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ABSTRACT

Administrative Delays as Barriers to Trade*

We study a two-country model where two firms, one domestic and the other foreign, must decide when to introduce their new product into the market. The home government may apply an import tariff, an administrative delay or both to the product of the foreign firm. An administrative delay imposes a waiting period between the time when the quality of the foreign product is determined and the time when the product can actually be sold. Our main interest is the differential effect of the tariff and the administrative delay on the timing of new product introductions and the resulting changes in home, foreign and world welfare. We show that administrative delays are less efficient instruments for maximizing home welfare than tariffs. With a tariff, the home government can affect the timing of entry to ensure that the domestic firm moves first at the socially optimal date. Although an optimally chosen delay can achieve the same pattern of introduction, it does not yield any tariff revenues. As a result, if the tariff may be set optimally, administrative delays are not used in a discriminatory manner. If trade liberalization constrains the import tariff to be below its domestically optimal level, discriminatory administrative delays may become part of the optimal policy of the home country. As the optimal delay policy leads to lower levels of world welfare than the optimal tariff, trade liberalization can be welfare decreasing.

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We study a two-country model where two firms, one domestic and the other foreign, must decide when to introduce their new product into the market. The home government may apply an import tariff, an administrative delay or both to the product of the foreign firm. An administrative delay imposes a waiting period between the time when the quality of the foreign product is determined and the time when the product can actually be sold. Our main interest is the differential effect of the tariff and the administrative delay on the timing of new product introductions and the resulting change in home, foreign and world welfare. We show that administrative delays are less efficient instruments for maximizing home welfare than tariffs. With a tariff, the home government can affect the timing of entry to ensure that the domestic firm moves first at the socially optimal date. Although an optimally chosen delay can achieve the same pattern of introduction, it does not yield any tariff revenues. As a result, if the tariff may be set optimally, administrative delays are not used in a discriminatory manner. If trade liberalization constrains the import tariff to be below its domestically optimal level, discriminatory administrative delays may become part of the optimal policy of the home country. As the optimal delay policy leads to lower levels of world welfare than the optimal tariff, trade liberalization can be welfare decreasing.

1 Introduction

International trade in goods and services is restricted by a variety of governmental policies. Most prominent among these are trade policies that are explicitly designed to discriminate against products that are produced abroad. Trade policies take many forms from explicit tariffs or quotas to voluntary export restraints or the enforcement of anti-dumping laws. International trade flows are also impeded by policies that apply to both foreign and domestic firms, such as tax policies, intellectual property laws, safety standards or technical standards. These 'internal' policies can affect trade in basically two ways. Firstly, the policies can be applied in a discriminatory manner: the relevant authorities can systematically take more time or be less accommodating when dealing with foreign products or foreign firms. Secondly, domestic firms might simply be more familiar with the local procedures so that local regulation is less of a burden for them than for their foreign competitors. In that case a country can effectively discriminate against foreign firms by adopting idiosyncratic rules and ignoring attempts to standardize administrative procedures across countries.

There is some evidence of systematic pro-domestic bias in the application of domestic policies. For example, the fact that most companies obtain significantly more patents at home than in other important markets suggests that they perceive the costs of filing and litigating abroad as higher than at home.¹ There also appears to be some systematic differences in the speed of administrative review of new products. The work of Dranove and Meltzer (1994) suggests that administrative delays may be greater for foreign-owned drug firms and that the additional administrative delay suffered by foreign firms differs across countries. For example, they find that French-made drugs have a "dramatic" advantage of approval within France while German-made drugs have a large advantage in Germany. U.S. made drugs are found to be approved two to three years earlier in the United States than

¹Another possible explanation for the discrepancy is that foreign companies feel that their products will not sell as well abroad because of the consumers' preference for domestic products. Expecting lesser sales, foreign companies would be less likely to invest in obtaining the patent even if the cost of patenting were the same at home and abroad. Still, this does not explain why international firms based in small countries would still have a greater propensity to patent at home than in much larger markets like the US.

in France, the United Kingdom or Germany. Such bias can be privately and socially costly. Dranove and Meltzer (1994) find that the average time from initial human subject testing until final FDA approval of drugs was nine years during the 1980s while Gieringer (1985) estimates that a one year delay in the introduction of new drugs results in between 32,000 and 76,000 additional deaths per decade.

This paper analyzes the special case of discriminatory administrative delays in the approval of new product designs. We study a two-country model where two firms, one domestic and the other foreign, must decide when to introduce their new product into the market. By waiting longer a firm increases the quality of its product but forgoes the current stream of profits. In the sub-game perfect equilibrium of our model, the timing of introduction and the quality of both the domestic and the foreign goods are determined endogenously. The home government may apply an import tariff, an administrative delay or both to the product of the foreign firm. An administrative delay imposes a waiting period between the time when the quality of the foreign product is determined and the time when the product can actually be sold. Our main interest is the differential effect of the tariff and the administrative delay on the timing of new product introductions and the resulting change in home, foreign and world welfare. We attempt to answer three questions. Firstly, can delays be an effective form of trade policy and, if the answer is 'yes', what would an optimal 'delay' policy look like? Secondly, how do administrative delays compare to traditional trade instruments such as a unit import tariff? Are these instruments equally efficient from the point of view of the home country? Do they affect world welfare in a similar manner? Finally, how would the home government and the firms react to a trade liberalization that imposes limits on the level of import tariffs? How would such trade liberalization affect the endogenous quality of the products? Would it necessarily improve world welfare?

The last question is of particular importance. As multilateral trade agreements progressively limit the use of the more traditional trade policy tools, policy makers are likely to make greater use of instruments that remain unregulated or that are harder to effectively monitor for evidence of discrimination. In fact, the virtual elimination of formal import quotas and the strict limits imposed on most import tariffs seems to be one of the reasons behind the proliferation of 'voluntary' export restraint agreements and

the flourishing of anti-dumping actions. The potential for substitution has long been recognized by the Gatt/WTO as the later rounds of discussion have tried-without much success- to address the issue of internal barriers to international trade.

Our results suggest that administrative delays are less efficient instruments for maximizing home welfare than tariffs. With a tariff, the home government can affect the timing of entry to ensure that the domestic firm moves first at the socially optimal date. Although an optimally chosen delay can achieve the same pattern of introduction, it does not yield any tariff revenues. As a result, if the tariff may be set optimally, administrative delays are not used in a discriminatory manner. Delays also lead to lower world-wide welfare than tariffs. Essentially this is because delays impose a period of unproductive waiting while a tariff let the foreign firm improve the quality of its product right up to the date of introduction. If trade liberalization constrains the import tariff to be below its domestically optimal level, discriminatory administrative delays may become part of the optimal policy of the home country. As the optimal delay policy leads to lower levels of world welfare than the optimal tariff, trade liberalization can be welfare decreasing.

To our knowledge, the formal analysis of administrative delays is new to the literature on international trade.² On the other hand the effect of tariff protection on the optimal timing of technology adoption has been studied in two recent papers.³ Myagiwa and Ohno (1995) discuss how import restrictions can affect a home firm 's incentives to 'close the technology gap' with respect to a foreign competitor. They use a technology adoption model that is similar to ours⁴ but assume that the foreign firm has already adopted the new technology. They then focus on how tariffs and quotas would affect the date at which the domestic competitor would also adopt. They cannot, however, examine, as we do, how trade policies influence the *order*

²Noll (1985) provides a synthesis of the work of many authors from other social sciences who have studied administrative delays.

³Also see Brander and Spencer (1983) for an analysis of the relationship between trade policies and innovation.

⁴They assume that the cost of adopting the new technology decreases over time while we assume that the quality of the product increases over time. The basic logic of these two classes of models is very similar.

of technological adoption between foreign and domestic firms. Chuman and Kusumoto (1995) extend the analysis of Myagiwa and Ohno to compare price and quantity setting competition under various specifications of demands. They show that the effect of tariff protection on the adoption behavior of the domestic firm does indeed depend on the nature of competition as well as on the precise shapes of demand and cost functions. We eschew such complications by assuming that consumer demand is perfectly inelastic at any point in time. This drastic simplification has numerous advantages. Firstly, as mentioned above, it makes it possible to study the timing decisions of *both* the foreign and the domestic firms. Indeed, the interaction between the firms' adoption strategies is central to our analysis. Secondly, with inelastic demands the profit-maximizing behavior of a single firm would be socially optimal. This ensures that all distortions arising in our model are rooted in the rivalry between the domestic and foreign producers.

The organization of the paper is as follows. Section I presents our benchmark free-trade model. Section II analyses the case where the home country has only the tariff at its disposal while Section III considers the exclusive use of administrative delays. Section IV compares the optimal policies of sections II and III and examines the effect of trade liberalization, allowing the home government to use both instruments simultaneously. Section V dis-

cusses the robustness of our results to changes in the timing of the policy decisions and in the type of demand functions. Section VI concludes. Most proofs have been relegated to the Appendix.

2 The Model and Benchmark Case

Two firms, A and B, must determine when to introduce their product in the market. Before time zero, neither firm is ready to sell a product that would be acceptable to consumers. From time zero on, each firm can introduce a product that incorporates the "state of the art" technology at the time of introduction. The rate of technological progress is exogenous to the firms. The longer the firm waits, the higher the quality of the good it can sell. More specifically, the quality of the good which is introduced at time t_i is $q_i = \theta t_i$. Once a firm has introduced its product, its quality

is fixed forever. This captures the idea that a firm cannot keep incorporating new technology into its product as fast once the product has been introduced and the basic design choices have been made.⁵ Finally, each firm can make only a single product introduction. The analysis would be essentially unchanged if firms were allowed to continuously incorporate improvements after the date of initial introduction *as long as the rate of quality improvement drops from θ to $\theta_L < \theta$* (see Dutta and Rustichini, 1993). One could also accommodate a larger number of 'discrete' introductions as long as the total number of introductions available to each firm were exogenous. This would, however, significantly complicate calculations and detract to the clarity of the presentation.⁶ While the main effects identified here would remain, the complexity of computations would be significantly increased and the presentation. Once a firm has introduced its version of the new good, it can produce at a constant marginal cost, c . For simplicity, we set c to zero. Firms compete on prices if both produce in the market.

