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**Effects of Trade Policy on Technology
Adoption and Investment**



Effects of Trade Policy on Technology Adoption and Investment*

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Comments are welcome

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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 low tariffs guarantee that the most productive technology available will be used. In contrast, under a quota as well as high tariffs the most productive technology available will not be used at all times. Further, in the latter case investment and the capital-labor ratio are smaller than in the former one. As a result, the GDP per capita is higher in the free trade economy than in the quota economy. This difference is inversely related with the level of protection in the quota economy.

JEL classificarion: O0,O4

1 Introduction

Productivity as well as income per capita differ over time and across countries. In this paper we argue that it is the difference in TFP (total factor

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productivity) across countries that explains the differences in the productivity as well as in the income per capita. The differences in the TFP across countries comes from the resistance of some groups to use the technologies available.¹

We use the following arguments to explain how the differences in TFP across countries drive the differences in the labor productivity and in the income per capita. First, if groups block the adoption of new technologies, then the marginal productivity of capital is affected. With less productive technology (smaller TFP) there is less investment and a smaller capital-labor ratio. Therefore, the differences in capital-labor ratio across countries are a result of differences in TFP. Second, the differences in labor productivity across countries are due to the differences in their capital-labor ratio and in the differences in TFP. Therefore the differences in the labor productivity across countries, controlled for human capital differences, are due to differences in TFP across countries. Third, much of these differences in TFP across countries are not due to the access to new technologies. Generally, the knowledge that is being used by the workers of the richest countries could be used by the workers of any other country, in particular poor countries. The point is why some countries do not adopt or use the most productive technologies available.

We argue that the interaction 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 interest groups 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, we take a small open economy where there is a group that can block the adoption of new technologies and study how the choice of trade policy affects their decision problem whether or not to block.²

We develop a two-sector growth model with international trade. Both sectors are competitive and in both sectors a more productive technology

¹Good examples of this resistance can be found in Parente and Prescott [12], Holmes and Schmitz [4], Mokyr [7, 8, 9].

²Baily and Gersbach [2] and Baily [1] pointed out that there is not enough evidence to justify differences in productivity by differential access to proprietary technology. Instead, they show some evidence that domestic competition is not enough to make domestic firms achieve the highest productivity. Luzio [5] is also a good case study of the consequences of protection over the development of the computer industry in Brazil.

becomes available every period. But technology differs. One sector uses only unskilled labor, 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 low tariffs; *(ii)* with a quota, firms generally will not use the most productive technology available; *(iii)* productivity and the income per capita are inversely related with the level of protection. 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 firms that are using the most productive technology. 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 low tariff levels, the domestic price equals the international price times a constant factor, the same argument as under free trade applies. In contrast, if a quota (or a high tariff) 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 their sector, consequently their income, by blocking the use of a new technology.

The ideas developed in this paper are related to those of Parente and Prescott [11, 12], and more particularly with Holmes and Schmitz [4]. The key idea of these papers is that the ability to invest and adopt new technologies determines the growth rate of an economy. Parente and Prescott [11] focus on barriers to investment coming from the internal structure of the economy. Parente and Prescott [12] shows how monopolies can interfere with the adoption of new technologies. Holmes and Schmitz [4] point that organized interest groups can have the power and find it in their interest to resist the adoption of new technologies. Furthermore, international trade will affect the behavior of these interest groups in resisting to 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 work with an infinite horizon. Besides, I introduce

a capital good. In Holmes and Schmitz, as in the model developed here, the decision to block or not is taken in order to maximize the workers income (wage). Without capital, the wage of the workers depend only on the TFP and on the price of the good they produce. When a new technology is not adopt, the price of the good goes up. If the increment in the price is sufficient to compensate the smaller TFP that comes from the resistance to adopt new technologies the workers block. With the introduction of a capital good the wage of workers depends on the TFP, the price of the good and on the capital-labor ratio. That is, with capital we have a game where there are two players: workers and capital owners. On the one hand, stopping the adoption of new technologies increases the price of the good and the income of the workers. On the other hand, without technological progress there is less investment and the economy ends up with smaller capital labor ratio, reducing the labor productivity and the wages. What we show in the model developed here is that the former effect dominates the later one.

Finally, Holmes and Schmitz analyze just two possibilities with respect to tariff level: infinity and zero. I analyze different levels of tariff and quotas, allowing me to compare the effects of tariff and quotas on the resistance to adopt new technologies.

