FUNDAÇÃO GETULIO VARGAS

EPGE
Escola de Pós-Graduação em Economia

SEMINÁRIOS DE PESQUISA ECONÔMICA

"Effects of Trade Policy on Technology Adoption and Investment"

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LOCAL
Fundação Getulio Vargas
Praia de Botafogo, 190 - 10º andar - Auditório

DATA
14/10/99 (5ª feira)

HORÁRIO
16:00h

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Effects of Trade Policy on Technology Adoption and Investment*

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September 24, 1999

Abstract

This paper studies the consequences of trade policy for the adoption of new technologies. It develops a dynamic international trade model with two sectors. Workers in manufacturing decide if new technologies are used, capital owners then choose investment. We analyze three different arrangements: free trade, tariffs, and quotas. In the model economy, free trade as well as tariffs guarantee that the most productive technology available will be used. In contrast, under a quota the most productive technology available will not be used at all times. Further, in the latter case investment and the capital stock are smaller than in the former one. Finally, there exists parameter values for which the computed difference in GDP is a factor of thirty.

1 Introduction

An important question in growth and development is why the technological level (Total Factor Productivity - TFP) differs over time and across countries. To answer this question we will start with the arguments of Prescott [?]. First, the observed difference in productivity across countries is not explained by the difference in the capital-labor ratio; instead the differences in the

*This paper is part of my PhD dissertation. I am greatfull to Ed Prescott, Tim Kehoe, Berthold Herrendorf, Ron Edwards, J. C. Conessa and Carlos Diaz. As usual, the remaining mistakes are mine.

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capital-labor ratio are caused by differences in total factor productivity. Second, the differences of productivity across countries by itself are a result of different growth rates of TFP over time and across countries. Third, the knowledge that is being used by the workers of the richest countries is available to be used by the workers of any other country, in particular poor countries.

The goal of the model developed here is to explain why different countries use different technologies. We argue that a combination of two factors can explain whether or not a country adopts a new technology: (i) its internal institutional arrangement; (ii) its trade policy. In particular, the internal institutional arrangement determines whether there are groups of interest that can resist the adoption of new technologies. The trade policy determines whether these groups find it optimal to resist the new technologies. For simplicity, I take as given that there are groups of interest that can block technologies and study how the choice of trade policy affects their decision problem whether or not to resist.

To model this idea, I develop a two-sector growth model with international trade. In both sectors there is exogenous technological progress: in each period a new and more productive technology becomes available. While in both sectors, there is perfect competition, the technology is different. More specifically, in one sector, the inputs into the production process are unskilled labor only, which any worker can supply. Hence, I assume that workers in that sector are not organized and cannot resist the introduction of new technologies. In the other sector, the production function uses both labor and capital. While labor may be unskilled or skilled, the most productive technology can only be operated by skilled labor. Skilled workers are therefore assumed to act in coalition, so they are able to resist new technologies. Given that skilled workers have chosen the technology that can be used, the capital owners non-cooperatively decide how much to invest.

The main results are: (i) with free trade, firms will always use the most productive technology available; this is also true with tariffs; (ii) with a quota, firms generally will not use the most productive technology available; (iii) investment and the capital stock are smaller with a quota than with free trade; (iv) there exists parameter values for which the difference between GDP with free trade and with quota is a factor of thirty. The intuitive reasons for these results are as follows. First, with free trade the prices are determined in the international markets and firms are in competition with the productivity leaders. Skilled labor then does not resist the adoption

of new technologies because given the price of its product, producing most efficiently maximizes its income (and thus their utility). Since under a tariff, the domestic price equals the international price times a constant factor, it does not break the link between the domestic and international price and so the same argument as under free trade applies. In contrast, if a quota is introduced then the domestic price becomes independent of the international price. In this case, skilled labor can increase the relative price of the good produced in its sector by blocking the use of a new technology. This can increase the income of skilled labor and so be in its interest if technological progress is not too rapid and skilled labor is a relatively small group that faces a relatively large internal market. The intuition is that on one hand, if the technology advances too rapid then the opportunity cost of not using the most advanced technology is too large. On the other hand, if the domestic market is relatively small, then the gain from manipulating the domestic price is not sufficient relative to the cost.

The ideas developed in this paper are related to those of Parente and Prescott [?], Parente and Prescott [?], and Holmes and Schmitz [?]. The key idea of these papers is that the ability to invest and adopt new technologies determines the growth rate of an economy. While Parente and Prescott [?] focus on barriers to investment coming from the internal structure of the economy, Parente and Prescott [?] shows how monopolies can interfere in the adoption of new technologies. Holmes and Schmitz make the complementary point that organized interest groups can have the power and find it in their interest to resist the adoption of new technologies. While some of my conclusions are similar in spirit to those of Holmes and Schmitz, my model is more general. In particular, their model has two periods only whereas I develop an infinite horizon model. Besides, I introduce a capital good. These features allow me to go considerably further than Homes and Schmitz in that I can generate artificial time series that can be compared with the data.

This paper is divided into five sections (including this introduction). In Section 2, we look at some empirical evidence to support our main thesis. In Section 3, we develop a model that studies the adoption of technology. First we study an economy under free trade, that is, there are no barriers to trade with other countries. Then, we study the same economy with tariffs. Finally, we study this economy with quota. Section 4 offers some quantitative results from computer simulations of the models developed in sections 3. section 5 concludes.

2 Some Evidence

In this part of the paper we will show some empirical evidence that supports the main ideas behind this paper. First, the technological level differs over time and across countries. Second, it is the exposure to external competition that stops groups from exercising their resistance to new technologies. Therefore, it is the exposure to external competition that explains the difference in the technological level and productivity across countries.

Here we will not show evidence of resistance to the adoption of new technologies across countries or that this resistance succeeds in stopping the technological progress in the countries. This evidence has been showed by Parente and Prescott [?], Holmes and Schmitiz [?], Mokyr [?], Mokyr [?] and Mokyr [?]. In particular, Parente and Prescott [?] and Holmes and Schmitiz [?] have summarized results. The basic idea behind these papers is that technological progress affects groups of agents differently. Some groups have their income increased by technological progress and some groups have their income reduced (at least in the periods immediately after the introduction of the new technology). In this case, the group harmed by the technological progress has incentive to resist the adoption of new technologies.

