To Open or Not to Open: The Causes, Timing, and Consequences of Protectionism

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September 17, 2007

Abstract

Recent history gives us evidence of the different timing and results of the opening up of several economies. When and why do governments open up their economies, and why do domestic firms survive or not to the opening up of the economy? This paper presents a game theoretic model that seeks to answer these questions. Our findings show that depending on the degree of impatience of the government and domestic firms, the costs of adopting new technologies including the legal and political costs, the gap between the old and the new technologies in terms of production costs, and the expectations of the agents, the economies will open at the outset, provoking widespread bankruptcies; will remain closed; or will open only when domestic firms are able to compete with their foreign counterparts. In contrast with the literature on these issues, this model shows that temporary protection may be effective to induce domestic firms to modernize and become internationally competitive. All the strategies found are subgame perfect Nash equilibrium and pass the renegotiation proof criterium.

1 Introduction

In this paper we address the issue of why and when policymakers decide to open up the economy and whether firms choose to invest in new technology or not. We develop a model in which the key variables are the degree of impatience of the government and the firms, the gap between the old and new technologies, the cost of adopting the new technology including the legal and political costs, and the proper expectations of the agents of the economy —meaning expectations in a game-theoretic sense— . Among other results, we give a new answers to the following questions: Why do countries follow different paths to openness, and what are the economic consequences of that? and, Why do some countries with protectionism policies have been successful in inducing firms to adopt new technologies and others have not?

Our general point of view is the following. There is historical evidence suggesting that protectionist trade policies are often the result of a complex interaction among unions, firms, and the government. When a new labor-saving and cost-reducing technology appears on the international scene, these three actors may find themselves better off in the short run by maintaining current technology. This is the case when specific economic, financial, and political conditions make them face as an alternative unemployment, widespread bankruptcies, and social unrest. Yet, every time the decision to change the technology and modernize the industry is postponed, the problem for the future worsens. If, at a given moment, the status quo is maintained for fear of unemployment and of firms' bankruptcies, as the gap between the technology used by the domestic industry and that of the industry's leaders elsewhere in the world widens, the danger of widespread unemployment and bankruptcies only increases. Thus, when the decision to modernize the industry and open up the economy is finally taken, the industry is hard hit.

For instance, the history of the Mexican textile industry closely fits this description of events, as is shown in Gómez-Galvarriato (2001). The comparison of production costs c. 1911 of one of the most modern and productive firms (the Compañía Industrial Veracruzana S.A.) with those of its international counterparts suggests that by that time the firm could compete with English cloth prices (although not with American cloth prices). Yet, as time went by, its competitive standing deteriorated as a result of legally binding industry-wide collective contracts that hindered the firm from adopting new technology. The first "wage list" was signed by firms' and workers' representatives in 1912. Yet it did not become legally binding until 1927 when, as a result of the Convention of Workers and Industrialists of 1925-27, a collective contract was agreed to with basically the same technical features as that of 1912. This collective contract fixed the maximum number of machines per worker and established specific wages per piece. Under these conditions, in-

Table 1. Ad-valorem Taxes

	1965	1975	1986	1988	1993	1994	1995	1996	1997	1998	1999
Cotton Yarn	25	25	22.5	15	15	12.70	10.2	7.6	5	1.65	0
Synthetic Yarn	21.5	25	25.64	13.48	14.28	8.91	7.18	5.40	3.61	1.34	0
Cotton Cloth	51.01	35	45	15	15	4.39	3.53	2.63	1.73	0.57	0
Synthetic Cloth	96.52	34.96	36.09	14.79	14.93	11.10	9.15	7.12	5.10	2.59	0

dustrialists had no incentive to introduce better machinery because it would not enable them to reduce labor costs, since wages per piece and the workers per machine had to remain invariable. It set, for example, the maximum number of looms per weaver to 6, when using Nortrhop automatic looms a weaver could tend 20. It also required that the companies maintain a fixed number and type of jobs. The 1925-27 Convention agreements may be understandable in light of the worldwide depression in the textile industry. Nevertheless, the precepts adopted were ratified over and over again, without any changes until at least 1951, and until 1972 with few modifications. It was not until 1994 that the industry-wide collective contract in this industry was abolished. Company documents tell of the difficulties firms faced in install modern machinery as a result of these regulations, making it many times simply impossible. These agreements were, of course, paralleled by rises in tariffs that the government carried out in order for the status quo to prevail. When tariffs were reduced after 1985, few of these firms survived.[1]

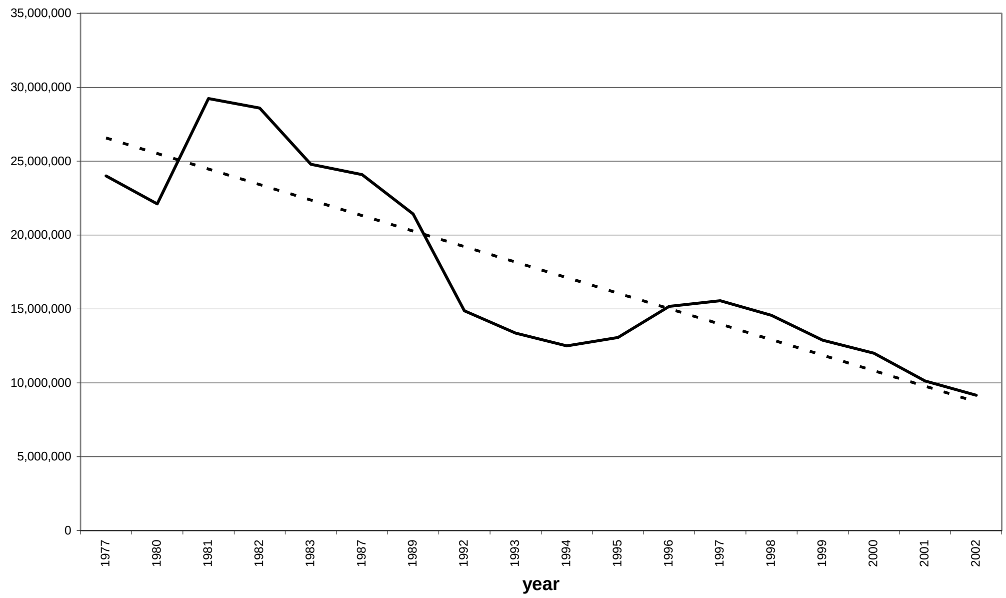
As Table 1 shows, tariffs for textile products fell steadily from 1965 on. This fall would be even more dramatic if we consider that many textile products were subject to import prohibitions before 1986. Whereas the fall in tariffs that took place from 1986 to 1988, a result of Mexico's entrance to the GATT, could not have been fully predicted by the agents, the decrease in tariffs after that date and especially after the signature of the NAFTA in 1993 (in a region that represents over 80% of Mexican exports) was completely predictable. Yet, textile companies were unable to adjust to the new competitive environment. As Figure 1 shows, the gross production of cotton and synthetic fell dramatically from 1980 to 2002 as a consequence of the opening up of the economy.[2]

[1] Sources for Table 1 are: *Anuario Estadístico del Comerio Exterior,* 1965, 1975, 1986,1988, 1993; *Diarios Oficiales,* 1965, 1975, 1988, 1993; *Secretaria de Comercio, Tarifa del impuesto general de importaciones*, 1980 y 1986.

Note: This represents the aggregate tariffs of cotton and synthetic weighted by their share in total imports.

[2] Sources for Figure 1 are: Estadística Industrial Anual, 1977, 1980, 1981, 1982; En-

Figure 1. Gross Production of Cotton and Synthetic Textiles in Mexico (Thousands of Pesos of 2002)



Whereas the case of the Mexican spinning and weaving industry may be an extreme example of a sector institutionally tied down in order not to modernize, we believe this story is not exceptional but a pattern experienced, to a lesser or greater degree, by several industries in many of the developing countries that have recently opened up their economies. Ana Revenga's (1997) study of Mexican manufacturing during 1984-90 indicates that the 1985-87 trade liberalization episode affected firm-level employment and wages through several channels. It shifted down the industry product

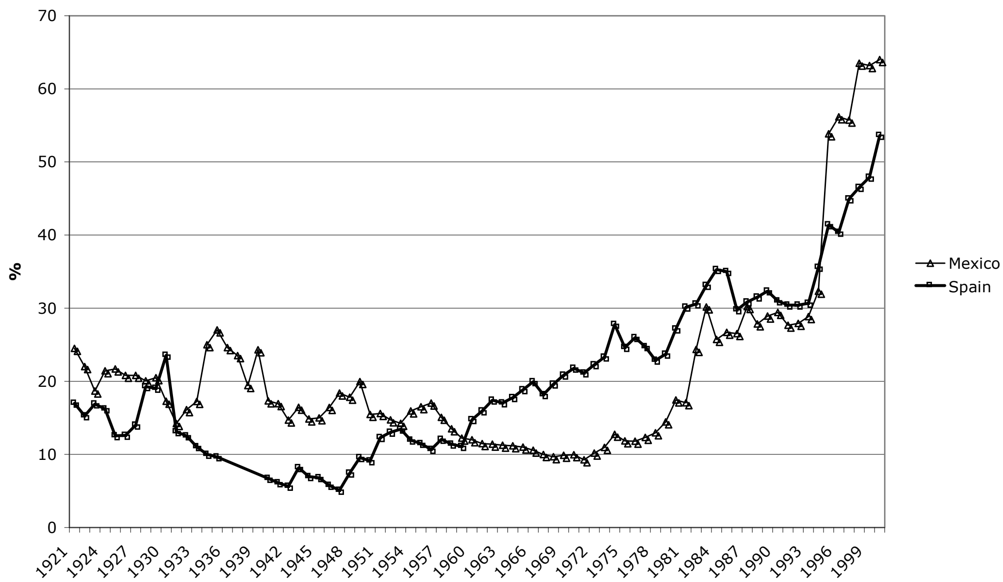
cuesta Industrial Anual, 1983; Encuesta Industrial Mensual Resumen, 1984; Encuesta Industrial Mensual, Resumen Anual, 1987, 1989; Encuesta Industral Anual, 1994-1996, 1998, 1999, 2000-2001, 2000, 2001-2002. Notes: From 1977 to 1983 the fractions considered include: hilado, tejido y acabado de algodón; fabricación de casimires, paños, cobijas y productos similares; fabricación de estambres; hilado, tejido y acabado de fibras artificiales. From 1987 to 1989: preparación de fibras blandas para hilado y tejido; fabricación de estambres; fabricación de casimires, paños, cobijas y productos similares; hilado, tejido y acabado de algodón; hilado, tejido y acabado de fibras artificiales.From 1994 to 2002: hilado de fibras blandas; fabricación de estambres de lana y fibras químicas; fabricación de telas de lana y sus mezclas; tejido de fibras blandas; acabado de hilos y telas de fibras blandas; hilado, tejido y acabado de fibras artificiales.

and labor demand. This in itself may have accounted for a 3%-4% decline in real wages on average (and for as much as 10%-14% decline in the more affected industries). Moreover, trade reform reduced the rents available to be captured by firms and workers. This had an additional negative effect on firm-level employment and wages.

The opening of the Mexican economy took many decades, but when it finally did open it occurred very quickly. This was not only the case for textile products (Table 1) but for the economy in general. Figure 2 compares the degree of openness of Mexico and Spain. While Spain opened up gradually through several decades, Mexico opened up its economy in only a decade. The different degrees of success that Spain and Mexico have had in the process of opening up their economies suggest that the timing and pace of opening could have important economic consequences. [3]

[3] Sources for Figure 2 are: México: Importaciones y Exportaciones 1950-1997 INEGI, "Estadísticas Históricas de México," Cuadro 18.1; 1998-2000 World Bank, "World Development Indicators 2004" Producción, INEGI, Banco de Información Económica, Serie Histórica del PIB.INEGI, Banco de Información Económica, página web. España: Importaciones y Exportaciones Antonio Tena, "Sector Exterior," en Estadísticas Históricas de España, cuadro 8.4, paginas 601-602, PIB Leandro Prados, "El Progreso Económico de España (1850-2000)," Apéndice K, Cuadro 2.

Figure 2. The Degree of Openess
Imports plus Exports as a Percetange of GDP



Several papers have addressed the question of why protectionist trade policies have failed to allow firms to reduce costs, which would eventually enable them to compete internationally. Their argument is based on the idea that governments are unable to credibly precommit to the unconditional elimination of protection, and thus protection generates a trade-off for the firm. "If during the program, the firm does not invest sufficiently in cost reductions, then it gains a renewal of future protection, and it saves the opportunity cost of capital. It loses, however, the benefits derived from cost reductions. If, at the margin, the gains are greater than the losses, then the firm will inevitably choose not to invest sufficiently" (Tornell, 1991). Temporary protectionist programs are thus "time inconsistent." Staiger and Tabellini (1987) have shown that an optimal trade policy may be time inconsistent, that a suboptimal but time-consistent policy involves an excessive amount of protection, and that when protectionist policies are time inconsistent tariffs may dominate production subsidies. Matsuyama (1990) has also found dynamic inconsistency of optimal temporary protection by examining whether or not there exists a sequence of credible government threats to liberalize in the future, which would induce the firms to invest as a subgame perfect equilibrium. Although such an equilibrium exists, it fails to pass the "renegotiation-proof" criterium, and thus time inconsistency results. Tornell (1991) shows that "investment-contingent subsidies" do not eliminate time inconsistency in protectionist programs. Wright (1995) shows the time inconsistency persists even when the firm effort and costs are publicly observable.

Our paper is in the line of the so called *The Political Economy of the Protectionism* (Hillman (1989)), since in our model the trade policy is endogenously determined by the interaction among some actors of the economy, in our case, the government, the industrials and unions. However, our model is neither a voting model, nor a pure lobbying model: Indeed, it is not an absurd hypothesis to assume that those political processes that lead to the conventions mentioned in the case of the Mexican textile industry were the result of pressures of some lobby groups, or at least in part. Or, in other words, in our model, the pressures of lobby groups are exogenous. (For papers in that line, see Grossman and Helpman (1994-1995a-1995b), or Hillman (1982)). We have chosen not to model endogenously those possible lobbying processes for three reasons: a) We do not expect essential changes in the results; b) To introduce that issue would complicate the model too much, but it would loose generality (we would be forced to focus on a particular form of lobbying); c) The histories that were the motivation of this paper — besides the proper interest of the issue —, are clearly understood under the light of our model as it is. For the same reasons, we have decided not to introduce political competition in the model.