This paper is divided into four sections (including this introduction). In Section 2, I develop a model that studies the adoption of technology. First I study an economy under free trade, that is, there are no barriers to trade with other countries. Then, I study this economy assuming that there is a quota. Finally, I study the same economy with tariffs. Section 3 offers some quantitative results from computer simulations of the models developed in Section 2. Section 4 concludes.

2 The Model

There are three types of agents, $i = 1, 2, 3$ and the measure of the type i is $\lambda_i > 0$. A type $i = 1, 2$ agent is endowed with one unit of time of labor of type i . A worker of type $i = 1$ supplies unskilled labor and a worker of type $i = 2$ supplies skilled labor. In the third group, group of type 3, each

agent owns capital that they rent to firms. This group has measure one³. 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.

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. Since capital income could also increase if there is blocking, this could jeopardize the labor income effect over the decision to block the adoption of new technologies. 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.

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.

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. In industry y the inputs into the production process are unskilled labor only, which we assume that any worker can supply. Therefore, there is no differentiation between labor of type 1 and 2 in the y industry. In the z industry while labor may be unskilled or skilled, the most productive technology can only be operated by skilled labor. Skilled labor has a higher productivity than unskilled labor in the z industry.

The consumption set of the agent of type 1 is

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

The consumption set of the agent of type 2 is

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

The consumption set of the agent of type 3 is

$$X_3(k) = \{x \in L_+ : l_y = l_{z1} = l_{z2} = 0, k^s \leq k\} \quad (3)$$

³This assumption is made just to facilitate the algebraic manipulation. It does not interfere in the results of this paper.

l_y is the amount of labor supplied by a worker to industry y and l_{zi} is the amount of labor supplied to industry z by a worker of type $i = 1, 2$. 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^s of capital services. The amount supplied, k^s , is smaller or equal to k .

• **Preferences**

The period utility function for all types is

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

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

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

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

• **Technologies**

We have three technologies. They are represented by the production set of good y , the production set of good z and the production set of the foreign trade technology.

The production set of good y is

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

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 production set of good z is

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

where $\gamma > 1$, k_i is the amount of capital services allocated with labor of type i . Since we are working in a competitive environment, we are assuming

that \bar{k} is very small relative to 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. The specific way that they are determined will become clear below.

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

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

we are assuming that this is a small open economy, that takes the external price of good z , p_{zt}^* , as given. $X_6(t)$ implies that there is 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

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

The exact form of the price of good z it is not important. The above form was used just to facilitate the algebraic manipulation.⁴

• 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 $\{0, \dots, t-1, t\}$.

During period t , type 2 decides what technology to use next period; that is, type 2 chooses $b' \in \{b, \dots, t, t+1\}$. If $b' > b$, that is a better technology is selected, then $a' = b$. If, however, $b' = b$, then $a' = a$. Thus, if type 2 chooses a better technology then type 1 gains access to the technology that type 2 was using. If type 2 chooses to continue using the b technology, type 1 does not get access to the b technology⁵.

• Definition

⁴This is particularly true in the Section 2.2, when we compute the balanced growth path.

⁵In period zero, since no technology has being abandoned, we are assuming that type 1 works in the production of good z with technology γ^{-1} .

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, type 3 non cooperatively chooses k' and prices and allocations are determined competitively. It should be noticed that there is no private information.

2.1 Dynamic Equilibrium

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

We restrict our attention to Markov equilibrium which is symmetric with respect to members of group 3.⁶ The state variables at the beginning of a period become (s, K) , where $s = (a, b, t)$. The integers a , b and t index the technology sets $X_4(t)$, $X_5(a, b)$ and $X_6(t)$ and K is the aggregate capital stock in the economy.

The maximization problem of a type 1 as well as the maximization problem of the firms are static. The maximization problem of a type 3, like the maximization problem of type 2, is a dynamic problem.

To understand the maximization problem of type 2 and the maximization problem of a type 3 we can break the equilibrium in two parts; a period competitive equilibrium and a Markov perfect equilibrium. Besides, it is better to analyze the model using backward induction. In the second stage of a period, given the economy states variable (s, K, s') and a type 3 state variables (s, K, k, s') 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. In the first stage, given these prices and state variables

⁶See Maskin and Tirole [6] for the definition of the Markov equilibrium.

(s, K, k) , the indirect utility correspondence of each type $i = 2, 3$ is determined (these correspondences will just depend on these state variables).