Harrigan [?] and Dollar and Wolf [?] estimated the differences in TFP across countries.[1] Harrigan [?] estimated differences in TFP across ten countries and six industries. More specifically, he estimated the difference between the TFP of each industry of each country with respect to the TFP of that industry in the USA. The period studied is 1980-89. The countries used in this study are: Australia, Canada, Finland, Germany, Italy, Japan, Netherlands, Norway and the US. The industries include the following: non-electrical machinery, office and computer equipment, electrical machinery, radio, TV and communications, motor vehicles, ship-building, aircraft and other transportation equipments. The US has a higher TFP in all but one industry. The exception is the electrical machinery industry where Japan, Australia and Canada have higher TFP than the USA.

Dollar and Wolf [?] estimated differences of TFP in manufacturing using a sample of twelve countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Sweden, the United

[1] See also Harrigan [?].

Kingdom and the US. The period studied is longer than the one covered by Harrigan [?]: 1965-85. At this more aggregate level the US has a higher TFP than any other country in the sample and for the whole period.

At this point we would like to have estimations of TFP for some developing countries to compare with the TFP of developed countries. But because of lack of data these estimations are not available. Nonetheless, we are taking the numbers presented above as an indicator of the existence of differences of TFP between less developed countries and developed countries.

Given these studies that estimate the differences of TFP across countries, let us show some empirical evidence for the second point listed in the beginning of this section. It is the exposure to external competition that explains differences in the technological level and productivity across countries.

Baily and Gersbach [?] studied 9 industries in 3 countries: Germany, Japan and the US. These industries account for 15% to 20% of the employment and 17% to 22% of the value added in the manufacturing sector. The basic conclusions of their study are: (*i*) physical capital can partially explain the differences of productivity in each industry across countries; however, the major part of the differences in productivity is explained by differences in the way that labor tasks are organized and the product design; (*ii*) there is not enough evidence to justify differences in productivities by differential access to proprietary technology; (*iii*) domestic competition is not enough to make domestic firms achieve the highest productivity; (*iv*) the greater the exposure of the domestic firms to the highest productivity firms the smaller was the difference in productivity. International trade and foreign investment force the adoption of the best practice or highest productivity production process.

Baily [?] studied service industries, airlines, retail banking, telecommunications and general merchandise retailing in France, Germany, Japan, the UK and the US. Again, the conclusions do not differ from Baily and Gersbach [?]. Regulations prevent adjustment in the industries and generate a non competitive market. Once more, the cost of these regulations are industries with low productivity (compared with the world best practice producer).

The last evidence that we present here comes from Luzio [?] who studied the microcomputer industry in Brazil from the beginning of the seventies until the beginning of the nineties.

Since the beginning of the seventies, the microcomputer industry (including software) in Brazil has been highly protected and regulated[2]. The

[2]See Luzio [?], section 1 summarizes the history of this industry in Brazil during these

support for protection at first was given by the military because the potential use of computers in weapons and defense equipments.

By the beginning of the eighties the protection of the microcomputer industry reached its highest level with the approval of the Informatica Law: imports were prohibited and the exceptions were analyzed by a special government agency created just to regulate the microcomputer industry, Special Secretariat for Informatica (SEI).[3]

The consequences that come from this long period of protection and regulation follow the lines of the studies analyzed before. "Neither the Brazilian micro-electronics nor the software industry developed as expected by SEI", "...the restrictions only increased the technological gap and the price/quality difference between domestic and foreign Informatica products"[4]. One of the reasons for this technological gap was the lack of investment in R&D and physical capital. Instead to generate an increment in the amount invested in this industry, protection had an opposite effect. "According to SEI there was little R&D related to production". Besides, "a major part of R&D expenses were directly or indirectly imposed by regulation".[5]

By the end of the eighties and the beginning of the nineties the Brazilian industry of micro-electronics and software was producing obsolete computers using obsolete technology. The more sophisticated computers produced in Brazil when compared with "similar" ones produced in the US would cost between 5 to 6 times more[6].

3 The Model

In this section we will develop a model with physical capital.[7] We introduce a capital good in the model, but only a certain type of agent can own capital. We have two reasons to introduce physical capital in this way. First, we want to see how resistance to adopt new technologies affects investment and

two decades.

[3]See Luzio [?, page 8].

[4]See See Luzio [?, pages 12–13].

[5]See Luzio [?, pages 94–95].

[6]See Luzio [?, page 110].

[7]In Teixeira [?] this model is also developed without a capital good. This is one of the generalizations that differentiate this paper from Parente and Prescott [?], and Holmes and Schmitz [?].As it is pointed out in Teixeira [?] the introduction of a capital good has a big influence in the quantitative results of the model.

the capital stock. Second, we want to study how the resistance to new technologies affects the capital owners income.[8] We would like to stress two ways that the resistance to new technologies affects and benefits the capital owners. First, it allows the capital owners to reduce investment, increasing the part of their income that can be used for consumption. Second, the resistance to new technologies in one sector increases the relative price of the good produced by this sector. Given the productivity of capital, the increment in the relative price of the good increases the rental price of capital. Thus, capital owners (and workers that resist) can be better off if there is blocking of new technologies.

In this section we will see that even if technological progress is faster in one sector (that I will call a manufacturing sector), protection will not increase the growth rate of the economy. In fact, protection generates a bigger manufacturing sector but it reduces the growth rate of the economy. That is, protection just generates an inefficient and stagnated manufacturing sector.

There are three types of agents, $i = 1, 2, 3$ and the measures of the type i are $\lambda^i > 0$. A type $i = 1, 2$ agent is endowed with one unit of time of labor of type i. In the third group, group of type 3, each agent owns capital that they rent to firms. This group has measure one. Moreover, just type 3 can own capital. The capital owners do not work. They are not endowed with one unit of time of labor in each period. Their income is the rent paid by the firms to use capital services. Their preferences are ordered by the same utility function of the other agents.