There are, on the other hand, some recent papers that study the issue of protectionism under the possible existence of dumping effects, as for example Blonigen and Jee-Hyeong Park (2004), or Cheng, Qiu and Kit Pong Wong (2001), but in our model there is no dumping —foreign firms declare its true costs—, so antidumping policies are not a possible reason of protectionism.

Informally, we obtain the following results:

There are four possible situations that display a type of equilibrium in which the economy is opened at $t = 0$ and none of the firms installs the new technology, provided the gap between the new and the old technology is very large: 1) the government is very impatient; 2) the two firms are very impatient; 3) the legal-political costs of installing the new technology are too high; 4) expectations of bad results. The first three situations may be thought of as causes, literally, since we obtain propositions of the form 'if, then.' The fourth is another kind of proposition. It says, roughly, the following: Provided that the gap between the technologies is very large, whatever be the degree of patience of the agents and the legal-political costs, the situation in which the economy is opened at the outset and both domestic firms go bankrupt is a subgame perfect Nash equilibrium.

In contrast, in a case when the gap between the new and the old technologies is not very large, we have two types of equilibrium in which the economy is never opened and the firms, along the equilibrium paths, never adopt the new technology: 1) the two firms are very impatient; 2) the legal-political costs of installing the new technology are very high.

Finally, we have two situations in which the economy is kept closed until at least one of the domestic firms (the patient one) has totally installed the new technology: 1) given that the gap between the two technologies is very high, if the government is very patient and at least one of the domestic firms is patient enough; 2) given that the gap between the technologies is not very large, if at least one of the domestic firms is patient enough. (If both domestic firms are patient enough, both of them adopt the new technology.)

Notice that in the situation in which the gap between the two technologies is very large and the government and at least one of the domestic firms is patient enough, we have two equilibria: 1) when the agents have bad expectations and the firms do not adopt the new technology, and the economy is opened at the outset; 2) when the agents have good expectations and at least one firm—the patient one—adopts the new technology and the economy is opened at $t = n$.

The case of the Mexican textile industry can be interpreted in terms of our model if we consider that the legal and political costs of opening were too high for a long period. In that case, regardless of the degree of impatience of the government or firms, the firms chose not to adopt the new technology as a unique strictly dominant strategy, and the government decided not to open given that the gap between the old and the new technologies was not large enough. Given that as time went by the gap increased, a moment arrived when the gap was big enough for the government to lift protectionist barriers, even though that would cause the bankruptcy of the domestic firms. The same result would be obtained if the domestic firms were sufficiently impatient even if the political and legal costs were not very high and the government sufficiently patient, or if the government were too impatient. Thus, the bad performance of the Mexican textile industry could be explained either by the high legal and political costs of adopting the new technology, by the short-term vision of the domestic firms, or by the short-term vision of the government.

The different timing and pace of the opening up of the economy that Mexico and Spain experienced from 1950 to 2000 could be interpreted in terms of the model in the following way: Spain must have had more patient firms and government and lower costs of opening up the economy than Mexico had until 1985. The reason Mexico opened up so abruptly after 1985 must have been either because the gap between the old and the new technologies became too wide or because the government became suddenly too impatient. In the Spanish case, the slow opening-up process, or temporary protectionism, allowed many firms to adopt new technologies and eventually become able to compete (Carreras y Tafunell, 2004).

The rest of the paper is organized as follows. Section II lays down the model. Section III discusses the results of the model. Section IV presents a trivial generalization of the model and conjectures about the possible other equilibria than those we find, if the firms are neither very impatient nor very patient. Section V concludes. All proofs are given in the Appendix.

2 The model

The general setup.

Time is discrete, and the horizon is infinite. In the economy, at the outset, there are two firms, one impatient and one patient, characterized by their discount factors $0 < \beta^I < \beta^P < 1$, respectively. These two firms and the government are the players of the game. The government has a discount factor $0 < \beta^G < 1$ and chooses the moment the economy opens (formal definitions are coming). A foreign firm enters the market at the moment the government opens the economy. That firm owns a new technology, more advanced than the technology that the national firms own. This last actor in the economy can be introduced as a player having a similar strategies' space as the two national firms, which we define later. Nevertheless, after the game is formalized and the results presented, the strategy of the foreign firm will be transparent if it was introduced as a player, which introduction will offer no substantial gains but only notational complications: As long as the foreign firm has always positive benefits, if the government opens the economy, its strategy is to enter the market. One comment: We suppose that a firm can only face costs at each period if it sells strictly positive quantities, implying that the credits are too expensive so that it is not possible for the firms to buy the new technology. Another comment: Our model cannot be thought of as a standard repeated game, as stage by stage the game's pay-off structure changes. At the outset of the game, the economy is closed and the national firms do not have the new technology. However, depending upon the conditions of the market, they will be able to buy the new technology, according to the structure that we formalize below.

The Payoff Functions and Strategies

Informally, the game is such that, in each period $t \geq 0$, the two national firms choose to continue or not to continue with the technology used until the moment they are making their decisions and compete à la Cournot in each period. They will then maximize, at time zero, a discounted sum of the time-period profits according to the costs and the corresponding discount factors. We will define, then, an extensive game with perfect information and simultaneous moves (Osborne and Rubinstein, 1994). Formally, the set of players is $\{I, P, G\}$, where I stands for the impatient firm, P for the patient firm, and G for the government. Let the set $\{N, T\}$ be the set of the following actions: N stands for the action *"not to change the actual technology"*, and T stands for the action *"to change the actual technology."* That is, if a firm $i \in \{I, P\}$ at $t-1$ is facing costs according to some technology (the foreign or the national one), if that firm at t decides N, it means that it has decided —for this period t—to continue with the technology that it was using at $t-1$ and, logically, the action T means exactly the opposite. The government at each $t \geq 0$ decides to open or to close the economy. If the economy is already opened, to choose open means, simply, that the economy for this period is also opened, and the analogous clarification applies to the case when the economy is closed. Let us define the set $A^g = \{C, O\}$ where C means that the economy is closed and O means that the economy is open. The general set of histories H then is given as follows. First we define $A^f = \{N, T\} \times \{N, T\}$, $A^g = \{C, O\}$ then $H = \{\varnothing\} \cup \left\{ \left(a_t^f, a_t^G\right)_{t=0}^{t=\infty} \middle| (a_t^f, a_t^G) \in A^f \times A^g,\, t \geq 0 \right\}$. Now, given $h = (a_t)_{t=0}^{l=\infty} \in H$, we implicitly use the interpretation that, for any $a_t = (a_t^I, a_t^P, a_t^G)$, the first coordinate of the tuple (a_t^I, a_t^P, a_t^G) is the action chosen by the firm I at period t and, similarly, the second coordinate is the action chosen by the patient firm, and finally the decision of the government at that period. The player function $\tilde{P} : H \to \{I, P, G\}$ is given by $\tilde{P}(h) \in \{I, P, G\}$ for all $h \in H$. Therefore, the set of strategies for the player $i \in \{I, P\}$ is given by $S^i = S = \left\{ \{s_h\}_{h \in H} \,| s_h \in \{N, T\}, \text{ for all } h \in H \right\}$ and, $S^G =$

$\left\{\{s_h\}_{h\in H}\,|s_h \in \{C,O\}\,,\text{ for all } h\in H\;\right\}$. As in any game, given a profile of strategies $\left(s^I,s^P,s^G\right)\in S\times S\times s^G$, this pair determines a path that is actually played, according to those strategies, of the form $\left(\left(a_t^I,a_t^P,a_t^G\right)\right)_{t=0}^{\infty}$, with $a_t^i\in\{N,T\}$ for all $t\geq 0$ ($i\in\{I,P\}$), which in turn, logically, determines a sequence of costs and periods of openness of the form $(((C_t^I,C_t^P))_{t=0}^{\infty},(t_l)_{l\geq 0})$, where C_t^i is the cost faced by the firm $i\in\{I,P\}$ at time t, and $(t_l)_{l\geq 0}$ is uniquely defined as follows: $(t_l)_{l\geq 1}$ is a nondecreasing sequence such that for all $l\geq 1$ such that, if l is odd, then if $t_{l+1}>t_l$, then for all $t_{l+1}>t\geq t_l$ we have that $a_t^G=O$, and if l is even, then if $t_{l+1}>t_l$, then for all $t_{l+1}>t\geq t_l$ we have that $a_t^G=C$. We use the following convention: If $t_1=\infty$, it is a path such that the economy is never opened, and if $t_1=0\geq t_l$ for all $l>1$, then the economy is opened at $t=0$ and will continue opened forever: We use the notation $t_1=\bar{t}$ and $t_\infty=0$ for referring to that situation in which the economy is opened at $\bar{t}$ and continues open forever. Let us denote by $O((t_l)_{l\geq 0})=\{t\geq 0\,|t_{l+1}>t\geq t_l,\, l \text{ odd}\}$ and similarly $C((t_l)_{l\geq 0})=\{t\geq 0\,|t_{l+1}>t\geq t_l,\, l\text{ is even}\}$. Notice, more generally, that if $(t_l)_{l\geq 0}$ is a finite sequence, it means that the economy, from some $\bar{t}\geq 0$, is closed forever or opened forever. Now, if the profile of strategies $(s^P,s^I,s^G)\in S\times S\times s^G$ is such that the corresponding associated sequence of costs and periods of openness is given by $(((C_t^I,C_t^P))_{t=0}^{\infty},(t_l)_{l\geq 0})$, then the payoff function of the firm i is given by

$$\Pi^i(\left(s^i,s^j,s^G\right))=\left\{\begin{array}{l}\sum\limits_{t\in C((t_l)_{l\geq 0})}(\beta^i)^t\pi^i(C_t^i,C_t^j)+\\ \sum\limits_{t\in O((t_l)_{l\geq 0})}(\beta^i)^t\pi^i(C_t^i,C_t^j,C^F)\end{array}\right. \tag{1}$$

with $i,j=I,P$, where $\pi^i(C_t^i,C_t^j)$ is the Cournot profit of firm $i\in\{I,P\}$ at time t, if the respective costs for that period are C_t^i and C_t^j and with the economy closed and, similarly, $\pi^i(C_t^i,C_t^j,C^F)$ is the Cournot profit of firm i at time t, if the national firms face C_t^i and C_t^j and the foreign firm faces C^F, at periods with the economy opened.

We assume an inverse demand funtion $p:\Re_+\to\Re_+$ given by $p(Q)=\max\{a-Q,0\}$. Due to strictly technical reasons, and without loss of generality, we set $0<a\leq 1$.

For the government's payoff we present two possible scenarios, one that we call *a consumer oriented government,* and the other that we call *a utilitarist government.*

A Consumer Oriented Government

Take a profile of strategies $(s^P, s^I, s^G) \in S \times S \times S^G$ such that the corresponding associated sequence of costs and periods of openness are given by $\left(\left(\left(C_t^I, C_t^P\right)\right)_{t=0}^{\infty}, (t_l)_{l\geq 0}\right)$, then the payoff function of the consumer oriented government is given by

$$\Pi^G(\left(s^P, s^I, s^G\right)) = \begin{cases} \sum\limits_{t\in C((t_l)_{l\geq 0})} (\beta^G)^t \frac{\left(Q_T(C_t^P, C_t^I)\right)^2}{2} + \\ \sum\limits_{t\in O((t_l)_{l\geq 0})} (\beta^G)^t \frac{\left(Q_T(C_t^i, C_t^j, C^F)\right)^2}{2} \end{cases}$$

where $Q_T(\cdot)$ is the total quantity of the good in the market, and hence $\frac{1}{2}\left(Q_T(\cdot)\right)^2$ is the consumer's surplus at the corresponding period.

A Utilitarist Government

Take a profile of strategies $(s^P, s^I, s^G) \in S \times S \times S^G$ and take the corresponding associated sequence of costs and periods of openness given by $\left(\left(\left(C_t^I, C_t^P\right)\right)_{t=0}^{\infty}, (t_l)_{l\geq 0}\right)$, then the payoff function of the utilitarist government, if τ is the tariffs over the production of the foreign firm, is given by

$$\Pi^G(s^P, s^I, s^G)) = \sum_{t\in C((t_l)_{l\geq 0})} (\beta^G)^t \begin{cases} \left[\frac{1}{2}\left(Q_T(C_t^P, C_t^I)\right)^2\right] + \left[\sum\limits_{i\in\{I,P\}} \pi^i(C_t^i, C_t^j)\right] + \\ \left[\frac{1}{2}\left(Q_T(C_t^i, C_t^j, C^F)\right)^2\right] + \\ \left[\sum\limits_{i\in\{I,P\}} \pi^i(C_t^i, C_t^j, C^F) + \tau q^F(C_t^i, C_t^j, C^F)\right] \end{cases} \tag{2}$$

where $q^F(C_t^i, C_t^j, C^F)$ is the Cournot quantity offered by the foreign firm and $\beta^G \in (0,1)$: At each t the term in the sum is simply the standard felicity function of the society at that time used in welfare economics, that is, the consumer's surplus plus the profits of the firms.

Remark 1 *We have chosen to express the utilitarian function of the government in terms of tariffs over the production of the foreign firm. However, all our results can be proven if instead of $\tau q^F(C_t^i, C_t^j, C^F)$ we write $\tau(q^F(C_t^i, C_t^j, C^F))^2$, with minor quantitative changes in the formal conditions. Thus, we have a better interpretation of the utilitarian function we propose: Setting $\tau = 1$, the $\tau(q^F(C_t^i, C_t^j, C^F))^2$ is not another thing than the profits of the foreign firm, so we may think that the foreign firm has decided to install a plant in the country. In this last case, depending upon the society, there is*

no reason to treat a foreign firm in a different way than the domestic firms. In other words, it is not necessary to interpret τ as a measure of openness and, from this last point of view, $\tau = 1$ is the most natural value for that parameter.
Anyhow, one may want to search for the corresponding results when $\tau = 0$. It is intuitive, on the other hand, that the results cannot be other than the following: The economy is opened only if the gap between the technologies is very large and the government is very impatient or both domestic firms are very impatient. In order to not present a very large paper, we drop the formal presentation of those results.
Alternatively, all our results may be interpreted as an analysis of the influence over a decision of a society of reinforcing or not reinforcing protection of the three following factors: 1) the degree of patience of the agents; 2) the gap between the technologies; and 3) the legal-political constraints.