Let us formalized the above ideas. Let S be the space of the state variables s . Given the assumed policy arrangement, type 2's choice set of s' is denoted $T(s)$ where⁷

$$T(s) = \{(a', b', t') : t' = t + 1, b' \leq t + 1, a' = a \text{ if } b' = b \text{ or } a' = b \text{ if } b' > b\}$$

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. The problem of a type 1 also is static since 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 maximization problem of a type 2 is dynamic. At the second stage their objective is

$$\hat{U}_2(s, K, s') = \max_x \{u(y, z) + \beta v_2(s', K')\}$$

$$\begin{aligned} s.t. \quad & p(s, K, s') \cdot x \leq 0 \\ & K' = G_3(s, K, s') \end{aligned}$$

here $\hat{U}_2(s, K, s')$ is the indirect utility function; $v_2(\cdot)$ is the present value of the equilibrium flows from the next period on conditional on next period's state variables and $p(s, K, s')$ is the vector of prices. 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 problem of a type 3 is also dynamic which leads to objective

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

$$\begin{aligned} s.t. \quad & p(s, K, s') \cdot x \leq 0 \\ & K' = G_3(s, K, s') \end{aligned}$$

⁷The space of the state variables s is $S \equiv \mathbb{N} \times \mathbb{N} \times \mathbb{N}$ and $T : S \rightarrow S$.

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) , the type 2 group solves the following problem,

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

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

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

• Dynamic Recursive Equilibrium

The equilibrium that we are working with is a Markov equilibrium 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;
 - 2) $K' = g_3(s, K, K, s') = G_3(s, K, s')$;
 - 3) Markets clear;
 - 4) $G_2(s, K) \in \operatorname{argmax}_{s' \in T(s)} \{\hat{U}_2(s, K, s')\}$ and

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

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

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

2.2 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.

We will focus our attention in the symmetric equilibrium with respect to the capital owners. For a dynamic equilibrium we need to look at the interaction between $G_2(s, K)$, $G_3(s, K, s')$ and $g_3(s, K, k, s')$. On the one hand, to choose the technology, agents of type 2 need to know how their choice will affect the investment and the accumulation of capital. We should notice that the stock of capital affects their marginal productivity and their wages. On the other hand, to choose k' a type 3 needs to know $G_3(s, K, s')$ and $G_2(s, K) = s'$.

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 type 2 will not block the adoption of new technologies⁸.

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 .*

The intuition behind Lemma 1 is as follows. The utility of a type 2 increases with the type 2 wage, since higher wages are associated with higher levels of consumption. The wage of a type 2 is equal to the internal price of good z times the marginal productivity of the labor of type 2. With free trade, the internal price of good z is equal to the external price. The marginal productivity of the labor of type 2 increases with b and K . Further, the capital stock also increases with b . Therefore, the wage (and the utility) of a type 2 increases with b . Given p_{zt} , the best strategy for the group 2 is to use the newest technology available.

⁸Proofs are available under request.

Using the Principle of Optimality we could show 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 optimum decision rule for the type 2 group, that is $G_2(s, K) = (t, t + 1, t + 1)$.

The next step is to study the type 3 behavior. We saw in Lemma 1 that in an open economy, that is, where there is no barriers to trade, group 2 does not block the adoption of new technologies. In this case, we will see that capital owners will keep investing. In equilibrium the amount invested keeps the marginal productivity of capital constant. The reason is that with free trade the newer and more productive technology is always been used. For a given aggregate capital stock, the marginal productivity of capital is increasing. Therefore, it is optimum for capital owners to invest, increasing the amount of capital in the economy. This is the intuition behind the next lemma. We define $\tilde{\beta} \equiv \beta(\gamma^{\frac{1-\alpha}{1-\theta}} \pi^\alpha)^\rho$ 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) $G_2(s, K) = (t, t + 1, t + 1)$; 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*

$$\frac{y_{t+1}}{y_t} = \frac{y_{t+1}^*}{y_t^*} = \frac{y_{it+1}}{y_{it}} = \pi \quad (10)$$

$$\frac{z_{t+1}}{z_t} = \frac{z_{t+1}^*}{z_t^*} = \frac{z_{it+1}}{z_{it}} = \frac{K_{t+1}}{K_t} = \gamma^{\frac{1}{1-\theta}} \quad (11)$$

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*

- (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

$$G_3(s, K, s') = g_3(s, K, K, s') = \gamma^{\frac{1}{1-\theta}} K$$

$$G_2(s, K) = (t, t + 1, t + 1)$$

that form a recursive dynamic equilibrium.

