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Essays on infrastructure, female labor force participation and economic development

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ESSAYS ON INFRASTRUCTURE, FEMALE LABOR FORCE PARTICIPATION

AND ECONOMIC DEVELOPMENT

by

German Cubas Norando

An Abstract

Of a thesis submitted in partial fulfillment of the
requirements for the Doctor of Philosophy
degree in Economics
in the Graduate College of
The University of Iowa

July 2010

Thesis Supervisors: Professor B. Ravikumar
Associate Professor Gustavo Ventura

ABSTRACT

A central question in economics is why some countries are substantially richer than others. The income per capita of the five richest countries in the world is 30 times the income of the five poorest. It is a fundamental quantitative question for which growth and development economists still have no definite answer. The first chapter of this dissertation contributes to this literature. The chapter offers new evidence on the sources of cross-country income differences by investigating the role public capital in development accounting. I explicitly measure private and public capital stocks, and I find large differences in both types of capital across countries. Moreover, differences in private capital are larger than the ones I find for total capital for the richest and poorest countries. The methodology I use implies a share of public capital in output of at most 10%. My findings indicate that differences in capital stocks can not account for a substantial part of the observed dispersion in income across countries.

Other macroeconomic facts of underdeveloped and developing economies may also explain their low income per capita. These facts may be related to economic policies that could distort the allocation of resources in these economies. In the second chapter of this dissertation I document differences in labor supply between a set of Latin American countries and the U.S. in the period 1990-2005. In the U.S. the female labor force participation was 69% by 1990, while in Brazil and Mexico was 39% and 37%, respectively. Females began to participate more in the labor market of these countries after more households acquired access to basic infrastructure and when distortive policies affecting the price of household appliances were partially removed. I use a model of home production with endogenous labor force participation to account for these facts. I conclude that the price of household appliances and access to infrastructure are quantitatively important in explaining cross-country labor supply differences.

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ABSTRACT

A central question in economics is why some countries are substantially richer than others. The income per capita of the five richest countries in the world is 30 times the income of the five poorest. It is a fundamental quantitative question for which growth and development economists still have no definite answer. The first chapter of this dissertation contributes to this literature. The chapter offers new evidence on the sources of cross-country income differences by investigating the role public capital in development accounting. I explicitly measure private and public capital stocks, and I find large differences in both types of capital across countries. Moreover, differences in private capital are larger than the ones I find for total capital for the richest and poorest countries. The methodology I use implies a share of public capital in output of at most 10%. My findings indicate that differences in capital stocks can not account for a substantial part of the observed dispersion in income across countries.

Other macroeconomic facts of underdeveloped and developing economies may also explain their low income per capita. These facts may be related to economic policies that could distort the allocation of resources in these economies. In the second chapter of this dissertation I document differences in labor supply between a set of Latin American countries and the U.S. in the period 1990-2005. In the U.S. the female labor force participation was 69% by 1990, while in Brazil and Mexico was 39% and 37%, respectively. Females began to participate more in the labor market of these countries after more households acquired access to basic infrastructure and when distortive policies affecting the price of household appliances were partially removed. I use a model of home production with endogenous labor force participation to account for these facts. I conclude that the price of household appliances and access to infrastructure are quantitatively important in explaining cross-country labor supply differences.

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CHAPTER 1
ACCOUNTING FOR CROSS-COUNTRY INCOME DIFFERENCES WITH PUBLIC CAPITAL

1.1 Introduction

Cross-country differences in income per worker are known to be very high. The observed income ratio between the richest and poorest countries is around 30. The goal of this paper is to investigate the role of public capital in accounting for this observed cross-country income dispersion. Specifically, I ask if differences in private and public capital stocks across countries can account for the large observed cross-country income differences.

I perform a development accounting exercise by introducing public capital into the production function. By using data on public and private capital investments I provide new measures for the corresponding capital stocks for a sample of 45 countries. In addition, I carefully measure the share of each type of capital for the U.S. economy, and I assume they take the same values for all countries. Given my measures for capital stocks and technology parameters, differences in private and public capital across countries cannot go far in explaining the observed income dispersion. This is the main result of this paper and suggests that income differences are largely due to Total Factor Productivity (TFP) differences.

To perform the accounting exercise I first measure capital stocks for a sample of 45 countries. For this purpose, I exploit data on capital investment by governments from the World Bank and OECD which allows me to measure private and public capital stocks separately, for both rich and poor countries. I find that the ratio of aggregate public stocks between the 90th (rich country) and 10th percentile (poor country) countries in my sample is 181. In per worker terms, the ratio of public and private capital stocks between the 90th and 10th percentile countries is 28 and 289, respectively.

In addition, if we divide the private capital-to-output ratio of the rich country between the private capital-to-output ratio of poor country we obtain a value of 10.8. If we now divide the total capital-to-output ratio of the rich country between the total capital-to-output ratio of poor country we obtain a value of 5. Differences in capital-to-output ratios between rich and poor countries have been interpreted as indicators of the distortion in the capital accumulation process in poor countries (see Restuccia and Urrutia (2001)). Therefore, since differences in private capital-to-output ratios are twice the differences in total capital-to-output ratios between rich and poor countries, we can say that the private sector accumulation process would be more distorted than what has been originally thought.

In this work I provide comparable measures of each type of capital stocks for a sample of countries that includes poor, middle-income and rich countries. Kamps (2004) provides estimates for government net capital stocks for 22 OECD countries. This author presents public capital stock estimates in international dollars for 1980, 1990 and 2000. In his paper he follows a different methodology to obtain measures in international dollars, since public capital stocks are first estimated in national currencies and then revaluated to international dollars. In addition, he uses PPPs for the GDP and not for investment goods as I do here. Arestoff and Hurlin (2006) estimate public capital stocks for 26 developing countries. These authors only provide measures of the stocks in national currencies.

I also provide new measures for the share of each type of capital in output for the U.S. by using data from NIPA (National Income and Product Accounts) tables. For my purposes, I need to compute the income that can be attributed to private capital and the values of services that come from the use of public capital. In my calibration methodology the values of these parameters depend on the value of the services that emerge from the use of public capital through two channels.

The share of public capital is directly affected by the computed value of its services. Since the measure of output that is taken from the NIPA tables does not include the services from public capital, these services need to be added to output and so they affect the share of both types of capital. Furthermore, the value of services from public capital depends upon the definition of public capital considered and the choice of the return rate on public capital investments. I consider public capital as a pure public good and public capital per worker (my approach to congestion). Regarding the return rate of public capital I also consider two cases: when it is equal to the value I obtain for the private return rate (8.3%) and when it is equal to the one suggested in Fernald (1999) (12%) for the U.S. road system (which I consider an upper bound). These different cases give values for the share of private capital in output that goes from 0.24 to 0.27. For the share of public capital in output, depending on the case considered, I find its share in output going from almost 0 to 0.096.

In my development accounting exercise I assume that the share of public capital in output is constant across countries. It can be argued that for poor countries, this parameter could be higher since the returns to public capital investment could be higher provided their low levels of public capital stocks. However, the main result of this paper is robust to this observation.

Kamps (2004) considers time varying depreciation rates in the calculation of public capital stocks provided that the structure of public capital can change across time. In addition, Arestoff and Hurlin (2006) states that depreciation rates of public capital are different between rich and poor countries. The effect of the introduction of these modifications in my methodology to measure public capital stocks goes in favor of the main result of this paper.

Several papers have contributed to establishing a consensus that TFP differences are more important than factors in accounting for cross-country income differences. (See, for example, Klenow and Rodrguez-Clare (1997), Prescott (1997), Hall and Jones (1999) and Caselli (2005).) This paper agrees with this view. In Caselli (2005), for instance, a standard development accounting exercise without splitting capital between private and public and with a Cobb-Douglas production function leads to the conclusion that factors of production explain less than 40% of the observed differences in income across countries (see Table 1 in Caselli (2005)).

If I take the factor measures provided in Caselli (2005) and the values of the technology parameters he used, the development accounting exercise would suggest that we need a TFP ratio between the richest and poorest countries of about 7 to explain the observed income ratio of 30. However, according to the literature that introduces public capital in the analysis, this result is somehow challenged in the sense that differences in factors can explain a substantial part of the observed income dispersion and so TFP differences between the richest and the poorest countries play a much smaller role. For instance, Chakraborty and Lahiri (2007) incorporate public capital in a neoclassical growth model where public agents produce public capital. The model is calibrated by using cross country data from World Development Indicators (WDI) (average 1990-1997) and it generates an income ratio of 33 with a TFP ratio of only 3. This result is reached with a ratio of public capital per worker between rich and poor countries of only 3 which is obtained by calibrating the parameters of their model (not by directly measuring the public capital stocks as I do in this paper) and technology parameters taken from previous work. Specifically, in their calculations the share of public capital in output is 0.17. In addition, Aschauer (1989) provides an estimated value of 0.39 for this parameter by including the U.S. aggregate public capital stock in the aggregate production function.

My measure for the share of public capital in output for the U.S. is at most 10%. The value of this parameter is crucial in analyzing the contribution of public capital in accounting for cross-country income differences. For instance, given my measures of capital stocks and the share of private capital in output, using the value of the share of public capital estimated in Aschauer (1989) would solve the development problem since nearly all the dispersion of income across countries would be explained. Note, however, that in order to obtain the value estimated in Aschauer (1989) using my methodology, I would have to assume a rate of return to public capital of 90%. Therefore, even though I find large differences in public capital stocks across countries the small value of the share of public capital in output I obtain leads me to conclude that differences in public capital cannot account for a substantial part of the observed income dispersion across countries.

Pritchett (2000) suggests that when doing development accounting we should not take investment data (i.e., data on capital formation) literally, particularly as it applies to public investment in poor countries. Intuitively, the value of investment goods is less than their cost (which is what the data represent). Moreover, this discrepancy between the value and the cost of investment goods coudl be different across countries. Related to Pritchett's view is the work by Hulten (1996) which distinguishes between public capital stock that is used effectively or ineffectively. In other words, due to poor maintenance or inadequate management of the total stock of public capital, only a portion makes an effective contribution to the production of output. This could be relevant in the case of infrastructure in poor countries.[1] Following Hulten's lead, it would appear promising to include in my analysis some notion of the differential effectiveness of public capital to help us explain income differences across countries. Along these lines, Caselli (2005) suggests that Prittchet's approach could be promising in accounting for cross-country income differences. To

[1]Hulten (1996) finds that differences in his effectiveness indicator explain 40% of the differences in growth performance between 1970 and 1990. Also, this effectiveness indicator is the most important source of divergence in growth across countries. Given this result, he interprets the effectiveness index as a proxy variable for TFP.

check for the robustness of the main result of this paper to the observations made by these authors, I adjust public capital stocks by assuming that 100% of the total public capital investments contributes to building the public capital stock in rich countries whereas in poor countries only 10% of public capital investments actually build their public capital stocks. Even in this extreme case factors cannot account for any substantial part of the observed dispersion in income across countries.

The chapter is organized as follows. In Section 1.2, I first present the development accounting framework where I introduce public capital in the production function. Then I present my measures of capital stocks and technology parameters. Finally, I present the development accounting results and the robustness analysis. In Section 1.3 I explain in detail how I measure public, private and human capital stocks for my sample of countries. Section 1.4 shows how to obtain the measures for the technology parameters for the US. Section 1.5 presents my conclusions.

1.2 Accounting with Public Capital

In this section I develop the development accounting framework. I include public capital into the aggregate production function in two different ways, as a pure public good and as a public good subject to congestion. Additionally, I present the main result of this study which comes by performing the development accounting exercise using my measures of public and private capital stocks, human capital and technology parameters.

1.2.1 Framework

I assume a Cobb-Douglas with constant returns to scale technology to specify the production function for economy i

$$Y_i = A_i KT_i^{\alpha_1} \left(h_i L_i\right)^{1-\alpha_1} \tag{1.1}$$

where Y_i is aggregate output in country i, KT_i is aggregate capital stock, L_i is number of workers, A_i is the parameter that represents total factor productivity in country i, h_i is a measure of country's i human capital and α_1 is the aggregate total capital share on output. Then, dividing (1.1) by L_i

$$y_i = A_i kt_i^{\alpha_1} h_i^{1-\alpha_1}, \tag{1.2}$$

where y_i and kt_i are output and total capital per worker in country i, respectively. I call this specification *Specification 1*, which is the standard specification that ignores the distinction between the public and private capital stocks. The term A_i is not observable, but I have data on y_i and I can measure kt_i, h_i and α_1. I rewrite (1.2) as follows

$$y_i = A_i y_{1,i}, \tag{1.3}$$

where $y_{1,i} = kt_i^{\alpha_1} h_i^{1-\alpha_1}$ refers to the definition of output implied by *Specification 1* by assuming that only factors of production determine output.

Now I introduce public and private capital separately into the production function of country i. Consider

$$Y_i = A_i G_i^{\lambda_2} K_i^{\alpha_2} \left(h_i L_i\right)^{1-\alpha_2}, \tag{1.4}$$

where G_i is the aggregate stock of public capital of country i, K_i is the aggregate stock of private capital of country i, α_2 is the share of aggregate private capital in output and λ_2 is the share of aggregate public capital in output. Note that this two parameters need not to be the same as in *Specification 1.* I therefore use the subscripts to distinguish them. Dividing both sides by L_i, we obtain an expression for output per worker

$$y_i = A_i G_i^{\lambda_2} k_i^{\alpha_2} h_i^{1-\alpha_2}. \tag{1.5}$$

In this specification, which I call *Specification 2*, I am assuming that public capital is a pure public good. As usual, we have constant returns to scale at the firm level which takes G, the public good, as given. We have increasing returns to scale at the aggregate level.

As in the case of *Specification 1*, I rewrite (1.5) as

$$y_i = A_i y_{2,i}, \tag{1.6}$$

where $y_{2,i}$ is the measured output implied by *Specification 2* when only factors of production are taken into account.

However, public capital is subject to congestion, i.e., services from public capital goods decrease as more agents use them. For instance, the productivity of one mile of an avenue in New York City is not the same as one mile of the same type of avenue in Iowa City, IA. That means that allowing for congestion, public capital is not a pure public good, which means that we can have potentially different degrees of non-rivalry in the use of the public good. In Fernald (1999) we can find empirical evidence about the importance of congestion in the case of the U.S. road system. One possible way to specify congestion could be the one suggested in Glomm and Ravikumar (1994) where public capital is given by $\widehat{G} = \frac{G}{K^{\theta}L^{\epsilon}}$, where G and K are aggregate stocks of infrastructure and private capital, respectively, and L is aggregate labor.

I take one possible form of congestion by assuming that $\theta = 0$ and $\epsilon = 1$. I define $g_i = \frac{G_i}{L_i}$ to define the technology corresponding to *Specification 3*, which is represented by the following production function:

$$Y_i = A_i g_i^{\lambda_3} K_i^{\alpha_3} \left(h_i L_i\right)^{1-\alpha_3} \tag{1.7}$$

where g_i is public capital per worker in country i.

As in *Specification 2*, we have constant returns to scale at the firm level and have increasing returns to scale at the aggregate level. The only difference is in the measure of the public good considered.

Since λ_3 represents the share of public capital in output, the value of this parameter changes with the specification of congestion we use and this is why it is different from λ_2. Similarly, the alpha (α) parameter, which is the share of private capital in output, changes under different specifications of the production function. I therefore attach subscripts to the alpha's. As we see in Section 1.4, any changes in the way we define congestion will affect our computed measure of the value of services from public capital and this will directly affect the value of the lambda (λ) parameter. In addition, changes in the value of services from public capital, in turn, modify the measure of output and, as such, indirectly affect the value of both α and λ.

Dividing both sides of (1.7) by L_i we obtain output in per worker terms

$$y_i = A_i g_i^{\lambda_3} k_i^{\alpha_3} h_i^{1-\alpha_3}. \tag{1.8}$$

Again, I rewrite (1.8) as

$$y_i = A_i y_{3,i}, \tag{1.9}$$

where $y_{3,i}$ is the measured output implied by *Specification 3*.

Since I want to account for the observed dispersion in income across countries, I assume that we have two countries, one rich (R, represented by the 90th percentile of income in the sample) and the other poor (P, represented by the 10th percentile of income in the sample). In addition, I assume that both are closed economies, are on a balanced growth path and have the same values for technology parameters in each specification of the production function. In Gollin (2002) we find empirical evidence about the constancy of $(1-\alpha)$ across countries. It can be argued that for countries in early stages of development λ could be higher since the returns to public capital investment could be higher provided low levels of infrastructure. In 1.2.3 I show that the main result of this paper is robust to this observation.