At each time, t , a mass, N , of new identical consumers arrives in the market. Each of these consumers buys at most one unit of the good. Either this purchase occurs immediately or the consumer disappears from the market forever⁷. A consumer who buys one unit of good j at time t enjoys benefits of $V_j = q_j$ where q_j is the quality of good j . The products of the two firms are not horizontally differentiated so that all consumers always prefer the good that offers them the highest quality price difference $q_j - p_j$.

We assume that all consumers are located in country A, to which we will refer as the 'home' or 'domestic' market. Firm A is located in country A as well, whereas firm B is located abroad and exports to market A. In our baseline case, country A has no policy instruments at its disposal to affect the firms' behavior.

⁵While we believe that this assumption is reasonable, it clearly does not apply to every industry. In particular, in industries where innovation benefits significantly from the input of customers, the rate of product improvement might in fact be larger once the first generation of the product has been introduced.

⁶On the other hand, this type of timing model does not easily accommodate endogenously determined numbers of discrete introductions. In fact, we are not aware of any oligopoly model where both the number of introductions (or innovations) and their timing (or the intensity of R&D) are endogenous.

⁷This assumption is made to rule out strategic waiting behavior on the part of consumers.

We solve for the subgame perfect equilibrium of the continuous time game⁸. The first point to understand is that the two firms will never decide to introduce their products simultaneously. Simultaneous introduction would drive down equilibrium prices to zero as both firms offer homogenous products of identical quality. In any equilibrium then there will be a 'leader' who introduces first and a 'follower'. Considering the problem of the second mover first, the introduction decision is determined by maximizing the discounted stream of profits that accrue to the follower after entry. Since the follower introduces later it offers the higher quality product. It can then charge a price equal to the difference between the value it offers, V_f and the value offered by the leader, V_l and still make all sales. If we define t_f as the delay between the introduction date of the leader and the follower, then the revenue earned by the follower per period is:

$$P_f N = N[V_f - V_l] = N[q_f - q_l] = \theta t_f N$$

and the stream of profits of the follower discounted back to the time of entry of the leader is:

$$\begin{aligned} \pi_f &= e^{-rt_f} \int_0^\infty \theta t_f N e^{-rt} dt \\ &= e^{-rt_f} \frac{\theta N t_f}{r} \end{aligned}$$

Maximizing this with respect to t_f , we obtain an optimal delay of $t_f^* = \frac{1}{r}$.

Similarly, the leader makes all sales from its date of entry until the follower's date of entry. During this time, the leader can extract the entire consumers' surplus $V_l N$ as revenue. This leads to the following expression for discounted profits of the leader:

$$\pi_L = e^{-rt_l} \int_0^{t_f} \theta t_l N e^{-rt} dt$$

⁸This is a slight abuse of language since the concept of subgame perfection is not properly defined in continuous time. One should think of our results as applying to the limit of a discrete time game as the time grid of the game becomes arbitrarily fine.

$$= e^{-rt_l} \frac{\theta N t_l}{r} (1 - e^{-rt_f})$$

Maximizing this with respect to t_l , we obtain an optimal entry date of $t_l^* = \frac{1}{r}$. We will call this the "stand alone" or the "maturation" entry date for the leader. This is the date of introduction which would maximize firm A's profits under the assumption that firm B will introduce its product later after its profit-maximizing delay. It will become important later in the paper to note that the leader's optimal introduction date is independent of the follower's entry date. In other words, the leader's entry date is determined by the trade-off between time of entry and the level of profit (quality of output) attainable per period. The follower's entry date affects the level of profits earned, but not this basic trade-off and so does not affect the choice of entry date by the leader.

[Figure 1 here]

Having described the profit-maximizing introduction dates of both leader and follower we can now characterize the (unique) subgame perfect equilibrium outcome of the game.⁹ This is illustrated in figure 1, where the horizontal axis measures the date of introduction of the leader. The discounted value of the follower's profits, Π^F , decreases as the leader waits longer to introduce. On the other hand, given the anticipated optimal reaction of the follower, the discounted value of the leader's profits, Π^L , attains its maximum at $t_M = 1/r$. Π^F intersects Π^L at time t_p . One of two situations might arise. If t_p is larger than t_M then both firms are happy to wait until t_M , where one of them introduces first.¹⁰ If t_p is smaller than t_M the profits of the follower at t_M are lower than the profits of the leader. The follower would therefore prefer to preempt the other firm and move first a little bit before t_M so that first introduction at t_M can no longer be an equilibrium. This incentive to preempt persists as long as leading is more profitable than following. The equilibrium outcome is therefore for one firm to introduce first at t_p , where leader and follower make the same profits. The "preemption" date t_p is formally defined as the time of first introduction equalizing the profits of the first and second movers, i.e., t_p is such that:

⁹We will limit ourselves to pure strategy equilibria.

¹⁰At t_M the profits of the follower exceed those of the leader. This does not mean that the 'leader' has an incentive to wait further. In any pure strategy equilibrium, each firm 'knows' whether it is 'destined' to be leader or follower. Hence the leader maximizes its profits by stopping at t_M . See Dutta and Rustichini (1993).

$\pi_L(t_f, t_p) = \pi_f(t_f, t_p)$ or, substituting t_f from above and simplifying,

$$t_p(1 - e^{-1}) = \frac{e^{-1}}{r}$$

This calculation yields a preemption time of $t^p = \frac{1}{r} \frac{e^{-1}}{1 - e^{-1}} < \frac{1}{r} = t_M$, ensuring a unique (up to a permutation of the two firms) subgame perfect equilibrium of the game where one firm introduces at t_p and the other follows at $t_p + t_f^* = t_p + \frac{1}{r}$.¹¹

The welfare of the home country, computed as the unweighted sum of consumer surplus and the profit of the home firm discounted at time 0 is:

$$W_A = \int_{t_0}^{t_p + t_f^{**}} N\theta t_p e^{-rt} dt + \int_{t_p + t_f^{**}}^{\infty} N\theta t_p e^{-rt} dt = \int_{t_p}^{\infty} N\theta t_p e^{-rt} dt = e^{-\frac{e^{-1}}{1 - e^{-1}}} \frac{N\theta}{r^2} \left[\frac{e^{-1}}{1 - e^{-1}} \right]$$

[Figure 2 here]

, where we have assumed that the domestic firm introduced first. Since the profits of the leader and follower are equalized, the welfare of country A would be the same if we had assumed that the foreign firm introduced first. The components of this welfare function are shown in figure 2. The domestic firm introduces at time t_l and captures instantaneous profits equal to the quality of its product. This quality corresponds to the height of the first rectangle. At $t_l + t_f$ the foreign firm introduces a product of higher quality. The quality advantage of the foreign firm is the height of the upper rectangle. This quality differential is completely appropriated by the foreign firm, leaving domestic consumers, and hence the home country, with an instantaneous surplus equal to the height of the lower rectangle. Since this height is equal to the quality of the domestic product, the instantaneous welfare of the home country is constant from the date of first introduction onwards. The welfare of the foreign country is equal to the discounted profits of the foreign firm, i.e. to:

$$W_B = \int_{t_p + t_f^{**}}^{\infty} N\theta t_f^* e^{-rt} dt = \frac{N\theta}{r^2} e^{-1} e^{-\frac{e^{-1}}{1 - e^{-1}}}$$

¹¹For a formal proof that this is the unique *subgame perfect* outcome, see Dutta and Rustichini (1993) or Prokop, Regibeau and Rockett (1993).

To be able to evaluate the effectiveness of trade policies we must also understand what the socially optimal pattern of introduction is. Consider first the benchmark where *both firms are domestic firms*. This will give us the world welfare maximizing dates of introduction. We can write

$$W = \int_{t_l}^{t_l+t_f} N\theta t_l e^{-rt} dt + \int_{t_l+t_f}^{\infty} N\theta(t_l + t_f) e^{-rt} dt$$

Maximizing this expression with respect to t_l and t_f yields the socially optimal dates of introduction $t_l = \frac{1-e^{-1}}{r}$ and $t_f = \frac{1}{r}$ so that the second firm introduces at $\frac{1}{r}(2 - e^{-1})$. The delay between first and second introductions is the same as would be chosen by the firms. On the other hand, the socially optimal date of first introduction comes earlier than the privately optimal 'stand alone' date of introduction: while the leader only cares about its own profits, the social planner considers the fact that a later date of first introduction also delays the introduction of the better quality second-generation product.

Now consider the situation where the social planner can still choose both t_l and t_f but A is a domestic firm and B is foreign. One can show¹² that the welfare of the home country is maximized if the home firm introduces first at time $t_l = \frac{1}{r}$. The introduction date of the foreign follower is irrelevant. The intuition for this result is straightforward. Since the foreign firm captures all of the surplus that it creates, the social planner only cares about maximizing the discounted value of the value created by the domestic firm. As the domestic firm also captures the whole consumer surplus during its period of monopoly, the socially optimal date of introduction is equal to the privately optimal 'stand alone' date of introduction¹³. At the social optimum we have $W_A^S = \frac{\theta N}{r^2} e^{-1}$. Hence we see that, in the presence of a foreign firm, the socially optimal introduction date is later than the equilibrium preemption date t_p . Moreover, the social planner is not indifferent as to the order of introduction: the country is better off if its home firm moves first.¹⁴ Pol-

¹²See appendix A for details.

¹³The domestic firm only captures the value θt_l from t_l to $t_l + t_f$ while country A as a whole enjoys this surplus from t_l to infinity. This just means that the discounted profits of the domestic firms are only equal to a fixed *proportion* of the discounted welfare of the home country so that their maximand is the same.

¹⁴This is because, for all $t_l > t_p$, the discounted profits of the leader exceed those of the follower. See Figure 1.

icymakers will therefore be interested in any instrument that can delay the date of first introduction and ensure that the home firm moves first.