Proposition 1 summarizes the results that we were looking for in this section. Since the results shown come from Lemmas 1-2 we will not repeat the intuition behind them.

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.

In the next subsection we will analyze equilibrium path of this economy once we introduce a quota in the imports.

2.3 The Economy with a Quota

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

Before we introduce a quota, we will define sufficient conditions for the economy to be an importer of the capital intensive good z . We are interested in this case because if z were not imported when there is no quota, nothing would change if we introduce a quota on the imports of z .

In the next proposition λ'' is a parameter and is defined as
$$\lambda'' = \eta \frac{\alpha K_0^\theta \lambda_2^{1-\theta} + (1-\alpha)(\gamma^{\frac{1}{1-\theta}} - 1 + \delta)K_0}{1-\alpha}$$

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 z and increases the domestic production, transferring some workers of type 1 to work in the z -sector.⁹

⁹See Woodland [14, pages 330-40].

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. In equilibrium Λ^* is constant, as we can see in Equation 11.

We are interested in study the effects of a quota in the adoption of technology and in the growth path of the economy.¹⁰ As in the previous section, to characterize the equilibrium we have to study the optimum decision rule for type 2 and type 3.

Next proposition studies the effects of the quota over the adoption of technology. The main result is that with a quota the type 2 will block the adoption of new technologies. After the introduction of a quota, the wages of the workers of type 2 will depend on the amount of capital that they have to work with and on the difference between a and b , the integers that index the z -technology that is being used by workers of type 1 and workers of type 2, respectively. The dependency of the type 2 wage from the amount of capital is straightforward. The intuition for the dependency on the difference $b - a$ is the following. The price of good z , after the introduction of a quota, is set in a level that permits the use of the less productive z -technology operated by labors of type 1 (that is, the technology indexed by letter a). Therefore, the further is the technology used by type 2 from the technology used by type 1 (the higher is the difference $d \equiv b - a$) the higher is the price of good z and the higher is the wage of a type 2. But, if d is big this means that the economy is operating very old and obsolete technologies.

Since the income of type 2 is increasing in $d \equiv b - a$ they would like to choose it as big as possible. But, d has an upper bound \bar{d} given by¹¹

$$d \leq (1 - \theta) \left[\frac{\log [(1 + \alpha)(1 - \theta)\lambda_1] - \log [(\Lambda + \alpha)\lambda_2]}{\log \gamma} \right] \equiv \bar{d} \tag{13}$$

¹⁰The introduction of a quota has effects over the price of z , production of y and z , allocation of the labor types across sectors and productivity of capital. We will not discuss these topics here. For those interested see Teixeira [13].

¹¹To calculate this upper bound just use the market clearing condition for good z and the demand function of each agent type.

The above inequality have some interesting properties. First, from the *Policy Arrangement* we know that $d \geq 1$. Therefore, a necessary condition for blocking is that the parameters of the economy in the above inequality make $d \geq 2$. As we can see above, there will be blocking only if the size of the group that is blocking (λ_2) is a small proportion of rest of the population (λ_1). Basically, blocking is good for the type 2 group because it affects the relative price of z , transferring income from type 1 to type 2. If the type 1 group is very small then it is not good to block. The amount of income transferred from type 1 group to type 2 group is not enough to compensate the effect that the increment in the price of good z causes in the type 2 consumption of good z . Second, the higher is the protection to the z -industry (smaller Λ), the bigger is d . The third property showed by inequality (13) is between the rate at which the technology is advancing (γ) and d . As we can see, if the technology is advancing very fast it is not optimal for the type 2 group to resist (since d is very small). The intuition is that the bigger is γ the bigger is the cost to resist to new technologies in terms of forgone output (and consumption).

Next lemma summarized the ideas discussed above (remember that we define $d \equiv b - a$).

Lemma 3 *If (i) $\lambda_1 > \lambda''$; (ii) $\tilde{\beta} \in (0, 1)$; and (iii) the government introduces a quota on imports of good z at period T then for d , α and β sufficient large, the best strategies for workers of type 2 is to block the adoption of new technologies. In this case, b' will be given by ($n \in \mathbb{N}$)*

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

To understand the hole played by d , α and γ in the above lemma, we state the maximization problem of type 2 group using a Bellman equation ($\underline{d} = 1$)

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

where $\hat{K} = \frac{K}{\gamma^{\frac{a}{1-\theta}}}$ and $\hat{k}_1 = \frac{K_1}{l_{z1} \gamma^{\frac{a}{1-\theta}}}$.