Then, using (1.2), (1.5) and (1.8), we have that

$$\frac{y_R}{y_P} = \frac{A_R}{A_P}\left(\frac{kt_R}{kt_P}\right)^{\alpha_1}\left(\frac{h_R}{h_P}\right)^{1-\alpha_1}, \tag{1.10}$$

$$\frac{y_R}{y_P} = \frac{A_R}{A_P}\left(\frac{G_R}{G_P}\right)^{\lambda_2}\left(\frac{k_R}{k_P}\right)^{\alpha_2}\left(\frac{h_R}{h_P}\right)^{1-\alpha_2}, \tag{1.11}$$

$$\frac{y_R}{y_P} = \frac{A_R}{A_P}\left(\frac{g_R}{g_P}\right)^{\lambda_3}\left(\frac{k_R}{k_P}\right)^{\alpha_3}\left(\frac{h_R}{h_P}\right)^{1-\alpha_3}. \tag{1.12}$$

In the development accounting exercise, the left hand side of eqs. (1.10)-(1.12), i.e., the ratio of rich-to-poor country income, are observable through data we have on country income. What we want is to dichotomize this ratio of aggregate income into its component parts, as represented by the expressions on the right-hand sides of eqs. (1.10)-(1.12). Now, the ratio of TFP's, i.e.,$(\frac{A_R}{A_P})$ between rich and poor countries is not observable and so I measure the other factors on the right-hand sides of eqs. (1.10)-(1.12), given values for the parameters and capital stocks. In this way, we are able to determine how much of the differences in the observed income ratios can be explained by each of my specifications. In other words, we can determine how much of the observed income ratios can be explained by factors and how much by TFP ratios in each of the specifications. This is clearly seen by using equations (1.10), (1.11) and (1.12) together with (1.3), (1.6) and (1.9);

$$\frac{y_R}{y_P} = \frac{A_R}{A_P}\frac{y_{1,R}}{y_{1,P}}, \tag{1.13}$$

$$\frac{y_R}{y_P} = \frac{A_R}{A_P}\frac{y_{2,R}}{y_{2,P}}, \tag{1.14}$$

$$\frac{y_R}{y_P} = \frac{A_R}{A_P}\frac{y_{3,R}}{y_{3,P}}, \tag{1.15}$$

Following Caselli (2005), I define a first measure of success of each of the model specifications in accounting for the observed income differences, denoted by $s_{I,j}$, as

$$s_{I,j} = \frac{y_{j,R}/y_{j,P}}{y_R/y_P}, \tag{1.16}$$

for $j = 1, 2, 3$.

Another way to perform the development accounting exercise is by decomposing the variance of observed country's incomes. I therefore decompose the observed variances of income using my three different specifications of the production function.

By applying logarithms and then the variance operator to equations (1.3), (1.6) and (1.9) we have

$$var\left[log(y)\right] = var\left[log(A)\right] + var\left[log(y_j)\right] + 2\ cov\left[log(A), log(y_j)\right], \tag{1.17}$$

for $j = 1, 2, 3$.

Since I want to analyze the explanatory power of each model specification, following Caselli (2005) I assume that $var\left[log(A)\right] = cov\left[log(A), log(y_j)\right] = 0$ and I define a second measure of success of each of the model specifications in accounting for the observed income dispersion, denoted by $s_{II,j}$, as

$$s_{II,j} = \frac{var\left[log(y_j)\right]}{var\left[log(y)\right]} \tag{1.18}$$

for $j = 1, 2, 3$.

1.2.2 Income differences with Public Capital

In order to perform the development accounting exercise given my specifications of the production function, first I need data on y. Second, I need measures of capital stocks h, k, G, g. Finally, I need values for the parameters α_j for $j = 1, 2, 3$ and λ_j for $j = 2, 3$.

From PWT (Penn World Tables) in Heston, Summers, and Aten (2006) I am able to obtain data on real GDP per capita, population and real GDP per worker. Then I can recover the number of workers for each country needed to compute k and g.[2]

[2]The variables from PWT used in this step are POP (population), rgdpch (real GDP per capita using chain rule) and rgdpwok (real GDP per worker using chain rule).

I first obtain measures of capital stocks by applying the perpetual inventory method. I calculate a depreciation rate for U.S. which I assume is constant across countries. In 1.2.3 I discuss the effect of this assumption on my results. The methodology to measure capital stocks is explained in detail in Section 1.3.

Table 1.1 presents the measures for capital stocks for the 90th and 10th percentiles in the sample.

Table 1.1: Dispersion in Capital Stocks in 2003

	G	g	k	kt	h
Rich (90^{th} pctile)	$406,434.8 \times 10^6$	$18,429.6$	$161,843.2$	$172,285.2$	3.0
Poor (10^{th} pctile)	$2,243.6 \times 10^6$	668.4	560.6	$1,343.1$	1.3
Ratios	181.2	27.6	288.7	128.3	2.3

Note: This table presents the measures of aggregate public capital stock (G), public capital stock per worker (g), private capital stock per worker (k), total capital stock per worker (kt) and human capital stock (h) in international dollars in 2003 for the 90^{th} *pctile* and 10^{th} *pctile* of the sample of countries. The last row contains the ratio between the value that each variable takes for the rich country over the value that takes for the poor country.

From Table 1.1 we can observe that the separation between private and public capital has important implications. There are large differences in both private and public capital stocks between rich and poor countries. For instance, note that the ratio between the 90th and 10th percentile for private capital stock is more than twice the one computed for total capital, both taken in per-worker terms. Recall that in Specification 2, public capital enters the production function in its aggregate form (i.e., as a pure public good). Table 1.1 shows that the dispersion in aggregate public capital stocks is also large but smaller that the ones observed for per-worker private capital stocks. The ratios of the 90th percentile over the 10th percentile are 181.2 and 288.7, respectively. When measuring public capital in per-worker terms (as it enters in Specification 3), there is still is a considerable dispersion (the ratio is more than 26) but it is substantially lower than the dispersion in per-worker private capital stock. The ratio of human capital between rich and poor countries is around 2, which is similar to the value reported in previous literature for the measure of human capital considered here.

Another way to compare capital stocks across countries is by looking at capital-to-output ratios. Table 1.2 presents those ratios for the 90th and 10th percentile in the sample.

Table 1.2: Capital-to-output ratios

	g/y	k/y	kt/y
Rich (90^{th} pctile)	0.61	2.92	3.16
Poor (10^{th} pctile)	0.11	0.27	0.63
Ratios	5.5	10.8	5.0

Note: This table presents the measures of public capital-to-output ratio (g/y), private capital-to-output ratio (k/y) and total capital-to-output ratio (kt/y) in international dollars in 2003 for the 90^{th} *pctile* and 10^{th} *pctile* of the sample of countries. The last row contains the ratio between the value that each variable takes for the rich country over the value that takes for the poor country.

The ratio of public capital-to-output ratios between rich and poor countries is 5.5, which is very close to 5.0, the ratio of the total capital-to-output ratios between rich and poor countries.[3] In the case of private capital, the ratio of capital-to-output ratios between rich and poor countries is 10.8, more than twice the ratio for the total capital. The reason is that the ratio of investment rates of private capital (the average in the period considered) between rich and poor countries is almost twice the ratio of investment rates of total capital.

We can interpret the differences in capital-to-output ratios as evidence of the relative distortion in capital accumulation between rich and poor countries. The separation of capital between private and private allows us to exclusively focus our analysis in the private sector, and this result strongly suggests that the private sector accumulation process would be more distorted than what has been originally thought.

The results of the accounting exercise depend crucially on the values of λ and α. In addition, when adding public capital in the production function, the value of these parameters depends on the specification of congestion used for public capital. I measure these parameters for the U.S. by using data from NIPA tables and I assume that they have the same values for all countries in the sample. In Gollin (2002) we find empirical evidence about the constancy of $(1-\alpha)$ across countries and in 1.2.3 I discuss the effect of assuming that λ is constant across countries. Details about the

[3]Note that ratio of total capital-to-output ratios between rich and poor countries of 5.0 is similar to the one obtained by taking almost the same sample of countries from the data reported in Caselli (2005). The only difference in the sample is that Burundi, Dominica, Korea and Swaziland are not included in the sample his sample.

procedure followed to measure these parameters are presented in Section 1.4.

In order to compare the development accounting with public capital (Specification 2 and 3) to the standard accounting exercise, where no separation of capital is considered (Specification 1), I take $\alpha_1 = 1/3$ which is the value widely used in previous literature. The entries of Table 1.3 and Table 1.4 are the values obtained for λ and α, respectively, both when public capital is a pure public good and in the congestion case where public capital is taken in per worker terms.

Table 1.3: Measures of λ for the U.S.

	Private rate	Fernald (1999)
λ_2 (Pure public good)	0.075	0.096
λ_3 (Per worker)	$\simeq 0$	$\simeq 0$

Note: This table presents the measures of the share of public capital in output for the U.S. both when public capital is a pure public good (λ_2) and when public capital is taken in per worker terms (λ_3). The second column presents the results when I use a private rate of return for public capital whereas the third column shows the values for these parameters when I assume a rate of return of 12% provided in Fernald (1999).

As it is explained in Section 1.4, the value of these parameters are also affected by the choice of the return rate on public capital. I consider two cases: when the return rate on public capital is equal to the value I obtain for the private return rate (8.3%) and when it is equal to the one suggested in Fernald (1999) for the case of the U.S. road system (12%) which I consider an upper bound.

Note in Table 1.3 that when separating the capital stock into private and

Table 1.4: Measures of α for the U.S.

	Private rate	Fernald (1999)
α_2 (Pure public good)	0.25	0.24
α_3 (Per worker)	0.27	0.27

Note: This table presents the measures of the share of private capital in output for the U.S. both when public capital is a pure public good (α_2) and when public capital is taken in per worker terms (α_3). The second column presents the results when I use a private rate of return for public capital whereas the third column shows the values for these parameters when I assume a rate of return of 12% provided in Fernald (1999).

public the contribution of public capital to output is much smaller than that of private capital. Interestingly, for the case of public capital in per worker terms (congestion) the value of λ is approximately zero.[4] This is in line with the value of λ obtained in Holtz-Eakin (1994). In the case of public capital being a pure public good the value of λ goes from 0.075 to 0.096. The value of 0.075 for λ is similar to the value that could be obtained by using the measures for the value of services from public capital found in Martin, Landefeld, and Peskin (1984). In addition, in Otto and Voss (1998) the estimated value of λ is 0.06 using Australian data and the same specification for the production function. However, it differs largely from the ones used by Chakraborty and Lahiri (2007) and the one estimated in Aschauer (1989). In Aschauer (1989) the estimate for λ is 0.39 using data on aggregate public capital stocks. Chakraborty and Lahiri (2007) use λ=0.17 with public capital in per worker terms.[5] In order to obtain

[4]Although I do not present the results here, this is also the case if I specify congestion as $\frac{G_t}{L_t^{0.5}K_t^{0.5}}$ or $\frac{G_t}{K_t}$ or $\frac{G_t}{Y_t}$.

[5]For a survey of the literature on the estimation of λ, see Chapter 14 in Batina and Ihori

the value estimated in Aschauer (1989), by using my methodology I would have to assume a rate of return to public capital of 90%.

Now I perform the development accounting exercises. That means, given my measures for capital stocks for each country and values for the parameters in each of the specifications, I compute $s_{I,j}$ and $s_{II,j}$ for $j = 1, 2, 3$.

Table 1.5: Development Accounting. Success s_I

	s_I
$s_{I,1}$	0.29
$s_{I,2}$ Private rate	0.32
$s_{I,2}$ Fernald's rate	0.34
$s_{I,3}$	0.26

Note: This table presents the values for $s_{I,1}$, $s_{I,2}$ and $s_{I,3}$ which are the values of the first measure of success considered for specifications 1, 2 and 3, respectively, of the production function (see 1.2.1 for the definitions).

Table 1.5 and Table 1.6 show the values for s_I and s_{II}, respectively, in each of the specifications of the production function considered.

First, using the standard specification (Specification 1) for the production function, the fraction of the observed income dispersion explained by factors is 0.29 in the case of s_I and 0.40 in the case of the alternative measure of success s_{II}. Note that these values are similar to the ones obtained by Caselli (2005) (0.34 and 0.39, respectively) and using the data in Hall and Jones (1999) (0.34 and 0.40, respectively).

(2005).

Table 1.6: Development Accounting. Success s_{II}

		s_{II}
$s_{II,1}$		0.40
$s_{II,2}$	Private rate	0.46
$s_{II,2}$	Fernald's rate	0.48
$s_{II,3}$		0.38

Note: This table presents the values for $s_{II,1}$, $s_{II,2}$ and $s_{II,3}$ which are the values of the second measure of success considered for specifications 1, 2 and 3, respectively, of the production function (see 1.2.1 for the definitions).

Recall that the dispersion in public capital stocks across countries was larger when it is defined as a pure public good (see Table 1.1). That means that Specification 2 (the one in which public capital enters in its aggregate form or is a pure public good) is the one that gives the best chance to public capital in accounting for the observed cross-country income differences. The measure of the success of Specification 2 goes from 0.32 or 0.34 (depending the rate of return on public capital considered) for the case of s_I (see the second and third rows of of Table 1.5) and the value of s_{II} goes from 0.46 or 0.48 (see the second and third rows of Table 1.6). Therefore, given public capital the best chance, these measures of success increase but not substantially.

As it is clear in Table 1.1, observed dispersion in physical capital stocks are amplified when separating capital between public and private so one might expect to obtain more explanatory power coming from this dispersion in factors across countries. However, since the value of λ is relatively small and α is smaller than the value considered in Specification 1, then the dispersion in income explained by the model is reduced, and the fraction of income dispersion across countries explained by factors of production remains under 50% in both measures of success considered.

The effect of the values of the parameters in the success of the models is even clearer when considering Specification 3. In Specification 3, the measured value of α is bigger than the one obtained in Specification 2 (0.27 versus 0.24) and so it raises the role of private capital in accounting for the observed income differences. In this specification, public capital is taken in per-worker terms (congestion), and as it is shown in Table 1.1, cross-country differences in public capital stocks are substantially reduced when comparing this definition of public capital to the one that considers it as a pure public good (see the second and third columns of Table 1.1). But also the fact that the share of public capital in output is approximately zero ($\lambda_3 \simeq 0$) eliminates the role of public capital in accounting for cross-country income differences. These two contrary effects together cause both measures of success to be reduced to values that are even smaller than the ones obtained under Specification 1 (from 0.29 to 0.26 in the case of s_I and from 0.40 to 0.38 in the case of s_{II}). Therefore, in this specification, where public capital is introduced into the production function in a more realistic way, the results of the development accounting exercise suggest that factors of production explain less of the observed cross-country income differences. Therefore, differences in capital stocks across countries cannot go far in explaining the observed income differences between them. This suggests that differences in income are largely due to TFP differences, which is the residual in these calculations.

1.2.3 Robustness

As it is detailed in Section 1.3, in my methodology to measure public capital stocks I take the average scrapping depreciation rate for U.S. government capital as an approximation to the depreciation rate which is assumed constant across time and countries. Kamps (2004) also uses scrapping depreciation rates calculated by using NIPA accounts to estimate public capital stocks for 22 OECD countries. However, this author considers a time varying pattern for the depreciation rate since in that way, one takes into account the effect of changes in the composition of the capital stock across time. He finds that the depreciation rate has increased in the U.S. over the last 40 years, probably due to a increasing weight of short lifetime assets.

Arestoff and Hurlin (2006) estimate public capital stocks for 26 developing countries. In their methodology, they also use time varying depreciation rates. In addition, they state that depreciation rates in poor countries need not to be the same as the one calculated for rich countries, given the different composition of the public capital stocks observed in Latin America. For this reason, using data on the depreciation rates for different types of assets in the U.S. and the weight of some assets in Latin American countries, they provide estimates of depreciation rates for developing counties for 1980 to 1998. They find that the estimated depreciation rates slightly increase during the period of analysis.