3 Tariffs

Assume that the home country A may impose a permanent per unit tariff μ on the imports of the foreign firm B. As we have just seen, for a *given date* of introduction by the domestic firm, the introduction of a second-generation product by the foreign firm does not affect the welfare of the home country. The only consequence of the foreign firm's entry is that what used to be the instantaneous profits of the domestic firms now become the surplus captured by domestic consumers. Therefore, the home country would be better off if it could simply exclude the foreign firm from the market. This would ensure that the domestic firm introduces at its 'stand alone' date $t_i^* = 1/r$, which is the same as the socially optimal date of introduction. Exclusion amounts to setting $\mu \rightarrow \infty$. Any other tariff would eventually be overcome as the foreign firm would simply wait until the quality of its product has improved enough to overcome its unit cost disadvantage.

The question, then, is whether the country can do better than this and capture some of the additional surplus created by the foreign firm. The answer to this question is 'yes'. Indeed, by setting an appropriate tariff, the home country can ensure that its domestic firm moves first, that it does so at the socially optimal time $t_i = 1/r$ and maximize the discounted value of its tariff revenues conditional on the foreign firm moving last.

We assume that the home country can commit to a tariff level μ at time zero.¹⁵ This tariff can drastically affect the nature of the subgame perfect equilibrium. Let us first consider the optimal waiting time of the follower. If the domestic firm moves last, its optimal waiting time is still $t_A^f = \frac{1}{r}$. If the foreign firm moves last, however, its discounted profits are now:

$$\pi_B^f = e^{-rt_f} \int_0^\infty N(\theta t_f - \mu) e^{-rt} dt$$

¹⁵The consequences of relaxing this assumption are discussed in section V.

$$= e^{-rt_f} \frac{N}{r} (\theta t_f - \mu)$$

Maximizing this expression with respect to t_f results in an optimal entry date of $t_B^f = \frac{1}{r} + \frac{\mu}{\theta}$. Hence, the tariff increases the delay in entry of the foreign firm when it is a follower. Intuitively, the tariff does not affect the marginal gain from waiting since the firm can still fully appropriate any increase in quality beyond the quality offered by the domestic incumbent. On the other hand the tariff decreases the marginal cost of waiting since it reduces the level of instantaneous profits that must be forgone.¹⁶

Turning to the introduction time of the leader, we see that the 'stand alone' entry date of the domestic firm is not affected by the tariff in spite of the fact that the domestic firm knows that the foreign follower will now introduce later. This is because, as mentioned earlier, the optimal delay of the follower only affect the discounted profits of the stand alone leader as a multiplicative factor, i.e. $\pi_L = \int_{t_l}^{t_l+t_f} N\theta t_l e^{-rt} dt = \frac{N\theta}{r} e^{-rt_l} (1 - e^{-rt_f})$. On the other hand, the stand alone entry date of a foreign leader is affected by the tariff in exactly the same manner as the foreign firm's optimal following delay was: the tariff decreases the marginal cost of waiting but leaves the marginal benefit unchanged. More formally, we have:

$$\pi_B^l = e^{-rt_l} \int_0^{t_A^f} N(\theta t_l - \mu) e^{-rt} dt = N(\theta t_l - \mu) e^{-rt_l} (1 - e^{-rt_A^f})$$

Notice that this expression has the same form as that of π_B^f , above, with the exception of the upper limit of integration. The profit-maximizing entry date, $t_B^l = \frac{1}{r} + \frac{\mu}{\theta}$, is therefore the same as the foreign firm's optimal delay t_B^f . A positive tariff induces a 'stand alone' foreign leader to delay its date of entry.

We still need to determine the effect of the tariff on the preemption dates. In the symmetric case, t_p was obtained by equating the discounted profits of a leader to the discounted profits of a follower. Because of the tariff, however, we must now distinguish between the preemption dates of the domestic and

¹⁶This suggests that an *ad valorem* tariff would leave the date of introduction of a foreign follower unchanged since it would affect the level of instantaneous profit and the marginal benefits from quality increase proportionally. However this 'neutrality' stems from assuming zero marginal costs of production. If the marginal cost is positive, it is easy to show that an *ad valorem* tariff would also delay the introduction of the foreign product.

foreign firms. The preemption date of the domestic firm is the date that equalizes the discounted profits of that firm as a stand alone leader to its discounted profits as a follower, i.e, t_l such that:

$$\int_{t_l}^{t_l+t_B^f} N\theta t_l e^{-rt} dt = \int_{t_l+t_A^f}^{\infty} N\theta t_A^f e^{-rt} dt$$

which yields $t_A^P = \frac{1}{r} \frac{e^{-1}}{1-e^{-1}e^{-r\frac{\mu}{\theta}}}$. Notice that this date is decreasing in μ : in the presence of a positive tariff the domestic firm is willing to move earlier in order to move first than under free trade. The intuition for this result is simple. Conditional on a first entry date t_l , the profits of the domestic firm as a follower are not affected by the tariff: it still introduces at $t_l + \frac{1}{r}$ and makes instantaneous profits of $\frac{N\theta}{r}$. On the other hand, for any given t_l , the domestic firm's profits as a leader increase because the foreign follower now introduces its product later, i.e. the domestic leader now enjoys a longer period of monopoly. Hence, at the initial tariff-free preemption date t_p , the domestic leader's profits with tariff exceed the domestic follower's profits with tariff. This makes the domestic firm willing to move even earlier in order to be first.

Similarly, the preemption date of the foreign firm is the date t_l that equalizes the foreign firm's profits as a leader to its profits as a follower, i.e.:

$$\int_{t_l}^{t_l+t_A^f} N[\theta t_l - \mu] e^{-rt} dt = \int_{t_l+t_B^f}^{\infty} N[\theta t_B^f - \mu] e^{-rt} dt$$

which yields $t_B^P = \frac{1}{r} \frac{e^{-1}}{1-e^{-1}} e^{-\frac{r\mu}{\theta}} + \frac{\mu}{\theta}$. This date is increasing in μ : in the presence of a tariff, the foreign firm is less willing to move early in order to be first than under free trade. The intuition is that, in the thought experiment that defines its preemption date, the foreign firm has an extra degree of freedom to react to the tariff when it is a follower. For a given date of introduction t_p by the domestic leader, the foreign firm can adjust its own date of introduction to lessen the adverse effect of the tariff. On the other hand, the profits of the foreign firm as a leader are computed for the same *given* date of first introduction so that no such adjustment is possible. Hence the foreign firm's profits as a leader are hurt more by the tariff than the foreign firm's profits as a follower.

In the free trade equilibrium, we had $t_p < t_l^* = 1/r$. The introduction of a tariff leaves $t_A^l = 1/r$, increases t_B^l to $\frac{1}{r} + \frac{\mu}{\theta}$, decreases t_A^P and increases t_B^P . This leaves us with two possible situations, depending on the size of the tariff.

$$\text{case 1: } \mu < \mu^\#: \quad t_A^P < t_B^P < t_A^l < t_B^l$$

$$\text{case 2: } \mu > \mu^\#: \quad t_A^P < t_A^l < t_B^P < t_B^l$$

In the first of these two cases, the unique subgame perfect equilibrium in pure strategies has firm A introduce first at t_B^P .¹⁷ Intuitively, the domestic firm is willing to move as early as t_A^P in order to be first. Still, it prefers to move first as closely as possible to its stand alone date t_A^l . Therefore firm A waits up to the date, t_B^P , where firm B would be willing to preempt it. In the second case, firm A knows that firm B cannot credibly preempt before t_B^P . Since $t_B^P > t_A^l$, A can wait until its preferred date of introduction and move first at t_A^l . One can show that the welfare-maximizing tariff must be high enough to lead to this second type of equilibrium.

Proposition 1 *The welfare maximizing tariff is $\mu^* = \frac{\theta}{r}$. At the optimal tariff, the domestic firm introduces first at time $t_l = \frac{1}{r}$ and the foreign firm introduces last at date $\frac{3}{r}$.*

Proof. : See Appendix ■

The level of home welfare under the optimal tariff policy is:

$$W_A^\mu = \int_{1/r}^\infty N\theta\left(\frac{1}{r}\right)e^{-rt} dt + \int_{3/r}^\infty N\frac{\theta}{r}e^{-rt} dt = \frac{N\theta}{r^2}e^{-1}(1 + e^{-2})$$

The optimal tariff increases the welfare of the home country in three ways. Firstly, it allows the domestic firm to introduce first at its preferred 'stand alone' date of $t_l = 1/r$, increasing its discounted profits. Secondly, the tariff

¹⁷For a formal characterization of these equilibria, see Prokop, Regibeau and Rockett (1993).

raises the quality of the home product. This imposes a more severe competitive constraint on the foreign entrant, ensuring that domestic customers obtain a larger surplus after the introduction of the second-generation product by the foreign firm. Finally, the government collects positive discounted tariff revenues.

The foreign firm clearly suffers from the tariff due to the loss of tariff revenue and its later introduction date. The effect of the tariff on world welfare is not a priori obvious. Because we have inelastic demands the tariff revenue is a pure transfer that leaves world welfare unchanged. The effect of the tariff on the dates of introduction actually lowers world welfare, for two reasons. Firstly, as we saw in our benchmark model, the worldwide optimal delay between the two introductions is equal to the delay, $1/r$, that firms would choose under free trade. The tariff increases this delay, resulting in a loss of welfare. Secondly, the tariff unduly postpones the introduction of the first generation product. Even though the date chosen under optimal tariff protection, $1/r$, is optimal for the home country, it fails to take into account that later introduction also postpones the arrival of the superior second-generation product. In fact, as the worldwide optimal date of first introduction is almost identical to the equilibrium date of introduction under free trade¹⁸, the tariff-induced delay actually decreases world welfare.

Proposition 2 *World welfare is lower under the optimal tariff than under free trade*

Proof. Under free trade, world welfare is equal to $W^F = \frac{e^{-1}N\theta}{r^2} [e^{-\frac{e^{-1}}{1-e^{-1}}}] [\frac{2-e^{-1}}{1-e^{-1}}]$.