As we can see, in the Bellman equation for d , α and γ 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 behavior of investment. 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 new technologies. In every period where there is a block of a new technology, the total factor productivity will be constant. Since we have a constant return to scale production technology, 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 as a consequence of blocking.

This is the intuition behind the lemma below. Before we state the lemma we define $\tilde{\beta} \equiv \beta(\gamma^{\frac{1-\alpha}{1-\theta}} \pi^\alpha)^\rho$ and $K^* = \left(l_{z1} + \gamma^{\frac{b-a}{1-\theta}} \lambda_2 \right) \left(\frac{\tilde{\beta}\theta}{1-\tilde{\beta}(1-\delta)} \right)^{\frac{1}{1-\theta}}$.

Lemma 4 *If (i) $\tilde{\beta} \in (0, 1)$; (ii) $\frac{1}{\tilde{\beta}} \leq \gamma^{\frac{1}{1-\theta}}$; 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 $\nu \in (0, 1)$.

The intuition for the behavior of K' given by the above lemma is the following. In the period where there is adoption of new technologies the price of the capital good goes down, since the marginal productivity of all factors increase. Therefore, in the period immediately before the introduction of a new technology the price of capital good is high. Every capital owner has incentive to sell capital in the period before the adoption of a new technology and buy more capital in the period where this new technology is introduced. As every capital owner wants to sell capital there is no buyers. In this case, the best that the capital owners can do is to consume part of their capital stock in the period immediately *before* a new technology is adopted and to buy (invest) more in the period where the new technology is introduced. Therefore, the capital stock goes down in the period where

before the introduction of a new technology and it goes up in the period where the technology is introduced.

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

Proposition 3 *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 $\{x_i\}_{i=1}^6$;*
- (iii) *policy functions $G_2(\cdot)$, $G_3(\cdot)$ and $g_3(\cdot)$ 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 equilibrium of the free trade economy and the quota economy looking at Proposition 1 and Proposition 3. First, investment is bigger in the free trade economy than in the quota 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 over time the economy with a quota has a smaller capital labor ratio and a smaller labor productivity than the free trade economy.

The idea behind protection is to incentive investment in some specific sectors of the economy. But, protection has two effects. On the one hand, protection increases the *actual* rental price of capital and this is an incentive for investment. On the other hand, protection reduces competition, postponing the adoption of new technologies. Since capital owners know that type 2 will block new technologies after the introduction of a quota, they stop investing. After all protection will reduce technological progress and investment. That is, the second effect dominates the first.

2.4 The Economy with a Tariff

In this subsection we will introduce a tariff on the imports of good z . Then we will analyze what happens in this economy with the adoption of new technologies. The main result is that for low values of a tariff the economy behaves like a free trade economy and there is no blocking. For high values of a tariff the economy behaves like a quota economy and there is block of new technologies.¹²

¹²See Woodland [14, pages 330-40] for a discussion about the equivalence between tariffs and quotas).

Proposition 2 specified sufficient conditions for the country to be an importer of good z absent tariffs. We are interested in this case because if z were not imported when the tariff was zero, nothing would change if a tariff is imposed on the imports of z . In what follows in this section we will be always assuming that $\lambda_1 > \lambda''$, that is, the Home Country imports good z . Suppose that the government introduces a tariff τ in the imports of good z and that the income collected by the in government is thrown away.

We want to show that in equilibrium for low levels of τ , there will be no blocking. The reason is that for low values of τ , the internal price will be always given by $(1+\tau)p_{zt}^*$. Since the income of a type 2 worker is given by the marginal productivity of the labor of type 2 times the internal price, given the internal price, the best that workers of type 2 can do is to use the most productive technology available. Therefore, for low levels of τ the economy behaves like in Section 2.2 and there is no blocking.¹³

Now suppose that you start raising τ . For low levels of τ , as we said before, we just increase the internal price of z , reducing consumption and the imports of z . After certain level, labors of type 1 will start moving from sector y to sector z as the price of z keeps increasing, raising the wage of type 1 in the z sector.¹⁴ By the same reason, as τ increases, domestic consumption of z , imports of z and export of y are reducing and domestic production of z is increasing. These movements persist until international trade is shutdown. From this point on, the internal price of good z is determined domestically and an increment in the tariff is not binding. Since the internal price is disconnected from the external price, the economy starts behaving like a quota economy and there is blocking of new technologies.¹⁵

Summarizing these results, there exists a $\tau^* > 0$, such that for $\tau \in [0, \tau^*]$ the Home Country behaves like a free trade economy studied in Section 2.2. For $\tau > \tau^*$ the Home Country behaves like a quota economy studied in Sections 2.3 .