Even though in the period I analyze, the scrapping depreciation rates I obtain for the U.S. do not vary much, in order to check for the robustness of my result and, in particular, of my capital stock measures, I incorporate the time varying scrapping rates. Specifically, I use the U.S. scrapping depreciation rates I calculated for each period, in my calculations of capital stocks for the OECD countries in my sample. In addition, to measure the capital stocks of the rest of the countries, I use the depreciation rates obtained in Arestoff and Hurlin (2006)[6]. The only effect these modifications is to minimally decrease the dispersion in public capital stocks across countries. Specifically, the ratio of aggregate capital stocks between rich and poor countries is 167.5 instead of 181.2 (second column of Table 1.1) and the ratio of the public capital stock per worker is 25.9 instead of 27.6 (third column of Table 1.1). More importantly, since the effect is to reduce public capital differences across countries, it lowers the explanatory power of factors of production in accounting for cross-country income differences. That means that these modifications goes in favor of the main conclusion of this paper.

In my methodology I assume that the share of public capital in output (λ) is the same for all countries. It can be argued that for countries in early stages of development λ could be higher since the returns to public capital investment could be higher provided low levels of public capital stocks. That means, the value of the parameter λ for poor countries would be higher than the one for rich countries. But again, if this is the case, since poor countries have lower public capital stocks than rich countries, we would have less dispersion the output obtained from the calibrated production function. In other words, differences in capital stocks would explain lower

[6]For years previous to 1980 I use the depreciation rate for 1980 and for years after 1998 the one obtained for 1998

portion of the observed cross-country income differences. For instance, in the case of public capital being a pure public good, if I take $\lambda_{rich} = 0.075$ (the same as before) and $\lambda_{rich} = 0.15$ (which is the maximum value one can obtain for in the US time series), the value of $s_{I,2}$ is 0.18 (compared to 0.32) and the value of $s_{II,2}$ is 0.24 (compared to 0.46).

According to Pritchett (2000), capital is different from what he calls Cumulated, Depreciated, Investment Effort (CUDIE). In general, when we use the data on government investment (or more precisely capital formation by governments) we are assuming that it represent the actual contribution to build the public capital stock. However, in Pritchett (2000) it is argued that the actual investment effort is not what the data represent and, furthermore, it is just a portion of it. In other words, governments investment goods purchases is what is registered in the data but a portion of them is lost because of inefficiencies, corruption, etc.. The investment data builds what he calls CUDIE and the data less the lost portion builds what would be the relevant stock of public capital. Pritchett shows that the difference between them is empirically relevant and it varies across countries.

In Chakraborty and Lahiri (2007) we find a similar idea but with some microeconomic foundations. In a neoclassical one sector growth model, public capital investments are not converted totally into public capital stocks. A portion of the public capital investments is lost because agents charged with carrying out public investment projects do not have the incentives to do their best.

We can relate Prittchet's point to Hulten (1996) who studies the effectiveness of public capital. Public capital stock can be used effectively or ineffectively in the sense of Hulten (1996). In other words, of the total stock of public capital, only a portion is used effectively and so contributes to the production of output. This could be due to poor maintenance or inadequate management and can be significant in the case of infrastructure in poor countries. The 1994 World Development Report presents estimates on the effectiveness of different types of infrastructure. Using these data, Hulten develops an effectiveness index that covers all types of infrastructure capital. This author finds that differences in the effectiveness indicator explain 40% of the difference in growth performance between 1970 and 1990 and that it is the most important source of divergence. Given this result, he interprets the effectiveness index as a proxy variable for TFP.

Caselli (2005) argues that Pritchett's point could be relevant in accounting for cross-country income differences. In particular, as suggested by Prittchet, when measuring public capital stocks we need to add an additional parameter in the perpetual inventory method equation. That means, for country i

$$G_{i_t} = \gamma_i I_{ipub_t} + (1-\delta) G_{i_{t-1}},$$

where G_{i_t} is the aggregate public capital stock of country i in period t, I_{ipub_t} is public capital investment of country i in period t, δ is the depreciation rate and γ_i is a parameter that represents the effectiveness of public investment to build public capital, i.e., the portion of the public investment that actually contributes to building the stock of public capital. For a developed country this parameter may be close to one and for a developing country would be less than one. According to the estimation results in Pritchett (2000), half or more of government investment spending has not created equivalent capital. In other words, 50% percent of the total government expenditures in investment goods is lost and does not actually contributes to building the stock of public capital.

For my purposes, I assume an extreme case when $\gamma_{rich} = 1$ and $\gamma_{poor} = 0.1$. Table 1.7 shows the dispersion in the new measured capital stocks which I call "adjusted" under this assumption.

Table 1.7: Dispersion in Capital Stocks in 2003. "Adjusted" public capital.

	G	g	k	kt	h
Rich (90^{th} pctile)	$333,388.2 \times 10^6$	$16,660.7$	$161,843.2$	$172,285.2$	3.0
Poor (10^{th} pctile)	432.7×10^6	124.8	560.6	784.6	1.3
Ratios	770.5	133.5	288.7	219.6	2.3

Note: This table presents the measures of aggregate public capital stock (G), public capital stock per worker (g), private capital stock per worker (k), total capital stock per worker (kt) and human capital stock (h) in international dollars in 2003 for the 90^{th} *pctile* and 10^{th} *pctile* of the sample of countries when only 10% of public investment in poor countries contributes to build their public capital stock ("Adjusted" public capital). The last row contains the ratio between the value that each variable takes for the rich country over the value that takes for the poor country.

Private capital and human capital stocks are the same as before since I do not change anything in the procedure to obtain measures of them. The ratio of aggregate public capital stocks between the 90th and 10th percentiles is now 770.5. Under this extreme assumption I am penalizing public capital investments in poor countries and this is why the dispersion in public capital stock is even larger than the previous case.

Table 1.8 and Table 1.9 present the values of s_I and s_{II}.

Table 1.8: Success s_I. "Adjusted" public capital

	s_I
$s_{I,1}$	0.34
$s_{I,2}$ Private rate	0.36
$s_{I,2}$ Fernald's rate	0.40
$s_{I,3}$	0.26

Note: This table presents the values for $s_{I,1}$, $s_{I,2}$ and $s_{I,3}$ which are the values of the first measure of success considered for specifications 1, 2 and 3, respectively, of the production function (see 1.2.1 for the definitions).

Note that in both cases, under Specification 1, the model does a better job than before, since I have amplified the dispersion of public capital stocks. However, if we compare the values of both measures of success with both Specification 2 and Specification 3 I obtain the same qualitative results. This suggests that the implications for the sources of cross-country income differences are robust against this alternative method of measuring public capital stocks. In other words, even in the extreme case when only 10% of public capital investment contributes to building the public capital stock in poor countries and taking public capital as a pure public good, income differences across countries may still be explained by TFP differences.

Table 1.9: Success s_{II}. "Adjusted" public capital.

		s_{II}
$s_{II,1}$		0.47
$s_{II,2}$	Private rate	0.50
$s_{II,2}$	Fernald's rate	0.54
$s_{II,3}$		0.38

Note: This table presents the values for $s_{II,1}$, $s_{II,2}$ and $s_{II,3}$ which are the values of the second measure of success considered for specifications 1,2 and 3, respectively, of the production function (see 1.2.1 for the definitions) in the case that only 10% of public investment in poor countries contributes to build their public capital stock("Adjusted" public capital).

1.3 Measuring Capital Stocks

To compute aggregate private capital stocks, as in Hall and Jones (1999) and Caselli (2005) among others, I use the perpetual inventory method

$$K_{it} = I_{ipriv_t} + (1-\delta)K_{it-1}, \tag{1.19}$$

where K_{it} is aggregate private capital stock of country i in period t, I_{ipriv_t} is aggregate private investment in country i in period t and δ is the depreciation rate.

I follow the same procedure to measure aggregate public capital stocks

$$G_{it} = I_{ipub_t} + (1-\delta)G_{it-1}, \tag{1.20}$$

where G_{it} is aggregate public capital stock of country i in period t, I_{ipub_t} is aggregate public investment in country i in period t and δ is the depreciation rate.

I approximate the depreciation rate δ to its implicit average scrapping rate for the U.S.. I calculate scrapping rates for private and public capital stocks for each period from 1950-2003, by dividing the depreciation over the next capital stock in the same period. Then I compute the average in the period. I use the depreciation data reported in NIPA tables 1.7.5, and 7.3A and 7.3B , for private and public capital stocks, respectively. The net stocks of private and public capital are obtained from NIPA tables 2.1, and 7.1A and 7.1B , for private and public capital stocks, respectively. I obtain a depreciation rate of 4% for both types of capital. I assume that this rate is the same for all countries and it is not time varying. I discuss these assumptions below.

First, I need to calculate initial capital stocks for both types of capital. Now, in performing a development accounting exercise, one assumes that all countries are on a balanced growth path, as in Hall and Jones (1999). Therefore, in order to obtain the needed initial capital stocks, I use the balanced growth path expression for both kinds of capital in the Solow model. In the case of private capital I have that

$$K_{i0} = \frac{I_{ipriv_0}}{[(1+\Upsilon)(1+n_i)-(1-\delta)]}, \tag{1.21}$$

where Υ is the rate of technological progress which is common for all countries and n_i is the population growth rate of country i.

Similarly, for public capital the expression for the initial stock is given by

$$G_{i0} = \frac{I_{ipub_0}}{[(1+\Upsilon)(1+n_i)-(1-\delta)]}. \tag{1.22}$$

I use data on Gross Fixed Capital Formation (GFCF) by governments in local currency obtained from the World Bank Development Indicators database and OECD.Stat Extract online database (series codes are NE.GDI.FPUB.CN and GP51P, respectively). In addition, I use total GFCF as a percentage of Gross Domestic Product (GDP), also form the World Bank's Development Indicators (series code NE.GDI.FTOT.ZS). From the PWT v. 6.2 database I can calculate GDP in local currency.[7] This allows me to recover private GFCF, as the difference between total GFCF and public GFCF. The first data point varies with countries (from 1960 to 1992). I drop countries for which I do not have data before 1987[8]. My sample includes 45 countries listed in Table 1.10.

Then I deflate public GFCF and private GFCF time series in order to convert them into a common basket of goods (also called international dollars). The deflator is a Purchase Power Parity (PPP) convertor for investment goods, denoted by $PPPinv$, which I define as $PPPinv = P_I{}^*XRAT/100$ where P_I are prices of investment goods, and $XRAT$ are purchase power parity exchange rates, both as reported in PWT.[9] Therefore, after deflating, I have time series data on I_{pub} and I_{priv} in international dollars for 45 countries from the first period for which data are available for each country to 2003.

To calculate initial capital stocks, from PWT I obtain population data for my sample of countries to compute the average growth rate from 1950 to 2003. Also,

[7] Specifically, I calculate GDP by multiplying the series cgd by the series PPP.

[8] In the case of Uruguay, the data are missing for 1988 and 1989 so I took the average of the adjacent years. For Zimbabwe the data for 2002 and 2003 are missing and so I use the values reported for 2001.

[9] Here, while knowing that it is not necessarily true, I am nevertheless assuming that prices are the same for both types of investment goods. However, to my knowledge, there are no separate time series data on prices for private or public investment goods.

$\Upsilon = 1.8\%$ which I calculate by averaging the growth rate of Real RGDP per worker for the U.S., also obtained from PWT.

Table 1.10: Capital Stocks, Income and Capital-to-output Ratios in 2003

Country	G	k	g	h	y	k/y	kt/y
U.S.A.	3, 380, 042, 102, 917.4	146, 764.2	22, 477.8	3.4	67, 865.4	2.2	2.5
Norway	69, 820, 997, 388.43	163, 684.3	29, 477.7	3.3	65, 698.8	2.5	2.9
Belgium	25, 599, 705, 113.1	188, 072.8	6, 008.3	2.7	61, 541.4	3.1	3.2
Austria	19, 572, 460, 871.7	184, 882.7	5, 208.7	2.7	59, 788.6	3.1	3.2
France	333, 939, 909, 312.0	161, 973.8	12, 340.1	2.6	56, 909.0	2.8	3.1
Netherlands	125, 529, 448, 744.8	162, 252.2	16, 877.6	2.8	56, 789.6	2.9	3.2
Australia	164, 507, 848, 914.8	136, 531.9	16, 335.4	3.0	54, 600.5	2.5	2.8
Italy	157, 995, 939, 016.8	161, 647.2	6, 194.7	2.3	52, 097.0	3.1	3.2
United Kingdom	386, 582, 190, 856.4	103, 925.5	13, 000.2	2.8	51, 923.9	2.0	2.3
Canada	332, 560, 632, 804.0	127, 984.4	19, 553.8	3.2	51, 795.9	2.5	2.8
Finland	24, 776, 978, 365.5	152, 206.2	9, 581.5	3.0	48, 015.7	3.2	3.4
New Zealand	26, 645, 935, 360.3	103, 910.8	13, 492.0	3.3	44, 346.6	2.3	2.6
Trinidad and Tobago	10, 843, 126, 409.1	64, 140.6	21, 220.1	2.5	39, 797.3	1.6	2.1
Mauritius	4, 868, 449, 284.0	35, 025.9	9, 117.8	2.0	37, 324.2	0.9	1.2
Korea, Rep.	481, 202, 783, 222.2	100, 330.0	19, 464.3	3.0	33, 783.7	3.0	3.5
Swaziland	3, 157, 956, 835.8	15, 534.1	7, 325.9	2.0	24, 108.6	0.6	0.9
Uruguay	15, 941, 181, 289.8	24, 317.6	10, 279.9	2.4	19, 491.3	1.2	1.8
Mexico	432, 856, 505, 126.4	29, 882.9	9, 735.2	2.3	18, 627.6	1.6	2.1
Dominica	16, 665, 540.4	22, 450.4	560.2	1.9	17, 701.3	1.3	1.3
Iran, Islamic Rep.	419, 669, 880, 879.4	22, 345.2	16, 620.0	1.8	17, 297.4	1.3	2.3
Algeria	99, 645, 113, 741.3	15, 617.7	8, 234.3	1.8	16, 254.0	1.0	1.5
Paraguay	10, 928, 245, 206.5	14, 960.2	4, 697.0	2.0	12, 237.2	1.2	1.6
Egypt, Arab Rep.	118, 528, 553, 307.0	3, 880.1	4, 016.7	1.9	12, 051.2	0.3	0.7
Turkey	240, 829, 206, 911.9	17, 280.6	7, 087.3	1.9	11, 812.4	1.5	2.1
Jordan	13, 537, 536, 183.0	11, 119.9	7, 564.1	2.4	11, 420.0	1.0	1.6
China	5, 915, 241, 385, 789.8	7, 051.7	7, 661.4	2.0	8, 283.8	0.9	1.8
Bolivia	13, 442, 821, 786.8	4, 666.0	3, 778.9	2.0	7, 256.0	0.6	1.2
Cameroon	4, 795, 690, 005.5	3, 664.0	734.2	1.5	6, 539.3	0.6	0.7
Honduras	7, 516, 065, 872.9	6, 434.4	3, 010.5	1.7	6, 121.0	1.1	1.7
Syrian Arab Rep.	18, 289, 432, 932.5	2, 594.1	3, 115.4	2.0	6, 039.0	0.4	0.9
Zimbabwe	9, 745, 985, 219.7	10, 690.9	1, 721.2	1.9	5, 416.6	2.0	2.3
Congo, Rep.	2, 570, 885, 926.3	5, 015.9	2, 141.6	1.8	3, 495.7	1.4	2.0
Senegal	4, 861, 365, 901.3	1, 677.6	1, 030.3	1.3	3, 154.1	0.5	0.9
Benin	4, 105, 097, 518.9	1, 281.6	1, 281.2	1.3	2, 956.7	0.4	0.9
Ghana	9, 091, 152, 625.3	939.0	887.3	1.7	2, 876.1	0.3	0.6
Mozambique	6, 067, 551, 613.0	652.8	624.4	1.2	2, 775.0	0.2	0.5
Mali	4, 348, 416, 980.0	1, 080.0	772.9	1.1	2, 446.2	0.4	0.8
Rwanda	1, 623, 238, 050.3	375.0	382.0	1.3	2, 392.6	0.2	0.3
Uganda	2, 494, 214, 398.5	499.7	200.8	1.5	2, 297.5	0.2	0.3
Sierra Leone	1, 003, 250, 470.5	679.2	474.2	1.3	1, 931.5	0.4	0.6
Togo	2, 076, 561, 079.6	1, 577.9	899.2	1.5	, 1855.0	0.9	1.3
Niger	5, 733, 967, 113.5	459.5	1, 131.8	1.1	1, 821.4	0.3	0.9
Gambia	685, 645, 238.8	1238.7	887.7	1.3	1, 820.7	0.7	1.2
Malawi	5, 332, 726, 393.7	488.5	954.7	1.4	1, 607.4	0.3	0.9
Burundi	2, 581, 525, 724.1	116.7	796.0	1.2	1, 434.8	0.1	0.6

Note: This table presents the measures of aggregate public capital stock (G), public capital stock per worker (g), private capital stock per worker (k), human capital stock (h), income per worker (y), private capital-to-output ratio (k/y) and total capital-to-output ratio (kt/y) for 2003 in international dollars for the whole sample of countries considered in this paper which are ordered by income per worker.

