel | 1.740 | 2.112 | 3.246 | -0.646 | -2.822 | 0.864 |
| Italy | 2.024 | 2.329 | 3.108 | -0.577 | -0.661 | 0.339 |
| Jamaica | -0.366 | 1.506 | 2.751 | -1.546 | -1.116 | 1.607 |
| Japan | 2.506 | 2.856 | 3.454 | 0.005 | -3.035 | 0.042 |
| Jordan | 2.428 | 1.782 | 2.738 | -0.610 | -4.389 | 1.371 |
| Kenya | 0.305 | 0.510 | 2.227 | -1.549 | 0.178 | 0.512 |
| Korea, Republic of | 6.081 | 3.481 | 3.497 | -0.796 | -1.002 | 0.454 |
| Malawi | 1.281 | 0.167 | 2.482 | -2.382 | -5.160 | 0.620 |
| Malaysia | 3.977 | 1.615 | 3.145 | -0.531 | 1.554 | 4.217 |
| Mauritius | 4.433 | 1.458 | 2.546 | -1.159 | -3.119 | 0.956 |
| Mexico | 1.347 | 1.574 | 2.907 | -1.799 | 0.746 | 1.563 |
| Netherlands | 1.884 | 2.817 | 3.115 | -0.344 | 1.899 | 2.992 |
| New Zealand | 0.657 | 3.042 | 3.032 | -0.652 | -1.161 | 3.252 |
| Nicaragua | -3.052 | 0.741 | 2.417 | -1.317 | -2.943 | 1.587 |
| Norway | 2.808 | 3.539 | 3.426 | -0.751 | 2.776 | 1.188 |
| Pakistan | 2.753 | 1.290 | 2.441 | -1.472 | -2.591 | 0.515 |
| Panama | 1.580 | 1.740 | 2.947 | -0.625 | -0.401 | 2.343 |
| Paraguay | 1.609 | 1.224 | 2.550 | -1.993 | -4.135 | 1.099 |
| Peru | -0.333 | 1.773 | 2.863 | -2.278 | -0.543 | 1.446 |
| Philippines | 0.943 | 1.641 | 2.747 | -1.319 | -2.463 | 1.120 |
| Portugal | 2.684 | 1.489 | 3.053 | -0.315 | -1.112 | 1.518 |
| Senegal | 0.392 | 0.405 | 1.907 | -1.276 | 0.294 | 0.836 |
| Singapore | 5.615 | 1.998 | 3.789 | -0.233 | 2.951 | 10.107 |
| South Africa | 0.067 | 1.004 | 2.372 | -0.680 | -0.373 | 0.214 |
| Spain | 1.857 | 1.899 | 3.166 | -0.274 | -0.943 | 1.588 |
| Sri Lanka | 2.816 | 2.188 | 2.554 | -1.705 | -1.292 | 0.851 |
| Sweden | 1.519 | 4.155 | 3.031 | -0.894 | 0.018 | 2.536 |
| Switzerland | 0.682 | 4.281 | 3.245 | 0.311 | -2.679 | 1.942 |
| Syria | 2.929 | 1.186 | 2.579 | -2.636 | 1.527 | 0.496 |

| Country | Growth | Schooling | I rate | PC | Oil | FDI |
|---|---|---|---|---|---|---|
| Thailand | 4.895 | 0.810 | 3.434 | -0.567 | -2.327 | 1.551 |
| Togo | -1.179 | 0.669 | 2.111 | -1.486 | -0.900 | 1.743 |
| Trinidad &Tobago | 2.006 | 2.238 | 2.386 | -1.273 | 3.050 | 4.661 |
| Tunisia | 2.735 | 1.017 | 2.723 | -0.677 | 0.943 | 1.949 |
| Turkey | 2.038 | 0.937 | 2.808 | -1.929 | -2.455 | 0.289 |
| UK | 2.006 | 2.331 | 2.881 | -0.298 | 0.584 | 2.312 |
| USA | 2.307 | 4.576 | 3.003 | -0.567 | -1.550 | 0.900 |
| Uruguay | 1.852 | 2.018 | 2.522 | -1.237 | -3.612 | 0.742 |
| Venezuela | -0.936 | 1.424 | 2.812 | -1.629 | 2.641 | 1.215 |

# Vita

Beatrice Farkas was born in Oradea, Romania. She holds a Bachelor of Science degree in Finance and Banking from Babeş-Bolyai University, Cluj-Napoca, Romania. She received her Master of Science degree in economics from Louisiana State University in May 2004. She worked as a research and teaching assistant at Louisiana State University. She taught economics principles, principles of macroeconomics, and principles of microeconomics classes and received the LSU Economics Department Excellence in Teaching Award in 2007. Her research interests lie in the areas of economic growth, economic development and macroeconomics. Currently, Beatrice is a candidate for the degree of Doctor of Philosophy in economics at Louisiana State University, which will be awarded at the December 2009 commencement.