In order to be able to evaluate the payoff functions on any history in H, we need the following remark.

Remark 2 (payoffs' valuation) *If for a given profile of strategies $\left(s^I, s^P, s^G\right)$, the corresponding sequences of costs $\left(\left(C_t^I, C_t^P\right)\right)_{t=0}^{\infty}$ is such that a firm $i \in \{I, P\}$ produces no positive quantities (or, equivalently, if it does not have positive time-period profits consistent with our assumptions over the costs that we define below),*[4] *of the good for $t \geq \tilde{t}$ for some $\tilde{t} \geq 0$, then, a) We say that the corresponding firm shuts down and leaves the market at time $t = \tilde{t}$; b) Similarly, if a profile of strategies $\left(s^I, s^P, s^G\right)$ is such that for a firm $i \in \{I, P\}$, the strategy s^i prescribes at some t the adoption of the new technology, but the time-period profits were zero when the new technology was being adopted (we mean, from t on), then we say that the new technology is not active for that firm, that is, the corresponding firm does not have the real possibility to use the new technology, just because, in fact, it is not covering the costs. Therefore, in this last situation, we assume that if the corresponding firm decides once again to adopt the new technology in later periods, it will have to face the costs from the last one that was paid. Notice, however, both the definition in a) the assumption in b) are innocuous, implying no economic assumptions. In a), clearly, being a definition. In b), the point is given only in order to evaluate strategies—something unavoidable in proving the results—along histories in which the new technology was in principle*

[4]See our lemma 1 in the Appendix.

adopted, but it was not possible to cover the costs, nothing else. c) Finally, if a firm has installed the new technology, but at some moment it decides to use the old one, anyway, if it needs to use the new one later, it does not have to pay again the costs of installing it.
Finally, when we say that a firm decides to use the new technology at a given time t, we assume that at t it is paying the lower cost not paid until t.

The Costs

The firms may use the extant national technology, characterized by its constant marginal cost C^N in each period, or they may adopt the new foreign technology, characterized by C^F, which is the cost that the foreign firm that owns it has to face. If the national firms want to adopt the new technology, they still have to face not only C^F but also some additional economic and political constraints costs, which are described below.

- *The economic costs*
  The extra economic costs are exogenously given and defined by a decreasing finite sequence C_0^e, C_1^e,...,C_n^e ($C_t^e > C_{t+1}^e$ for all $0 \leq t \leq n-1$), where C_n^e is a permanent cost that the national firm adopting the new technology may have to pay to the owner of said technology. In this way, we capture the idea that at the beginning the economic costs are high but decrease over time until stabilizing at the level C_n^e, which may represent the royalty paid to the owner of the foreign technology; in any case, C_n^e may be zero as well, which certainly is the simplest case.[5] Hence, if at $t = \bar{t}$ the new technology is adopted, the economic costs paid by the firm from that moment are $C_{\bar{t}\ +t} = C^F + C_t^e$ for all $0 \leq t \leq n$, and the firm faces $C^F + C_n^e$ from $t = \bar{t}\ +n$; that is, $C_t = C^F + C_n^e$ for all $t \geq \bar{t}\ +n$. In other words, if the foreign technology is adopted at $t = \bar{t}$, the sequence of costs that the firm faces is given by $(C_t)_{t=0}^{\infty}$, where $C_t = C^N$ for all $0 \leq t < \bar{t}$, $C_t = C^F + C_{t-\bar{t}}^e$ for all $\bar{t} \leq t < \bar{t} + n - 1$, and $C_t = C^F + C_n^e$ for all $t \geq \bar{t} + n$.
  The time length n is the number of periods that a national firm needs to completely install the new technology, that is, the number of periods

[5] An alternative interpretation for the permanent cost C_n^e can be given: The owner of the technology is the person who produces it, and only this person. Therefore, C_n^e may represent his profits, if we understand that he is selling not the new technology but the strategic elements to use it. These elements cannot be produced by anyone but the owner; thus, the buyer cannot develop that new technology.

needed in order to have the new technology at its lower cost, which is $C^F + C^e_n$. It is reasonable to think of these costs as decreasing, since normally installing a new technology causes some exceptional costs at the beginning, but then the costs are lower. We assume that $n > 0$. If $n = 0$, the two firms install the new technology at $t = 0$, and there is no trade-off between to install or not to install (provided the legal-political costs are not too high; see the next point) the new technology.

- *The legal-political constraint costs*

  We do not model the political process that leads to the assignment of collective contracts that hindered the firms from adopting new technology. We simply assume the existence of some costs that are legally imposed over a firm if it decides to adopt a foreign technology, whose imposition is a consequence of conventions between unions and firms. We call those costs *political constraints costs*, which are exogenously given and defined by a possibly infinite sequence $(C^p_t)^l_{t=0}$ $(l \leq \infty)$ —to endogenize those costs is an issue itself, left for future research—. Each C^p_t represents the extra cost that the firm has to pay if it adopts the new technology at time t, but once and for all, due to, for instance, the fact that the firm may have to dismiss some workers who are not useful anymore. These costs depend on negotiations between the firms, the government, and the trade unions. The more powerful the trade unions are, the larger these costs will be. It would be reasonable to assume that those costs are increasing because as the gap between the domestic and the foreign technology widens it is likely that more workers will be redundant when the foreign technology is adopted. Nonetheless, without that assumption, the model can be used to assess situations under which those costs can become constant or even decreasing —at least temporarily— as is the case in some countries in Europe, like Spain, for example.

- *Technical assumptions*

Some fundamentals of the economy satisfy the following general conditions:[6]

[6] In order to see the formal expresion from which we drew the assumptions' interpretations, we refer to the lemma 1 in the Appendix.

A1 $C^N < a$.

This is the minimal hypothesis to assume in order to make sensible the maximization problem of the firms: It simply implies that it is possible to produce positive quantities of the good.

A2 $a - C^N \leq \frac{a-C^F}{2}$

This means that the foreign technology not only is more efficient than the national one but also that the national one is not competitive, in the sense that it can only produce zero quantities of the good if it competes face to face with the foreign technology. Notice that A2 implies that $C^F < C^N$.

A3 A3.1) $C^N < C^e_t + C^F < a$ for all $0 \leq t \leq n-1$; A3.2) $\frac{a+C^N}{2} > C^e_0 + C^F$; and A3.3) $\frac{C^F+a}{2} > C^e_n + C^F$.

This assumption captures the following idea: The new technology is more costly–but not too costly–than the national one at the beginning (A3.1), it can be installed (A3.2) but, at some moment, once it is completely installed, it becomes not only more efficient than the national one but also, if it is used by the two national firms, it is capable of producing positive quantities even when the economy is already opened (A3.3). Notice that A2 and A3.1 imply that $a - (C^e_t + C^F) < \frac{a-C^F}{2}$ for all $0 \leq t \leq n-1$ and, hence, we will have it that the only way to survive, after the economy is opened, is to have the new technology completely installed. Also, observe that A2 and A3.3 imply that $C^N > C^e_n + C^F$.

Therefore, the extensive game with perfect information that resumes our model is given by $\Gamma = \left\langle \{I, P, G\}, H, \tilde{P}, (\Pi^i)_{i\in\{I,P,G\}} \right\rangle$.

3 The Results

For the sake of the exposition, we first give the intuition of a result and then we announce formally the corresponding theorem. In this section, no proofs are presented. All formal proofs are given in the Appendix.

The first result responds to the following intuition. If the political constraints costs are too high—this is formally expressed by the condition $a - (C^e_0 + C^F) < C^p_t$ for all $t \geq 0$—the firms will never choose to adopt the new technology, simply because they do not have the possibility to afford the initial costs of installing the new technology. If that is the case, there are only two possible market structures at each time: A duopoly with the two national firms with the old technology, or a monopoly with the foreign firm. Depending on which of them is more efficient and therefore allows for better welfare of the society, it will be the choice of the government. We have then the following two possible equilibria:[7] a) If the old technology is too inefficient in relation to the foreign technology, which is formally expressed and quantified by the conditions $\frac{1}{2}(\frac{a-C^F}{2})^2+(\frac{a-C^F}{2}) > \frac{4}{9}(a-C^N)^2$ and if the government is utilitarist (a similar condition is obtained if the government is consumer oriented), then the economy is opened at $t=0$ and none of the firms survives, this situation being a subgame perfect Nash equilibrium; b) In the other case, that is, if the gap between the national and the foreign technology is not too large, which is formally expressed and quantified by the condition $\frac{4}{9}(a-C^N)^2 > \frac{1}{8}(a-C^F)^2+(\frac{(a-C^F)}{2})$ and if the government is utilitarist, and a similar condition appears if the government is consumer oriented, then the economy is never opened, and both national firms never adopt the new technology and survive forever, this situation also being a subgame perfect Nash equilibrium. All of this is independent of the firms' degree of impatience.

A very important result, and very intuitive, is that, given that the gap between the technologies is very large, if we have $a-(C_0^e+C^F) < C_t^p$ for all $t \geq 0$ or both of the domestic firms are very impatient, the equilibrium found is unique—the intuition of the uniqueness is quite clear: The firms always choose never to adopt the new technology, which is a strictly dominant strategy, and hence the government has a strictly dominant response to those strategies, given the market structure. But, even if the political constraints are favorable for the adoption of the new technology, if the government is too impatient or the two domestic firms are very impatient, the same equilibria appear, that is, depending upon the relation between the new and the old technology, the government opens the economy at $t=0$, or never opens the economy.

The degree of patience of the firms and the government also plays a fundamental role in the appearance of the possible equilibria of the model.[8]

[7] Here and in the Appendix we assume that $C_n^e=0$, just for simplicity. Replacing the condition $C_n^e=0$ for C_n^e *small enough* ($C_n^e \to 0$), then all our results hold.

[8] As will be clear from the proofs, for the equilibria in which the firms adopt the new technolgy, it is necessary, in principle for them to have a high degree of patience. We conjecture that it is possible to find an expresion of a limit value for the discount factor

As we said in the introduction, in essence, what we obtain is the following:

There are four possible situations that display a type of equilibrium in which the economy is opened at $t = 0$ and none of the firms installs the new technology, provided the gap between the new and the old technology is very large: 1) the government is very impatient; 2) the two firms are very impatient; 3) the legal-political costs of installing the new technology are too high; and 4) bad expectations. The first three situations may be thought of as causes, literally, since we obtain propositions of the form "if, then." The fourth is another kind of proposition. It says, roughly, the following: Provided that the gap between the technologies is very large, whatever is the degree of patience of the agents and the legal-political costs, the situation in which the economy is opened at the outset and both domestic firms go bankrupt is a subgame perfect Nash equilibrium.

In contrast, when the gap between the new and the old technology is not very large, we have two types of equilibria in which the economy is never opened and the firms, along the equilibrium paths, never adopt the new technology: 1) if the two firms are very impatient; 2) if the legal-political costs of installing the new technology are very high.

Finally, we have two situations in which the economy is kept closed until at least one of the domestic firms (the patient one) has totally installed the new technology: 1) given that the gap between the two technologies is very high, if the government is very patient and at least one of the domestic firms is patient enough; 2) given that the gap between the technologies is not very large (a stronger version of this statement), if at least one of the domestic firms is patient enough. (If both domestic firms are patient enough, both of them adopt the new technology.)

Notice that in the situation in which the gap between the two technologies is very large and the government and at least one of the domestic firms is patient enough, we have two equilibria: 1) when in the economy the agents have bad expectations, the firms do not adopt the new technology, and the economy is opened at the outset; 2) when in the economy the agents have good expectations, at least one firm—the patient one—adopts the new technology, and the economy is opened at $t = n$.

In the case of the utilitarian function of the government, the equilibria pass the renegotiation proof criterion trivially, since the very definition of that

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such that from that value the firm is patient, otherwise impatient (see section 4.2). We leave this for future research.

utilitarian function entails that in each period the government is maximizing the utility of all the agents, including the foreign firm.

In all the results that follow, when the condition $a-(C_0^e+C^F)<C_t^p$ for all $t\geq 0$ is not required, it is implicit that the condition prevailing is $a-(C_0^e+C^F)>C_t^p$ for all $t\geq 0$ —as we commented in due time, we do not analyze the other situation in which none of the preceding conditions hold.

Formally:[9]

Theorem 1 *Assume the government is utilitarist with τ large enough (close to one). Then:*
(1.1) If $C^F\leq -\frac{72}{11}+a$ (the new technology is very efficient) and $\frac{1}{8}(a-C^F)^2+(\frac{a-C^F}{2})>\frac{4}{9}(a-C^N)^2$ (the gap between the domestic technology and the new technology is very large), then:
(1.1.1) If the government is very impatient and the two national firms are very patient, then there is a subgame perfect Nash equilibrium, given by $(s^P,s^I,s^G)=\left(\{s_h(N,1)\}_{h\in H},\{s_h(N,1)\}_{h\in H},s^G(0)\right)$, where, given $h_t=\left((a_l^I,a_l^P,a_l^g)\right)_{l=0}^t\in H$, $s_{h_t}(N,1)$ prescribes to use the domestic technology, unless the new technology can be totally installed at $t+1$ or, at $t+2$ (that is, the firm has paid all the costs of the new technology but C_n^e, but C_{n-1}^e and C_n^e and the economy is closed at $t+1$), and $s^G(0)$ is such that $s^G(0)\left(h_t\right)=O$ for all $h_t=\left((a_l^I,a_l^P,a_l^g)\right)_{l=0}^t\in H$. Furthermore, $s^G(0)$ is a strictly dominant strategy.[10]
(1.1.2) If the government is very impatient and the two national firms are very impatient, then $\left(\{s_h(N,2)\}_{h\in H},\{s_h(N,2)\}_{h\in H},s^G(0)\right)$ is a subgame perfect Nash equilibrium, where $\{s_h(N,2)\}_{h\in H}$ prescribes to use the domestic technology, unless the new technology can be totally installed at $t+1$. Furthermore, if a firm is very impatient, then $\{s_h(N,2)\}_{h\in H}$ is a strictly dominant strategy.
(1.1.3) If the government is very impatient and only one firm is very impatient, then $\left(\{s_h(N,1)\}_{h\in H},\{s_h(N,2)\}_{h\in H},s^G(0)\right)$ is a subgame perfect equilibrium. $\{s_h(N,1)\}_{h\in H}$ is adopted by the patient firm and $\{s_h(N,2)\}_{h\in H}$ is adopted by the impatient firm.
(1.1.4) If the two domestic firms are very impatient, but the government is very patient, then $\left(\{s_h(N,2)\}_{h\in H},\{s_h(N,2)\}_{h\in H},s^G(0)\right)$ is a subgame perfect Nash equilibrium.