In order to measure human capital stocks, I follow Caselli (2005), who uses the specification provided by Hall and Jones (1999) in which human capital is given by

$$h_i = e^{\phi_{S_i} S_i}, \tag{1.23}$$

where S_i is the average years of schooling in the population over 25 years old of country i and ϕ_{S_i} is a coefficient that depends on the value of S_i and represents the returns on schooling years. To compute human capital stocks I use the data provided in Barro and Lee (2001) for 2000.[10] From Caselli (2005), I take the following estimates of ϕ_S (common for all countries):

- 0.13 for $S \leq 4$,
- 0.10 for $4 < S \leq 8$, and
- 0.07 for $8 < S$.

The results are presented in columns 2-4 of Table 1.10 for the whole sample of countries and in columns 2-4 of Table 1.1 for the 90th and 10th percentile of the sample.

Kamps (2004) provides estimates for government net capital stocks for 22 OECD countries. This author presents public capital stock estimates in PPP for 1980, 1990 and 2000. However, instead of converting the investment series into international dollars to then use them to construct the capital stocks, these stocks are first estimated

[10] 2000 is the year nearest to 2003 for which Barro and Lee (2001) provide data.

in national currencies and then revaluated to international dollars. In addition, this author uses PPP for GDP, not for investment goods as I do here.

Arestoff and Hurlin (2006) estimate public capital stocks for 26 developing countries. These authors only provide measures of the stocks in national currencies.

I use (1.21) and (1.22) to compute an initial measure of the stocks. In order to analyze the impact of this way of calculating initial stocks, I follow Caselli (2005) by computing the portion of the initial stock (which I call η_j for $j = K, G$) that survives the sample period, given the depreciation rate δ. In other words, what fraction of the initial stock is part of the stock in 2003? This is given by

$$\eta_K^j = \frac{(1-\delta)^t K_0}{(1-\delta)^t K_0 + \sum_{i=0}^{t}(1-\delta)^i I_{priv_{t-i}}},$$

for private capital, and

$$\eta_G^j = \frac{(1-\delta)^t G_0}{(1-\delta)^t G_0 + \sum_{i=0}^{t}(1-\delta)^i I_{pub_{t-i}}},$$

for public capital, for country j, where $t = 2003$, and 0 represents the year for which I have the first data point on investment for each country which are the same for both η_K and η_G. The average across countries of η_K is 0.08 and the values computed for each country are not correlated with their GDP per worker (the correlation coefficient is 0.02). In the case of public capital stocks, η_G is 0.09 but the values computed are negatively correlated with GDP per capita (correlation coefficient is -0.28) which means that I may be overestimating public capital stock for poor countries. However, as it is pointed out in 1.2.3, this does not affect the main result since it is mainly driven by the small value of the parameter λ.

1.4 Technology Parameters for the U.S.

Let λ be the share of public capital in output. That means that λ is the value of services that come from public capital divided by output,

$$\lambda = \frac{VS}{VS + GNP}, \tag{1.24}$$

where VS is the Value of Services from public capital and GNP is Gross National Product. Note that I divide by $GNP + VS$ as an approximation to actual output, since VS is not included in measured GNP.

However, it is not straightforward to compute the value of services from public capital because they are not normally traded in markets, as is the case with private capital. Following Martin, Landefeld, and Peskin (1984), I compute the value of services by computing the cost of public capital assuming that all public investment projects are financially evaluated. Therefore, using this cost approach, the value of services is the sum of depreciation (Dep) and the net returns from public capital ($Net\ Returns$),

$$VS = Dep + Net\ Returns. \tag{1.25}$$

Depreciation is the annual allowance for using up public capital. $Net\ Returns$ are measured by multiplying a rate of return on public capital, r_{pub}, by the value of the net stock of public capital ($Net\ Stock$), that means

$$Net\ Returns = r_{pub}{}^{*}(Net\ Stock). \tag{1.26}$$

In this approach, r_{pub} represents the opportunity cost of invested capital and I take two different values of this rate to measure $Net\ Returns$. This means, of course, that I am going to have two different values for VS. First, I use the return rate on public capital of 12% (which I consider an upper bound) estimated in Fernald (1999) for the case of the U.S. road system.

Second, I use the return rate on private capital calculated following the procedure described in Cooley and Prescott (1995). That means, I first define income from private capital as unambiguous income (UI) plus its ambiguous component (AI) plus Depreciation (DEP). Let I_K be the income from private capital, so that

$$I_K = UI + AI + DEP. \tag{1.27}$$

The unambiguous component of private capital income is given by

$$UI = Rental\ Income\ +\ Corporate\ Profits\ +\ Net\ Interest \tag{1.28}$$

The ambiguous component of income from private capital includes Proprietors Income (PI) and the difference between Net National Product (NNP) and National Income (NI). Here I follow the same strategy as in Cooley and Prescott (1995): I assign this ambiguous income according to the share of private capital in measured GNP which I call α_M and it is defined as

$$\alpha_M = \frac{I_K}{GNP}, \tag{1.29}$$

that means

$$I_K = \alpha_M GNP. \tag{1.30}$$

Therefore

$$AI = \alpha_M [PI + (NNP - NI)]. \tag{1.31}$$

Then from (1.27) and (1.30) we have

$$UI + AI + DEP = \alpha_M GNP, \tag{1.32}$$

and by substituting (1.31) we get

$$UI + \alpha_M(PI + NNP - NI) + DEP = \alpha_M GNP. \tag{1.33}$$

Now from (1.33) we can solve for α_M

$$\alpha_M = \frac{UI + DEP}{GNP - (PI + NNP - NI)}. \tag{1.34}$$

I calculate UI by using data on the three terms on the right hand side of (1.28) obtained from NIPA Table 1.12 for each year from 1950 to 2003; specifically lines 12, 13 and 18 are *Rental Income*, *Corporate Profits* and *Net Interest*, respectively. In addition, from the same table PI (line 9) is obtained. From NIPA Table 1.7.5 I obtain DEP (line 6), NNP (line 14), NI (line 16) and GNP (line 4) for the same period. I compute α_M for each year from 1950 to 2003 and then I take the average over this period. The value is 0.27.

Now I move to calculate the return rate for private capital (r) which is given by

$$r = \frac{I_K}{K}, \tag{1.35}$$

where K is the net stock of private capital. By using the value obtained for α_M and (1.30) I calculate I_K from 1950 to 2003. I obtain K from line 1 in NIPA Table 2.1 for each year for the period considered. From (1.35) I calculate r for each year and take the mean which is 8.3%.

According to equations (1.24), (1.25) and (1.26) we still need values for $Net\ Stock$ and Dep of public capital in order to measure λ. From line 1 in NIPA Tables 7.3A and 7.3B, I obtain data for the amount of depreciation of the U.S. government (Federal and State and Local) fixed assets (Dep in equation (1.25)), and from line 1 in NIPA Tables 7.1A and 7.1B I have estimates for the value of the net stock of U.S. government fixed assets ($Net\ Stock$), from 1950 to 2003. I measure λ both for the case of public capital as a pure public good and in the congestion case when public capital enters in the production function in per-worker terms. Hence, in the case of pure public good, I use the amount of depreciation and the net stocks of fixed assets as it is given in the NIPA tables, and in the case of public capital in per-worker terms, I divide these variables by the number of workers of the U.S. economy calculated from PWT. Therefore, we have a different value for λ for the return rate on public capital used and with the definition of public capital considered. Table 1.3 shows the values obtained for λ.

Now I operationalize α which, is the share of private capital in output. Since the value of services from public capital is not measured in GNP, the correct measure for the share of private capital in output is given by

$$\alpha = \frac{I_K}{GNP + VS}.$$

Given the data for GNP and the values calculated for VS and I_K obtained when I measure λ, we can compute α for each period and then take the average. However, the measure for VS depends on the return rate of public capital used and also on whether public capital is a pure public good or is subject to congestion. So, as in the case of λ, α varies with these two measures of VS. In Table 1.4 I present the values calculated for α.

1.5 Conclusions

This chapter offers new evidence on the sources of cross-country income differences by investigating the role of the composition of capital between public and private across countries. Using data on public capital investments, I provide new measures for public and private capital stocks for a sample of 45 countries. Two important results emerge from my calculations. First, I find large differences in public capital stocks across countries. Second, the ratio of private capital-to-output ratios between rich and poor countries is twice the one for total capital-to-output ratio. The latter has been interpreted as an indicator of the distortion in the capital accumulation process in poor countries relative to rich countries. The separation of capital between private and private allows me to exclusively focus the analysis in the private sector, and this finding suggests that the private sector accumulation process would be more distorted than it has been originally thought. In addition, I carefully measure the share of each type of capital for the U.S. economy. When public capital is taken in per-worker terms (my approach to congestion), I find that the share of public capital in output is almost zero, and when it is a pure public good its share in output is less than ten percent. My calculations have important implications in accounting for cross-country income differences. Giving the best chance to public capital (pure public good), differences in factors of production across countries cannot go far in explaining the observed income differences between them. This conclusion is unchanged even when assuming that only ten percent of the public capital investments in poor countries effectively contributes to the building of the stock of public capital. This result confirms the view that cross-country income differences are largely due to TFP differences. My specification of the production function implies a minimum departure from the previous literature in developing accounting, and implies complementarities between private and public capital. Future research should investigate the specification of production technologies with public capital and provide the proper microfoundations.

CHAPTER 2
DISTORTIONS, INFRASTRUCTURE AND FEMALE LABOR FORCE PARTICIPATION IN LATIN AMERICAN COUNTRIES

2.1 Introduction

The existing literature in development has focused on analyzing cross-country differences in GDP per worker. There is a consensus that almost 50% of these differences are accounted for by TFP (Total Factor Productivity) differences (see Hall and Jones (1999), Caselli (2005) and Restuccia (2008) for the case of Latin American countries). However, cross-country gaps between GDP per capita and GDP per worker, driven by differences in labor force participation across countries, have not attracted much attention in existing work.

Many authors, Prescott (2004) and Rogerson (2009) among many others, have studied differences in the labor supply between developed countries, mainly between Europe and the U.S. In this chapter I focus on labor supply differences in the developing world. In a sample of Latin American (LA, henceforth) countries I find large differences in labor force participation (LFP), relative to the US, of people aged 25 years and older. By performing a simple accounting exercise, I show that these differences in LFP account for around 15% of the differences in GDP per capita between the LA countries and the U.S. in the period 1980-1990. The aim of this study is to explain these observed labor supply differences. I argue that cross-country differences in labor supply are mainly due to access to infrastructure and distortive policies in developing countries.

There are three novel aspects of the data that motivate this study. I first uncover new data based on household surveys to document differences in LFP of males and females between a set of LA countries and the U.S.. I show that LFP participation differences are mainly due to differences in the participation of women in the labor market. In the U.S. the female labor force participation was 69% by 1990, while in Brazil and Mexico was was 39% and 37%, respectively. Furthermore, this observed gap in female LFP started to decrease at the beginning of the nineties: In 2005 female LFP was 66% and 48% in Brazil and Mexico, respectively. In addition, the survey data show substantial differences in the use of durable household goods across countries. For instance, in the US, about 80% of households operated a washing machine in 1990, whereas in Brazil and Mexico only 24% and 36% of households operated one, respectively.

Second, by using new data obtained from national statistical offices I show a particular pattern for the evolution of the relative price of appliances observed in LA countries. In almost all the LA countries in my sample the relative price of appliances was constant or increased until the beginning of the nineties. This behavior of prices may reflect the effect of many distortions operating in these countries, being trade barriers one of them.

Latin American countries constitute excellent laboratories to analyze the effects of changes in trade policy. Until the mid-1980s, trade policies applied in these countries aimed at keeping sectors protected through high tariffs and import restrictions (also called Import Substitution policies). The collapse of these economies in the 1980s eliminated the credibility of the import-substitution model and set the stage for trade reforms. Since the end of the eighties LA countries have drastically reduced their tariff and non-tariff restrictions. Data on the evolution of average tariff rates in this period suggest a link between the evolution of these prices to the changes in the trade policy just described.

In addition, the access to basic infrastructure and the link with the development process has been a concern in the development literature and policymakers. By using compiled data from household surveys, I am able to document substantial differences in the access to electricity and running water both across countries and within countries in the period analyzed. In the US almost all households had access to running water circa 1990, whereas in Brazil and Mexico only 78% and 81% of the households had access to this service, respectively. Interestingly, when we look at data on the access to infrastructure by income quintile in developing countries in the pre-reform period, we observe large differences in the access to infrastructure between households in different income groups. Around 1990, 97% and 92% of the households in the top income quintile had access to these two services in Brazil and Mexico, but only 35% and 47% of the households in the bottom income quintile had access to these infrastructure services, respectively. This unequal access to basic infrastructure dramatically changed in the post-reforms period: between circa 1990 and 2005 the access to electricity and running water for the bottom income quintile increased by 94% and 53% in Brazil and Mexico, respectively.

In the second part of this chapter I use economic theory that incorporates these salient features of the data in order to analyze the economic forces behind these observations. I interpret the evolution of prices and access to infrastructure as barriers to technology adoption by LA households that operated until circa 1990 which then were partially removed by 2005. For this purpose, I develop a simple overlapping generation model with home production that builds on Greenwood, Seshadri, and Yorukoglu (2005) (GSY, henceforth). The key features of the model are: i) heterogeneity in households ability levels and, ii) the access to infrastructure needed to operate household durable goods. More critically, I specifically model the interplay between this type of heterogeneity and the access to infrastructure services in determining the adoption of time saving household technologies.

Each country is a closed economy populated by heterogeneous households, each composed by a male and a female. Household members get utility from the consumption of market goods, home goods and leisure. Households are heterogeneous in their ability levels which is fixed for their entire life. Males always work in the market, and in each period the household decides whether the female does the housework (home work) or offers labor in the market (market work). In addition, each period households choose the amount of savings and whether to buy a composite durable good. There are two types of technologies. A standard Cobb-Douglas production function describes the production of market goods by competitive firms. The home production technology is assumed to be the Leontief type. Once the household purchases the durable good, it operates a new technology that allows the female to save time in performing the household chores.

Countries differ the in the distribution of ability levels which lead to differences in the mean and dispersion of household income, a feature that is suggested by the data. In developed countries, more households choose to buy the durable good. Constrained by low income, fewer households in developing countries buy the durable good, and hence more females do housework. In addition, households of different countries face different market prices of durable goods. These prices are potentially higher in developing countries, so they operate as a barrier to the adoption of new household technologies. In a similar fashion, countries exogenously differ in their access to basic infrastructure which is essential for the household to adopt the durable good. I also exogenously introduce a wedge in the income females receive compared to the income that males receive. This captures the gender earnings gap observed in the data. Finally, countries differ in their technology levels to produce market goods.

I then calibrate the model to the U.S. and compute the steady state predictions for each of the countries in my sample in the pre-reform period (circa 1990) and in the post-reforms period (2005). By using the calibrated model, I vary country specific parameters in order to ask, how much of the observed differences in female labor supply are accounted for by the model both in 1990 and 2005. Specifically, I take average human capital levels, household income inequality, access to basic infrastructure by income quintile, gender earnings gap, total factor productivity and relative price of household appliances to be country specific.

In the case of the US, the model is calibrated for 1990 such that it matches both the adoption and female LFP levels in that year. In addition, I use the model to predict the levels of these variables in 2005, and it closely matches the level of adoption in that year of and predicts an increase in female LFP that is close to the one observed in the data.

More importantly, for the case of Brazil, in the pre-reforms period, I find that the model can account for 63% of the observed female LFP. In the post-reforms period the model accounts for 93% of the observed female LFP in this country. More importantly, the model accounts for 93% of the observed change in female LFP between these two periods. When I compute the model predictions for Mexico, I find that the model overpredicts the levels of female LFP in both periods. However, it succeeds in predicting a higher adoption level than the ones observed in Brazil. In addition, it quantitatively does a good job in accounting for the observed change in female LFP between these two periods: it accounts for 50% of the observed change in female LFP.