At the optimal tariff we have $W^\mu = \int_{1/r}^{\infty} N\theta(\frac{1}{r})e^{-rt} dt + \int_{3/r}^{\infty} N\theta(\frac{2}{r})e^{-rt} dt = \frac{e^{-1}N\theta}{r^2} [1 + 2e^{-2}] < W^F$. ■

4 Administrative Delay

We analyze the case where country A may impose a delay, λ , on the foreign firm before it can actually sell its products in the home market. We assume

¹⁸The worldwide optimal date is $\frac{1-e^{-1}}{r}$, which is barely higher than the preemption date $\frac{e^{-1}}{r(1-e^{-1})}$.

that firm B cannot continue improving the quality of its product once the delay has begun, reflecting the idea that λ represents an administrative delay required to gain approval for sale of a particular product (as opposed to sale by a particular firm) in market A.

Let us now recalculate the equilibrium entry dates for the firms. If the foreign firm moves last, its discounted profits can be written as follows:

$$\begin{aligned}\pi_B^f &= e^{-r(t_f+\lambda)} \int_0^\infty N\theta t_f e^{-rt} dt \\ &= e^{-r(t_f+\lambda)} \frac{\theta N}{r} t_f\end{aligned}$$

, where t_f is the time that elapses between the introduction of the home product and the date at which the foreign firm begins the approval process. Accordingly we will refer to t_f as the 'application delay'. Note that, because the design of the product (and, hence, its quality) is fixed at the beginning of the administrative delay, the per period profit of the foreign firm does not include an allowance for an increment in quality while the approval process runs its course. Maximizing this expression with respect to t_f yields a profit-maximizing delay of $t_{fB}^\lambda = \frac{1}{r}$. This means that the foreign product is actually for sale in the market $\frac{1}{r} + \lambda$ later than the home product. The entry delay that would be chosen by a domestic follower is the same as in the baseline case, i.e. $t_{fA}^\lambda = \frac{1}{r}$.

If the foreign firm is a leader, its discounted profits can be written as follows:

$$\begin{aligned}\pi_B^L &= \int_{t_l+\lambda}^{t_{fA}^\lambda+t_l} \theta N t_L e^{-rt} dt \\ &= \frac{(e^{-r\lambda} - e^{-rt_f})\theta N}{r} [t_L e^{-rt_l}]\end{aligned}$$

, provided that $\lambda \leq t_{fA}^\lambda = \frac{1}{r}$.¹⁹ Maximizing this expression with respect to t_l yields an optimal application date of $t_{lB}^\lambda = \frac{1}{r}$, corresponding to an optimal introduction date of $\frac{1}{r} + \lambda$. Note that the administrative delay does not affect the per period profit that can be earned by the leader since quality

¹⁹If the administrative delay exceeds $\frac{1}{r}$, then a foreign leader always finds itself preempted by the domestic 'follower' as the domestic firm optimally enters at $t_l + \frac{1}{r}$. Therefore, the foreign firm never moves first, letting the domestic firm introduce at $t_l = \frac{1}{r}$.

is fixed at the beginning of the delay. Rather, the delay merely shortens the period during which profits can be earned. This is the case as long as the administrative delay is short enough that there is no change in the order of entry that has been assumed (i.e., the foreign firm is the leader and the domestic firm is the follower). In other words, the administrative delay must not exceed $\frac{1}{r}$.

If the leader is the domestic firm, its profits can be written as:

$$\begin{aligned}\pi_A^L &= e^{-rt_l} \int_0^{t_f+\lambda} \theta N t_L e^{-rt} dt \\ &= e^{-rt_L} \frac{\theta N t_L}{r} (1 - e^{-r(t_f+\lambda)})\end{aligned}$$

so that the administrative delay prolongs the profit period, but does not affect the trade-off that determines the optimal entry time. Therefore, the entry time for a domestic leader is the same as that of a foreign leader: $t_{LA}^\lambda = \frac{1}{r}$.

We can now assess the impact of an administrative delay on the preemption dates of the two firms. Equating the profits for a domestic leader to those of a domestic follower, substituting in the optimal waiting times of the followers, results in the following expression:

$$\begin{aligned}e^{-rt_l} \int_0^{t_{fB}^\lambda} \theta N t_l e^{-rt} dt &= e^{-r(t_l+t_{fA}^\lambda)} \int_0^\infty \theta N t_{fA}^\lambda e^{-rt} dt \\ &\iff t_l(1 - e^{-1}e^{-r\lambda}) = \frac{e^{-1}}{r}\end{aligned}$$

, where the t_l on the right hand side of the first expression stands for the *application* date of the foreign leader. The preemption date of the domestic firm is $t_{PA}^\lambda = \frac{1}{r} \frac{e^{-1}}{1 - e^{-1}e^{-r\lambda}}$. This is earlier than the preemption date in the baseline case. Intuitively, for a given date of first entry t_l , the administrative delay does not affect the domestic firm's discounted profits as a follower but it increases the profits of the domestic firm as a leader by delaying the introduction of the second-generation product. Hence, at the preemption time of the baseline case, the domestic firm has higher profits as a leader than as a follower so that it is willing to move even earlier in order to move first.

To obtain the foreign preemption date we equate the profits of the foreign firm, assuming that it leads, with the profits of the foreign firm, assuming that it is a follower to obtain:

$$e^{-rt} \int_{\lambda}^{t_{fA}^{\lambda}} \theta N t_l e^{-rt} dt = e^{-r(t_l + t_{fB}^{\lambda} + \lambda)} \int_0^{\infty} \theta N t_{fB}^{\lambda} e^{-rt} dt$$

$$\iff e^{-rt_l} N t_l (e^{-r\lambda} - e^{-1}) = e^{-r(t_l + \frac{1}{r} + \lambda)} \theta N (\frac{1}{r})$$

so that the earliest date at which the foreign firm would be willing to preempt is $t_{PB}^{\lambda} = \frac{e^{-1}e^{-r\lambda}}{r(e^{-r\lambda} - e^{-1})}$. Note that, at a zero administrative delay, this preemption date is the same as the baseline preemption date. Further, $\frac{\partial t_{PB}^{\lambda}}{\partial \lambda} > 0$ ²⁰. Intuitively, the administrative delay hurts the discounted profits of a foreign follower less than those of a foreign leader because the fruitless period between application and actual introduction intervenes at a later date. This makes the foreign firm less eager to move early in order to be first.

Summarizing, an administrative delay λ does not affect the stand alone date of a domestic leader, delays the stand alone date of a foreign leader by exactly λ , decreases the preemption date of the domestic firm and increases the preemption date of the foreign firm. For small values of λ , then, we have $t_{PA}^{\lambda} < t_{PB}^{\lambda} < t_{lA}^{\lambda} = \frac{1}{r} < t_{lB}^{\lambda} = \frac{1}{r} + \lambda$. In the unique subgame perfect equilibrium, the domestic firm introduces first at t_{PA}^{λ} . The foreign firm applies for approval at time $t_{PB}^{\lambda} + \frac{1}{r}$ and begins selling its product after a further delay of λ . This ranking remains valid as long as:

$$t_{PB}^{\lambda} \leq t_{lA}^{\lambda} \iff e^{-r\lambda} \geq \frac{e^{-1}}{1 - e^{-1}}$$

For all greater values of λ , we have $t_{PA}^{\lambda} < t_{lA}^{\lambda} = \frac{1}{r} < t_{PB}^{\lambda} < t_{lB}^{\lambda} = \frac{1}{r} + \lambda$ so that the domestic firm introduces first at time $\frac{1}{r}$. As we saw in the benchmark case, $\frac{1}{r}$ is the welfare maximizing date of first introduction for the home country. Moreover, home welfare is independent of the date

²⁰ $\frac{\partial t_{PB}^{\lambda}}{\partial \lambda} = -e^{-1} \left[\left\{ 1 - \frac{e^{-r\lambda}}{e^{-r\lambda} - e^{-1}} \right\} e^{-r\lambda} / (e^{-r\lambda} - e^{-1}) \right]$
 which is positive for $\lambda < \frac{1}{r}$.

of introduction of the second-generation product. This implies that home welfare is maximized by setting the administrative delay is set at or above λ^* s.t. $e^{-r\lambda^*} = \frac{e^{-1}}{1-e^{-1}}$. With the optimal delay, the welfare of Country A is:

$$W_A^\lambda = \frac{e^{-1}\theta N}{r^2} = W_A^S < W_A^\mu$$

In other words, just like the optimal tariff, the optimal delay ensures the best possible timing of product introduction for country A but it does not yield any tariff revenue. Therefore, as long as tariffs are not bounded, the home country will maximize welfare by using its trade policy and will not discriminate against the foreign firm in its administrative approval process. Administrative delays will only be used if trade liberalization decrease the maximum allowable tariff significantly below $\mu = \frac{\theta}{r}$.

We can now compute world welfare under the optimal delay, W^{λ^*} and compare it to world welfare under the optimal tariff, W^{μ^*} :

$$\begin{aligned} W^{\lambda^*} &= \int_{1/r}^{\infty} \theta N\left(\frac{1}{r}\right) e^{-rt} dt + \int_{\frac{2}{r}+\lambda}^{\infty} \theta N\left(\frac{1}{r}\right) e^{-rt} dt = \frac{N\theta}{r^2} e^{-1} (1 + e^{-1} e^{-r\lambda^*}) \\ W^{\mu^*} &= \frac{N\theta}{r^2} e^{-1} (1 + 2e^{-2}) \end{aligned}$$

From the definition of the optimal administrative delay, however, we know that:

$$e^{-r\lambda^*} = \frac{e^{-1}}{1-e^{-1}} < 2$$

Therefore, from the point of view of world welfare, the optimal tariff is preferable to the optimal administrative delay. This result is not a priori obvious since tariff revenues are a pure transfer that has no effect on world welfare and the date of first introduction is the same under both policies. The only differences between the two policies lie in the timing of introduction of second generation products and in their quality. On the one hand, second generation products are introduced earlier with the optimal delay than with

the optimal tariff²¹. On the other hand, with the delay, the quality of the second generation product only keeps increasing over the interval between the first introduction and the date of *application* of the foreign firm. This is followed by a period of length λ^* during which the product goes through the approval process without any further quality improvements. This contrasts with the tariff regime, where the quality of the second-generation product keeps increasing over the whole interval between the two introduction dates. This second effect dominates.