[9] Recall that the market structure at the outset is that the two national firms have not paid any cost of the new technology.

[10] Notice that if $(C^N,C^F)\to(a,0)$, the two conditons of this item are satisfied.

(1.1.5) If $a - (C_0^e + C^F) < C_t^p$ *for all* $t \geq 0$*, then whatever be the degree of patience of the agents,* $\left(\{s_h(N,2)\}_{h\in H}, \{s_h(N,2)\}_{h\in H}, s^G(0)\right)$ *is a subgame perfect equilibrium*
(1.1.6) Whatever be the degree of impatience of the agents and the gap between the technologies and the legal-political costs, $\{s_h(N,2)\}_{h\in H}$ *is a best response of* $s^G(0)$ *and, reciprocally,* $s^G(0)$ *is a best response of* $\{s_h(N,2)\}_{h\in H}$ *— therefore,* $\left(\{s_h(N,2)\}_{h\in H}, \{s_h(N,2)\}_{h\in H}, s^G(0)\right)$ *is always a subgame perfect equilibrium.*
(1.2) If $\frac{4}{9}(a - C^N)^2 > \frac{1}{8}(a - C^F)^2 + (\frac{(a-C^F)}{2})$ *(the gap between the domestic technology and the new technology is not too large), then :*
(1.2.1) Whatever be the degree of patience of the government, if both of the domestic firms are very impatient, then there is a subgame perfect Nash equilibrium, given by $\left(s^P, s^I, s^G\right) = \left(\{s_h(N,2)\}_{h\in H}, \{s_h(N,2)\}_{h\in H}, s^G(\infty)\right)$*, where* $\{s_h(N,2)\}_{h\in H}$ *is such that* $s_h(N,2) = N$*, if* $h_t = \left((a_l^I, a_l^P, a_t^G)\right)_{l=0}^t \in H$ *is such that the technology that was in use at* t *was the national one, unless the new technology can be totally installed at* $t+1$*, and* $s^G(\infty)$ *is given by* $s^G(\infty)(h_t) = O$ *for all* $h_t \in H$ *such that at least one of the domestic firms can have the new technology totally installed at* $t+1$*, otherwise* $s^G(\infty)(h_t) = C$*.*
(1.2.2) If it happens that $a - (C_0^e + C^F) < C_t^p$ *for all* $t \geq 0$ *(the legal-political costs are too high) then, whatever be the degree of impatience of the agents,* $\left(\{s_h(N,2)\}_{h\in H}, \{s_h(N,2)\}_{h\in H}, s^G(\infty)\right)$ *is a subgame perfect equilibrium.*

The following two comments are in order:

First, notice that when the gap between the technologies is very large, we have presented equilibria for all the combinations of the degree of patience of the agents, and in all those situations the economy is opened at the outset and both domestic firms go bankrupt. Nevertheless, the different items reflect the different possible causes of that situation. In the items (1.1.1)-(1.1.3), the cause is the impatience of the government. In (1.1.4) the cause is the impatience of the two domestic firms. In (1.1.5) the cause is that the legal-political costs are very large. However, item (1.1.6) is a very striking one: Even in the case when the firms and the government are very patient, that situation may be an equilibrium, in which the economy is opened at the outset and both domestic firms shut down. It represents a clear example of a sentence of the type "bad expectations may cause bad outcomes."It is pertinent to wonder if there is in our model also an example of the other type of sentence: "Good expectations may cause good outcomes." Theorem

3 below says that this is the case, that is, if the two domestic firms (or only one) and the government are very patient, even if the gap between the two technologies is very large —in fact, whatever be that gap— the economy is only opened after the two (or only one) domestic firms have the new technology totally installed, and the welfare of the society, after that moment ($t = n$), is better than when the economy is never opened. In theorem 3 we also present the other possible equilibria of the model. Because of expositional reasons, we present those results separately.

Second, notice that when the gap between the technologies is not very large, we have found equilibria for all the combinations of the degree of the agents, but the cases when the government is either patient or impatient and at least one of the domestic is patient enough. As before, the results for those cases are shown separately in theorem 3. Essentially, we will obtain the result that, if there is patience, the economy is opened once the domestic patient firms have totally installed the new technology.

We obtain similar result if the government is consumer oriented.

Theorem 2 *Assume the government is consumer oriented. Then, if in theorem 1 we replace the condition* $\frac{1}{8}(a - C^F)^2 + (\frac{a-C^F}{2}) > \frac{4}{9}(a - C^N)^2$ *(the gap between the domestic technology and the new technology is very large) for* $\frac{1}{8}(a-C^F)^2 > \frac{4}{9}(a-C^N)^2$ *and the condition* $\frac{1}{8}(a-C^F)^2+(\frac{a-C^F}{2}) < \frac{4}{9}(a-C^N)^2$ *(the gap between the domestic technology and the new technology is not very large), the same equilibria as in theorem 1 exist.*

For future reference, when we say the item (2.1) or (2.2) (or also, (2.1.1), etc.), we will be referring to the analogous result to the one in theorem 1. For instance, when we say the item (2.1.1), we are referring to the equilibrium $(s^P, s^I, s^G) = \left(\{s_h(N,1)\}_{h\in H}, \{s_h(N,1)\}_{h\in H}, s^G(0)\right)$, in the case of the consumer oriented government, the one obtained in the item (1.1.1), in the case of theorem 1.

Some comments are in order.

In all the results given so far, both firms essentially choose the same strategy, in which they do not adopt the new technology. In (1.1) and (2.1), the economy is operating with an efficient technology, at the cost of having the domestic industry shutting down. In (1.2) and (2.2), the economy has two national firms operating forever, at the cost of having an inefficient technology but perhaps not too inefficient.

The last results of this paper are the equilibria found when the government is very patient, and at most only one firm is very patient.

As one may have expected, the firms' strategies are not the same in all situations. That is, a patient firm has a different strategy if the other firm is an impatient one than if the other firm is a patient one. When both firms are patient, both decides on the same strategy, which is, roughly, as follows: A firm adopts the new technology at $t+1$ only if it has paid at least the same number of costs of the new technology as the other firm, otherwise it adopts the old technology. In the second situation, when only one is a patient firm, that one always decides to adopt the new technology, and the impatient firm never adopts the new technology unless at $t+1$ that firm can have totally installed the new technology, that is, it adopts $\{s_h(N,2)\}_{h\in H}$.

Formally. Given $h = (a_l)_{l=0}^{l=t} \in H$, denoting by $((C_l^I, C_l^P)_{l=0}^{l=t}$ the corresponding costs paid by the firms, define the set

$$\wp(i,h) = \left\{ l \in \{0,..,n-1\} \;\middle|\; \begin{array}{c} \exists k \leq t, \text{ such that, } a_k^g = C \\ C_k^i = C_l^e + C_k^p + C^F \text{ if } l = 0 \\ C_k^i = C_l^e + C^F \text{ if } l \neq 0 \text{ and} \\ \pi_k^i(C_k^i, C_k^j) > 0. \end{array} \right\} \text{ and let}$$

$C(i,h) = |\wp(i,h)|$ its cardinality. Simply, $C(i,h)$ is the number of costs of the new technology that the firm i has indeed paid along the history h (notice that if even the economy is closed, the other domestic firm may have had the new technology totally installed before t). We define $\{s_h(T,1)\}_{h\in H}$ as follows: If $h \in H$ is such that $C(i,h) = n$ or $C(i,h) < n$ and $C(i,h) \geq C(j,h)$, with $j \neq i$, then $s_h(T,1) = T$ if the technology used at t was the old one, and $s_h(T,1) = N$ if the technology used at t was the new one; but, if $C(i,h) < n$ and $C(i,h) < C(j,h)$, then $s_h(T,1) = N$ if the technology used at t was the old one, and $s_h(T,1) = T$ if the technology used at t was the new one.

On the other hand, define $\{s_h(T,2)\}_{h\in H}$ as follows: $s_h(T,2) = T$ if the technology used at t was the old one, otherwise $s_h(T,2) = N$.

The theorem.

Theorem 3 *Assume that the government is utilitarist with τ close to one, or it is consumers oriented. Then:*
3.1) Assume that the gap between the technologies is very large, the government and both domestic firms are patient enough, then, $(s^P, s^I, s^G) = \left(\{s_h(T,1)\}_{h\in H}, \{s_h(T,1)\}_{h\in H}, s^G(n)\right)$ is a subgame perfect equilibrium where, given $h = \left((a_l^I, a_l^P, a_l^g)\right)_{l=0}^{t} \in H$, $s^G(n)(h) = C$ if none of the firms can have the new technology totally installed at $t+1$, otherwise $s^G(n)(h) = O$.
3.2) Assume that the gap between the technologies is very large, the government is patient enough, one firm is patient enough (P) and the other is very

impatient (I), then $(s^P, s^I, s^G) = \big((\{s_h(T,2)\}_{h\in H}, \{s_h(N,2)\}_{h\in H}, s^G(n)\big)$ *is a subgame perfect equilibrium.*
3.3) Assume that $\frac{4}{9}(a-(C^F+C_0^e))^2 > \frac{1}{8}(a-C^F)^2 + (\frac{(a-C^F)}{2})$ *if the government is utilitarist or* $\frac{4}{9}(a-(C^F+C_0^e))^2 > \frac{1}{8}(a-C^F)^2$ *if the government is consumer oriented (a stronger version of "the gap between the technologies is not very large"), the government is either patient or impatient, and both domestic firms are patient enough, then* $(s^P, s^I, s^G) = \big((\{s_h(T,1)\}_{h\in H}, \{s_h(T,1)\}_{h\in H}, s^G(n)\big)$ *is a subgame perfect equilibrium.*
3.4) Assume that $\frac{4}{9}(a-(C^F+C_0^e))^2 > \frac{1}{8}(a-C^F)^2 + (\frac{(a-C^F)}{2})$ *if the government is utilitarist, or* $\frac{4}{9}(a-(C^F+C_0^e))^2 > \frac{1}{8}(a-C^F)^2$ *if the government is consumer oriented (the strongest version of "the gap between the technologies is not very large"), the government is either patient or impatient, one firm is patient enough (P) and the other is very impatient (I), and the gap between the technologies is not very large, then* $(s^P, s^I, s^G) = \big((\{s_h(T,2)\}_{h\in H}, \{s_h(N,2)\}_{h\in H}, s^G(n)\big)$ *is a subgame perfect equilibrium.*

Notice that in the items (3.1) and (3.2) of theorem 3 there are not any assumptions over the relative efficiency between the technologies. That is, those results hold both assuming that the gap is too large and assuming the contrary. Also, notice the sharp contrast between the results in the items (3.3) and (3.4) of theorem 3 and the items (1.2.1) and (2.2.1) of theorems 1 and 2: In the first ones, after the adoption of the new technology of the patient firm, the economy is opened, and in the second set of items, the economy is closed and none of the firms has adopted the new technology, so that, after $t = n$, in the first situation the economy is in a better welfare situation than in the second situation: Indeed, in the first situation, there are in the market, after $t = n$, three firms with the new technology, and in the second situation there are only two firms with the old technology.

Finally, notice that, except for non-extreme values of the discount factors, we have shown equilibria for all the possible situations. That is, we have shown equilibria for all the possible combinations among the extreme values of the parameters—very large, or very low— the condition over the relative efficiency between the technologies, and the two extreme situations in relation to the legal-political costs.

In principle, we expect that other equilibria may exist. In the next section, we comment with more detail on the possible existence of other equilibria.

4 Generalizations and other possible equilibria

4.1 Generalizations

We have explicitly chosen to show how the model works if we assume that in each period the firms compete à la Cournot under the simplest situation in which the inverse demand function is linear. Also, concomitantly with that setup, we expressed in quantitative terms some conditions that are in essence qualitative conditions, namely: "the gap between the new technology and the old one is very large," "the new technology is very efficient," "the legal-political costs are too high," and others. It is intuitive, and clear from the proofs, that all those quantitative expressions may be replaced by qualitative ones consistently chosen with a more general setup in relation to the type of the firms' competition in each period. The three fundamental requirements to make in relation to the market structure are the following: 1) For the firms it is not good—lower profits—if more firms enter the market; 2) New inversions make present profits to decrease but increase future profits; 3) If a firm enters the market with a much better technology than the another firm is using, without new inversions the latter firm will have to shut down.

Also, due to this trivial generalization in relation to the firms and the structure of the market, we may generalize even more about the instantaneous utility function of the government. The two key requirements for that utility function are the following: 1) The larger the number of firms competing in the market, the larger is the society's instantaneous utility; 2) The better is the technology used in the industry, the larger is the society's instantaneous utility.

Once we assume those requirements, we will obtain the equilibria with our explicit assumptions, that is, depending upon the agents' degree of patience, the gap between the new technology and the domestic one, and the legal-political costs, the economy is opened or not, the government protects or not, and the firms adopt the new technology or not.

4.2 Other possible equilibria

As noted in the final remark of the last section, our results assume extreme values of the discount factors, that is, very close to one, or very close to zero. On the other hand, we assume relative efficiency between the technologies, extreme conditions, that is, the gap is very large or is not very large, but assuming strict inequalities. Given the assumed conditions, we have made an exhaustive analysis, as noted in due time.

Nevertheless, some issues in relation to the appearance of other equilibria are open.

We are not sure about what the result could be if we allowed for intermediate values of the agents' discount factors. We have the intuition that the payoffs both for the firms and the government are monotonic, in the sense that a limit value may exists for the discount factors such that above the given value the strategy is one (the agent very patient), and below the given value the strategy is another thing (the agent is very impatient), given the conditions of the game and the strategies of the other agents. That is, we conjecture that the classification of the agents as very patient and very impatient is binary. Also, the issue is open of what we would be the results if we allowed for equality over the relative efficiency between the technologies.

Also, we recall that in relation to the legal-political restrictions we assumed two extreme expressions, which are $a - (C_0^e + C^F) > C_t^p$ for all $t \geq 0$ and $a - (C_0^e + C^F) < C_t^p$ for all $t \geq 0$.