2.2 Labor Force Participation Differences

In this section, I document differences in labor supply between a set of developing countries and the U.S. by uncovering new comparable data on labor force participation. In addition, I argue that these differences are important in explaining observed differences in GDP per capita in the period 1980-2005. All the data sources are described in the Appendix.

2.2.1 Labor Force Participation

Figure 2.1 shows the evolution of total LFP for Brazil and Mexico with respect to the US in the period 1908-2005.

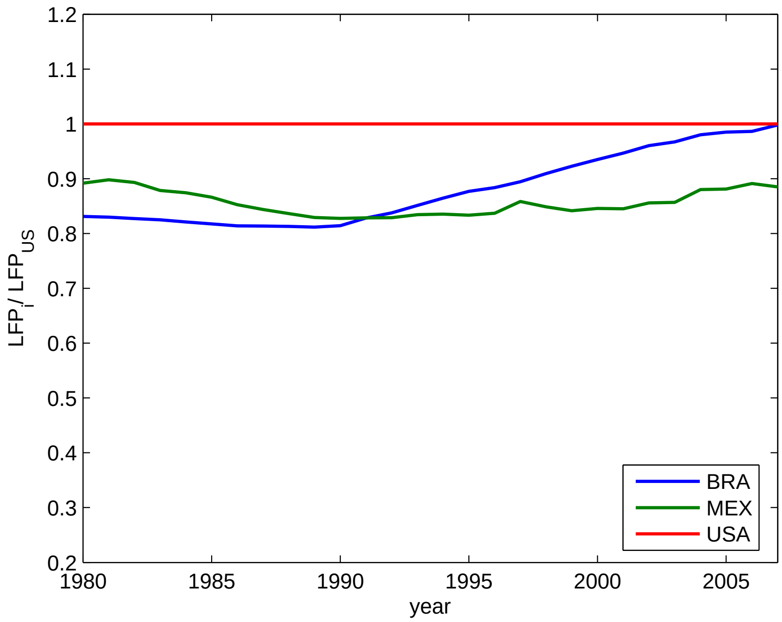

Figure 2.1: Labor Force Participation relative to the U.S.

In 1980 total LFP in Brazil was around 80% of the US level. In the case of Mexico it was around 90% of the US level. Interestingly, in both countries total LFP participation decreased or remained constant relative to the US until the beginning of the nineties when it started to increase. For instance, in the case of Brazil it totally caught up with the US level by 2005.

More importantly, by decomposing the participation rates by sex, we observe that the observed cross-country differences in total LFP come from differences in *female* LFP. As Figure 2.2 shows, we do not observe substantial changes in the participation of males during the period with respect to the US.

However, by inspecting Figure 2.3 we see that all the action comes from changes in female LFP.

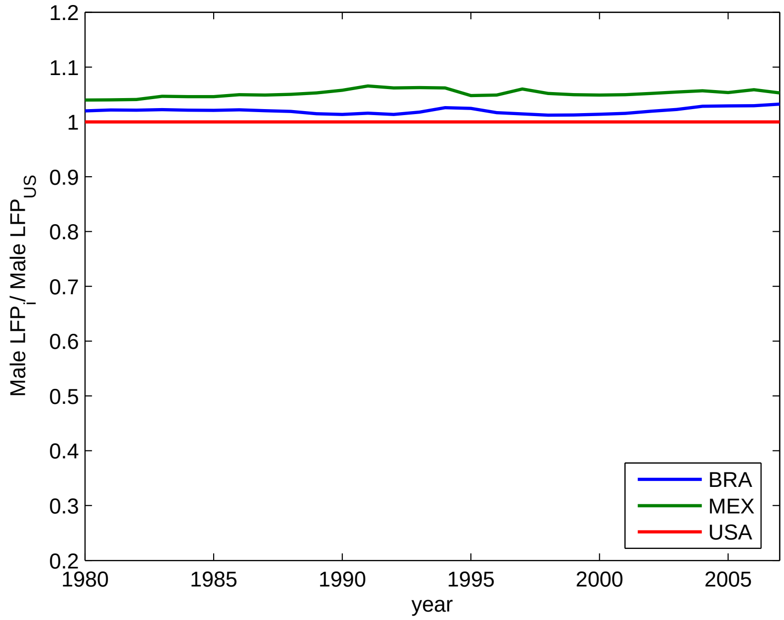

Figure 2.2: Male Labor Force Participation Relative to the U.S.

We observe a clear break in circa 1990 in the evolution of the female LFP in these developing countries. Note that in the period 1980-1990 the participation of women in the labor market decreased in the case of Mexico and remained constant in Brazil. In the period 1990-2005 it substantially increased in both countries. I focus my exposition on these two countries (the largest of the region) but the same pattern is observed in the majority of LA countries in the period analyzed.[1] Table 2.1 shows the stunning differences in the participation of women in the labor markets in 1990 between Brazil and Mexico and the US and the substantial increase observed between 1990 and 2005.

[1]For the average of LA countries, the female LFP grew at an average rate of 1.4% a year from 1980 through 1990 to then grow at an average rate of 2.6% in the rest of the period.

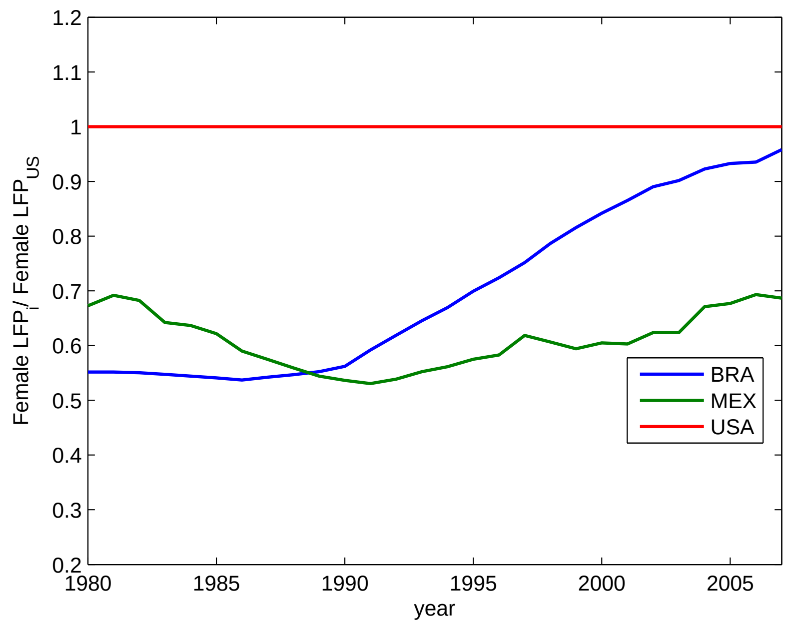

Figure 2.3: Female Labor Force Participation Relative to the U.S.

For instance, Brazil's female LFP went from 39% to 66% in just 15 years.

2.2.2 Labor Supply and Development in Latin America

In order to assess the importance of differences in labor supply in the development process we can perform the following accounting exercise. For a particular year or period we can compare the GDP per capita of country i relative to country j and decompose this ratio between the ratio of GDP's per worker and LFP.

By definition,

$$\frac{GDP_{pw,i}}{GDP_{pw,j}} = \frac{\frac{GDP_i}{LF_i}}{\frac{GDP_j}{LF_j}}, \tag{2.1}$$

where GDP_i is the GDP in country i, $GDP_{pw,i}$ is the GDP per worker of country i

Table 2.1: Female LFP levels (%)

	1990	2005
Brazil	39	66
Mexico	37	48
United States	69	72

Note: This table presents the female labor force participation rates for Brazil, Mexico and the US in 1990 and 2005.

and LF is the labor force or number of workers of country i.

Since

$$LF_i = LFP_i \times POP_i, \tag{2.2}$$

where LFP_i and POP_i represent the labor force participation and total population of country i, respectively. Then substituting (2.2) into (2.1), we get

$$\frac{GDP_{pw,i}}{GDP_{pw,j}} = \frac{\frac{GDP_i}{LFP_i \times POP_i}}{\frac{GDP_j}{LFP_j \times POP_j}}. \tag{2.3}$$

Using the definition of GDP per capita and rearranging terms

$$\frac{GDP_{pw,i}}{GDP_{pw,j}} = \frac{GDP_{pc,i}}{GDP_{pc,j}} \times \frac{LFP_j}{LFP_i}, \tag{2.4}$$

or

$$\frac{GDP_{pc,i}}{GDP_{pc,j}} = \frac{GDP_{pw,i}}{GDP_{pw,j}} \times \frac{LFP_i}{LFP_j}. \tag{2.5}$$

The previous literature in developing accounting has focused on the observed differences in GDP per worker across countries (the first term of the right hand side of (2.5)) and not much in labor force participation differences (the second term of the right hand side of (2.5)). By using (2.5) to compare the average of LA to the U.S. in the period 1980-2005, we have

$$\frac{GDP_{pc,LA}}{GDP_{pc,US}} = \frac{GDP_{pw,LA}}{GDP_{pw,US}} \times \frac{LFP_{LA}}{LFP_{US}}. \tag{2.6}$$

By taking logarithms in both sides of (2.6) we can find the contribution of the documented differences on labor force participation to explain the observed differences in GDP per capita in that period. Interestingly, in both Brazil and Mexico, differences in labor force participation explain around 20% of the differences in GDP per capita between these countries and the U.S. in 1990. Providing the dramatic increase in LFP after the beginning of the nineties, by 2005 LFP differences explain only 1% and 10% of the GDP per capita differences between Brazil and Mexico and the US, respectively.[2] As it is argued below, this study provides a detailed explanation for this non trivial amount of the observed cross country differences in income per capita.

2.3 Differences in Household Technologies

In this section, I document differences in the diffusion of new household technologies across countries in the period 1990-2005 by exploring data at the household level for a set of LA countries and the U.S. All the data sources are described in the Appendix.

[2]For the average LA country, differences in labor force participation explain more than 15% of ratio of GDP per capita between LA and the U.S. in 1990.

2.3.1 Adoption of Appliances

I explore compiled data from household surveys to document evidence cross-country differences in the technologies used at the household level. The available data start in circa 1990 which is the year in which all the major changes in female LFP began in the region. As an approximation of the adoption of time saving devices I have access to data on the percentage of households with washing machines in circa 1990 and circa 2005.

Table 2.2 shows the adoption of washing machines for Brazil, Mexico and the US.

Table 2.2: Households with Washing Machines (%)

	circa 1990	2005
Brazil	24	36
Mexico	36	64
United States	80	90

Note: This table presents data on the percentage of households with washing machines in Brazil, Mexico and the US in the periods circa 1990 and 2005.

In circa 1990, 80% of households operated a washing machine in the U.S., but less than 40% and 30% of Brazilian and Mexican households, respectively, have one. The adoption of washing machines substantially increased during the period. From circa 1990 to circa 2005, the percentage of households with washing machines increased by 50% (from 24% to 36%) in Brazil and by 77% (from 36% to 64%) in Mexico.

2.4 Barriers to Technology Adoption

In this section, I provide evidence on barriers to the adoption of new technologies at the household levels in a set of LA countries. I first show differences in the access to basic infrastructure across countries. In addition, I provide unique data on the evolution of the price of household appliances for these developing countries that present an interesting pattern which we can connect to the different observed figures regarding the adoption of new technologies by Latin American households. Finally, I provide data on average tariff levels before and after the reforms that took place at the beginning of the nineties which I argue could be one of the reasons behind the particular evolution of prices reflected in the data.

2.4.1 Infrastructure

In order to adopt the technology embodied in new appliances, the proper infrastructure needs to be available for the household: electricity and/or running water depending on the specific appliance. Table 2.3 shows the mean access to electricity for Brazil, Mexico and the US in circa 1990 and 2005.

Table 2.3: Households with access to Electricity

	circa 1990	2005
Brazil	90	97
Mexico	91	99
United States	100	100

Note: This table presents data on the percentage of households with access to electricity in Brazil, Mexico and the US in the periods circa 1990 and 2005.

In the period analyzed, we see a notable increase in the access to this basic service in the case of Brazil (from 90% to 97%) and Mexico (from 91% to 99%) which I will argue has a non trivial effect on the increase in the labor force participation in these countries. The mean access to running water is depicted in Table 2.4.

Table 2.4: Households with access to Running Water

	circa 1990	2005
Brazil	78	90
Mexico	81	91
United States	100	100

Note: This table presents data on the percentage of households with access to running water in Brazil, Mexico and the US in the periods circa 1990 and 2005.

Again, Brazil and Mexico experienced a substantial expansion in the access to this basic service: the percentage of households with access to running water increased by 15.4% and 12.3% in Brazil and Mexico, respectively.

These figures refer to the mean access to these basic infrastructure services, but by exploring data on the access to infrastructure by income quintile we can obtain a better picture of the substantial changes in this margin experienced by the households of these countries. Table 2.5 presents the percentage of households with access to electricity *and* running water by income quintile in Brazil in circa 1990 and 2005.

We can clearly see the high inequality in the access to infrastructure in 1990:

Table 2.5: Brazil: Access to Infrastructure by Income Quintile

	circa 1990	2005	%Change
Top	97	99	2.1
Second	84	96	14.3
Third	73	89	21.9
Fourth	58	82	41.4
Bottom	35	68	94.3

Note: This table presents data on the percentage of households with access to both electricity and running water by income quintile in Brazil in the periods circa 1990 and 2005. *Top* refers to the top income quintile, *Second* to the second income quintile and so forth.

while almost all the households at the top of the income distribution has access to these services, only 35% of the poorest households could use these infrastructure services. That means that for the majority of poor households, even in the case they could afford new durable goods they could not adopt the new households technologies due to the lack of access to the infrastructure needed to use them. The picture dramatically changed in 2005. As we observe in the third column of Table 2.5, by 2005 we observe much less inequality in the access to infrastructure providing the major improvements in the access to these services for poor households. The access rates increased by 41% and 94% for the households in last two income quintiles.

We observe the same pattern for Mexico. As Table 2.6 shows, in 1990 92% of households in the top income quintile had access to electricity and running water whereas only 47% of the households at the bottom had access to these basic services.

Again, by 2005 we observe a more equal distribution in the access to infrastructure: access rates increased by 53% for the households in the bottom income

Table 2.6: Mexico: Access to Infrastructure by Income Quintile

	circa 1990	2005	%Change
Top	92	98	6.5
Second	86	96	11.2
Third	78	92	17.9
Fourth	64	86	34.4
Bottom	47	72	53.2

Note: This table presents data on the percentage of households with access to both electricity and running water by income quintile in Mexico in the periods circa 1990 and 2005. *Top* refers to the top income quintile, *Second* to the second income quintile and so forth.

quintile.

2.4.2 Price of Household Appliances

In order to explore the possible causes behind the different adoption pattern across countries observed in the labor participation data I look at the evolution of the relative price of household appliances for each of the countries analyzed. The idea is to use relative prices as indicators of distortions that vary across countries and time. There is a vast literature that focus on the differences in relative prices of investment goods to explain differences in investment rates of physical capital across countries observed in the data (see Restuccia and Urrutia (2001) among others). It is argued that these price differences reflect distortions to the accumulation of physical capital. However, it has been difficult to identify the origin of such distortions or the policies that could explain this disparity on prices levels of investment goods. The novelty here is that I focus on an specific type of investment goods (household appliances) and a particular channel through which they affect the labor supply of a particular country.

I uncover new data from national statistical agencies for some countries in the sample in order to observe the particular dynamics of the relative price of appliances. Figures 2.4 and 2.5 present the evolution of the relative price of household appliances for Brazil and Mexico, respectively.