Finally, the foreign firm is better off under the optimal delay, earning discounted profits of $\frac{N\theta e^{-2}}{(1-e^{-1})r^2}$ than under the optimal tariff policy for which its discounted profits would be equal to $\frac{N\theta e^{-2}}{r^2}$. In other words, the disadvantage of facing a period λ^* of stunted product development is outweighed by the burden of the optimal tariff.

5 Trade Liberalization

Trade liberalization often takes the form of mutually agreed reduction in quotas and or tariffs. While significant effort has been expended to also restrict the use of other, less obvious, discriminatory policy instruments the results so far appear to be less than spectacular. Accordingly we will assume that 'trade liberalization' sets an upper limit on the tariff that can be used by the home country but that it does not constrain the use of administrative delays.

The effects of a drastic trade liberalization are quite striking. If tariffs can no longer be used at all, the home country will switch from the optimal tariff policy to the optimal trade policy. As we have just seen, this switch would result in lower welfare for the home country and the world, even though it would be applauded by the foreign firm. In other words, the prohibition on tariffs would force the home country to rely on an instrument that is less efficient both for itself and for the world economy.

²¹Formally, $\frac{2}{r} > \frac{1}{r} + \lambda^*$. At the optimal administrative delay, $e^{-r\lambda} = \frac{e^{-1}}{1-e^{-1}}$ and the right hand side of this equation is strictly greater than e^{-1} . This implies that λ^* is strictly less than $\frac{1}{r}$.

The effect of less extreme degrees of trade liberalization are illustrated in figure 3. The tariff cap is on the horizontal axis and the combination of tariff and delay that maximizes domestic welfare is on the vertical axis. Let us consider a progressive tightening of the tariff cap. For values of μ_{\max} in $[\mu^{\#}, \frac{\theta}{r}]$, the optimal policy of the home country is to set the maximum tariff allowed and not impose any administrative delay. Such a policy still ensures that the first introduction occurs at the optimal date $\frac{1}{r}$ and that the discounted value of tariff revenues is as large as possible. Interestingly, this policy is still optimal for a range below $\mu^{\#}$: even though tightening the cap now implies that the domestic firm introduces earlier than $\frac{1}{r}$, the home country still prefers not to use administrative delays. Intuitively, for values of μ close to $\mu^{\#}$, the gains from pushing the introduction date back toward $\frac{1}{r}$ are small²². On the other hand delaying the first introduction involves a significant decrease in the discounted values of the tariff revenues²³. As the tariff cap is tightened further, however, one reaches a point where the marginal benefit of delaying the first introduction outweighs the marginal cost of pushing back the date at which tariff revenues are collected. From that point on the home country uses both the maximum possible tariff and a positive administrative delay.

[Figure 3 here]

As long as the home country does not rely on administrative delays, trade liberalization increases world welfare. For $\mu_{\max} \in [\mu^{\#}, \frac{\theta}{r}]$, liberalization decreases the delay between first and second introduction, bringing it closer to the optimal value of $\frac{1}{r}$. Further liberalization has the additional benefit of also speeding up the date of introduction of the first product. However, once the domestic country begins to impose a substantial administrative delay, the dates of introduction of the two products get pushed back so that further liberalization results in lower levels of world welfare.

Proposition 3 *Moderate trade liberalization increases world welfare. Further liberalization gives rise to administrative delays and decreases world welfare.*

²²Formally, this follows from the envelope theorem.

²³In the absence of tariff cap, there was no such trade off since the value of μ that maximized the discounted value of tariff revenues was high enough to also ensure first introduction at $\frac{1}{r}$. The difference here is that the tariff rate is *fixed* at μ_{\max} so that further delay does not add to tariff revenues.

Proof. See Appendix A. ■

6 Robustness

6.1 Credibility of the tariff and delay policies

We have so far adopted the traditional timing of trade policy models and assumed that the level of tariffs and administrative delays could be committed to before the firms made their own choices. However, the extent to which governments can credibly commit to various types of economic policies is a, yet unresolved, empirical question. It is therefore interesting to examine how our analysis is affected if we vary the commitment power of the policy maker.

The optimal administrative delay obtained in section III remains optimal at any point of the game and is therefore credible in the absence of any exogenous commitment power. After the domestic firm moves first, the policy maker becomes indifferent between all possible values of the delay because, from then on, the instantaneous welfare of the country is equal to Nq_A whatever the date of introduction and quality of the foreign follower happens to be. If the foreign firm were to move first then the administrative delay has no effect on the rest of the game so that, again, the policy maker is indifferent between all possible values of λ .

The optimal tariff policy derived in section 3 clearly suffers from one type of time-inconsistency: once the foreign firm has actually introduced its own product, country A would wish to revise its optimal tariff. By setting a unit tariff equal to the quality advantage of the foreign product country A would appropriate the entire surplus created by the second product introduction, leaving the foreign firm with zero profits. If there is any arbitrarily small but positive cost of entry, such an opportunistic policy on the part of country A would keep the foreign firm out of the industry altogether. Since country A is better off when the foreign firm actually enters one can at least say that it has an incentive to commit not to revert to this opportunistic tariff policy if it possibly can.

On the other hand, $\mu = \theta/r$ remains the optimal value of the tariff as long as the foreign firm has not introduced its product. To see this, suppose that the home government could change the tariff once the home firm has introduced first. At that point, the home government only cares about maximizing the discounted value of its tariff revenues. The value of the superior quality embedded in second generation products is completely appropriated by the foreign firm and does not enter into the domestic welfare function. Hence the government chooses the value of μ that maximizes:

$$\int_{t_{fB}^{\mu}}^{\infty} \mu e^{-rt} dt, \text{ where } t_{fB}^{\mu} = \frac{1}{r} + \frac{\mu}{\theta}$$

yielding $\mu^* = \frac{\theta}{r}$, which is the same as the optimal tariff that would be chosen at the beginning of the game.

6.2 Demand

We have assumed that consumer demand for either product is perfectly inelastic at any point in time. Inelastic demands have the nice property that a monopolist would behave in a socially optimal way as it is able to appropriate the whole consumer surplus created by its product. This helps ensure that any departure from the socially optimal pattern of introduction has its source in the rivalry between the domestic and foreign firms. Still, inelastic demands have some important limitations.

The first limitation is that import tariffs do not result in the usual dead-weight loss. Hence inelastic demands bias the world welfare comparison in favor of the tariff policy. The second peculiarity of inelastic demands is that they allow each quality leader to fully appropriate the value of its quality advantage. This is why the home government was indifferent as to the precise level of quality attained by a foreign follower: local consumers could not appropriate any part of this increased quality. To investigate the effect of this special feature, we reconsider the analysis of sections 1I through 4 under the assumption that the foreign firm can only appropriate a fraction α of its

quality advantage. Hence the instantaneous profits of a foreign leader would be $\alpha\theta t_l$ and the profits of a foreign follower would be $\alpha\theta t_f$. When a tariff is imposed, we assume that a proportion α is borne by the foreign firm and a proportion $1 - \alpha$ by local consumers.²⁴

[Figure 4 here]

With this specification $(1 - \alpha)$ enters all profit maximization problems as a multiplicative factor, leaving the dates of introduction of leaders and followers as well as 'preemption' dates unchanged. Since these dates are independent of α , the effect of tariffs and delays on the behavior of the firms is still as described in the previous sections. On the other hand, the welfare function of country A now includes some of the surplus created by the foreign firm so that country A now cares about not overly delaying the introduction of the foreign product. This makes the use of both delays and tariffs less attractive, for two reasons. Firstly, for a given date of introduction by the domestic leader, administrative delays and tariffs push back the introduction of the foreign good. Secondly, tariffs and delays also defer the date of introduction of the domestic leader, further postponing the introduction of the second product.

The optimal tariff and delay policies are shown as a function of α in figure 4. As expected, both instruments are used less aggressively when α is low. Interestingly, there is a critical value α_o below which the optimal administrative delay is zero. The intuition for this discrete jump can be obtained from figure 5. Country A's welfare is made of two parts. The first component, $W1$, is the value of the product of the domestic firm. This value is appropriated by the home firm from the first to the second introduction and by domestic consumers after that. $W1$ only depends on the delay λ through its effect on the date of introduction of the domestic product. As we saw in the previous sections, $W1$ is maximized by an introduction date of $\frac{1}{r}$, which occurs for λ larger than λ_o . Over this range, then, $W1$ is independent of α . Below λ_o , $W1$ is increasing in λ . The second component, defined as $W2$, represents the share $(1 - \alpha)$ of the foreign firm's quality advantage

²⁴This assumption would hold for linear demands, where the proportion between profit and consumer surplus is independent of the tariff level. Alternative assumptions about the sharing of the tariff burden would not significantly affect the nature of the results.

that is captured by country A. Since a larger delay pushes back the date of introduction of the foreign product and also freezes its quality for a longer period, W_2 is decreasing in λ . The sum of W_1 and W_2 is two-peaked, with a local maximum at $\lambda = 0$ and another one at $\lambda^* > 0$. As the share of the foreign firm's quality advantage appropriated by the home country increases so does the relative importance of W_2 and, therefore, the relative height of the $\lambda = 0$ peak. For $\alpha < \alpha_o$ then, W is maximized at $\lambda = 0$.²⁵

[Figure 5 here]

While the introduction of the parameter α does not affect our positive results or the qualitative analysis of the home country's welfare it can change the implications of trade liberalization for world welfare. Since α only determines how surplus is shared between the foreign firm and country A it does not have any *direct* effect on world welfare. Its impact comes through the induced changes in the optimal policies of country A. As long as the optimal delay is positive, our previous conclusion still holds: world welfare is higher under country A's optimal tariff than under its optimal delay. Hence drastic liberalization would lower world welfare. However, as soon as α hits the critical value for which the optimal delay jumps to zero, the policy conclusion is reversed: the optimal delay policy ensures the prevalence of free trade while the optimal tariff results in undesirably late introductions. Therefore, for α low enough, drastic trade liberalization would increase world welfare.