Finally, even with the conditions assumed, is still an issue the uniqueness of the equilibria under the assumed conditions.

We leave the study of these issues for future research.

5 Conclusions

The model developed in this paper offers a new point of view on the issue of temporary protectionism. In a similar way to Staiger and Tabellini (1987), Matsuyama (1990), and Tornell (1991), we ask if temporary protection could be time consistent and induce firms to modernize and become capable to eventually compete internationally, but in contrast with those papers we find that temporary protection can be not only time consistent but also part of a subgame perfect strategy. Additionally, we offer new reasons why a government may decide to open or not open the economy and when. The key variables to the model are the degree of patience of the firms and of the government, the gap between the domestic and foreign technologies, the political and economic costs of adopting the new technologies, and the expectations. As expected, if the political and economic costs of opening the economy are too high, firms never adopt the new technology, and an impatient government will not open the economy until the gap between the domestic and foreign technologies becomes very large. On the other hand, even if the gap is large, a patient government may decide to give firms time to modernize. If the firms are patient enough, they will invest in new technology and take advantage of this time to become competitive. However if the firms are impatient, they will never modernize, independent of government behavior. Finally, bad expectations may cause a bad equilibrium, in which the economy is opened at the outset and widespread bankruptcies follow.

The case of the Mexican textile industry described in the introduction becomes intelligible with this model. Long-term protection was useless to developing a competitive industry because a combination of high political and economic costs to modernizing and a high degree of firm impatience, did not allow firms to adopt new technologies. Apparently, the impatient government opened up the economy suddenly when the gap between the domestic and new technologies was too big, and at that moment a large number of those firms went bankrupt. However, the model does not consider this as the only possible consequence of protectionism. Lower political and economic costs combined with more patience on the part of firms could have produced firms that could have competed internationally once the economy was opened up, a result that contrasts with those of Tornell (1991). We give in this paper an answer to the contrast between the Spanish and the Mexican opening up of their economies, both in terms of their timing and of their consequences, and suggest the need of more empirical studies on the comparison of the different degrees of success or failure of temporary protectionism.

Finally, as a by-product the model represents a theoretical and formal example of the following well-known idea: The degree of patience may be the key variable to development, as commented on the end of section 3.

6 Appendix

First, we recall some well-known results in relation to Cournot Competence.

Lemma 1 *Suppose that the inverse demand function is given by* $P(Q) = a - Q$. *Then*
a) If there are two firms facing constant marginal costs C^1 *and* C^2 *that compete à la Cournot, and* $a - C^i > 0$ *for* $i = 1, 2$, *then if* (q^1, q^2) *denotes the*

Nash equilibrium, we have

$$\left(q^k\right)_{k\in\{1,2\}} = \begin{cases} q^i = \frac{a-2C^i+C^j}{3} \text{ if } a-C^i > \frac{a-C^j}{2} \text{ for } i,j\in\{1,2\}\,,\ i\neq,j \\ q^i = \frac{a-C^i}{2}, q^j=0, \text{ if } a-C^j \leq \frac{a-C^i}{2} \text{ for } i,j\in\{1,2\}\,,\ i\neq,j \end{cases},$$

and the Cournot profits of the firm $i\in\{1,2,3\}$ *are given by* $\pi^i(C^i,C^j)=\left(q^i\right)^2$ *for* $i=1,2$*; and*

b) If there are three firms facing constant marginal costs C^i *with* $i=1,2$ *and* 3 *that compete á la Cournot, then if* $\left(q^k\right)_{k\in\{1,2,3\}}$ *denotes a Nash equilibrium, we have that*

$$\left(q^k\right)_{k\in\{1,2,3\}} = \begin{cases} q^i = \frac{a-3C^i+\sum\limits_{j\neq i} C^j}{4} \text{ if } a-C^i > \sum\limits_{j\neq i}\frac{(a-C^j)}{3}, \text{ for } i\in\{1,2,3\} \\ \left\{\begin{array}{l} q^i=0,\ q^j=\frac{a-2C^j+C^k}{3},\ \text{ if } a-C^i\leq\sum\limits_{j\neq i}\frac{(a-C^j)}{3} \\ \text{and } a-C^j > \frac{a-C^k}{2} \text{ for } j,k\in\{1,2,3\}\setminus\{i\}\,,\ j\neq k, \end{array}\right\}_{i\in\{1,2,3\}} \\ \left\{q^i=\frac{a-C^i}{2}, q^j=0 \text{ for } j\neq i,\ \text{if } \frac{a-C^i}{2}\geq a-C^j \text{ for } j\neq i\right\}_{i\in\{1,2,3\}} \end{cases};$$

the Cournot profits of the firm $i\in\{1,2,3\}$ *are given by* $\pi^i(C^i,C^{-i})=\left(q^i\right)^2$.

Proof: Routine and omitted.

For all the proofs we will use the one-stage deviation principle for discrete-infinite-horizon games (theorem 4.2, in Fudenberg and Tirole (2002)). As we comment in due time, our game, as far as we can see, cannot be thought of as a repeated game and thus no techniques used in those types of games are applicable.

We will prove in detail all the results, especially those that we think are clear from the preceding arguments. Also, in order to make the exposition as short as possible, all the items of theorems 1 and 2 are proven, when possible, in one shot. That is, as we are making the arguments, we will be pointing out when an argument applies to another item and then when the corresponding result is proven. Only the most obvious proofs are dropped. We do it in that manner because arguments are common. Only theorem 3 is a little bit different, mainly because at least one domestic firm, a patient one, adopts the new technology, and the government is patient enough to give time to a patient firm to adopt the new technology.

1 Proof of theorems 1 and 2

Following Osborne and Rubinstein (1994), we introduce the following notation. Given the extensive game form with perfect information $\Gamma = \left\langle \{I, P, G\}, H, \tilde{P}, (\Pi^i)_{i\in\{I,P\}} \right\rangle$, if $\tilde{h} = \left((a_l^I, a_l^P, a_t^G)\right)_{l=0}^t \in H$, then $\Gamma(\tilde{h}) = \left\langle \{I, P, G\}, H|_{\tilde{h}}, \tilde{P}\Big|_{\tilde{h}}, (\Pi^i|_{\tilde{h}})_{i\in\{I,P,G\}} \right\rangle$ will denote the subgame of Γ that follows the history $\tilde{h}$, where $H|_{\tilde{h}}$ is the set of sequences h' of actions for which $\left(\tilde{h}, h'\right) \in H$, $\tilde{P}\Big|_{\tilde{h}}$ is defined by $\tilde{P}\Big|_{\tilde{h}}(h') = \tilde{P}(\tilde{h}, h')$ for each $h' \in H|_{\tilde{h}}$ and $\Pi_r^i|_{\tilde{h}}$ is defined by h' is at least as good as h'' if and only if $(\tilde{h}, h')$ is as good as $(\tilde{h}, h'')$. Similarly, given a strategy s, $s|_{\tilde{h}}$ will denote the strategy that s induces in the subgame $\Gamma(\tilde{h})$, that is, $s|_{\tilde{h}}(h') = s\left(\tilde{h}, h'\right)$ for each $h' \in H|_{\tilde{h}}$.

With this notation in place, we proceed to present the proofs. From now on, we assume $C_n^e = 0$.

In what follows, in order to take into account the initial history $h = \emptyset$, one may think that the game started at $t = -1$, but at that time there are no alternative decisions: The economy is closed, the firms are using the old technology, and that situation is taken as given.

First, the firms.

1.1.F Suppose that the government is too impatient.

Essentially, the same proof applies for all the items ((1.1.1.)-(1.1.6), (2.1.1)-(2.1.6)). To fix ideas, consider $(s^I, s^P, s^G) = (\{s_h(N,1)\}_{h\in H}, \{s_h(N,1)\}_{h\in H}, s^G(0))$. From now on, we use the notation $\{s_h^i(N,1)\}_{h\in H} = \{s_h(N,1)\}_{h\in H}$ for $i \in \{I, P\}$. The intuition is the following: In all the situations in the results previously cited, the domestic firms either do not have time to install the new technology or at most they have two chances to do it, and then they will never adopt it if they need more than two periods, or they do not have incentives to invest due to their degree of impatience. Formally, we will prove that $\{s_h^i(N,1)\}_{h\in H}$ is such that, for any $\tilde{h} \in H$, $\{s_h(N,1)\}_{h\in H}\big|_{\tilde{h}}$ is a best response to $(s^j, s^G)\big|_{\tilde{h}}$ for $i \neq j \in \{I, P\}$. Take $\tilde{h} = \left((a_l^I, a_l^P, a_l^G)\right)_{l=0}^t$ such that, for the firm i, the new technology can neither be totally installed at $t+1$ nor at $t+2$ and consider the payoffs $\Pi^i((s^i, s^j, s^G)\big|_{\tilde{h}}\big|_{\tilde{h}})$ and $\Pi^i\left(\{\tilde{s}_h^i\}_{h\in H}\big|_{\tilde{h}}, (s^j, s^G)\big|_{\tilde{h}}\right)\big|_{\tilde{h}}$, where $\tilde{s}^i = \{\tilde{s}_h^i\}_{h\in H}$ is such that $\tilde{s}_h^i = s_h(N,1)$ for all $h \neq \tilde{h}$ and $\tilde{s}_{\tilde{h}}^i \neq s_{\tilde{h}}(N,1)$. Then, s^i prescribes, given $(s^P, s^G)\big|_{\tilde{h}}$, to adopt the old tech-

nology for all $l \geq t+1$ and $\tilde{s}^i = \{\tilde{s}^i_h\}_{h \in H}$ prescribes, given $\left.(s^P, s^G)\right|_{\tilde{h}}$, to adopt the new technology at $t+1$, but to adopt the old one for all $l \geq t+2$, because, as the government opens the economy at all $l \geq t+1$ along both game paths, the one defined by (s^I, s^P, s^G) and the one defined by $(\tilde{s}^I, s^P, s^G)$, the firm i has neither time to install the new technology with (s^I, s^P, s^G) nor with $(\tilde{s}^I, s^P, s^G)$, and hence we have, for $i \in \{I, P\}$,$\Pi^i(\left.\left.(s^i, s^j, s^G)\right|_{\tilde{h}}\right|_{\tilde{h}}) = \Pi^i\left(\left.\{\tilde{s}^i_h\}_{h \in H}\right|_{\tilde{h}}, \left.(s^j, s^G)\right|_{\tilde{h}}\right)\Big|_{\tilde{h}} = 0$, since, by A1-A3, that firm i shuts down at $t+1$. Notice that the same reasoning applies if we consider $\{s^i_h(N,2)\}_{h \in H}$ instead of $\{s^i_h(N,1)\}_{h \in H}$.
If $\tilde{h}$ is such that the new technology can be totally installed at $t+1$, the reasoning is simpler: $\tilde{s}^i$ prescribes to use the old technology at $t+1$, but the new technology for all $l \geq t+2$.
Thus $\left(\Pi^i(\left.\left.(s^i, s^j, s^G)\right|_{\tilde{h}}\right|_{\tilde{h}}) - \Pi^i\left(\left.\{\tilde{s}^i_h\}_{h \in H}\right|_{\tilde{h}}, \left.(s^j, s^G)\right|_{\tilde{h}}\right)\Big|_{\tilde{h}}\right)(\beta^i)^{-(t+1)} = \left(\pi^i_{t+1}(\left.(s^i, s^j, s^G)\right|_{\tilde{h}}) - \pi^i_{t+1}\left(\left.\{\tilde{s}^i_h\}_{h \in H}\right|_{\tilde{h}}, \left.(s^j, s^G)\right|_{\tilde{h}}\right)\right)$ where
$\pi^i_{t+1}(\left.(s^i, s^j, s^G)\right|_{\tilde{h}})$ is the Cournot profit of the firm i at $t+1$ using the technology according to s^i, that is, the old technology, and an analogous definition applies to $\pi^i_{t+1}\left(\left.\{\tilde{s}^i_h\}_{h \in H}\right|_{\tilde{h}}, \left.(s^j, s^G)\right|_{\tilde{h}}\right)$ but using the new technology not totally installed (the firm j is using the same technology in both situations, either with $\{s^i_h(N,1)\}_{h \in H}$ or with $\{s^i_h(N,2)\}_{h \in H}$), thus $\left(\Pi^i(\left.\left.(s^i, s^j, s^G)\right|_{\tilde{h}}\right|_{\tilde{h}}) - \Pi^i\left(\left.\{\tilde{s}^i_h\}_{h \in H}\right|_{\tilde{h}}, \left.(s^j, s^G)\right|_{\tilde{h}}\right)\Big|_{\tilde{h}}\right)$, since the new technology, once it is totally installed, is more efficient than the old one, due to A1-A3.
Finally, given s^G, the case when the new technology can be totally installed at $t+2$ but not at $t+1$ is not a possible equilibrium path, since the government never keeps the economy closed, and hence there is nothing to prove.
Notice that we have shown that $\{s^i_h(N,1)\}_{h \in H}$ is such that, for any $\tilde{h} \in H$, $\left.\{s_h(N,1)\}_{h \in H}\right|_{\tilde{h}}$ is a best response to $\left.(s^j, s^G)\right|_{\tilde{h}}$ for $i \neq j \in \{I, P\}$, independently of the conditions of the degree of patience of the firms, that is, the optimality of the firms' strategies for the items (1.1.1)-(1.1.3) and (1.1.6) is proven. Nevertheless, notice that from what we have done, it follows at once that if a domestic firm is very impatient or the legal-political costs are very large, it has a dominant strategy, namely $\{s^i_h(N,1)\}_{h \in H}$, and hence that optimality for the items (1.1.4) and (2.1.5) is also proven. Therefore, due to these last comments and remarks 3-6, the proof is done.

1.1.G The government

As for the case of the firms, the same proof applies for all the items ((1.1.1.)-(1.1.6), and (2.1.1)-(2.1.6)). To fix ideas, consider $(s^I, s^P, s^G) = (\{s_h(N,1)\}_{h\in H}, \{s_h(N,1)\}_{h\in H}, s^G(0))$. We will prove that $\{s_h^G(0)\}_{h\in H}$, for any $\tilde{h}\in H$, $\{s_h^G(0)\}_{h\in H}\Big|_{\tilde{h}}$, is a best response to $(s^I, s^P)|_{\tilde{h}}$. We have two situations: a) If $\tilde{h} = \left((a_l^I, a_l^P, a_l^g)\right)_{l=0}^{t}$ is such that none of the firms can have totally installed the new technology at $t+1$; b) If at least one can.

a) Take $\tilde{h} = \left((a_l^I, a_l^P, a_l^g)\right)_{l=0}^{t}$ such that none of the firms can have totally installed the new technology at $t+1$. Since $s^G(0)(\tilde{h}) = O$, then $\tilde{s}^G(\tilde{h}) = C$.