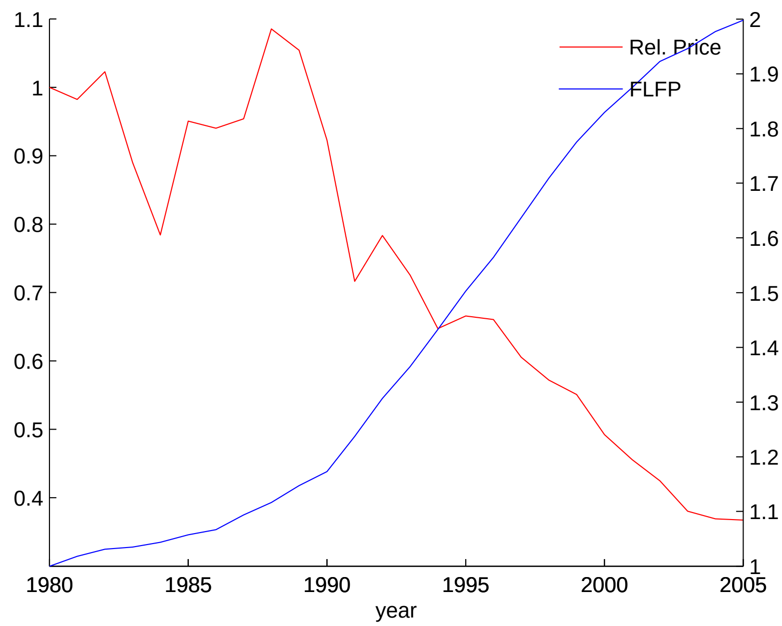

Figure 2.4: Relative Price of Appliances and Female LFP in Brazil

For the US case, the seminal work by GSY shows that the observed declining path of the price of household appliances is the main force that spurred the adoption of new durable goods by households which consequently explains the increase in the female LFP in the U.S. during the 20th century. Interestingly, in the case of

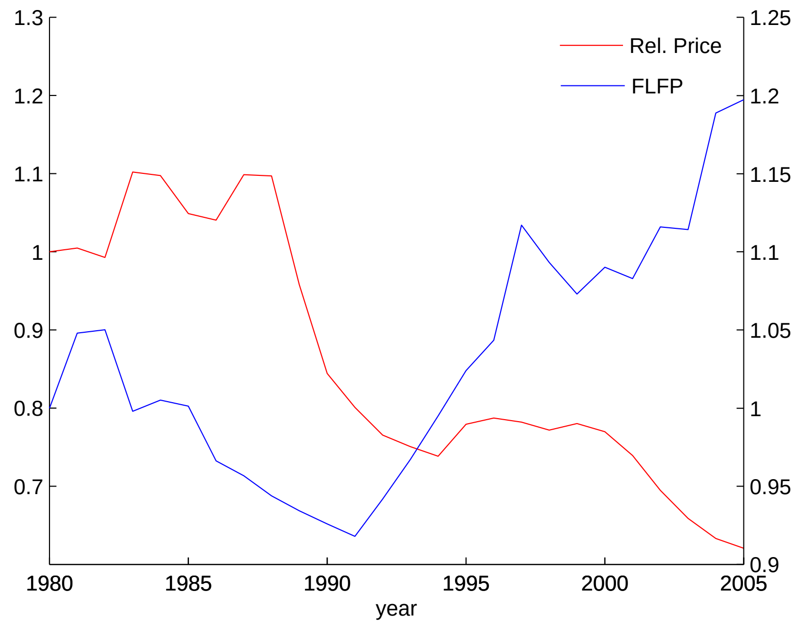

Figure 2.5: Relative Price of Appliances and Female LFP in Mexico

LA countries the relative price of household appliances show an upward or constant trend until the end of the eighties to then start to decline at a very fast rate until the end of the period analyzed. This is shown in Figures 2.4 and 2.5. In the case of Brazil, the relative price declined 60% between 1990 and 2005, and in Mexico by 26% between these two periods. Also tote that the price of home appliances started to decline at the beginning of the 90's and this coincides with the increase in female LFP documented above as it is also depicted in the figures.

Why do we observe a different pattern in the evolution of prices in LA countries? The timing of the break in the trend of the price of household appliances in LA countries coincides with the the timing of the trade liberalization period which was characterized by the removal of trade policies that introduced distortions in the price of imported goods in the period I study. Among them, we have the import substitution policies applied until the beginning of the nineties. These policies sought to promote and develop a domestic manufacturing industry through the application of tariffs and para-tariff barriers on imported goods. To provide some evidence in this direction, Table 2.7 shows the average effective applied tariff rates in Brazil and Mexico in the period that preceded the reforms (circa 1990) and in the post reforms period (2005).

Table 2.7: Average Tariff Levels (%)

	All Products		Manufactured Products	
	circa 1990	2005	circa 1990	2005
Brazil	43	12	44	13
Mexico	14	9	14	9

Note: This table presents data on average applied tariffs rates in Brazil and Mexico for all products and manufactured products.

By just looking at the average tariff levels in in circa 1990, we can notice that on average, Brazilian consumers had to pay an extra 43% when purchasing imported goods. In the case of Mexico, the average tariff rates are lower since the trade reforms were initiated earlier than in Brazil. Yet, in both countries, tariff rates were reduced between these two periods. In Brazil, average tariff rates decreased by 70%. This value is close to the observed reduction on the price of household appliances between the same two periods (60%). In Mexico, tariffs were reduced by 30% and the price of appliances declined 26%. The changes in tariff rates are similar for the case of manufactured goods, as it is also depicted in Table 2.7. There is some evidence that for the case of consumer durables the level of protection was even more aggressive as it is documented in Table 8 in Cole, Ohanian, Riascos, and Schmitz (2005). For instance, the average nominal tariff applied to durables was 266% in Argentina in 1960. In addition, it is well known that measures of tariff rates are just an approximate indicator of trade restrictions since they do not take into account para-tariff barriers (duties and custom fees) and quantitative restrictions. Other measures of trade restrictions in the pre-reforms and post reforms periods are documented in Loayza and Palacios (1997) which show a similar pattern of changes in trade restrictions.

This evidence suggest that the removal of these distortive policies may be the main reason behind the break in the pattern of relative prices observed in the figures and could potentially contribute to explain the rise in the adoption of appliances by LA households observed in the data. The link suggested by the presented facts about the adoption of modern household technologies, relative price of household appliances and its evolution (that may reflect distortions or barriers) and, access to infrastructure (which also operates as a barrier) are introduced in a home production model which is described in the next section.

2.5 The Model

A stationary description of the model environment is provided below.

2.5.1 Model Environment

2.5.1.1 Preferences, Endowments and Heterogeneity

Time is discrete. The economy is populated by a continuum of individuals of measure one. A household of age-j belongs to the set $\mathcal{J} = 1, 2, ..., J$. There are J overlapping generations of households, each of them with an exogenous weight $\theta_j \in \mathcal{J}$ in the total population, with $\theta_1 + ... + \theta_J = 1$. Households are born with no assets and are heterogeneous in their ability levels (efficiency units of labor) denoted by h, which is realized at the beginning of their life. Ability is drawn from the distribution $\pi(h)$, and it is fixed over their life cycle.

The household is composed by a male and a female, each of them endowed with one unit of time. They also share the same ability level h. The male splits its time between market work and leisure, whereas the female can spend its time in market work, home work and leisure. It is assumed that labor is indivisible and the portion of time that is allocated to market work is fixed and given by ω. Males always supply labor to the market and their income is given by $w\omega h$, being w the wage rate. For females, in case they work in the market they obtain $\phi w\omega h$, where ϕ stands for the gender earnings gap. Households get utility from the consumption of market goods, home goods and leisure time.

The objective of a household is to maximize

$$\sum_{j=1}^{J} \beta^{j-1} \left[\lambda \ln c_m(j) + \nu \ln c_n(j) + (1 - \lambda - \nu) \ln l(j)\right],$$

where $c_m(j)$ is the consumption of market goods at age-j, $c_n(j)$ is the consumption of home goods at age-j, $l(j)$ is leisure at age-j. β is the discount factor, λ

is the weight of market goods and ν is the weight of home goods.

2.5.1.2 Technologies

The technology for producing home goods is given by

$$c_n = \min\{d, \zeta \times n\} \tag{2.7}$$

where c_n denotes the quantity of home goods produced and consumed in the household, d represents the durable good which is assumed to be lumpy, ζ is the level of the technology to produce home goods, and n is the home labor done by the female, which is indivisible.

There are two technologies available for the household to produce home goods. When households are born they are endowed with the *Old* technology, which we can interpret as the one used to produce hand made home goods. The *New* technology requires the purchase of a durable good at the exogenous price q. Once the household purchase the durable good it will operates the new technology for its entire life. In addition, in order to adopt the new technology, it is required for the household to have access to the basic infrastructure needed for that purpose. For instance running water and electricity are necessary in order to operate a washing machine. The access to infrastructure is given to the household when they are born and, it is introduced in the model as an exogenous variable $\gamma \in 0, 1$. If $\gamma = 1$ the household has access to infrastructure, and if $\gamma = 0$ it has no access to infrastructure.

There is a standard Cobb-Douglas technology that describes the production of market goods by competitive firms, and it is given by

$$y = zK^{\alpha}(L)^{1-\alpha}, \tag{2.8}$$

where y is total output, K is the aggregate stock of physical capital, L represents the labor input, z is the technology parameter and α is the share of physical capital in output.

Capital is accumulated according to

$$K' = (1-\chi)K + i, \tag{2.9}$$

where χ describes the depreciation rate and i the investment done by firms operating in competitive markets.

The resource constraint reads

$$y = c_m + i + qd. \tag{2.10}$$

2.5.2 Household Decision Problem

A recursive description of the household decision problem is presented below.

For and age-j household optimization consists of choosing the amount of assets to carry to the next period a' and two discrete choices: if the female participates in the market or stays at home and, if it purchases the durable good or not. Besides its age j, relevant to its decisions will be the assets it enters to the period, a; the efficiency units which it is endowed with, which together with the wage rate will determine both the income of the male and the female in case she works in the market; if it has adopted the new technology in the past or not and; if it has access to infrastructure, since absent the access to basic infrastructure the household can not adopt the new technology in any period. So, the state of a household is summarized by the vector $x = (a, h, \gamma, \tau, j)$. τ is the state variable describing the adoption of technologies by the age-j household. It takes the values $\{0, 1\}$, where $\tau = 0$ means that the household has adopted the new technology in the past and, $\tau = 1$ means that the household has not adopted the new technology in the past. a is the asset level, h is the ability level and γ describes the access to infrastructure for this household as it is described above.

Define the participation of the female in the market by the indicator function I_P which takes the value 1 if the household chooses that the female works in the market and 0 if she stays at home. In the same way, whether to continue operating the old technology (for which she is endowed with) or purchase the durable good at price q and operate the new technology be described by the indicator function I_A, that takes the value 1 if the household purchase the durable good and 0 if not. Let also define $V_\tau(a, h, \gamma, \tau, j)$ as the lifetime utility of age-j household.

First, consider the case of an age-j household that is born with access to infrastructure (i.e. $\gamma = 1$) and has adopted the new technology sometime in the past (i.e. $\tau = 0$). This household chooses the level of assets it is going to carry to the next period and if the female participates in the market or stays at home performing the household chores. Its budget constraint reads

$$c_m = w\omega h + (\phi w\omega h)I_P + ra - a' \tag{2.11}$$

The value function obeys the following recursion.

$$\begin{aligned} V(a,h,1,0,j) = \max_{a', I_P \in \{0,1\}} \Big[& \lambda \ln(w\omega h + (\phi w\omega h)I_P + ra - a') + \\ & \nu \ln(c_n) + (1-\lambda-\nu)\ln(l) + \beta V(a',h,1,0,j+1)\Big], \end{aligned} \tag{2.12}$$

subject to

$$c_n = \min\{d, \zeta \times n\}. \tag{2.13}$$

Now consider the age-j household that is born with access to infrastructure (i.e. $\gamma = 1$) and has *not* adopted the new technology in the past (i.e. $\tau = 1$). This household chooses if it is going to purchase the durable good (adopt the new technology) in the current period or not, in addition to the assets level to carry to the next period and, if the female participates in the market or not. Its budget constraint is given by

$$c_m = w\omega h + (\phi w\omega h)I_P + ra - a' - qI_A. \tag{2.14}$$

Therefore its value function reads

$$\begin{aligned} V(a,h,1,1,j) = \max_{a', I_P \in \{0,1\}, I_A \in \{0,1\}} \Big[& \lambda \ln(w\omega h + (\phi w\omega h)I_P + ra - a' - qI_A) + \\ & \nu \ln(c_n) + (1-\lambda-\nu)\ln(l) + \\ & \beta[I_A V(a',h,1,0,j+1) + (1-I_A)V(a',h,1,1,j+1)]\Big], \end{aligned} \tag{2.15}$$

subject to

$$c_n = \min\{d, \zeta \times n\}. \tag{2.16}$$

Finally, we have the households that are born without access to infrastructure (i.e. $\gamma = 0$). It is assumed that the household needs to have access to infrastructure in order to operate modern technologies (i.e. electricity and running water to use a washing machine). Therefore, without access to infrastructure they can not purchase the durable good in their entire life. In this case we have that

$$I_A = 0 \quad \text{for} \quad j = 1, .., J. \tag{2.17}$$

Each period the household chooses its asset levels to carry to the next period and if the female works in the market or not. The value function reads as follows

$$\begin{aligned} V(a, h, 0, 1, j) = \max_{a', I_P \in \{0,1\}} \Big[& \lambda \ln(w\omega h + (\phi w \omega h) I_P + ra - a') + \\ & \nu \ln(c_n) + (1 - \lambda - \nu) \ln(l) + \beta V(a', h, 0, 1, j + 1) \Big], \end{aligned} \tag{2.18}$$

subject to

$$c_n = \min\{d, \zeta \times n\}. \tag{2.19}$$

Abusing notation somewhat, denote the optimal decision rules for assets by $a'(x)$, the female participation function $I_P(x)$ and, the adoption function $I_A(x)$.

2.5.3 Aggregates

For aggregation purposes it necessary to specify the position of households across states.

Let $\psi_j(B, H; \gamma, \tau)$ be the mass of households, with asset position $a \in B$, efficiency units $h \in \mathcal{H}$, $j \in \mathcal{J}$, access to infrastructure γ and adoption state τ. The measure ψ is defined for all $B \in \mathcal{B}$ the class of Borel subsets of $\mathbb{R}$, all Borel subsets $H \subset \mathcal{H}$, all $j \in \mathcal{J}$, $\gamma \in \{0, 1\}$ and $\tau \in \{0, 1\}$. The dynamic evolution of the mass of households reads as follows.

The realization of γ determines the mass of newborns without access to infrastructure

$$\psi_1(B, H; 0, 1) = \theta_1 \int_{\mathbb{R}\times H} I_{\{\gamma=0\}} z(h) dh \quad if \quad 0 \in B.$$

Recall that the no access to infrastructure status stays constant for the entire lifetime which prevent these households to adopt the new technology. For $1 < j \leq J$, we need to consider the mass of households without access to infrastructure for which $a \neq 0$. That means,

$$\psi_{j+1}(B, H; 0, 1) = \theta_j \int_{\mathbb{R}\times H} I_{\left\{a'(a,0,1)\in B\right\}} d\psi_j(a, h; 0, 1).$$

Similarly, the mass of households with access to infrastructure

$$\psi_1(B, H; 1, 1) = \theta_1 \int_{\mathbb{R}\times H} I_{\{\gamma=1\}} z(h) dh \quad if \quad 0 \in B.$$

Notice that I am using the assumption that a newborn is endowed with the old technology and so has not adopted the technology in the past ($\tau = 1$).

Since all households die at J, we have that

$$\psi_{J+1}(B, H; \gamma, \tau) = 0.$$

For $1 < j \leq J$, ψ obeys the following recursion.

For the case of past adopters, i.e. $\tau = 0$,

$$\psi_{j+1}(B,H;1,0) = \theta_j \int_{\mathbb{R}\times H} I_{\left\{a'(a,1,0,j)\in B\right\}} d\psi_j(a,h;1,0) + \theta_j \int_{\mathbb{R}\times H} I_{\left\{a'(a,1,1)\in B\right\}} I_A(a,1,1,j) d\psi_j(a,h;1,1).$$

In words, the mass of past adopters in $j+1$ is equal to the mass of past adopters in j (first term on the right hand side) plus the mass of new adopters (second term on the right hand side).

In the same way, the mass of no adopters in $j+1$ is given by,

$$\psi_{j+1}(B,H;1,1) = \theta_j \int_{\mathbb{R}\times H} I_{\left\{a'(a,1,1,j)\in B\right\}} \Big(1 - I_A(a,1,1,j)\Big) d\psi_j(a,h;1,1).$$

Now we have all the elements to provide an equilibrium definition.