At each date, there are two goods y and z. Good y is food and good z is a manufacture. Good z can be used as consumption good or as capital good. The production of good z uses labor and capital services as inputs. The production of good y uses only labor input. There is no borrowing and lending and no capital accumulation.

As we said before, the reason to introduce a group that owns capital, instead to allow group of type 1 and group of type 2 to be the owners is to isolate the effects of technology blocking over the capital income and over the labor income. We want to stress that workers of type 2 will be better off if they block the new technology even if they do not have any capital income. Since capital income also increases if there is blocking, this could

[8]Resistance to new technologies benefits both the workers that resist and the capital owners. See Mokyr[?] for a historical evidence.

jeopardize the labor income effect over the decision to block the adoption of new technologies.

The period commodity space in the model is $L = R^6$ with a point in L being $x = (y, z, l_y, l_{z1}, l_{z2}, k)$. This different kinds of labor depend on who supplies and the industry that uses the labor (it will become clear later on in the paper). It should be stressed that there is no differentiation between workers of type 1 and 2 in the y industry.

The consumption set of the agent of type 1 is

$$X_1 = \{x \in L_+ : l_y + l_{z1} \leq 1, \ l_{z2} = k = 0\} \tag{1}$$

The consumption set of the agent of type 2 is

$$X_2 = \{x \in L_+ : l_y + l_{z2} \leq 1, \ l_{z1} = k = 0\} \tag{2}$$

The consumption set of the agent of type 3 is

$$X_3(k) = \{x \in L_+ : l_y = l_{1z} = l_{z2} = 0, k^s \leq k\} \tag{3}$$

We abuse the notation and use k to denote both stock and flow of capital service, as a unit of capital provides a unit of services. A type 3 agent with k units of capital good can supply k of capital services. The amount supplied, k^s, is smaller or equal to k.

- **Preferences**

The period utility function for all types is

$$u(y, z) = \frac{(y^{\alpha} z^{1-\alpha})^{\rho}}{\rho} \tag{4}$$

where y, $z \geq 0$ and $\rho \leq 1$. Besides, we are assuming that preferences are time separable. In a dynamic environment preferences are represented by

$$\sum_{t=0}^{\infty} \beta^t \frac{\left(y_t^{\alpha} z_t^{1-\alpha}\right)^{\rho}}{\rho} \tag{5}$$

- **Technologies**

We keep three technologies. The production set of good y does not change,

since it does not use capital as input. The same is true for foreign trade technology.

The production set of good y is

$$X_4(t) = \{x \in L_+ : y \leq \pi^t\, l_y,\ z = 0\} \tag{6}$$

where $\pi > 1$. Equation (6) implies an exogenous technological progress in the y production sector. Besides, Equation (6) implies that both kinds of workers have the same productivity in the y sector.

The second technology produces good z. Its production set is

$$X_5(a,b) = \{x \in L_+ : z \leq \gamma^a\, k_1^\theta\, l_{z1}^{1-\theta} + \gamma^b\, k_2^\theta\, l_{z2}^{1-\theta},\ k_1 + k_2 \leq \bar{k},\ y = 0\} \tag{7}$$

where $\gamma > 1$, $\bar{k}/K$ is very small and K is the stock of capital in the economy. Elements $a < b$ are integers that index the z-production in a period. These elements are determined by past policy decisions. We assume that $\gamma > \pi$.

The third is a foreign trade technology that transforms one good into the other at a rate p_{zt}^* in period t. Its technology set is

$$X_6(t) = \{x \in L : y + p_{zt}^*\, z = 0,\ l_y,\ l_{z1},\ l_{z2} \geq 0\} \tag{8}$$

$X_6(t)$ implies that there is no borrowing or lending and no transportation cost. Since the external prices of goods y and z are exogenous (and good y is a numeraire), we will assume that the external price of good z at period t is given by

$$p_{zt}^* = \eta \left(\frac{\pi}{\gamma^{\frac{1}{1-\theta}}} \right)^t \tag{9}$$

The reason why ownership of technologies is not considered is that all technologies displays constant return to scale. Therefore, profits in equilibrium must be zero.

• Policy Arrangement

The integers a and b, where $a < b$ index the technology set $X_5(a,b)$, which produces good z. These integers a and b at date t belong to the set $\{0, ..., t-1,\ t\}$.

During the period t, type 2 decides what technology to use next period; that is, type 2 chooses $b' \in \{b, ...,\ t,\ t+1\}$. If $b' > b$, that is a better technology is selected, then $a' = b$. If, however, $b' = b$, then $a' = a$. Thus, if the

type 2 choose a better technology the type 1 gain access to the technology that the type 2 were using. If the type 2 choose to continue using the b technology, type 1 does not get access to the b technology[9].

- **Definition**

We will say that the group of type 2 is *blocking* the adoption of new technologies or there is *blocking of technologies* if $b < t$.

- **Timing**

In the beginning of each period workers of type 2 get together and define the technology index that they will use next period. This choice becomes public knowledge and it cannot be changed in the future. Once type 2 has announced their decision, non cooperatively type 3 chooses k'. It should be noticed that there is no private information.

3.1 Dynamic Equilibrium

This is a discrete time dynamic game with two stages in each period. At the first stage group of type 2 chooses b'. At the second stage members of groups 3 chooses k' non cooperatively and price and allocations are determined competitively.

We restrict our attention to Markov equilibrium which is symmetric with respect to members of group 3.[10] The state variable, at the beginning of a period, becomes (s, K), where as before $s = (a, b, t)$.[11] The integers a, b and t index the technology sets $X_4(t)$, $X_5(a, b)$ and $X_6(t)$. The maximization problem of the agent of type 1 as well as the maximization problem of firms do not change with the introduction of capital.

The maximization problem of a type 3, like the maximization problem of type 2, is a dynamic problem. At the beginning of the period the relevant state variable for a type 3 is (s, K, k). To study the maximization problem of type 2 and the maximization problem of a type 3 we will

[9] In period zero, since no technology has being abandoned, we are assuming that type 1 works in the production of good z with technology α^{-1}.