7 Conclusion

Various administrative procedures can be used to discriminate against foreign firms. Discrimination can occur either because foreign firms are treated unfairly or simply because the idiosyncracies of the process favor the more experienced domestic firms. In this paper we focussed on the case of product approval where discrimination imposes additional delays on the introduction of new products by foreign competitors. We wished to compare the effects

²⁵See appendix B for a description of the proofs and simulations on which the results of this section rely.

of such administrative delays with those of more traditional trade policy instruments such as tariffs. Using a simple model of the timing of product introduction we showed that both tariffs and delays postpone the date of introduction of both foreign and domestic products and allow the domestic firm to be first to market. We also established that, if both instruments are available, the domestic country prefers to only rely on the tariff. Although obtained for the special case of inelastic demands, these positive results are rather robust to changes in demand and cost conditions. We also compared welfare under the domestic country's optimal tariff policy to the level of welfare attained under its optimal delay policy. While the foreign country is better off with administrative delays, world welfare is higher under the optimal tariff. This implies that a drastic trade liberalization that bans the use of tariffs but is ineffective in controlling less transparent policies like delays would actually make the world worse off. In fact one can show that, while imposing a binding cap on tariffs initially increases worldwide welfare, there is a level below which further tightening the cap is undesirable. These normative results are significantly less robust than the results on the firms' behavior. In particular one can show that they are sensitive to the share of the quality advantage of the (late-moving) foreign firm that can be appropriated by domestic consumers. This in turn would depend on the precise specification of demand and on the type of competition between domestic and foreign firms. Our conclusion that drastic trade liberalization would decrease world welfare should therefore be taken as a cautionary tale, not as robust guidance for policy. A more general normative insight from the paper is that constraining the use of a subset of trade-related instruments does not necessarily lead to more palatable equilibrium policies. An interesting extension of our analysis would be to allow both countries to have active trade policies. For this to affect our results, there must of course be some kind of link between the two markets. One natural assumption would be that simultaneous introduction in both markets is more economical than staggered entry.

8 References

- Brander, J.A. and B. Spencer, 1983, "International R&D Rivalry and Industrial Strategy", *Review of Economic Studies*, 50: pp. 707-722.

- Chuman, E. and S.-I. Kusumoto, 1995, "On the Optimal Timing of Technology Adoption by the Home Firm under Tariff Protection or Free Trade", mimeo, University of Tsukuba.
- Dranove, D. and D. Metzler, 1994, "Do Important Drugs Reach the Market Sooner?", *Rand journal of Economics*, Autumn, pp. 402-423.
- Dutta, P.K. and A. Rustichini, 1993, "A Theory of Stopping Time Games with Applications to Product Innovations and Asset Sales", *Economic Theory*, 3, 743-764.
- Gieringer, D.H., 1985, "The Safety and Efficacy of New Drug Approval", *Cato Journal*, Vol. 5, pp. 177-201.
- Myagiwa, K. and Y. Ohno, 1995, "Closing the Technology gap under Protection", *American Economic Review*, September, pp. 755-770.
- Noll, R., 1985, "Government Regulatory Behavior: A Multidisciplinary Survey and Synthesis", in R. Noll (ed.), *Regulatory Policy and the Social Sciences*, Berkeley, university of California Press.
- Prokop, J., P. Regibeau and K. Rockett, 1993, "Minimum Quality Standards and Novelty Requirements in a Onse-Shot Development Race", Working Paper, Northwestern University, Department of Management and Strategy.
- Regibeau, P. and K. Rockett, 1996, "The Timing of Product Introduction and the Credibility of Compatibility Decisions", *International Journal of Industrial Organization*, 14, 801-823.

9 Appendix A

1. Derivation of the optimal tariff in case 2

The home country's welfare is written as follows:

$$W_A = \int_{1/r}^{\infty} N\theta\left(\frac{1}{r}\right)e^{-rt}dt + \int_{\frac{2}{r}+\frac{\mu}{\theta}}^{\infty} N\mu e^{-rt}dt$$

Maximizing this expression with respect to μ yields $\mu^* = \frac{\theta}{r}$.

2. Showing that μ^* is the globally optimal tariff for the home country when only the tariff may be used.

Welfare of Country A is composed of two terms, as written above: a term that represents the sum of profits and consumers' surplus net of the tariff revenue, and a second term reflecting tariff revenue:

$$W_A = \int_{t_l}^{\infty} N\theta t_l e^{-rt} dt + \int_{t_l+t_f}^{\infty} \mu N e^{-rt} dt$$

The first term is maximized at $t_l = \frac{1}{r}$. Therefore, to prove that the optimal tariff occurs for $\mu > \mu^\#$ we only need to show that the second term is maximized for $\mu > \mu^\#$. We maximize the following expression with respect to the tariff level:

$$\max e^{-rt_L} e^{-et_f} \frac{N\mu}{r}$$

subject to:

$$\begin{aligned} t_f &= \frac{1}{r} + \frac{\mu}{\theta} \\ t_l &= \frac{e^{-1} e^{-\frac{r\mu}{\theta}}}{r(1-e^{-1})} + \frac{\mu}{\theta} \end{aligned}$$

The first order conditions of this maximization problem are:

$$e^{-rt_L} e^{-rt_f} \frac{N}{r} [1 - r\mu(t'_L + t'_f)] = 0$$

where the primes indicate first derivatives, which can be calculated as follows:

$$\begin{aligned} t'_L &= \frac{1}{\theta} \left(1 - \frac{e^{-1} e^{-\frac{r\mu}{\theta}}}{1-e^{-1}}\right) > 0 \\ t'_f &= \frac{1}{\theta} > 0 \end{aligned}$$

In order to have an interior maximum the expression in square bracket in the first order condition must be equal to zero. This expression is positive at $t_l = \frac{1}{r}$ and decreases in the tariff level (ie, its derivative with respect to the tariff is negative for $\mu < \frac{\theta}{r}$). This implies that any possible interior solution must occur for $t_l > \frac{1}{r}$ or, equivalently, for $\mu > \mu^\#$.

This means that the maximum of expected profit over the range $\mu \in [0, \mu^\#]$ must be at a corner. Clearly, expected tariff revenues cannot be maximized for $\mu = 0$. They cannot be maximized for $\mu = \mu^\#$ either: at this point the expression for discounted tariff revenues is continuous and, by definition of $\mu^* = \frac{\theta}{r}$ we know that discounted tariff revenues are higher at μ^* than at $\mu^\#$.

3. Derivation of the optimal entry dates for both firms when the home country can control both firms' entry dates

In order to derive the optimal entry dates for both firms from the point of view of Country A, we must maximize welfare with respect to both the entry dates of the leader and the follower. Since consumers' surplus is the same as profits, Country A's welfare is simply the expression at the top of the page with the tariff set to zero. This expression is independent of the entry date of the follower, indicating that the optimal entry date for the follower is indeterminate. Maximizing the expression with respect to the leader's entry date yields an optimal time of entry of $t_l = \frac{1}{r}$. Welfare for Country A is the same as in the monopoly case, not surprisingly.

The optimal entry dates from the point of view of world welfare are calculated by maximizing world welfare with respect to the entry dates of the leader and the follower. The welfare of Country A is as specified in the previous paragraph, while the welfare of Country B is simply the discounted profits of the follower, as calculated in the first equation of the Appendix (setting the tariff equal to zero). Maximizing world welfare yields a follower entry delay of $\frac{1}{r}$ (since the optimal date is indeterminate from the point of Country A, and a delay of $\frac{1}{r}$ maximizes the follower's profits, as in the baseline case discussed in the text). The first order condition that determines the leader's entry date is:

$$e^{-rt_l} \frac{\theta}{r} [1 - rt_l - e^{-1}] = 0$$

so that the optimal entry date for the leader is $t_l = \frac{1-e^{-1}}{r}$. This is earlier than the optimal entry date from the point of view of Country A since world welfare takes into account Country B's welfare, and from the point of view of Country B, the leader's entry date merely serves to postpone the date at which profits will accrue to Country B. At the world welfare maximizing entry dates for the two firms, welfare is as follows:

$$e^{1-e^{-1}}(1 - e^{-1}) \frac{\theta N}{r^2} = W_A \quad e^{-1} \frac{\theta N}{r^2} = W_B \quad \frac{e^{-1} \theta N}{r^2} (1 + e^{e^{-1}}(e^2 - e)) = W$$

4. Partial Liberalization.

We first consider the range $\mu_{\max} \in [\mu^\#, \frac{\theta}{r}]$. The welfare of the home country has two components, $W_o = e^{-rt_l} N \theta t_l$ and the tariff revenue $T = e^{-rt_l} e^{-1} e^{-r \frac{\mu}{\theta}} \mu$. The first component is maximized by any $\mu \geq \mu^\#$ since $t_l = \frac{1}{r}$ for all $\mu \geq \mu^\#$. Moreover T is concave in μ and $\operatorname{argmax} T = \frac{\theta}{r}$. Hence, for $\mu \in [0, \mu_{\max}]$ $\operatorname{argmax} T = \mu_{\max}$. Hence the optimal policy is to set $\mu = \mu_{\max}$. As the date of first introduction is unchanged but the date of second introduction moves closer to the worldwide optimum, liberalization over this range increases world welfare.