2.5.4 Equilibrium

In this economy, a stationary competitive equilibrium consists of value functions $V(x)$, decision rules $a'(x)$, $I_P(x)$, $I_A(x)$; aggregate variables K and L; a measure ψ, and a set of prices w, r and q, such that:

1. Optimal decision rules $a'(x)$, $I_P(x)$, $I_A(x)$ solve the households' dynamic problem given w, r and q and, $V(x)$ are the resulting value functions.

2. Factor prices are competitive:

$$w = (1-\alpha)z(L/K)^{-\alpha}$$

$$r' = \alpha z(L'/K')^{(1-\alpha)} + (1-\chi)$$

3. Labor and capital markets clear:

$$L = \sum_{j=1}^{J} \theta_j \omega \int_{\mathbb{R}\times H} h d\psi(x) + \phi\omega \sum_{j=1}^{J} \theta_j \int_{\mathbb{R}\times H} h I_P(x) d\psi(x),$$

and

$$K = \sum_{j=1}^{J} \theta_j \int_{\mathbb{R}\times H} a d\psi(x).$$

4. Measure of agents is generated as described above.

2.6 The Benchmark Economy

2.6.1 Specification of the Household Technology

In order to take the model to the data, following GSY, it proves convenient to parameterize the home production technology in the following way. Assume there are two types of technology, the *old* and the *new* one. If the household operates the old technology the amount of durable goods is given by

$$d = \delta, \tag{2.20}$$

and when it operates the new technology it is given by

$$d' = \overbrace{\kappa}^{>1} \delta > d. \tag{2.21}$$

Regarding the amount of labor, n, required to produce home goods with the old technology, assume that

$$n = \overbrace{\rho}^{>1} \eta, \tag{2.22}$$

and when it operates the new technology it is given by

$$n' = \eta < n. \tag{2.23}$$

Combining these four equations, we have that the productivity to produce home goods with the old technology is given by

$$\zeta = \frac{\delta}{(\rho\eta)}, \tag{2.24}$$

and when it operates the new technology it is given by

$$\zeta' = \frac{\kappa\delta}{\eta} = \kappa\rho\zeta > \zeta. \tag{2.25}$$

Given the Leontief specification for the production of home goods, this implies that the quantity of home goods produced with the old technology is

$$c_n = \min\{d, \zeta n\} = \delta, \tag{2.26}$$

and with the new technology

$$c_n' = \min\{d', \zeta' n'\} = \kappa\delta > c_n. \tag{2.27}$$

2.6.2 Parameterization

I calibrate the model to the US economy in 1990. The model period is 13 years with $J = 4$. The first three periods are working periods and the last one is a retirement period in which members of the household do not work. In the model, households start life at the age of 25 and retire at the age of 64 (which is consistent with the age of the workers in the data I aim to target), they die when they are 77 years old. The parameter that represents the technology in market production, z, is set to be 1. Regarding the weight of each generation in the total population, I use data on population by age from the International Data Base of the US Census Bureau. According to these data, I set $\theta_1 = 0.42, \theta_2 = 0.28, \theta_3 = 0.14, \theta_4 = 0.16$.

There are eight parameters, $\alpha, \chi, \omega, \eta, \rho, \kappa, \delta$; that I also take directly from data. The share of capital in market production, α, is set to 0.3. The depreciation rate, χ, is set to 10% which is the estimated depreciation rate of physical capital (without including durable goods) by the Bureau of Economic Analysis.

The remaining five parameters have to do with the production of home goods. ω is set to 0.36 by assuming that a market worker works in the market 40 hours a week of her 112 hours of non sleeping time. η and ρ set the allocation of time of female to perform household chores with and without household appliances. According to Lebergott (1993), using household appliances females spend on average 18 hours a week to produce home goods, that means, $\eta = 18/112 = 0.16$. However, when they did not have access to these durable goods they had to spend 58 hours a week, and so $\rho \times \eta = 58/112 = 0.52$ which means $\rho = 3.25$. κ and δ control the aggregate relative stock of appliances before and after the adoption of the durable goods. According to the data in NIPA, the stock of appliances when household adopt the new technologies is eight times the one observed when almost none household use these durable goods. Therefore, after fixing $\delta = 1$ we have that $\kappa = 8$.

For the efficiency units, I assume that h are distributed $log(h) \sim N(\mu_h, \sigma_h)$. I normalize the US distribution by setting $\mu_h = 0$. In the US, the proportion of households with access to to electricity *and* running water is close to 100%, so I set $\gamma = 1$ for all the households.

It remains to pin down values for $\phi, \sigma_h, \beta, \lambda, \nu, q$. These are picked together to match: i) the observed GINI index for household income, ii) female labor force participation, iii) the percentage of nondurable goods consumption over GDP (non-durables plus services), iii) the percentage of households with washing machines, iv) female earnings as a percentage of male earnings reported by the Bureau of Labor Statistics, and v) the capital to output ratio; all in 1990. The parameter values are the following: $\phi = 0.86$, $\lambda = 0.23$, $\nu = 0.2$, $q = 0.22$, $\beta = 0.96$ and $\sigma = 0.76$. The fit of the model to the targets is shown in detail in Table 2.8.

2.7 Model Mechanics: Steady State Effects

In this section, the model framework is explored by considering a hypothetical economy where the long-run consequences of changing the price of household appliances, average efficiency units of labor, the dispersion of efficiency units of labor, access to infrastructure and, total factor productivity are investigated. Highlighting

Table 2.8: Calibration - Targets

Target	Model	Data	Source
Female Participation in 1990	69%	69%	ILO
Non-durables Consumption/GDP	0.43	0.56	NIPA
Adoption of Washing Machines in 1990	79%	80%	Household Survey
Access to Electricity and Water in 1990	100%	100%	Household Survey
Capital-to-output ratio	2.8	2.8	NIPA
Gini income	0.43	0.43	BLS
Female Earnings/Male Earnings	0.73	0.73	BLS

Note: This table presents the results of the calibration exercise when the model is calibrated to the US in 1990. It describes the targets in the data and their values computed by suing the model. It briefly shows the data sources for the targets.

the long-run effects and the role of the various forces at work, steady states for the aggregate economy are compared with the benchmark economy. In order to analyze the general equilibrium effects on the variables of interests, I perform the experiments for both the case where factor prices are fixed and for equilibrium factor prices.

2.7.1 The Effects of Changing Average Ability Levels

In the first experiment I only change the parameters that govern the distribution of ability levels or efficiency units of labor. Specifically, I lower μ_h to -0.54 and raise σ_h to 0.97 such that the average efficiency units is this hypothetical economy is 70% of the one in the benchmark economy, but maintaining the variance of the efficiency units (the log-normal distribution) constant across these two economies. The experiment is aimed to analyze the effects of reducing the average income of households through the efficiency units channel. Since my study focuses on the population aged 25 and older, we could interpret this change in efficiency units of labor as changes in average human capital levels across different economies, an issue that will be addressed below. Table 2.9 summarizes the results.

Table 2.9: Model Mechanics: Average Efficiency Units

	Benchmark	Fixed Prices	Equilibrium Prices
Adoption	79	50	49
Female LFP	69	49	49
Gini Income	0.43	0.55	0.55
Output	100	72	72

Note: This table presents the results of the first experiment done to explore the model mechanics: an exogenous change in the average efficiency units of households labor. It presents the value of the variables of interest for the benchmark economy (second column), resulting from the experiment when factor prices are fixed (third column) and resulting from the experiment with equilibrium factor prices (fourth column). The units for Adoption and Female LFP are percentage points. The value of output is normalized to 100 in the benchmark economy.

The percentage of households with durable goods goes down significantly, from 79% to 50%. As a result, female LFP declines, going from 69% to 50%. The results are similar in both the case of fixed prices and equilibrium prices. There is a cutoff level of efficiency units that divides the households between the ones for which is optimal to purchase the durable good and the ones for which it is not. The fact that we reduce the average efficiency units of labor in this economy and maintain the price of household appliances, prevent a large percentage of households to purchase the durable good or adopt the new technology (the poorer ones). As a result, less females are able to participate in the labor market. It is also interesting to note, that the fact that less females participate in the market, which are also the poorer ones in the income distribution, makes the economy more unequal. This is observed in the increase in the Gini for income, which goes from 0.43 to 0.55.

2.7.2 The Effects of Changing Income Inequality

Now I consider an hypothetical economy with higher income inequality compared to the benchmark one. In order to perform this experiment, I change the parameters of the distribution of efficiency units of labor so that the log-normal distribution of my hypothetical economy has a higher variance than the benchmark economy but they share the same average level of efficiency units. Specifically, I set $\mu_h = -0.1$ and $\sigma_h = 0.88$. I present the results in Table 2.10.

Table 2.10: Model Mechanics: Income Inequality

	Benchmark	Fixed Prices	Equilibrium Prices
Adoption	79	74	74
Female LFP	69	59	59
Gini Income	0.43	0.49	0.49
Output	100	94	94

Note: This table presents the results of the second experiment done to explore the model mechanics: an exogenous change in household income inequality. It presents the value of the variables of interest for the benchmark economy (second column), resulting from the experiment when factor prices are fixed (third column) and resulting from the experiment with equilibrium factor prices (fourth column). The units for Adoption and Female LFP are percentage points. The value of output is normalized to 100 in the benchmark economy.

In this case the adoption levels slightly go down, from 79% to 74%. This change in the adoption level causes that less females participate in the market, their participation goes from 69% to 59%. The changes in the parameters of the distribution generates a higher variance in the efficiency units of labor. This generates both a larger mass of households in the lower efficiency unit levels and more high type households. In this experiment, the first force dominates and so we have a higher concentration of low ability households compared to the benchmark economy. Therefore, a smaller mass of households can adopt the new technology which cause that less females participate in the labor market. However, the changes as not as large as in the previous case in which the movement in the distribution of ability was more significant. As expected, income inequality raises as it is evident from the Gini Indexes in shown in Table 2.10. Finally, again we do not see much general equilibrium effects in driving the results as we can notice by comparing columns 2 and 3 of Table 2.10.

2.7.3 The Effect of Changes in the Price of Appliances

In this experiment I consider an economy in which households face a higher relative price of household appliances which potentially prevent the adoption of new household technologies. For that purpose I raise q so that the price of appliances is 40% higher than in the benchmark economy. Table 2.11 shows the results of this experiment.

As we increase the price of household appliances, we have a smaller mass of households for which it is optimal to adopt the new household technology. As a result,

Table 2.11: Model Mechanics: Higher Price of Household Appliances

	Benchmark	Fixed Prices	Equilibrium Prices
Adoption	79	58	58
Female LFP	69	54	52
Gini Income	0.43	0.48	0.47
Output	100	94	94

Note: This table presents the results of the third experiment done to explore the model mechanics: an exogenous change in the relative price of household appliances. It presents the value of the variables of interest for the benchmark economy (second column), resulting from the experiment when factor prices are fixed (third column) and resulting from the experiment with equilibrium factor prices (fourth column). The units for Adoption and Female LFP are percentage points. The value of output is normalized to 100 in the benchmark economy.

the proportion of households that adopt the new technology goes down (from 79% to 58%) and we have less females participating in the labor market (from 79% to 58%). Again, the fact that we have less females working in the market raises the income inequality. Note that in this case, the effect on female LFP is slightly different if we compare the fixed prices case and the equilibrium prices case.

2.7.4 The Effect of Changes in Infrastructure

Now I move to consider the effect of changes in the access to basic infrastructure which as it was discussed above, could also operate as a barrier to the adoption of new technologies by households. Motivated by household surveys data, I set the proportion of households with access to infrastructure depending on their location in the income distribution. Specifically, as I will discussed below in my cross country analysis, I have access to data on access to electricity and running water by income quintile. Therefore, in my experiment, I set different proportion of households with access to infrastructure by income quintile. In this experiment, I consider the case where 50% of the households in the first income quintile have access to infrastructure, 70% of the households in the second income quintile, 82% of the households in the third, 85% of the households in the fourth and, 92% of the households in the last one. Table 2.12 shows the results.

Table 2.12: Model Mechanics: Less Access to Basic Infrastructure

	Benchmark	Fixed Prices	Equilibrium Prices
Adoption	79	30	30
Female LFP	69	22	20
Gini Income	0.43	0.50	0.51
Output	100	89	94

Note: This table presents the results of the fourth experiment done to explore the model mechanics: an exogenous change in the access to basic infrastructure. It presents the value of the variables of interest for the benchmark economy (second column), resulting from the experiment when factor prices are fixed (third column) and resulting from the experiment with equilibrium factor prices (fourth column). The units for Adoption and Female LFP are percentage points. The value of output is normalized to 100 in the benchmark economy.

This experiment is the one that shows the major effects. Note that adoption is reduced by more than 60% (it goes from 79% to 30% in both cases). This dramatic change in the adoption of new technologies reflects the infrastructure restrictions that households face in this hypothetical economy. Since access infrastructure is a necessary condition to adopt the new technology, for instance, 50% of the households in the lower income quintile can not adopt the new technology and this affects the households decisions regarding the female participation. Note, that female LFP dramatically changes, going down from 69% to 20%. As a result, the Gini Index increases from 0.43 to 0.51.

2.7.5 The Effect of Total Factor Productivity

Finally, I analyze the effect of changes in total factor productivity. In the model, it enters as a technology parameter, z, which was set to one for the benchmark economy. In this experiment I lower z to 0.8. The results are depicted in Table 2.13.

Table 2.13: Model Mechanics: Total Factor Productivity

	Benchmark	Fixed Prices	Equilibrium Prices
Adoption	79	79	58
Female LFP	69	69	54
Gini Income	0.43	0.43	0.48
Output	100	83	72

Note: This table presents the results of the fifth experiment done to explore the model mechanics: an exogenous change in total factor productivity. It presents the value of the variables of interest for the benchmark economy (second column), resulting from the experiment when factor prices are fixed (third column) and resulting from the experiment with equilibrium factor prices (fourth column). The units for Adoption and Female LFP are percentage points. The value of output is normalized to 100 in the benchmark economy.

By comparing column 2 and 3 of this table, we see that this is the case where the general equilibrium effects play a crucial role. Note that when prices are fixed we do not observe changes in both the adoption percentages and female LFP. However, in the case of having equilibrium factor prices, through changes in total factor productivity, the marginal product of labor is much lower than in the benchmark economy (the wage rate goes from 0.36 to 0.26). This lowers the labor income of households and, for the same price of the durable good, there are less households for which it is optimal to adopt the new technology (adoption goes from 0.79% to 0.58%). The change in the adoption lowers the female LFP which is also affected by the change in the wage rate since it makes the labor market less attractive for females.

2.8 Model Predictions for the US

I now compute the model's predictions for the US in 2005. The experiment consist in picking the price of durable goods in 2005 in the units of the model, i.e. q_{2005}, to reproduce the change in the relative price of household appliances we observe in the data between 1990 and 2005:

$$\frac{q_{2005}}{q_{1990}} = 1 + \pi$$

where π is the change in the relative price of durable goods we observe in the data and q_{1990} is the relative price of durable goods in 1990 in the model's units. Since I observe a drop of 33% the prices, I set $q_{2005} = 0.15$. In addition, I set $\phi = 1.17$ in order to match and observed gender earnings gap of 0.81 in 2005. Furthermore, since the Gini coefficient is higher in 2005, specifically 0.46, I raised σ to 0.93. Finally, since all households had access to electricity and running water both in 1990 and 2005, there no need to do changes in this margin. Table 2.14 presents the results.

The first row contains the predicted and actual levels of female LFP and

Table 2.14: Model Predictions US

	Female LFP (%)		Adoption (%)	
	Data	Model	Data	Model
1990	69	69	80	80
2005	72	75	90	90

Note: This table presents the predictions of the model for the US. It presents the predicted and actual values of female labor force participation (second and third column) and adoption rates (fourth and fifth column).

adoption of washing machines in 1990. Given that the price q_{1990} was chosen to match the adoption levels in the calibration exercise, the model does very well in matching the adoption data for that year. The same applies for the female LFP levels in 1990 since it was also targeted in the calibration of the US (the benchmark economy). However, both the adoption and the female LFP in 2005 are freely determined by the forces at work in the model. By looking at the second row of the table we can notice the good performance of the model for the case of the US: It perfectly predicts the adoption level and slightly overpredicts the female LFP. I consider this exercise as good test for the model which I will use for other countries in the sections that follow.