[10] See Maskin and Tirole [?].

[11] We will use s_t instead of s when the context is not clear.

break the equilibrium in two parts; a period competitive equilibrium and a Markov perfect equilibrium. Given (s, K) there is a set of price functions $P = \{p_y = 1, p_z, w_y, w_{z1}, w_{z2}, r\}$ and allocation functions for consumers and firms that form a period competitive equilibrium. Given these prices and state variables (s, K, k), the indirect utility correspondence of each type is determined. That is, these correspondences will just depend on these state variables. In addition, for the structure considered here, these correspondences will be single value and they will be functions.

Given S, the space of the state variables, and the assumed policy arrangement, type 2's choice set of s' is denoted $T(s)$ where[12]

$$\begin{aligned} T(s) &= \{(a', b', t') : t' = t + 1,\ b' \leq t + 1,\ a' = a \ if \ b' = b \ or \\ &\quad a' = b \ if \ b' > b\} \end{aligned}$$

In each period the game is analyzed using backward induction from stage 2 to stage 1. In the last stage of a period the state variables of the economy are (s, K, s'). Firms of both sectors have a static problem. With a Markov equilibrium, the objective function for a type 1 is simply

$$U_1(x) = u(y, z) = \frac{(y^\alpha z^{1-\alpha})^\rho}{\rho}$$

The problem of a type 1 is not dynamic.

I am following convention used in the national income and product account and more generally in macroeconomics rather than those used in mathematical economics. With the convention used here all quantities are positive (or zero). The price of the factor inputs are negative. The rental price are the negatives of these and therefore positive.

The maximization problem of a type 2 is dynamic. First, let $U_2(x) = u(y, z)$. At the second stage their objective is

$$\hat{U}_2(s, K, s') = \max_x \{U_2(x) + \beta v_2(s', K')\}$$

$$s.t. \ \ p(s, K, s') \cdot x \leq 0$$
$$K' = G_3(s, K, s')$$

here $\hat{U}_2(s, K, s')$ is the indirect utility function; $v_2(.)$ is the present value of the equilibrium flows from the next period on conditional on next period's state variables.

[12]The space of the state variables s is $S \equiv N \times N \times N$ and $T : S \to S$.

The problem of a type 3 is also dynamic which leads to objective

$$\hat{U}_3(s,K,k,s') = \max_{y,z,k'}\{u(y, z - k' + (1-\delta)k) + \beta v_3(s',K',k')\}$$

$$s.t.\ \ p(s,K,s')\cdot x \leq 0$$
$$K' = G_3(s,K,s')$$

The k' is the individual's capital stock tomorrow and K' is the aggregate capital stock. Remember that the z-good can be used for z-consumption and investment. If a type 3 purchases z units of good z and chooses k' then consumption of z-good is $z - k' + (1-\delta)k$.

At the first stage of the game the state variables are (s, K), type 2 group solves the following problem,

$$G_2(s,K) \in argmax_{s'\in T(s)}\{\hat{U}_2(s,K,s')\}$$

In the first stage of period t a type 3 does not move and his payoff is

$$\hat{v}_3(s,K,k) = \hat{U}_3(s,K,k,G_2(s,K))$$

- **Dynamic Recursive Equilibrium**

The equilibrium that we are working with is a Markov equilibrium[13] with respect to the state variables (s, K). An equilibrium is the following set of elements:

(i) price functions $p(s,K,s') = \{p_y = 1, p_z, w_y, w_{z1}; w_{z2}, r\}$;

(ii) households allocations $\{x_i(s,K,s')\}_{i=1}^{2}$ and $x_3(s,K,k,s')$;

(iii) firms allocations $\{x_i(s,K)\}_{i=4}^{6}$;

(iv) laws of motion $k' = g_3(s,K,k,s')$, $K' = G_3(s,K,s')$ and $s' = G_2(s,K)$;

(v) value functions $v_2(s,K)$, $v_3(s,K,k)$;

(vi) Indirect utility functions $\hat{U}_2(s,K,s')$ and $\hat{U}_3(s,K,k,s')$, such that

1) Given $p(s,K,s')$, (s,K,s'), (s,K,k,s') in the case of a type 3 and $K' = G_3(s,K,s')$, $\{x_i\}_{i=1}^{3}$ solves the consumers' problem and $\{x_i\}_{i=4}^{6}$ solves the firms' problem;

[13] See Maskin and Tirole [?].

2) $K' = g_3(s, K, K, s') = G_3(s, K, s')$;

3) Markets clear;

4) $G_2(s, K) \in argmax_{s' \in T(s)}\{\hat{U}_2(s, K, s')\}$ and

$$v_2(s, K) = \hat{U}_2(s, K, G_2(s, K));$$

5) $g_3(s, K, k, s') \in argmax\{\hat{U}_3(s, K, k, s')\}$ and

$$v_3(s, K, k) = \hat{U}_3(s, K, k, G_2(s, K))$$

3.2 The Equilibrium with Free Trade

In this section we will characterize the equilibrium path of the model economy with free trade. We assume that there are no barriers to trade and no transportation cost.

Before we go any further let us analyze more carefully how we can determine the equilibrium in this model. First, we can break the equilibrium in two parts: a Markov perfect equilibrium and a period competitive equilibrium.

Since we are interested in the symmetric equilibrium with respect to the capital owners, for a dynamic equilibrium we need to look at the interaction between $G_2(s, K)$ and $G_3(s, K, s') = g_3(s, K, K, s')$. That is, to choose the technology, agents of type 2 need to know how their choice will affect the investment of the firms.

In what follows, to simplify the solution of this model, we will take the following steps. First, we will show that with free trade, no blocking is the best strategy for type 2, that is, $b = t$. This completely characterizes $G_2(s, K)$ (See Lemma 1). Second, given $G_2(K, s)$ and $G_3(s, K, s')$, we will show that there exists an optimum policy rule for type 3 $g_3(s, K, k, s')$ and that $G_3(s, K, s') = g_3(s, K, K, s')$ (See Lemma 2). Finally, we use Lemmas 1-2 to proof the existence of a dynamic recursive equilibrium.