Now we show that, in the neighborhood of $\mu_{\max} = \mu^\#$, the optimal policy does not involve a positive administrative delay. In the absence of any delay, the optimal tariff policy is still to set $\mu = \mu_{\max}$ as $\frac{dW_o}{d\mu}(\mu = \mu_{\max}) > 0$ and $\frac{dT}{d\mu}(\mu = \mu_{\max}) > 0$. At $\mu = \mu_{\max}$ we have $\frac{dW}{d\lambda} = \frac{\partial W_o}{\partial t_l} \frac{dt_l}{d\lambda} + \frac{dT}{d\lambda}$. At $\mu = \mu_{\max} = \mu^\#$, $\frac{\partial W_o}{\partial t_l} = 0$ by the envelope theorem (since for $\mu = \mu^\#$, $t_l = \frac{1}{r} = \operatorname{argmax} W_o$). Since $\frac{dT}{d\lambda} < 0$ we have $\frac{dW}{d\lambda} < 0$. One can therefore find an arbitrarily small neighborhood to the left of μ_{\max} where $\frac{dW}{d\lambda}$ remains negative.

The precise shape of the functions displayed in figure 3 for $\mu_{\max} < \mu^\#$ were obtained through numerical simulations based on Maple V.

10 Appendix B

We now assume that the foreign firm can only appropriate a share α of its quality advantage. We first show that the introduction of α does not affect the various dates of introduction. Clearly the maximization problem of the domestic firm as a leader or as a follower do not depend on α . The maximization problem of a foreign follower becomes

$Max_{t_f} e^{-rt_f} \alpha [\theta t_f - \mu]$ so that $t_f^* = \frac{1}{r} + \frac{\mu}{\theta}$ and $Max_{t_f} e^{-rt_f + \lambda} \alpha \theta t_f$ so that $t_f^* = \frac{1}{r}$ and the delay before actual introduction is $\frac{1}{r} + \lambda$.

Similarly, the maximization problems of a foreign leader are:

$Max_{t_i} e^{-rt_i} \alpha (\theta t_i - \mu) (1 - e^{-rt_i A})$ so that $t_i^* = \frac{1}{r} + \frac{\mu}{\theta}$ and $Max_{t_i} e^{-rt_i + \lambda} \alpha \theta t_i$ so that $t_i^* = \frac{1}{r}$ and the delay before actual introduction is $\frac{1}{r} + \lambda$.

The preemption dates of the domestic firms clearly do not depend on α . For the foreign firms, the preemption dates are obtained as follows. With a tariff,

$e^{-rt_p} e^{-1} e^{-r\frac{\mu}{\theta}} \alpha [\frac{\theta}{r} + \mu - \mu] = e^{-rt_p} \alpha (\theta t_p - \mu) [1 - e^{-1}]$ so that $t_{pB} = \frac{1}{r} \frac{e^{-1}}{1 - e^{-1}} e^{-\frac{r\mu}{\theta}} + \frac{\mu}{\theta}$. With a delay, $e^{-rt_p} e^{-1} e^{-r\lambda} \alpha \frac{\theta}{r} = e^{-rt_p} \alpha \theta t_p (e^{-r\lambda} - e^{-1})$ so that $t_{pB} = \frac{e^{-1} e^{-r\lambda}}{r(e^{-r\lambda} - e^{-1})}$.

Results on optimal policies could not be obtained analytically for all ranges of parameters. We, therefore, relied on numerical simulations based on Maple V. The simulations are quite straightforward as the only parameters of the problem are θ and r . In fact, the only magnitude of relevance is the relative size of these two parameters so that one can set $\theta = 1$ and determine the optimal delay and tariff policies for different values of r . As the qualitative results are the same for all values of r , the figures 4 and 5 in the text simply show a 'typical' outcome. The expressions used in the simulations are:

$$W(\mu) = \frac{e^{-rt_i}}{r} [\theta t_i + \alpha \mu e^{-1} e^{-r\frac{\mu}{\theta}} + (1 - \alpha) (\frac{1}{r} + \mu) \theta e^{-1} e^{-r\frac{\mu}{\theta}}]$$

$$W(\lambda) = \frac{e^{-rt_i}}{r} [\theta t_i + (1 - \alpha) \frac{\theta}{r} e^{-1} e^{-r\lambda}]$$

$$WW(\mu) = \frac{e^{-rt_i}}{r} [\theta t_i + \theta (\frac{1}{r} + \mu) e^{-1} e^{-r\frac{\mu}{\theta}}]$$

$$WW(\lambda) = \frac{e^{-rt_l}}{r} [\theta t_l + \frac{\theta}{r} e^{-1} e^{-r\lambda}]$$

where $t_l = \min[t_{pB}, \frac{1}{r}]$.