2.9 Model Predictions for Brazil

I first compute a steady state for Brazil in 1990. The experiment is done as follows. I first use data from the 1985 benchmark of the Penn World Tables to get the relative price of washing machines of Brazil relative to the US. According to the data I set q_{1990}^{BRA} such that $q_{1990}^{BRA}/q_{1990}^{US} = 0.8$, which gives $q_{1990}^{BRA} = 0.18$.

There is a set of parameters that are specific to Brazil. They are picked together to reproduce a set of moments but each of them is linked to a particular moment in the data. Regarding the distribution of abilities, I set $\sigma_h = 0.94$ to resemble a Gini coefficient of Brazil in 1990 of 0.59. In addition, I set $\mu_h = -0.73$ so that the mean of h in Brazil over the mean of h is 0.56 which corresponds to the ratio of average human capital levels between Brazil and the US in 1990 computed by using data on average years of education of people aged 25 and older and the Mincerian returns calculated in Hall and Jones (1999).

The population structure varies across countries. Specifically, there are relatively more young adults in developing countries. For these reasons, I set the weights of the four different age groups in Brazil such that 51% the population are of the first age group, 29% of the second, 12% of the third and 8% of the fourth group.

As it is clear in the data, access to infrastructure varies across countries. In addition, it varies within each of the developing countries according to the position of households in the income distribution. Recall that this is relevant in my computation providing that, by construction, households without access to basic infrastructure cannot purchase the durable good and so adopt the new technology. Therefore, when computing the steady state for Brazil in 1990, I assign to each household a $\gamma = 1$ or $\gamma = 0$ such that, in the steady state equilibrium, 35% of Brazilian households in the first income quintile have access to electricity *and* running water, 58% in the second income quintile, 73% in the third, 84% in the fourth and 97% in the fifth.

We also observe differences in the gender earning gaps across countries. This is an endogenous object in the model that depends on the type and percentage of females that participate in the market in equilibrium and the wage rate gap ϕ. For Brazil I change ϕ to match female earnings as a percentage of male earnings observed in the data, that is 0.65. Finally, according to the Penn World Tables data (version 6.2) the output per worker in international dollars in Brazil was 40% of the one in the US, I lower the technology parameter z to 0.75.

The second row of Table 2.15 depicts the levels of female LFP and adoption predicted by model and their data counterpart.

Table 2.15: Model Predictions Brazil

	Female LFP (%)		Adoption (%)	
	Data	Model	Data	Model
1990	38	34	24	9
2005	66	54	36	42

Note: This table presents the predictions of the model for Brazil. It presents the predicted and actual values of female labor force participation (second and third column) and adoption rates (fourth and fifth column).

The model does a really good job in explaining the level of female LFP which is the main object of the exercise: It accounts for 89% of the observed female LFP in 1990. Moreover, if we compare US and Brazil female LFP levels, the model accounts for 63% of the gap in female LFP between the US and Brazil in 1990. This suggests that the theory proposed is quantitatively important in accounting for observed differences in female labor supply between these two countries. However, by exploring the adoption levels in Table 2.15, we see that the model falls quite short in in accounting for the levels of adoption of durable goods. This is not surprising considering that the adoption levels in the data are just for washing machines and the model refers to a composite durable good. Still the model qualitatively succeeds in predicting a much lower adoption rate in Brazil compared to the US, as we observe in the data.

I now compute a steady state for Brazil in 2005. As in the case of the US experiment, I set the relative price of durable goods, q_{2005}^{BRA}, to be consistent with the decline of 60% in this price observed in the data between 1990 and 2005. Specifically, I set $q_{2005} = 0.07$. In addition, according to the data, in 2005 the relative earnings of females with respect to males is 0.86, so I set ϕ_{2005} accordingly. I also raise $\mu_h = -0.53$ so that the relative human capital level (computed as before) of Brazil with respect to the US in 2005 is 0.63, higher than its level in 1990. Furthermore, I set $\sigma = 1.15$ to resemble a lower Gini coefficient for income in 2005, that is 0.54.

Additionally, I assign to each household a $\gamma = 1$ or $\gamma = 0$ such that in the steady state equilibrium 68% of Brazilian households in the first income quintile have access to electricity *and* running water (the access level was 35% in 1990), 82% in the second income quintile (it was 58% in 1990), 89% in the third (it was 73% in 1990), 96% in the fourth (it was 84% in 1990)and, 99% in the fifth (it was 97% in 1990). For Brazil I set $\phi = 1.26$ to match female earnings as a percentage of male earnings observed in the data, that is 0.65. Finally, I lower the technology parameter z to 0.55 providing that GDP per worker in Brazil was 25% of the US one in that year.

The third row of Table 2.15 shows the female LFP and adoption levels that the model predicts and their data counterpart in 2005. The model accounts for 82% of the observed female LFP level in this year. Moreover, the model accounts for 78% of the observed differences in female LFP between Brazil and the US. As in the case of the 1990 steady state, the model is not as successful in predicting the adoption levels but the same caveats apply here since we are comparing the model predictions with just the adoption of washing machines. However, it does a really good job in predicting an increase in the number of households that use the new technologies embedded in the durable goods as we observe in the data for the case of washing machines. [3]

Another important dimension to evaluate the theory at work is to compare the predicted and observed change in female LFP for each country. This is shown in Table 2.16 for the case of Brazil.

Table 2.16: Brazil: Female LFP 1990 versus 2005

	Data	Model
Brazil 1990	100	100
Brazil 2005	174	159

Note: This table presents the change in female labor force participation observed in the data and the change predicted by the model for Brazil between 1990 (=100) and 2005.

[3] As another approximation for the adoption of new technologies we can also look at available data on the the percentage of households with refrigerators. According to these data, from 1990 to 2005 the percentage of households with refrigerators in Brazil increased by 24%.

According to the data female LFP rose by 74% between these two periods and the model predicts an increase of 59%, that means, the model accounts for 91% of the observed change in female LFP. The model succeeds in this dimension which I interpret to be the most important of the experiment. The results suggest that the economic forces incorporated in the theory proposed are quantitatively important in accounting for observed changes in female labor participation observed in this country.

2.10 Model Predictions for Mexico

I now the take the model to the Mexican data. I first compute a steady state for 1990. As before, I use data from the 1985 benchmark of the Penn World Tables v.6.2 to get the relative price of washing machines of Mexico relative to the US. Therefore, I pick q_{1990}^{MEX} such that $q_{1990}^{MEX}/q_{1990}^{US} = 0.94$, which gives $q_{1990}^{MEX} = 0.21$.

Again, there is a set of parameters that are specific to Mexico. I set $\sigma_h = 0.76$ to resemble a Gini coefficient of Mexico in 1990 of 0.49. In addition, I set $\mu_h = -0.43$ so that the average human capital level of Mexico is 65% of the one computed for the US in 1990.

The population structure of Mexico is similar to the one observed in Brazil and so I set the weights of the four different age groups such that 52% the population are of the first age group, 28% of the second, 11% of the third and 8% of the fourth group.

Regarding the access to infrastructure in Mexico, when computing the steady state, I assign to each household a $\gamma = 1$ or $\gamma = 0$ such that, in equilibrium, 47% of

Mexican households in the first income quintile have access to electricity *and* running water, 64% in the second income quintile, 78% in the third, 86% in the fourth and 92% in the fifth.

I also pick ϕ to match female earnings as a percentage of male earnings observed in the Mexican data, that is 0.73. Finally, according to the Penn World Tables data (version 6.2) the output per worker in international dollars in Mexico was 50% of the one in the US, I lower the technology parameter z to 0.76.

In addition, I compute another steady state for Mexico but now in 2005. As before, I set the relative price of durable goods, q_{2005}^{MEX}, to be consistent with the decline of 26% in this price observed in the data between 1990 and 2005. Specifically, I set $q_{2005}^{MEX} = 0.15$. In addition, according to the data, in 2005 the relative earnings of females with respect to males is slightly higher, 0.77, so I change ϕ accordingly. I also raise $\mu_h = -0.29$ to reflect a narrower gap in human capital levels between Mexico and the US: the human capital level of Mexico in 2005 is 74% of the calculated for the US in the same year. Furthermore, I set $\sigma = 0.8$ to resemble a Gini coefficient for income in 2005 of 0.49.

Additionally, in order to reflect the improvements in access to infrastructure observed in the data, I now assign to each household a $\gamma = 1$ or $\gamma = 0$ such that in the steady state equilibrium 72% of Mexican households in the first income quintile have access to electricity *and* running water (the access level was 47% in 1990), 86% in the second income quintile (it was 64% in 1990), 92% in the third (it was 78% in 1990), 96% in the fourth (it was 86% in 1990)and, 98% in the fifth (it was 92% in

1990). Finally, I lower the technology parameter z to 0.66 providing that GDP per worker Mexico was 35% of the US one in that year (as in the case of Brazil, Mexico got poorer relative to the US between 1990 and 1005).

Table 2.17 shows the adoption levels in Mexico in the model versus the data.

Table 2.17: Model Predictions Mexico

	Female LFP (%)		Adoption (%)	
	Data	Model	Data	Model
1990	37	55	36	31
2005	48	63	64	47

Note: This table presents the predictions of the model for Mexico. It presents the predicted and actual values of female labor force participation (second and third column) and adoption rates (fourth and fifth column).

It accounts for 86% and 74% of the adoption levels observed in the data in 1990 and 2005 respectively. However, the same caveats apply for the Mexican case: Even though the model does a much better job than in the Brazilian case, the adoption levels in the data only refers to the adoption of washing machines. Still, as the data shows, the model qualitatively succeeds in three important dimensions: i) it predicts lower adoption rate compared to US, ii) an adoption rate that is higher than Brazil and, iii) an increase in the adoption rate between 1990 and 2005 (it accounts for 67% of the observed increase in the adoption rate).

Table 2.17 depicts the levels of female LFP and adoption predicted by model and their data counterpart. Contrary to the Brazilian case, the model overpredicts the levels of female LFP in both 1990 and 2005: by 48% in 1990 and by 31% in 2005. Apparently, for the case of Mexico, there are variables that were not incorporated in this simple model that makes it fail to reproduce the observed levels of female LFP. Compared to the US, even though the model predicts a narrower gap in female LFP between Mexico and the US compared to the data (this is a direct consequence of overpredicting the levels for Mexico), qualitatively it still does a good job since it predicts a lower female LFP for Mexico as we observe in the data. More importantly, by looking at Table 2.18 we see that the exogenous variables incorporated in the model account for 50% of the observed changes in female LFP in this country.

Table 2.18: Mexico: Female LFP 1990 versus 2005

	Data	Model
Mexico 1990	100	100
Mexico 2005	130	115

Note: This table presents the change in female labor force participation observed in the data and the change predicted by the model for Mexico between 1990 (=100) and 2005.

This suggests that the theory proposed is quantitatively important in accounting for observed changes in female LFP in this country.

2.11 Conclusions

I document that differences in the access to basic infrastructure and relative price of household appliances are quantitatively important in accounting for differences in female LFP between a set of LA countries and the US. In addition, because total factor productivity (and the wage level) and human capital levels are lower in developing countries, households purchase fewer time saving household durable goods that prevent females to participate in the market. I support the theory uncovering new disaggregated data based on household surveys for a set of LA countries, and with a model of home production with endogenous female LFP. One important implication of this study is that distortive policies that affect household production, like trade restrictions (applied in these countries until the beginning of the nineties), may have very undesirable effects in the labor supply. Moreover, by analyzing the interplay between the access to basic infrastructure and labor force participation, this study provides new insights regarding the returns to infrastructure investments, which will be the object of future research.

APPENDIX
DESCRIPTION OF DATA SOURCES AND COMPUTATION OF THE MODEL IN CHAPTER 2

A.1 Data Sources

A.1.1 Labor Force Participation

The data on labor force participation comes from the 5th edition of Key Indicators of the Labor Markets database issued by the International Labor Organization (ILO). The labor force participation rate is calculated by expressing the number of employed and unemployed persons in the labor force as a percentage of the population of age between 25 and 64. Both formal and informal sector participants are taken into account. The data can be accessed at $http://www.ilo.org/empelm/what/lang--en/WCMS_114240$.

A.1.2 Gender Earnings Gap

The gender earnings gap is calculated as the average income of employed women as a percentage of the average income of employed men, in urban areas. The data is provided by the Economic Commission for Latin American and the Caribbean (ECLAC) and it was prepared based on household surveys of each country. The data can be accessed at *http://websie.eclac.cl/sisgen/ConsultaIntegrada.asp?idAplicacion =11&idTema =194&idIndicador=1140*

A.1.3 Relative Price of Household Appliances

For the pre-reforms period (circa 1990) I use the 1985 benchmark data of the PWT which presents data across counties of the price of washing machines and the aggregate consumption in international dollars. For each country I compute the relative price of washing machines and then I divide that ratio by the relative price computed for the US. The data can be accessed at *http://pwt.econ.upenn.edu/Downloads/benchmark/benchmark.html*.

The time series for the relative price of household appliances for each country is calculated by dividing the price index of household appliances over the general price index. In the case of the U.S. the data is obtained from Bureau of Labor Statistics (BLS) and the specific category used to represent the price of household appliances is called Major Appliances (Series ID: WPU 1241), which is a subcategory of the group called Furniture and Household Durables. The general price index is obtained from the same source (Series ID: WPU 00000000).

For Brazil and Mexico, I use the general price index and the price index of Furniture, Appliances and household accessories. The source for Mexico is the Bank of Mexico and the data can be accessed at *http://dgcnesyp.inegi.org.mx/cgi-win/bdieintsi.exe/NIVL1000100020001*
00020#ARBOL. For Brazil I obtained the data on wholesale price indexes from the Fundacao Getulio Vargas. The data can be accessed at *http://portalibre.fgv.br/main.jsp?lumChannelId=402880811D8E34B*
9011D92B6F9D30FAE.

A.1.4 Population

The data on the population structure of each country was obtained from the International Data Base (IDB) of the Census Bureau. The data can be accessed at *http://www.census.gov/ipc/www/idb/country.php*

A.1.5 Infrastructure and Income Gini Indexes

From the Socio-Economic Database for Latin America and the Caribbean (CEDLAS and The World Bank) I obtain data on the percentage of households with a washing machine and the access to electricity and running water by income quintile. In addition, the Gini Indexes for household income are reported for the set of countries covered in the data set. All statistics are computed from micro-data of the main household surveys in these countries. The data can be accessed at *http://www.depeco.econo.unlp.edu.ar/sedlac/eng/index.php*.

In the case of the US, the data on household appliances is obtained from the Appliance Reports of the Energy Information Administration. The data can be accessed at *http://www.eia.doe.gov/emeu/reps/appli/contents.html*

A.1.6 Human capital levels

Human capital measures are calculated by using the average years of education of people aged 25 to 65 from CEDLAS and The World Bank data and, by using Mincerian returns to schooling computed in Hall and Jones (1999).

A.1.7 Tariff rates

The data on average tariff rates was obtained from the World Development Indicators Database. It refer to the simple mean of effectively applied rates for all products subject to tariffs calculated for all traded goods and for manufactured traded goods. The data can be accessed at *http://databank.worldbank.org/ddp/home.do?Step =12&id=4&CNO=2*.

A.1.8 GDP per capita

Data on GDP per worker used in my calculations are from Penn World Table v. 6.2. The data can be accessed at $http://pwt.econ.upenn.edu/php_site/pwt62/pwt62_form.php$.

A.2 Computation of the Model

In order to solve the model I first discretize the distribution of household abilities. I form a grid of 50 points in the support of the log-normal distribution, given values for the parameters of the distribution. In addition, I also form a grid of the asset levels for each of the different ability levels obtained in the previous step, each of them containing 80 points.

The algorithm used to compute the steady states in the model is outlined in the following steps.

1. I first guess a value for the equilibrium interest rate $r^{(0)}$.

2. Given $r^{(0)}$, using the factor prices expressions the wage rate is automatically

pinned down, and we obtain

$$w^{(0)} = (1-\alpha)z\left(\frac{r^0 - \psi}{\alpha z}\right)^{\frac{\alpha}{\alpha-1}}$$

3. Given these values for the factor prices we solve the household maximization problem and aggregate as described in Section 2.5.2 of Chapter 2.

4. In the previous step, when aggregating, I obtain values for the aggregate labor and capital stock. I obtain a new guess for the interest rate, $r^{(1)}$. If $r^{(1)} \cong r^{(0)}$, I stop. Otherwise, return to step 1.

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