The first proposition of this section shows that with free trade there is no blocking of technology.

Lemma 1 *If there is free trade, that is, every agent has access to $X_6(t)$ technology and K is increasing on b, then the workers of type 2 will not block the adoption of the new technology. That is, $b = t$, for all t.*

We could state a proposition showing that there exists a value function $v_2(s, K)$ and a policy function $G_2(s, K)$ for the maximization problem of type 2 group. But, the above lemma give us the necessary result, that is $G_2(s, K)$.

The next step is to study the type 3 behavior. We will see that in a open world, that is, where there is no barriers to trade, group 2 does not block the adoption of new technologies and the firms invest an amount that keeps the marginal productivity of capital constant. In other words, in an open world group 2 does not use his option to block the adoption of technology.[14]

Since we are working in the case of unbounded returns, we will not be able to use standard techniques using the variables of the original model.[15] Therefore, we will redefine all variables such that the solution of the maximization problem of the the representative firms problem is equivalent to the problem using these redefined variables. More important, this redefined problem will be solved using bounded return techniques[16].

From Lemma 1 we know that in a free trade environment $b = t$, since there is no blocking. Let $\tilde{\beta} \equiv \beta(\gamma^{\frac{1-\alpha}{1-\theta}} \pi^{\alpha})^{\rho}$ and $\hat{\eta} \equiv \eta(1-\theta)(\frac{K_0}{\lambda_2})^{\theta}$.

Lemma 2 *If (i) $1 \leq \hat{\eta} \leq \gamma$; (ii) $\tilde{\beta} \in (0, 1)$; (iii) $G_2(s, K) = s' = (t-1, t, t+1)$; and (iv) there is free trade, then there exists a law of motion of the aggregate capital stock and a policy function for a type 3 where $G_3(s, K, s') = g_3(s, K, K, s') = \gamma^{\frac{1}{1-\theta}} K$ and*

$$\frac{y_{t+1}}{y_t} = \frac{y^*_{t+1}}{y^*_t} = \frac{y_{it+1}}{y_{it}} = \pi \tag{10}$$

$$\frac{z_{t+1}}{z_t} = \frac{z^*_{t+1}}{z^*_t} = \frac{z_{it+1}}{z_{it}} = \frac{K_{t+1}}{K_t} = \gamma^{\frac{1}{1-\theta}} \tag{11}$$

In the above lemma, y^* and z^* are the volumes of good y and z, respectively, traded in the international market. Now, using Lemmas 1-2, we will show that there exists a recursive dynamic equilibrium.

Proposition 1 *If (i) $1 \leq \hat{\eta} \leq \gamma$; (ii) $\tilde{\beta} \in (0, 1)$; and (iii) there is free trade, then there are*

[14]This dynamic policy equilibrium where all variables are growing at a constant rate and the marginal productivity of capital is constant will be called *a balanced growth path.*

[15]See Stokey and Lucas (1989), section 4.2

[16]See Stokey and Lucas (1989), section 4.2.

(i) price functions $P = \{p_y = 1, p_z, w_y, w_{z1}, w_{z2}, r\}$*;*
(ii) households and firms allocations $\{x_i\}_{i=1}^{6}$*; and*
(iii) policy functions $G_2(s, K) = s'$, $G_3(s, K, s') = g_3(s, K, K, s') = \gamma^{\frac{1}{1-\theta}} K$
that form a recursive dynamic equilibrium.

Proposition 1 summarizes the results that we were looking in this section. By a *Balanced Growth Path* we mean an equilibrium path where all variables are growing at a constant rate. Proposition 1 proves that there exists a balanced growth path in this economy. Notice that the wage premium is constant. In this case, workers do not switch sectors where they are working. In the next subsection we will analyze equilibrium path of this economy once we introduce a quota in the imports.

3.3 The Economy with a Quota

In this subsection we will introduce a quota on imports of the Home country. Then, we will see how this quota affects the adoption of technology and the equilibrium of the economy.

The introduction of a tariff on imports does not affect the adoption of technology.[17]

Now we will prove a proposition defining sufficient conditions for the economy to be an importer of the capital intensive good z. Define $\lambda'' = \eta \frac{\alpha K_0^{\theta} \lambda_2^{1-\theta} + (1-\alpha)(\gamma^{\frac{1}{1-\theta}} - 1 + \delta) K_0}{1-\alpha}$

Proposition 2 *If* $1 \leq \hat{\eta} \leq \gamma$*, there are no barriers to trade among countries and no transportation cost then*

(i) if $\lambda_1 > \lambda''$ *the Home Country will import good* z*;*

(ii) if $\lambda_1 < \lambda''$ *it will export good* z*;*

(iii) if $\lambda_1 = \lambda''$*, there is no trade.*

In what follows we will assume that $\lambda_1 > \lambda''$, that is, the Home country is an importer of good z and the government introduces *an effective quota* on imports of good z at period T. By an effective quota it should be understood a quota that reduces the imports of good y and increases the domestic production, transferring some workers of type 1 to work in sector two.

[17] This proof can be seen in Teixeira [?].

Moreover, I will assume that only the government can import or export. The income that the government makes, given by the difference between internal and external prices, is thrown away.

We will define a quota Q_{zt} by

$$Q_{zt} = \Lambda z_t \tag{12}$$

where $\Lambda \in (0, \Lambda^*)$ and $z_t^*/z_t \equiv \Lambda^*$ is the fraction of imports over the national production (that is constant in equilibrium - See Equation 11).

After the introduction of a quota, the domestic relative price of good z becomes independent of the external price, and it is endogenously determined. Besides, workers of type 1 start to work in the z-sector. It follows that $w_{yt} = w_{zt}^1$ and

$$p_{zt} = \frac{\pi^t}{(1-\theta)\gamma^a \hat{k}_{1t}^{\theta}} \tag{13}$$

where $k_{1t} = K_{1t}/l_{1t}$.