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

¹³We will not repeat the propositions and the proofs here. To convince the reader about this result just redo the steps given in the Section 2.2 using $(1+\tau)\hat{\eta}$ rather than $\hat{\eta}$.

¹⁴More specifically, for $(1+\tau)\hat{\eta} > \gamma$.

¹⁵Again, we will not repeat the propositions and the proofs of Section 2.3. To understand this result just think the economy of Section 2.3 with a quota equal to zero.

3 Computer Simulation of the Model

In this section, using the propositions proved in Sections 2.2 - 2.3, particularly, Propositions 1 and 3 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 just to show the potential of this model to explain the difference of income per capita across countries. We parameterize the model and, then, we did some simulations. For parameter that are not specific to this model we picked common values in the literature. For parameters specific to our model we chose values that satisfies the hypothesis of the propositions of our model. The basic conclusions from the simulation of the model are:

1) The GDP is greater in the free trade economy than in the quota economy. This difference in the GDP per capita is inversely related to the level of protection (Λ). Further for high levels of protection (small Λ values) this difference is a factor of thirty;

2) In the quota economy the resistance to new technologies (d) is inversely related to rate of the technological progress and to the level of protection. The bigger is γ or the smaller is Λ the smaller is d .

3.1 Analysis of Results

Table 1 shows the values of the parameters used to simulate the models. The values were chosen to satisfy the assumptions of the propositions proved in this paper. 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 the first result listed in the beginning of this section. Looking at Table 2 we see that the real GDP of the free trade economy is higher than real GDP of the quota economy for any value of Λ . Further, this difference in the GDP of both economies is inversely related to the level of protection. The higher is the level of protection (smaller Λ) the higher is the difference in the GDP. With a quota there is always a group of workers using an old and less productive technology. 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. It should be noticed that it is the difference in TFP across countries that explains the differences in their income per capita.

Parente and Prescott [10] and Chari, McGrattan and Kehoe [3] 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.

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, for $\Lambda = 1$ than we get this difference to be equal to the values found by Parente and Prescott [10] and Chari, McGrattan and Kehoe [3].

Now let us look at the second result listed above. This result is straightforward, as we can see looking at Equation 13. The intuition is as follows. The bigger is γ the faster is the growth rate of the labor and capital productivity in the z sector. In this case, the longer is the period that the workers of type 2 stay without adopting new technologies the higher is the cost in terms of output loss. Or, the smaller is Λ (high protection) the bigger is the power of the type 2 group to resist to adopt new technologies (the bigger is d).

4 Conclusions

We started this paper asking why the technological level and the income per capita differ over time and across countries. In this paper we answered these questions using international trade policy and the institutional arrangements.

The importance of the institutional arrangements comes from their capacity to control or to allow groups to block the adoption of new technologies. On the other hand, given the internal arrangements, the international trade policy determines if it is optimum or not for groups to block the adoption of new technologies. The basic results of our model are: (i) Free trade (or low tariffs) guarantees that there is no blocking. That is, firms use the best technology available; (ii) With quota (or for high levels of tariffs) there is resistance to adopt new technologies and firms generally do 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 workers do not resist the adoption of new technologies because given the price international price, they should use the most productive technology available to maximize their income and their utility. Low levels of tariff do not break the link between the domestic and international price. The same intuition used for free trade still applies.

In contrast, with a quota or for high levels of tariff 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 it would be better for the skilled group to resist to 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. 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 to compensate the cost to consume a good with a higher price.

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 is

less investment and a smaller capital stock and a smaller capital-labor ratio. A smaller capital-labor ratio with smaller TFP explains the smaller labor productivity of closed countries. Furthermore, a smaller capital-labor ratio used with an old and less productive technology explains the differences in the GDP between the free trade and the quota economy. This difference is directly related with the level of protection. The higher is the protection the further behind is the technology of a country with respect to the frontier and the bigger it will be the difference of GDP per capita with respect to open economies.

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 our 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.

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, in equilibrium 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.

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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