A priori, we have two cases, the first if for one or two domestic firms it happens that at $t+2$ the new technology can be totally installed, the other if none of them can. Clearly, if we were considering $\left(\{s_h(N,2)\}_{h\in H}, \{s_h(N,2)\}\right)$, neither case would be a possible equilibrium path, nor a possible alternative path, and therefore we have nothing to prove.

In the former case, when the two domestic firms can install the new technology (if only one can, the inequality between the Cournot profits at $t+1$ is lower than in the previous case, but anyhow is positive) at $t+2$, both domestic firms react to $\tilde{s}^G(\tilde{h})$ adopting the new technology for all $l\geq t+1$, independently of what the government does at that period — but the government opens the economy at $t+2$ —and then we have that

$\left(\Pi^G((s^G, s^I, s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^G\left(\{\tilde{s}_h^G\}_{h\in H}\Big|_{\tilde{h}}, (s^I, s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}}\right)(\beta^G)^{-(t+1)} =$

$\left\{\frac{1}{2}(\frac{(a-C^F)}{2})^2 + \tau(\frac{(a-C^F)}{2})\right\} -$

$\left\{\frac{1}{2}\left[\frac{2}{3}(a-(C^F+C_{n-1}^e)\right]^2 + 2\left[\frac{1}{3}(a-(C_{n-1}^e+C^F))\right]^2\right\}$ and then

$\lim_{(\beta^P,\tau)\to(0,1)}\left(\Pi^G((s^G, s^I, s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^G\left(\{\tilde{s}_h^G\}_{h\in H}\Big|_{\tilde{h}}, (s^I, s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}}\right)(\beta^G)^{-(t+1)} =$

$\left\{\frac{1}{2}(\frac{(a-C^F)}{2})^2 + (\frac{(a-C^F)}{2})\right\} -$

$\left\{\frac{1}{2}\left[\frac{2}{3}(a-(C^F+C_{n-1}^e)\right]^2 + 2\left[\frac{1}{3}(a-(C^F+C_{n-1}^e)\right]^2\right\}$.Hence,

$\lim_{\beta^G\to 0}\left(\Pi^G((s^G, s^I, s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^i\left(\{\tilde{s}_h^G\}_{h\in H}\Big|_{\tilde{h}}, (s^I, s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}}\right)(\beta^G)^{-(t+1)} >$

0 if $\frac{1}{8}(a-C^F)^2 + (\frac{(a-C^F)}{2}) > \frac{4}{9}(a-C^N)^2$, since $\frac{4}{9}(a - C^N)^2 > \left\{\frac{1}{2}\left[\frac{2}{3}(a - (C^F + C^e_{n-1})\right]^2 + 2\left[\frac{1}{3}(a - (C^F + C^e_{n-1})\right]^2\right\}$, due to A1-A3.

Then,

$\lim_{\beta^G \to 0} \left(\Pi^G((s^G, s^I, s^P)\big|_{\tilde{h}}\big|_{\tilde{h}}) - \Pi^i \left(\left\{ \tilde{s}^G_h \right\}_{h \in H}\Big|_{\tilde{h}}, (s^I, s^P)\big|_{\tilde{h}} \right)\Big|_{\tilde{h}} \right) (\beta^G)^{-(t+1)} > 0$. This case is proven.

Remark 3 *The case of the consumer-oriented government. Here we have* $\lim_{\beta^P \to 0} \left(\Pi^G((s^G, s^I, s^P)\big|_{\tilde{h}}\big|_{\tilde{h}}) - \Pi^G \left(\left\{ \tilde{s}^G_h \right\}_{h \in H}\Big|_{\tilde{h}}, (s^I, s^P)\big|_{\tilde{h}} \right)\Big|_{\tilde{h}} \right) (\beta^G)^{-(t+1)} = \left\{\frac{1}{2}(\frac{(a-C^F)}{2})^2\right\} - \left\{\frac{1}{2}\left[\frac{2}{3}(a - (C^F + C^e_{n-1}))\right]^2\right\} = \frac{1}{8}(a - C^F)^2 - \frac{2}{9}(a - C^e_{n-1})^2$. *Then, if* $\frac{1}{8}(a - C^F)^2 - \frac{2}{9}(a - C^N)^2 > 0$, *we have* $\frac{1}{8}(a - C^F)^2 - \frac{2}{9}(a - (C^F + C^e_{n-1}))^2 > 0$. *This remark is in order to prove (2.1) in the theorem 2.*

Remark 4 *Notice that the condition* β^G *being small enough in the two previous reasonings is unavoidable, so that if the government is very patient, either utilitarist or consumer-oriented it is optimal for it to close the economy at* $t+1$ *if none of the firms can have the new technology totally installed until* $t+1$*, but at least one can install it at* $t+2$*. However, as we will see in what follows, here is the unique step at which the impatience of the government is necessary, as a response to* $\{s_h(N,1)\}_{h \in H}$*. As commented before, if we consider* $\left(\{s_h(N,2)\}_{h \in H}, \{s_h(N,2)\}\right)$ *instead of* $\left(\{s_h(N,1)\}_{h \in H}, \{s_h(N,1)\}\right)$ *or* $\left(\{s_h(N,1)\}_{h \in H}, \{s_h(N,2)\}\right)$*, we do not need to assume the impatience of the government at the previous step, since according to* $\{s_h(N,2)\}_{h \in H}$ *the firms only adopt the new technology if at the next period is totally installed. Thus, the items ((1.1.4)-(1.1.6)) and ((2.1.4)-(2.1.6)) will be done after the next steps.*

In the other case, when none of the firms can totally install the new technology at $t+2$, both firms react to $\tilde{s}^G(\tilde{h})$ using the old technology, the same reaction to $s^G(0)(\tilde{h})$.

Then, $\lim_{\tau \to 1} \left(\Pi^G((s^G, s^I, s^P)\big|_{\tilde{h}}\big|_{\tilde{h}}) - \Pi^G \left(\left\{ \tilde{s}^G_h \right\}_{h \in H}\Big|_{\tilde{h}}, (s^I, s^P)\big|_{\tilde{h}} \right)\Big|_{\tilde{h}} \right) (\beta^G)^{-(t+1)} = \lim_{\tau \to 1} \left(\left\{\frac{1}{2}(\frac{(a-C^F)}{2})^2 + \tau(\frac{(a-C^F)}{2})^2\right\} - \left\{\frac{1}{2}\left[\frac{2}{3}(a - C^N)\right]^2 + 2\left[\frac{1}{3}(a - C^N)\right]^2\right\} \right) = \left(\frac{1}{8}(a - C^F)^2 + (\frac{(a-C^F)}{2})^2 - \frac{4}{9}(a - C^N)^2 \right) > 0$ for all $\beta^G \in (0,1]$. Then, $\Pi^G((s^G, s^I, s^P)\big|_{\tilde{h}}\big|_{\tilde{h}}) - \Pi^G \left(\left\{ \tilde{s}^G_h \right\}_{h \in H}\Big|_{\tilde{h}}, (s^I, s^P)\big|_{\tilde{h}} \right)\Big|_{\tilde{h}} > 0$ for all $\beta^G \in (0,1]$.

Remark 5 *The case of the consumers-oriented government. Now we have* $\left(\Pi^G((s^G,s^I,s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^G\left(\left\{\tilde{s}^G_h\right\}_{h\in H}\Big|_{\tilde{h}}, (s^I,s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}}\right)(\beta^G)^{-(t+1)} =$ $\left(\left\{\frac{1}{2}(\frac{(a-C^F)}{2})^2\right\} - \left\{\frac{1}{2}\left[\frac{2}{3}(a-C^N)\right]^2\right\}\right) = \frac{1}{8}(a-C^F)^2 - \frac{2}{9}(a-C^N)^2 > 0$ *for all* $\beta^G \in (0,1]$. *This remark is in order to prove theorem 2.*

Notice that in the last two reasonings the condition that β^G be small enough is not necessary.

The case (a) is concluded.

b) Now, to end the proof, take $\tilde{h} = \left((a^I_l, a^P_l, a^g_l)\right)^t_{l=0}$ such that one or two of the national firms can have totally installed the new technology at $t+1$. Once again, we have that $s^G(0)(\tilde{h}) = O$, then $\tilde{s}^G(\tilde{h}) = C$. We will show first the reasoning for the situation in which both domestic firms can have totally installed the new technology at $t+1$. In this situation, none of the firms change their strategy, that is, they continue with the new technology forever, and then we have
$\lim_{\tau\to 1}\left(\Pi^G((s^G,s^I,s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^i\left(\left\{\tilde{s}^G_h\right\}_{h\in H}\Big|_{\tilde{h}}, (s^I,s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}}\right)(\beta^G)^{-(t+1)} =$ $\left[\frac{1}{2}(3\frac{(a-C^F)}{4})^2 + 2(\frac{(a-C^F)}{4})^2 + \frac{(a-C^F)}{4}\right] - \left[\frac{1}{2}(\frac{2}{3}(a-C^F))^2 + 2(\frac{1}{3}(a-C^F))^2\right] =$ $-\frac{11}{288}a^2 + \frac{11}{144}aC^F - \frac{11}{288}C^{2F} + \frac{1}{4}a - \frac{1}{4}C^F =$ $(a-C^F)(\frac{1}{4} - \frac{11}{288}(a-C^F))$. The roots of the polynomial $(a-C^F)(\frac{1}{4} - \frac{11}{288}(a-C^F))$ in C^F are $\left\{C^F = a\right\}$ and $\left\{C^F = -\frac{72}{11} + a\right\}$, therefore, we have that $\lim_{\tau\to 1}\left(\Pi^G((s^G,s^I,s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^i\left(\left\{\tilde{s}^G_h\right\}_{h\in H}\Big|_{\tilde{h}}, (s^I,s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}}\right)(\beta^G)^{-(t+1)} \geq 0$ if and only if $C^F \leq -\frac{72}{11} + a$. The case is done.

One comment here is in order.

Notice that
$\lim_{\tau\to 0}\left(\Pi^G((s^G,s^I,s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^i\left(\left\{\tilde{s}^G_h\right\}_{h\in H}\Big|_{\tilde{h}}, (s^I,s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}}\right)(\beta^G)^{-(t+1)} =$ $\left(\left\{\frac{1}{2}(\frac{3}{4})^2 + 2(\frac{1}{4})^2\right\} - \left\{\frac{1}{2}\left[\frac{2}{3}\right]^2 + 2\left[\frac{1}{3}\right]^2\right\}\right)(a-C^F)^2(\frac{13}{32} - \frac{8}{18}) < 0$. Therefore, it is necessary to impose τ close to one for the proposed strategy to be optimal.

Remark 6 *Suppose that the government is consumer-oriented and take* $\tilde{h} = (a_l)^t_{l=0}$ *such that both national firms can have totally installed the new technology at* $t+1$. *As before, we have that* $s^G(0)(\tilde{h}) = O$, *then* $\tilde{s}^G(\tilde{h}) = C$. *Hence* $\left(\Pi^G((s^G,s^I,s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^i\left(\left\{\tilde{s}^G_h\right\}_{h\in H}\Big|_{\tilde{h}}, (s^I,s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}}\right)(\beta^G)^{-(t+1)} =$ $\left[\frac{1}{2}(3\frac{(a-C^F)}{4})^2\right] - \left[\frac{1}{2}(\frac{2}{3}(a-C^F))^2\right] = \frac{1}{2}(a-C^F)^2(\frac{9}{16} - \frac{4}{9}) > 0$. *This remark is in order to prove theorem 2.*

It remains to show when only one of the domestic firms can have totally installed the new technology at $t+1$. We have again that $s^G(0)(\tilde{h}) = O$, $\tilde{s}^G(\tilde{h}) = C$, and even if the other firm can have totally installed the new technology at $t+2$, none of the firms changes its strategy from $l \geq t+2$ and one is having the new technology totally installed and the other does use the old technology—the firm that may have totally installed the new technology cannot do it, even having the economy closed, and the other domestic firm has the new technology totally installed at $t+1$—, so $\left(\Pi^G((s^G, s^I, s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^i \left(\left\{ \tilde{s}^G_h \right\}_{h \in H} \Big|_{\tilde{h}}, (s^I, s^P)|_{\tilde{h}} \right) \Big|_{\tilde{h}} \right) (\beta^G)^{-(t+1)} =$ $((\frac{1}{2}(\frac{2}{3}(a - C^F))^2 + (\frac{(a-C^F)}{3})^2 + \tau \frac{(a-C^F)}{3}) - (\frac{1}{2}(\frac{a-C^F}{2})^2 + (\frac{a-C^F}{2})^2)$, since after $t+2$ the two game paths coincide.

We have that
$\lim_{\tau \to 1} \left(\Pi^G((s^G, s^I, s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^i \left(\left\{ \tilde{s}^G_h \right\}_{h \in H} \Big|_{\tilde{h}}, (s^I, s^P)|_{\tilde{h}} \right) \Big|_{\tilde{h}} \right) (\beta^G)^{-(t+1)} =$ $((\frac{1}{2}(\frac{2}{3}(a - C^F))^2 + (\frac{(a-C^F)}{3})^2 + \frac{(a-C^F)}{3}) - (\frac{1}{2}(\frac{a-C^F}{2})^2 + (\frac{a-C^F}{2})^2) = -\frac{1}{24}a^2 + \frac{1}{12}aC^F - \frac{1}{24}C^{2F} + \frac{1}{3}a - \frac{1}{3}C^F = \frac{1}{3}(a - C^F)(1 - \frac{a-C^F}{8}) > 0$, since $(1 - \frac{a-C^F}{8}) > 0$ —recall that $a \leq 1$—because the firm that cannot have totally installed the new technology at $t+1$ shuts down due to the fact that the other firm is much more efficient (it has C^F as its marginal costs). Hence, we have $\left(\Pi^G((s^G, s^I, s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^i \left(\left\{ \tilde{s}^G_h \right\}_{h \in H} \Big|_{\tilde{h}}, (s^I, s^P)|_{\tilde{h}} \right) \Big|_{\tilde{h}} \right) (\beta^G)^{-(t+1)} > 0$ for all τ large enough. Thus, the case is proven. Notice how important it is, for the firm that can have the new technology totally installed at $t+1$, that the other firm can have the new technology totally installed at $t+1$.