Another effect of the quota is to increase the marginal productivity of capital (MPK). To see that, notice that before the quota $l_{1t} = 0$ and the capital labor ratio is K_{2t}/λ_2 where $K_{2t} \equiv K_t$ is the capital sock in the economy. After the introduction of a quota, $l_{1t} > 0$. Therefore K_{2t}/λ_2 reduces since $K_{2t} < K_t$, increasing the MPK. This could induce an increase in the investment of the firms and the production of the z-sector.

The next proposition describes the behavior of production in the z-sector. The growth rate of production of good y decreases since the amount of people working in this sector reduces.

Proposition 3 *If $1 \leq \hat{\eta} \leq \gamma$, $\lambda_1 > \lambda''$ and the government introduces a quota (as defined in Equation (12)) on imports of good z at period T then the rate of growth of production of z increases. That is,*

$$\frac{z_T}{z_{T-1}} = \gamma^{\frac{1}{1-\theta}} \left(1 + \gamma^{\frac{-1}{1-\theta}} \frac{l_{z1}}{\lambda_2}\right)^{1-\theta} > \gamma^{\frac{1}{1-\theta}} \tag{14}$$

The proposition above shows what happens with investment in the period that a quota is introduced. This is one of the components to determine the equilibrium path after the introduction of a quota. Another issue is to determine what happens with the adoption of technology. This is what we

will try to show in the next steps. Once we have the capital stock in period T and the technology adoption policy we can determine the equilibrium path with a quota.

As we will see in the next proposition, after the introduction of a quota, income of the workers of type 2 will not depend on the amount of capital that they have to work with. In other words, income of the workers of type 2 will not depend on k_{2t}. The type 2 income will depend just on the difference between a and b. More precisely, the bigger is $d \equiv b - a$, the bigger is the wage of workers of type 2. In this case, type 2 will block the adoption of technology. Clearly, this will affect and reduce investment, reducing the growth rate of the z-sector.

Since the income of type 2 is increasing in d they would like to choose it as big as possible. But, d has an upper bound $\bar{d}$ given by[18]

$$d \leq (1-\theta)\left[\frac{\log\left[(1+\alpha)(1-\theta)\lambda_1\right] - \log\left[(\Lambda+\alpha)\lambda_2\right]}{\log\gamma}\right] \equiv \bar{d} \qquad (15)$$

Now, we are going to follow the same steps given to prove Proposition 1. First, in the next two lemmas we will prove that there exist policy functions for type 2 and firms. Second, we will prove this policy functions form a Markov perfect equilibrium. Moreover, with price functions and allocation functions these policy functions form a recursive dynamic equilibrium.

In the next lemma we will show that workers of type 2 will block the adoption of technology for any strategy followed by the firms with respect to investment in capital. That is, blocking is a strictly dominant strategy after the introduction of a quota.

Lemma 3 *If (i) $\lambda_1 > \lambda''$ (ii) $\tilde{\beta} \in (0,1)$; and (iii) the government introduces a quota on imports of good y at period T then for d, θ, α and β sufficient large, the best strategies for workers of type 2 is to block the adoption of new technologies. The policy function $s' = G_2(s, K)$ will be given by*

$$b' = \begin{cases} b, & \text{if } t \neq T + nd,\ n \in IN, n > 1 \\ b + d, & \text{if } t = T + nd,\ n \in IN, n > 1 \end{cases}$$

[18]To calculate this upper bound just use the market clearing condition for good z and the demand function of each agent type.

Once again, we could state the maximization problem of type 2 group using the Bellman equation. Making the same transformations used below (see Lemma 4) we would get ($\underline{d} = 1$)

$$v_2(s, \hat{K}) = \max_{\underline{d} \leq d \leq \bar{d}} \{ \frac{(\hat{k}_1^{\theta(1-\alpha)} \gamma^{\frac{d}{1-\theta}})^\rho}{\rho} + \tilde{\beta} v_2(s, \hat{K}) \}$$

As we can see, for α and θ sufficient large, type 2 is better off if they block the adoption of new technologies, independent of the capital owners reactions.

The last step to characterize the equilibrium path of this economy is to determine the investment of the capital owners. We saw above that after the introduction of a quota there exist sufficient conditions under which workers of type 2 will block the adoption of the new technology. This happens because the wage of type 2, after the introduction of a quota, depends only on the difference $d = b - a$. The higher is d the higher is the type 2 wage.

In every period where there is a blocking of the new technology, the total factor productivity will not grow. Besides, since we have a constant return to scale production function, any increase in the stock of capital just reduce the marginal productivity of capital. As a result, after a quota, there is a reduction in the investment.

Furthermore, in the period that there is an introduction of new technologies the price of the capital good goes down. In the period immediately before the introduction of new technologies the price of capital good is higher. Therefore, every capital owner has the incentive to sell part of his capital stock in the period before the introduction of the capital good. Since everybody wants to sell there is no buyers. In this case, the best that the capital owners can do is to consume part of their capital stock. The capital stock goes down in the period where there is an introduction of new technologies. This is the intuition behind the lemma below.

Before we state the next lemma remember that $\tilde{\beta} \equiv \beta(\gamma^{\frac{1-\alpha}{1-\theta}} \pi^\alpha)^\rho$ and let us define $K^* = \left(l_{z1} + \gamma^{\frac{b-a}{1-\theta}} \lambda_2\right) \left(\frac{\tilde{\beta}\theta}{1-\tilde{\beta}(1-\delta)}\right)^{\frac{1}{1-\theta}}$.

Lemma 4 *If (i) $\tilde{\beta} \in (0, 1)$; (ii) $\frac{1}{\beta} \leq \gamma^{\frac{1}{1-\theta}}$; and (iii) $G_2(s, K)$ is given by Lemma 3 then there is an aggregate law of motion of the capital stock and a policy function for a type 3 where $K' = G_3(s, K, s') = g_3(s, K, K, s')$ is given by*

$$K' = \begin{cases} \gamma^{\frac{a'}{1-\theta}} K^*, & \text{if } a' = a \\ \nu\gamma^{\frac{a'}{1-\theta}} K^*, & \text{if } a' = a + d \end{cases}$$

where $\nu \in (0, 1)$.