Remark 7 *Suppose that the government is consumer-oriented and take $\tilde{h} = (a_l)_{l=0}^t$ such that only one of the domestic firms can have totally installed the new technology at $t+1$. As before, we have that $s^G(0)(\tilde{h}) = O$, then $\tilde{s}^G(\tilde{h}) = C$. Hence $\left(\Pi^G((s^G, s^I, s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^i \left(\left\{ \tilde{s}^G_h \right\}_{h \in H} \Big|_{\tilde{h}}, (s^I, s^P)|_{\tilde{h}} \right) \Big|_{\tilde{h}} \right) (\beta^G)^{-(t+1)} =$ $(\beta^G)^{-(t+1)}((\frac{1}{2}(\frac{2}{3}(a - C^F))^2) - (\frac{1}{2}(\frac{a-C^F}{2})^2) > 0$, if C_n^e is small enough, as in the preceding reasoning. This remark is in order to prove theorem 2.*

As commented in due time, all the remarks in this section but 4, are in order to prove item (2.1) of theorem 2. Also, as the impatience of either the firms or the government only was necessary when considering $\{s_h(N,1)\}_{h \in H}, \{s_h(N,1)\}$, the proof of items (1.1) and (2.1) of theorems 1 and 2 is done.

1.2 The proofs of (1.2) and (2.2).

1.2.F First, the firms. Consider $(s^I, s^P, s^G) = (\{s_h(N,2)\}_{h\in H}, \{s_h(N,2)\}_{h\in H}, s^G(\infty))$. As we will see, the arguments here are similar to the ones in the case when the economy is opened at the outset. Nevertheless, in order to reinforce those intuitions and to clearly show how the firms' impatience is a necessary condition, we present the following reasoning. We will prove that $\{s^i_h(N,2)\}_{h\in H}$ is such that, for any $\tilde{h} \in H$, $\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}$ is the best response to $(s^j, s^G)\big|_{\tilde{h}}$ for $i \neq j \in \{I, P\}$.

Take $\tilde{h} = \left((a^I_l, a^P_l, a^G_t)\right)_{l=0}^t$ such that, for the firm i, the new technology cannot be totally installed at $t+1$. Consider the payoffs $\Pi^i((s^i, s^j, s^G)\big|_{\tilde{h}}\big|_{\tilde{h}})$ and $\Pi^i\left(\{\tilde{s}^i_h\}_{h\in H}\big|_{\tilde{h}}, (s^j, s^G)\big|_{\tilde{h}}\right)\big|_{\tilde{h}}$, where $\tilde{s}^i = \{\tilde{s}^i_h\}_{h\in H}$ is such that $\tilde{s}^i_h = s_h(N,2)$ for all $h \neq \tilde{h}$ and $\tilde{s}^i_{\tilde{h}} \neq s_{\tilde{h}}(N,1)$. We have that s^i prescribes, given $(s^P, s^G)\big|_{\tilde{h}}$, to adopt the old technology for all $l \geq t+1$. $\tilde{s}^i = \{\tilde{s}^i_h\}_{h\in H}$ prescribes, given $(s^P, s^G)\big|_{\tilde{h}}$, to adopt the new technology at $t+1$, but the old technology for all $l \geq t+2$, if the new technology cannot be totally installed at $t+2$, and the new technology for all $l \geq t+2$, in the other case. Whatever be the situation, we have $(\Pi^i((s^i, s^j, s^G)\big|_{\tilde{h}}\big|_{\tilde{h}}) - \Pi^i\left(\tilde{s}^i_{h\in H}\big|_{\tilde{h}}, (s^j, s^G)\big|_{\tilde{h}}\right)\big|_{\tilde{h}})(\beta^i)^{-(t+1)} \rightarrow$
$\left(\pi^i_{t+1}((s^i, s^j, s^G)\big|_{\tilde{h}}) - \pi^i_{t+1}\left(\{\tilde{s}^i_h\}_{h\in H}\big|_{\tilde{h}}, (s^j, s^G)\big|_{\tilde{h}}\right)\right)$as $\beta^i \rightarrow 0$,
where $\pi^i_{t+1}((s^i, s^j, s^G)\big|_{\tilde{h}})$ is the Cournot profit of the firm i at $t+1$ using the technology according to s^i, that is, the old technology, and an analogous definition applies to $\pi^i_{t+1}\left(\{\tilde{s}^i_h\}_{h\in H}\big|_{\tilde{h}}, (s^j, s^G)\big|_{\tilde{h}}\right)$ but using the new technology not totally installed. Now, if the firm $j \neq i$ can have the new technology totally installed at $t+1$, the economy is open at $t+1$, then $\pi^i_{t+1}((s^i, s^j, s^G)\big|_{\tilde{h}}) = \pi^i_{t+1}\left(\{\tilde{s}^i_h\}_{h\in H}\big|_{\tilde{h}}, (s^j, s^G)\big|_{\tilde{h}}\right) = 0$. In the other case, the economy is closed, because none of the firms can have the new technology totally installed at $t+1$, then $\pi^i_{t+1}((s^i, s^j, s^G)\big|_{\tilde{h}}) > \pi^i_{t+1}\left(\{\tilde{s}^i_h\}_{h\in H}\big|_{\tilde{h}}, (s^j, s^G)\big|_{\tilde{h}}\right)$, since the old technology is more efficient than the new one, if that new technology is not totally installed (due to A1-A3). In any case $(\Pi^i((s^i, s^j, s^G)\big|_{\tilde{h}}\big|_{\tilde{h}}) - \Pi^i\left(\tilde{s}^i_{h\in H}\big|_{\tilde{h}}, (s^j, s^G)\big|_{\tilde{h}}\right)\big|_{\tilde{h}}) \geq 0$.

Now, take $\tilde{h} = \left((a^I_l, a^P_l, a^G_t)\right)_{l=0}^t$ such that, for the firm i, the new technology can be totally installed at $t+1$. This case, as in (1.1.F), is quite intuitive, since the new technology, once it is totally installed, it is more efficient than the old one, providing more Cournot benefits (the other firm does not change its strategy if it can have the new technology totally installed, nor if it cannot).

The optimality of the firms' strategies is finished.

1.2.G The government

Take $\tilde{h} = \left((a_l^I, a_l^P, a_t^G)\right)_{l=0}^t$ such that at least one of the firms can have the new technology totally installed at $t+1$. Since $s^G(\infty)(\tilde{h}) = O$, then $\tilde{s}^G(\tilde{h}) = C$, but the government, as with $s^G(\infty)$, will open the economy for all $l \geq t+2$. Then, assumed that τ is large enough or that the government is consumer-oriented, due to the same reasonings done before, the case is done (the society is better off when there is one more firm in the market).

Assume now that none of the domestic firms can have the new technology totally installed at $t+1$. Since $s^G(\infty)(\tilde{h}) = C$, then $\tilde{s}^G(\tilde{h}) = O$, but the government, as with $s^G(\infty)$, will close the economy for all $l \geq t+2$. Then $\lim_{\tau \to 1}(\beta^G)^{-(t+1)}(\Pi^G((s^G, s^I, s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^G\left(\left\{\tilde{s}_h^G\right\}_{h\in H}\Big|_{\tilde{h}}, (s^I, s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}}) =$ $\lim_{\tau \to 1}\left[\left\{\left[\frac{1}{2}\left(2\frac{(a-C^N)}{3}\right)^2 + 2\left(\frac{(a-C^N)}{3}\right)^2\right]\right\} - \left\{\frac{1}{2}(\frac{(a-C^F)}{2})^2 + \tau(\frac{(a-C^F)}{2})\right\}\right] =$ $\frac{4}{9}(a-C^N)^2 - \frac{1}{8}(a-C^F)^2 - (\frac{(a-C^F)}{2}) > 0$, by assumption.

Remark 8 *If the government is consumer-oriented, we have* $(\beta^G)^{-(t+1)}(\Pi^G((s^G, s^I, s^P)|_{\tilde{h}}|_{\tilde{h}}) - \Pi^G\left(\left\{\tilde{s}_h^G\right\}_{h\in H}\Big|_{\tilde{h}}, (s^I, s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}}) =$ $\left\{\left[\frac{1}{2}\left(2\frac{(a-C^N)}{3}\right)^2 + 2\left(\frac{(a-C^N)}{3}\right)^2\right]\right\} - \left\{\frac{1}{2}(\frac{(a-C^F)}{2})^2\right\} > 0$, *by assumption.*

Theorems 1 and 2 are proven.

3 Proof of theorem 3.

Without loss of generality, we assume that the legal-political costs are zero. (Recall that we are assuming that they are not very large.)

3.1 First consider $(s^P, s^I, s^G) = ((\{s_h(T,1)\}_{h\in H}, \{s_h(T,1)\}_{h\in H}, s^G(n)))$.

3.1.F The firms. We will prove that $\{s_h(T,1)\}_{h\in H}$ is such that, for any $\tilde{h} \in H$, $\{s_h(T,1)\}_{h\in H}\big|_{\tilde{h}}$ is the best response to $(s^j, s^G)\big|_{\tilde{h}}$ for $i \neq j \in \{I, P\}$. We have three possible situations: a) If $\tilde{h} \in H$ is such that $C(i,h) = n$; b) If $\tilde{h} \in H$ is such that $C(i,h) \geq C(j,h)$ and $C(i,h) < n$; c) If $\tilde{h} \in H$ is such that $C(i,h) < C(j,h)$ and $C(i,h) < n$.

a) Take $\tilde{h} \in H$ such that $C(i,h) = n$ for $i \in \{I,P\}$. Suppose first that $C(i,h) = n$. Then, $s_{\tilde{h}}(T,1)$ prescribes to use the new technology at $t+1$ and that technology is totally installed at $t+1$. As in other situations analyzed before, this decision gives to the firm i more benefits than any other decision. This case is done.
b) Now, assume $C(i,h) \geq C(j,h)$ and $C(i,h) < n$ for $i \in \{I,P\}$. Then, none of the firms has the new technology totally installed at $t+1$ and $s_{\tilde{h}}(T,1)$, given $(s^j, s^G)\big|_{\tilde{h}}$, prescribes to use the new technology at $t+1$, since the government closes the economy at $t+1$ and will keep the economy closed until a firm can have the new technology totally installed, the firm i in this case. Since $C(i,h) \geq C(j,h)$ the firm i, according to $\{s_h(T,1)\}_{h\in H}$, will continue using the new technology until it pays all the remaining costs and will totally install the new technology sooner or later—the other firm may be adopting the new technology or may be not doing it, depending upon if $C(i,h) > C(j,h)$, or if $C(i,h) = C(j,h)$—. However, if we consider $\tilde{s}^i = \{\tilde{s}^i_h\}_{h\in H}$ such that $\tilde{s}^i_h = s_h(T,1)$ for all $h \neq \tilde{h}$ and $\tilde{s}^i_{\tilde{h}} \neq s_{\tilde{h}}(T,1)$, we have that $\tilde{s}^i_{\tilde{h}}$ prescribes to use the old technology at $t+1$. To continue the reasoning, consider the history $(\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}}))$ determined by the reactions to $\tilde{s}^i_{\tilde{h}}$ of the firm j and the government, according to their proposed strategies, and consider $C(i, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}})))$. Necessarily, $C(i, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}}))) < n$, since $\tilde{s}^i_{\tilde{h}}$ prescribes to use the old technology at $t+1$. We have two situations, one if $C(i, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}}))) \geq C(j, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}})))$ and the other if $C(i, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}}))) < C(j, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}})))$ —notice that given $\tilde{s}^i_{\tilde{h}}$, the firm j, according to s^j, may decide to adopt the new technology: Imagine the case when $C(i,h) = C(j,h)$—. If $C(i, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}}))) \geq C(j, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}})))$, then $\tilde{s}^i$ prescribes to adopt the new technology and to install it, the government keeps the economy closed until the firm i finishes installing the new technology. Thus, if $C(i, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}}))) > C(j, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}})))$ —the case when
$C(i, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}}))) = C(j, (\tilde{h}, (\tilde{s}^i_{\tilde{h}}, s^j_{\tilde{h}}, s^G_{\tilde{h}})))$ is quite similar and omitted—
,

$$(\Pi^i((s^i, s^j, s^G)\big|_{\tilde{h}}\big|_{\tilde{h}}) - \Pi^i\left(\tilde{s}^i_{h\in H}|_{\tilde{h}}, (s^j, s^G)\big|_{\tilde{h}})\right|_{\tilde{h}})(\beta^i)^{-(t+1)} =$$
$$\pi^i_{t+1}((C^e_{C(i,h)} + C^F), C^N) - \pi^i_{t+1}\left(C^N, C^N\right) +$$
$$\sum_{l\geq 1}^{l=n-(C(i,h)+1)} (\beta^i)^l \left[\pi^i_{t+1}((C^e_{l+C(i,h)} + C^F, C^N) - \pi^i_{t+1}((C^e_{C(i,h)+l-1} + C^F, C^N)\right] +$$