Now we are ready to prove a proposition similar to Proposition 1.

Proposition 4 *Take all the assumptions of Lemma 3 and Lemma 4, then for* $t > T + 1$ *there are*
(i) price functions $P = \{p_y = 1, p_z, w_y, w_{z1}, w_{z2}, r\}$*;*
(ii) households and firms allocations $\{x_i\}_{i=1}^{6}$*; and*
(iii) policy functions $G_2(s, K)$ *and* $G_3(s, K, s') = g_3(s, K, K, s')$ *given by Lemmas 3-4*
that form a dynamic recursive equilibrium.

The above proposition summarizes the results of this section. We now can compare the recursive equilibrium of the free trade economy and the economy with a quota. First, investment is bigger in the free trade economy. Second, the economy with a quota usually uses obsolete technologies, in the sense that they do not use the most productive technique available. It follows that the economy with a quota has a smaller capital labor ratio, even when they use the same technology used by the free trade economy. The marginal productivity of labor is smaller than in the free trade economy. Last but not least, there is a difference in the pattern of the relative price of the capital intensive good. In the free trade economy the relative price of the capital intensive good declines over time. In the economy with a quota the relative price of the capital intensive good is increasing. Therefore, the relative price of the capital intensive good is generally higher in the economy with a quota than in the free trade economy.

The idea behind protection is to incentive investment in some sectors of the economy. But, protection has two effects. On one hand, protection increases the *actual* rental price of capital and it incentives investment (since it increases the price of the capital good). On the other hand, protection reduces competition, postponing the adoption of new technologies. The use of old technologies eliminates the growth rate of the TFP (and consequently eliminates the growth rate of the productivity of capital). Since capital owners know that type 2 will block new technologies with the introduction of a quota, they stop to invest. After all protection will reduce technological

progress and investment. The capital stock is permanently smaller in the quota economy.

Before we end this section we still can try to answer another question. What would happen in the economy with a quota if blocking was not allowed? That is, suppose that the institutional arrangements create a competitive internal market, not allowing any group to make coalition to block the adoption of technology. In this case, would the quota increase the growth rate of the economy?

To answer this question we need to follow the same steps given to prove Proposition 4. We will not repeat these steps here, but the proof comes straightforward from the proof of Lemma 4.

Proposition 5 *If (i) $\lambda > \lambda''$; (ii) $\tilde{\beta} \in (0, 1)$; (iii) the government introduces a quota in the imports of good y at period T; and (iv) no blocking is allowed, that is $b = t$, then for $t > T + 1$ there are*
(i) price functions $P = \{p_y = 1, p_z, w_y, w_{z1}, w_{z2}, r\}$;
(ii) households and firms allocations $\{x_i\}_{i=1}^{6}$; and
(iii) policy functions $G_2(s, K) = s'$ and $K' = G_3(s, K, s') = g_3(s, K, K, s') = \gamma^{\frac{1}{1-\theta}} K$
that form a dynamic recursive equilibrium.

Although the production of good z increases, as we see in Proposition 3, the growth rate of real GDP reduces with the introduction of a quota. The growth rate of production of good y is negative in the period that the quota is introduced. Besides, the price of good z increases (we will see this in the next section).

In the next section we simulate the model for a free trade economy and for a quota economy and we compare the results.

4 Computer Simulation of the Model

In this section, using the propositions proved in Sections 3.2 - 3.3, particularly, Propositions 1, 4 and 5, we will go over the quantitative results of our model. The figures are in the Appendix. Before we go any further, we should stress that it is not our intention here to do a calibration. Instead, our objective is jut to show the potential of this model to explain the difference of income per capita across countries. To do that, we just parametrized the

model and, then, we did some simulations. The basic conclusions from the simulation of the model are:

1) GDP is greater in the free trade economy than in the quota economy. Further for some parameter values this difference is a factor of thirty;

2) In the quota economy the resistance to new technologies is inversely related to technological progress. If the technology is advancing very fast (a big γ) there is no blocking;

3) The price of good z is smaller in the free trade economy than in the quota economy; The difference between these prices behaves cyclically;

4) If block is not allowed, a quota economy has a higher GDP than the free trade economy. Using Lucas [?] definition a quota generates a level effect;

4.1 Analysis of Results

Table 1 shows the values of the parameters used to simulate the models. Some of these parameters we keep fixed for all simulations since they do not change the basic results. Every time we change a parameter it will be noted. Therefore, unless otherwise stated, the parameters of Table 5.1 are used.

The relative price of good z changes over time. We will use the price of one period to compute real GDP. The real GDP in period t is

$$GDP_t = x_t \cdot P_0$$

That is, real GDP is measured in prices of period *zero*. Further, since the population is constant the growth rate of real GDP and of real GDP per capita are the same.

To compute the growth rate of GDP we will follow the procedure of the US government's Bureau of Economic Analysis. For $t \geq 2$, we calculate the growth rate of GDP in period t, g_t, in the following way:

$$g_t = \left(\frac{x_t P_t}{x_{t-1} P_t} \frac{x_t P_{t-1}}{x_{t-1} P_{t-1}} \right)^{\frac{1}{2}}$$

where $x_t = (y_t, z_t)$ and $P_t = (1, p_{zt})$.

A little bit more about notation should be said. After each variable we introduce a letter f or q indicating that the value of the variable is from

the Free Trade economy or the Quota Economy, respectively. For example, $GDPf(t)$ is the value of the GDP in the Free Trade Economy in period t.

Now, let us analyze one of the results listed in the beginning of this section[19]:

1) GDP is greater in the free trade economy than in the quota economy. Further for some parameter values this difference is a factor of thirty;

Looking at Table 2 we see that real GDP of the free trade economy is higher than real GDP of the quota economy for any value of $\Lambda > 1$. The reason for this persistent difference between GDP in both economies is as follows. With a quota there is always a group of workers using an old technology (a smaller TFP). This group of workers has smaller productivity and, consequently, a smaller capital-labor ratio. As a result the quota economy has a smaller capital-labor ratio and a smaller TFP than the free trade economy. These two factors together explain the difference of GDP between the free trade and the quota economy.

Parente and Prescott [?] and Chari, McGrattan and Kehoe [?] using a sample of countries calculated the difference of income per capita between the richest and the poorest countries. In both papers this difference is around 30 times.[20]

As we see in Table 2, the GDP per capita of the free trade economy compared with the quota economy is on average more than 30 times for $\Lambda > 1$. But, this difference is sensitive to the amount of protection that the z sector receives. In other words, the difference is sensitive to the value of Λ. We compute the average value of the ratio of GDP in the free trade economy to the GDP in the quota economy for different values of Λ. As we can see if $\Lambda = 1$ than we get this difference to be equal to the values found by Parente and Prescott [?] and Chari, McGrattan and Kehoe [?]. Now let us look at the second result listed above.

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[19] The tables and graphs of the other results are available by request.It also can be seen in Teixeira [?].

[20] Good surveys of the approaches that tried to explain the difference of per capita income across countries are Schmitz [?] and McGrattan and Schmitz [?].

5 Conclusions

We started this paper asking why the technological level differs over time and across countries. In this paper we answered this question using international trade and the institutional arrangements.

The importance of the institutional arrangements comes from their capacity to control groups that otherwise would block the adoption of new technologies. On the other hand, international trade (the free trade arrangement or the tariff arrangement) guarantees that any firm, producing in any country, will use the best technology available in the world. With quota there is resistance to adopt new technologies and firms generally will not use the most productive technology available.

The intuition behind these results is the following. First, with free trade the prices are determined in the international markets and firms are in competition with the productivity leaders. Skilled labor then does not resist the adoption of new technologies because given the price of its product, producing most efficiently maximizes its income and its utility. Under a tariff, the domestic price equals the international price times a constant factor (one plus tariff). It does not break the link between the domestic and international price and so the same argument as under free trade applies.[21] In contrast, if a quota is introduced then the domestic price becomes independent of the international price. In this case, skilled labor can increase the relative price of the good produced in its sector by blocking the use of a new technology. This can increase the income of skilled labor and so be in its interest to resist new technologies. This is the case if technological progress is not too rapid (small γ) and skilled labor is a relatively small group that faces a relatively large internal market. The intuition is that on one hand, if the technology advances too rapid then the opportunity cost of not using the most advanced technology is too large. On the other hand, if the domestic market is relatively small, then the gain from manipulating the domestic price is not sufficient relative to the cost.

In our model the difference in productivity between the free trade economy and the quota economy is not explained by the difference in the capital-labor ratio; instead the difference in the capital-labor ratio are caused by differences in total factor productivity. The use of old technologies (a smaller TFP) reduces the productivity of capital. With a lower productivity there

[21] In a certain range of the parameters value.

is less investment and a smaller capital stock. A smaller capital stock with smaller TFP explains the smaller labor productivity. Furthermore, a smaller capital stock used with an old and less productive technology explains the difference in the GDP between the free trade and the quota economy.

A poor country is one where workers have smaller productivity and hence a smaller income per capita. In this paper countries are poor (and save less) because they do not use the best technologies available. The reason countries use different technologies is that their internal arrangements allow groups to resist adoption of new technologies. In other words, countries are poor not because they have smaller capital labor ratio, but they have smaller capital labor ratio because they are poor.

In this model, there exists no open poor economies. A poor country that opens itself to international trade would grow faster than the other economies catching up, eliminating all differences in the income per capita.

Closed economies, on the other hand, could be richer than a free trade economy, which would depend on the internal institutional arrangements. If the internal institutional arrangements were able to control groups that otherwise would resist new technologies, then a country would not depend on international trade to keep technological progress (see Proposition 5). Moreover, with quota and no blocking, this economy can have a higher GDP than the free trade economy. Once the market is closed investment jumps. This has a permanent effect on the capital stock. Consequently it has a permanent effect on production of the protected sector and on GDP. In this case, a quota has a level effect in GDP. This level effect increases the growth rate of the economy during the transition. But, as we saw before, with quota and if groups can resist new technologies the same technology will be used for a longer period than in the free trade economy. As a consequence of this lack of technological progress, the quota economy gets a smaller TFP, reducing the productivity of capital that reduces investment and GDP.

These different results for closed economies seem to match with the experiences of some countries. We could take Japan, after the Second War, Korea, after the Korean War, and even the USA in the second half of the 19th century as examples of closed countries with higher growth rates because the increase in the growth rate generated by the level effect. On the other hand, other closed countries as Brazil and Argentina until the beginning of the 90s and Chile (until 1972) could be taken as examples of trade barriers lowering their growth rates. An important point is that the model generated results that match the experiences of closed countries growing faster and

closed countries growing at low rates.

For future research adopting the approach used in this paper there are some constraints that we could relax. One constraint is about population growth. This could be easily introduced into the model if all groups have the same growth rate. In this case, the growth rate of the GDP would increase by the value of the growth rate of population. The growth rate of GDP per capita would not change. If we assume different growth rates for groups then we could have some different results. For example, if the type 2 group grows faster than the other groups the proportion of type 2 in the population would increase over time. In this case, the type 2 coalition would end in a finite number of periods.

Another constraint that we could relax, and maybe a more interesting one, is the movement of capital across and inside the country. What would happen in this model if capital could move across countries? My intuition is that we still would have some difference of GDP per capita between free trade and quota economies. But, this difference would be smaller. After the introduction of a quota, the rental price of capital goes up. Capital inflow would equalize rental price of capital across countries. The difference of capital labor ratio would be smaller with movement of capital, but it would not be eliminated since there is still differences in the TFP.

Appendix

Table 1: Parameters

Parameters	Values
α	0.7
ρ	0.5
β	0.96
δ	0.05
γ	1.02
π	1.015
θ	0.7
η	16.4
Λ	0.05
λ_1	98
λ_2	2

Table 2: GDPf/GDPq for Different Levels of Protection

Λ	Average GDPf(t)/GDPq(t)
0.05	98.1
0.5	45.5
1	28.7
1.5	19.8
2	15