$\frac{(\beta^i)^{n-C(i,h)}}{(1-\beta^i)}\pi^i_{t+1}((C^F,C^F),$
then $\lim_{\beta^i\to 1}(\Pi^i((s^i,s^j,s^G)|_{\tilde h}|_{\tilde h}) - \Pi^i\left(\tilde s^i_{h\in H}|_{\tilde h},(s^j,s^G)|_{\tilde h}\right)|_{\tilde h})(\beta^i)^{-(t+1)} = \infty$ (in spite of having $\pi^i_{t+1}((C^e_{C(i,h)}+C^F),C^N) - \pi^i_{t+1}\left(C^N,C^N\right) < 0$, and $\pi^i_{t+1}((C^e_{l+C(i,h)}+C^F,C^N) - \pi^i_{t+1}((C^e_{l+C(i,h)-1}+C^F,C^N) < 0$ for all $0 \le l \le n$ (C^e_l is decreasing).This case is done.[11]
Notice how crucial is the assumption that the firm i is patient enough. Now, if $C(i,(\tilde h,(\tilde s^i_{\tilde h},s^j_{\tilde h},s^G_{\tilde h}))) < C(j,(\tilde h,(\tilde s^i_{\tilde h},s^j_{\tilde h},s^G_{\tilde h})))$ —notice that $C(j,(\tilde h,(\tilde s^i_{\tilde h},s^j_{\tilde h},s^G_{\tilde h}))) = C(i,h)+1$—, then $\tilde s^i$ prescribes to adopt the old technology for all $l \ge t+1$, the firm j adopts the new technology at for all $l \ge t+1$, and the government keeps the economy closed until the firm j finishes installing the new technology.
Then $(\Pi^i((s^i,s^j,s^G)|_{\tilde h}|_{\tilde h}) - \Pi^i\left(\tilde s^i_{h\in H}|_{\tilde h},(s^j,s^G)|_{\tilde h}\right)|_{\tilde h})(\beta^i)^{-(t+1)} =$
$\pi^i_{t+1}((C^e_{C(i,h)+1}+C^F),C^N) - \pi^i_{t+1}\left(C^N,C^e_{C(i,h)+1}+C^F\right) +$
$\sum_{l\ge 1}^{l=n-(C(i,h)+1)}(\beta^i)^l\left[\pi^i_{t+1}((C^e_{l+C(i,h)+1}+C^F),C^N) - \pi^i_{t+1}((C^N,C^e_{l+C(i,h)+1}+C^F)\right] +$
$(\beta^i)^{n-C(i,h)}\pi^i_{t+1}((C^F,C^F)\frac{1}{1-\beta^i}$ since, according to $\tilde s^i$, the firm i leaves the market at $t+1+n-C(i,h)$. Therefore, $\lim_{\beta^i\to 1}(\Pi^i((s^i,s^j,s^G)|_{\tilde h}|_{\tilde h}) - \Pi^i\left(\tilde s^i_{h\in H}|_{\tilde h},(s^j,s^G)|_{\tilde h}\right)|_{\tilde h})(\beta^i)^{-(t+1)} = \infty$, as before.
c) Take $\tilde h \in H$ such that $C(i,h) < C(j,h)$ and $C(i,h) < n$ for $i \in \{I,P\}$. This case is the simplest one: The firm i never can finish installing the new technology before the firm j, then it is better for i not to adopt the new technology at $t+1$. The proof is finished. Notice that the proof applies also for the item (3.2).

Remark 9 *In order to prove the optimality of $\{s_h(T,2)\}_{h\in H}$, it suffices to observe that this case is quite analogous to the cases (a) and (b) above, and then it is omitted. Further, the proof applies also for items (3.3) and (3.4), since the proofs only use that the government plays $\left\{s^G_h(n)\right\}_{h\in H}$, not an explicit assumption over the gap between the technologies.*

3.1.G The government. For simplicity, we show the argument in the case of

[11] If $P(i,\tilde h)+1=n$,
the term $\sum_{l\ge 1}^{l=n-(P(i,\tilde h)+1)}(\beta^i)^l\left[\pi^i_{t+1}((C^e_{l+P(i,\tilde h)}+C^F,C^N) - \pi^i_{t+1}((C^e_{P(i,\tilde h)+l-1}+C^F,C^N)\right]$
disappears, and the argument is the same. (Recall that we have assumed $C^e_n = 0$.)

the consumer-oriented utility function. The argument for the utilitarist utility function is analogous and thus omitted. Consider $(s^I, s^P, s^G) = (\{s_h^I(T,1)\}_{h\in H}, \{s_h^P(T,1)\}_{h\in H}, s^G(n))$. We will prove that $\{s_h^G(n)\}_{h\in H}$, for any $\tilde{h} \in H$, $\{s_h^G(n)\}_{h\in H}\Big|_{\tilde{h}}$ is the best response to $(s^I, s^P)\big|_{\tilde{h}}$. Take a history $\tilde{h} = (a_l)_{l=0}^{l=t}$ such that none of the firms can have the new technology totally installed at $t+1$. We have that $s_{\tilde{h}}^G(n) = C$, hence $\tilde{s}_{\tilde{h}}^G = O$. We have two possibilities, one if $C(i,h) = C(j,h)$, the other if $C(i,h) \neq C(j,h)$. Consider first the case when $C(i,h) \neq C(j,h)$; without loss of generality we assume that $C(j,h) > C(i,h)$. As the firm i does not adopt the new technology, we have $(\beta^G)^{-(t+1)}(\Pi^G((s^G, s^I, s^P)\big|_{\tilde{h}}\big|_{\tilde{h}}) - \Pi^G\left(\{\tilde{s}_h^G\}_{h\in H}\Big|_{\tilde{h}}, (s^I, s^P)\big|_{\tilde{h}}\right)\Big|_{\tilde{h}}) =$

$$\begin{bmatrix} (\frac{1}{2}((\frac{1}{3}(a - 2(C^e_{C(j,h)+1} + C^F) - C^N) + \frac{1}{3}(a - 2C^N + \\ (C^e_{C(j,h)+1} + C^F))^2) - (\frac{1}{2}(\frac{a-C^F}{2})^2) + \\ \sum_{l\geq 1}^{l=n-(C(j,h)+1)} (\beta^G)^l(\frac{1}{2}(\frac{1}{3}(a - 2(C^e_{C(j,h)+1+l} + C^F) + C^N) + \\ \frac{1}{3}(a - 2C^N + C^e_{C(j,h)+1+l} + C^F))^2 - \\ (\frac{1}{2}(\frac{1}{3}(a - 2(C^e_{C(j,h)+1+l-1} + C^F) + C^N) + \\ \frac{1}{3}(a - 2C^N + C^e_{C(j,h)+1+l-1} + C^F))^2) \\ (\beta^i)^{n-C(j,h)}\frac{1}{1-\beta^G}((\frac{1}{2}(2\frac{a-C^F}{3})^2) \end{bmatrix}$$

because the firm i leaves the market at the moment the economy is opened, that is, at the moment the firm j has totally installed the new technology, if $C(j,h) < n$.

Remark 10 *Observe that if we assume the stronger version of "the gap between the technologies is not very large," then* $(\frac{1}{2}((\frac{1}{3}(a - 2(C^e_{C(j,h)+1} + C^F) - C^N) + \frac{1}{3}(a - 2C^N + (C^e_{C(j,h)+1} + C^F))^2) - (\frac{1}{2}(\frac{a-C^F}{2})^2) > 0$. *Also, notice that*
$\sum_{l\geq 1}^{l=n-(C(j,h)+1)} (\beta^G)^l(\frac{1}{2}(\frac{1}{3}(a-2(C^e_{C(j,h)+1+l}+C^F)+C^N)+\frac{1}{3}(a-2C^N+C^e_{C(j,h)+1+l}+C^F))^2$
$-(\frac{1}{2}(\frac{1}{3}(a-2(C^e_{C(j,h)+1+l-1}+C^F)+C^N)+\frac{1}{3}(a-2C^N+C^e_{C(j,h)+1+l-1}+C^F))^2) > 0$
for all $l \geq 1$, *since the economic costs of installation are decreasing. Therefore, we have* $(\beta^G)^{-(t+1)}(\Pi^G((s^G, s^I, s^P)\big|_{\tilde{h}}\big|_{\tilde{h}}) - \Pi^G\left(\{\tilde{s}_h^G\}_{h\in H}\Big|_{\tilde{h}}, (s^I, s^P)\big|_{\tilde{h}}\right)\Big|_{\tilde{h}}) > 0$ *for all* $\beta^G \in [0,1]$.

If $C(j,h)=n$, we have
$(\beta^G)^{-(t+1)}(\Pi^G((s^G,s^I,s^P)|_{\tilde{h}}|_{\tilde{h}})-\Pi^G\left(\left\{\tilde{s}_h^G\right\}_{h\in H}\Big|_{\tilde{h}},(s^I,s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}})=$
$(\beta^i)^{n-C(j,h)}\frac{1}{1-\beta^G}((\frac{1}{2}(2\frac{a-C^F}{3})^2)$. Therefore, in either case,
$\lim_{\beta^G\to 1}(\beta^G)^{-(t+1)}(\Pi^G((s^G,s^I,s^P)|_{\tilde{h}}|_{\tilde{h}})-\Pi^G\left(\left\{\tilde{s}_h^G\right\}_{h\in H}\Big|_{\tilde{h}},(s^I,s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}})=\infty.$
Now, if $C(j,h)=C(i,h)$, similarly, we have $(\beta^G)^{-(t+1)}(\Pi^G((s^G,s^I,s^P)|_{\tilde{h}}|_{\tilde{h}})-$
$\Pi^G\left(\left\{\tilde{s}_h^G\right\}_{h\in H}\Big|_{\tilde{h}},(s^I,s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}})=$

$$\left[\begin{array}{l}((\frac{1}{2}(\frac{2}{3}(a-C^e_{C(i,\tilde{h})+1}-C^F))^2-(\frac{1}{2}(\frac{a-C^F}{2})^2)+\\ \sum_{l\geq 1}^{l=n-(C(i,\tilde{h})+1)}(\beta^G)^l(\frac{1}{2}(\frac{2}{3}(a-C^e_{C(i,\tilde{h})+1+l}))^2-\\ \frac{1}{2}(\frac{2}{3}(a-C^e_{C(i,\tilde{h})+1+l-1}-C^F))^2\\ (\beta^i)^{n-C(i,h)}\frac{1}{1-\beta^G}((\frac{1}{2}(3\frac{a-C^F}{4})^2)\end{array}\right],$$

therefore $\lim_{\beta^G\to 1}(\beta^G)^{-(t+1)}(\Pi^G((s^G,s^I,s^P)|_{\tilde{h}}|_{\tilde{h}})-\Pi^G\left(\left\{\tilde{s}_h^G\right\}_{h\in H}\Big|_{\tilde{h}},(s^I,s^P)|_{\tilde{h}}\right)\Big|=$ ∞ as well —if $C(i,h)=n$, we apply the same reasoning as before—. Now, if we take a history $\tilde{h}=(a_l)_{l=0}^{l=t}$ such that at least one of the firms can have the new technology totally installed at $t+1$, the reasoning is simpler, since the firm/s that can do it will do it, and therefore the two payoffs $\Pi^G((s^G,s^I,s^P)|_{\tilde{h}}|_{\tilde{h}})$ and $\Pi^G\left(\left\{\tilde{s}_h^G\right\}_{h\in H}\Big|_{\tilde{h}},(s^I,s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}})$ differ only at time $t+1$, which difference is positive, provided that letting a foreign firm enter the market gives more instantaneous utility to the government than not allowing it. Therefore, items (3.1) and (3.2) are proven.

Remark 11 *Observe, once again, that if we assume the stronger version of "the gap between the technologies is not very large," then* $((\frac{1}{2}(\frac{2}{3}(a-C^e_{C(i,\tilde{h})+1}-C^F))^2-(\frac{1}{2}(\frac{a-C^F}{2})^2)>0$ *and, as in the previous remark,* $\sum_{l\geq 1}^{l=n-(C(i,\tilde{h})+1)}(\beta^G)^l(\frac{1}{2}(\frac{2}{3}(a-C^e_{C(i,\tilde{h})+1+l}))^2-\frac{1}{2}(\frac{2}{3}(a-C^e_{C(i,\tilde{h})+1+l-1}-C^F))^2>0$ *for all* $l\geq 1$, *because of the same reason. Therefore, we have* $(\beta^G)^{-(t+1)}(\Pi^G((s^G,s^I,s^P)|_{\tilde{h}}|_{\tilde{h}})-\Pi^G\left(\left\{\tilde{s}_h^G\right\}_{h\in H}\Big|_{\tilde{h}},(s^I,s^P)|_{\tilde{h}}\right)\Big|_{\tilde{h}})>0$ *for all* $\beta^G\in[0,1]$.

Due to the last three remarks, items (3.3) and (3.4) are proven.
The proof of theorem 3 is concluded.

7 References

Blonigen, Bruce, and Jee-Hyegon Park. 2004. "Dynamic Pricing in the Presence of Antidumping Policy: Trade and Policy." *American Economic Review* 94(1): 134-154.

Carreras, Albert, and Xavier Tafunell. 2004. *Historia Económica de la España Contemporánea*. Barcelona: Crítica.

Cheng, Leonard, Larry Qiu, and Kit Pong Wong. 2001. "Antidumping Measures as a tool of Protectionism: A Mechanism Design Approach." *The Canadian Journal of Economics* 34(3):639-660.

Fudenberg, Drew, and Jean Tirole. 2002. *Game Theory.* Cambridge: The MIT Press.

Grossman, Gene, and Elhaman Helpman. 1994. "Protection for Sale." *American Economic Review* 84(4): 833-50.

— 1995a. "Trade Wars and Trade Talks." *Journal of Political Economy* 103(4): 675-708.

— 1995b. "The Politics of Free-Trade Agreements." *American Economic Review* 85(4): 667-90.

Hillman, Arye. 1982. "Declining Industries and political-support Protectionist Motives." *American Economic Review* 72(5): 1180-7.

— 1989. *The Political Economy of Protection.* New York: Hardwood Academic.

Gómez-Galvarriato, Aurora. 2007. "The Political Economy of Protectionism. The Mexican Textile Industry, 1900-1950." In *The Decline Of Latin American Economies. Growth, Institutions, and Crises*, ed. Sebastian Edwards, Gerardo Esquivel and Graciel Márquez, 363-406. Chicago: National Bureau of Economic Research.

Matsuyama, K. 1990. "Perfect Equilibrium in a Trade Liberalization Game." *American Economic Review* 80(3): 480-92.

Osborne, Martin J., and Rubinstein, Ariel. 1994. *A Course in Game Theory.* Cambridge: The MIT Press.

Revenga, A. 1997. "Employment and Wage Effects of Trade Liberalization: The Case of Mexican Manufacturing." *Journal of Labor Economics,* 15(2): S20-S43.

Staiger, Robert, and A. Tabellini. 1987. "Discretionary Trade Policy and Excessive Protection." *American Economic Review,* 77(5): 823-36.

Tornell, Aron. 1991. "Time Inconsistency of Protectionist Programs." *Quarterly Journal of Economics,*106(3): 963-974.

Wright, D. 1995. "Incentives, Protection, and Time Consistency." *The Canadian Journal of Economics,* 28(4a): 929-938.