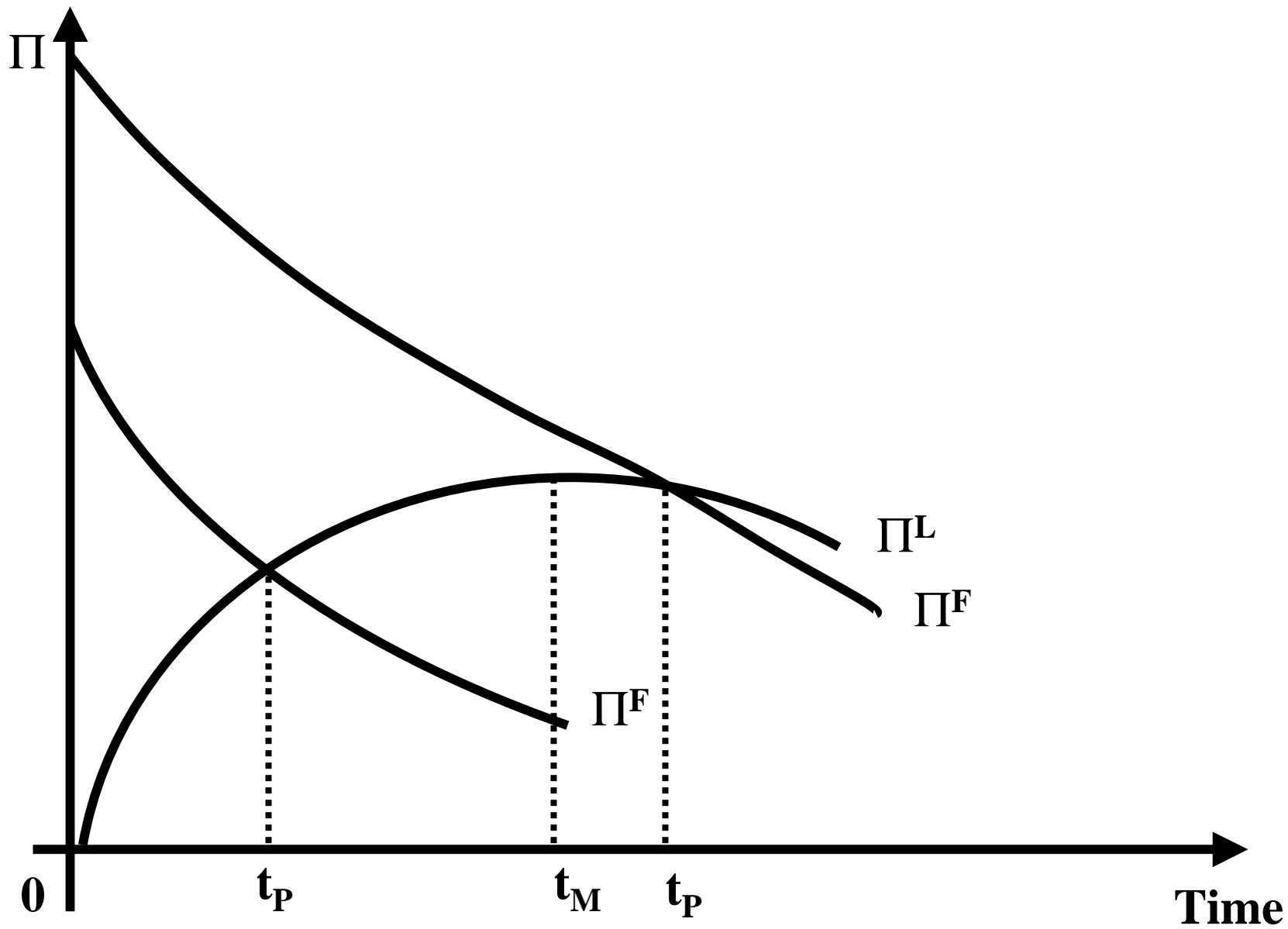


Figure 1

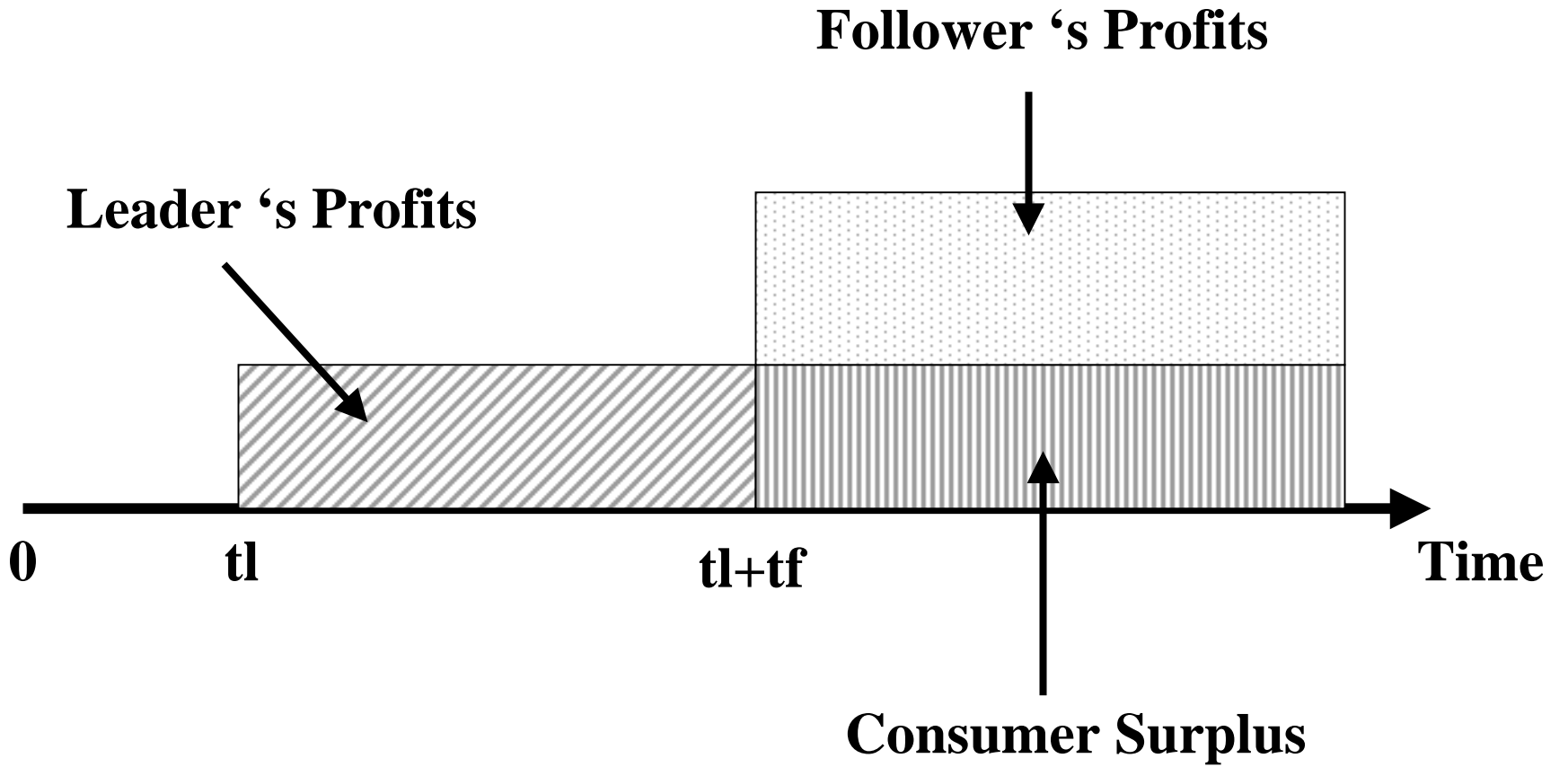
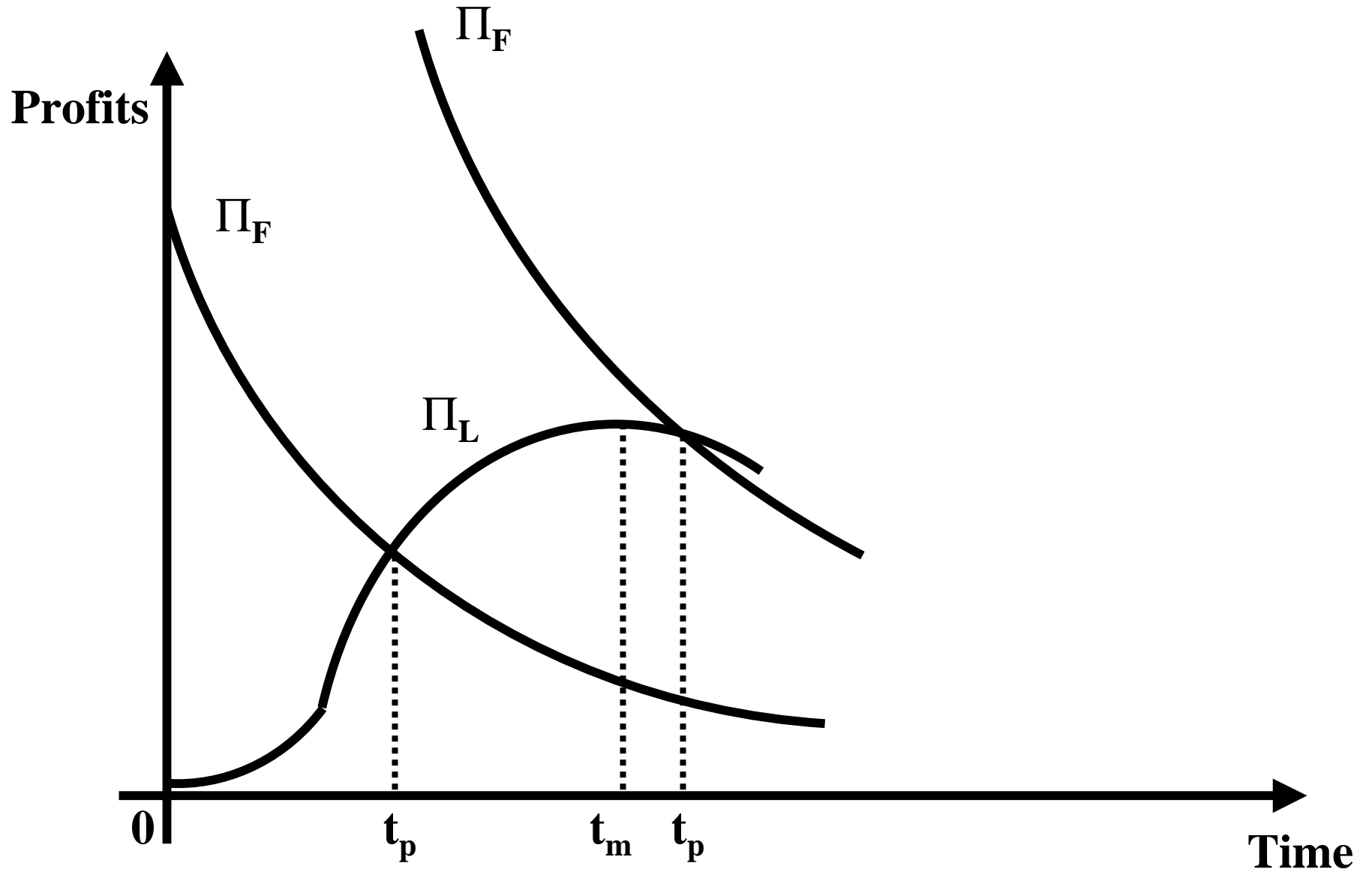


Figure 2



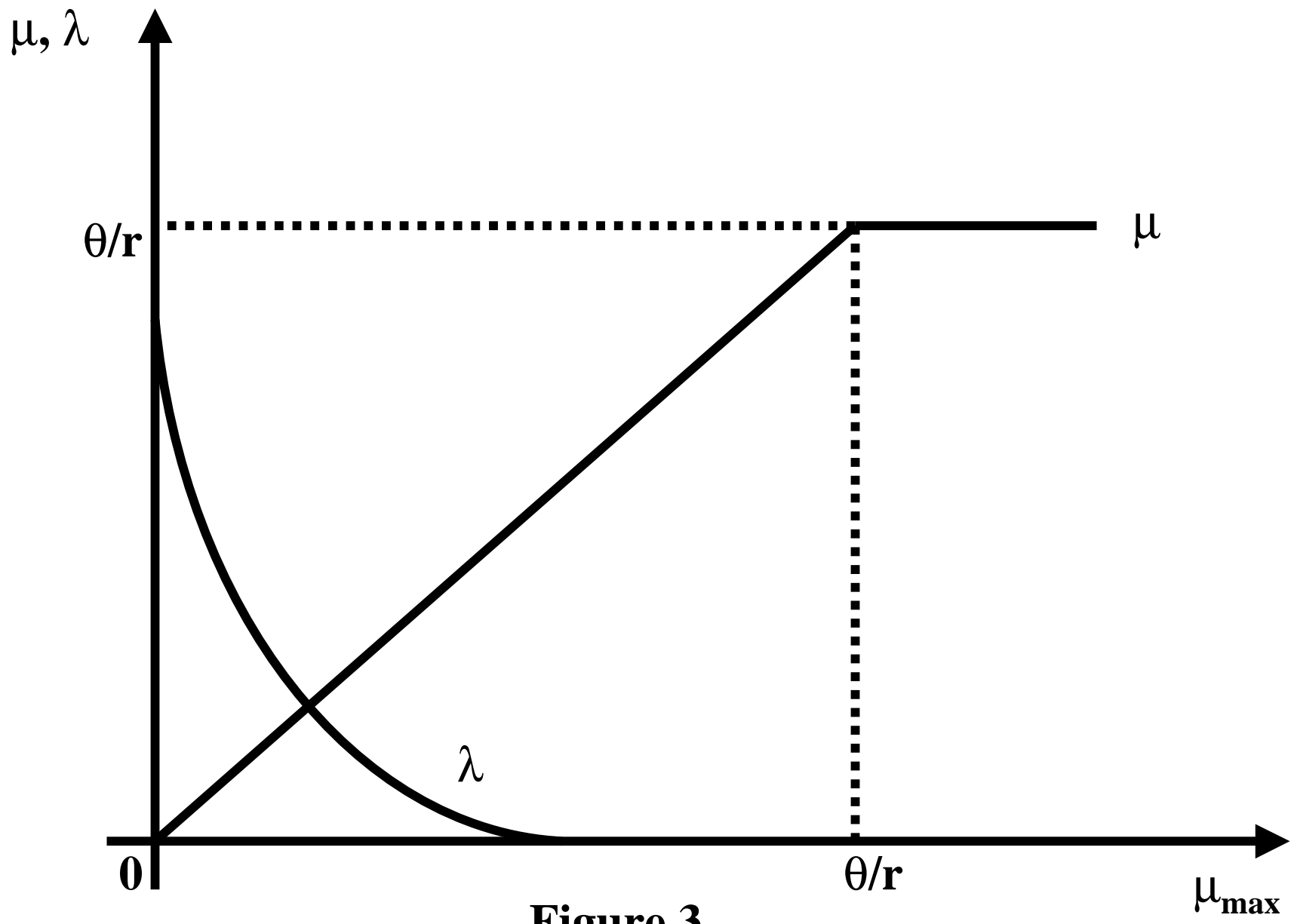


Figure 3

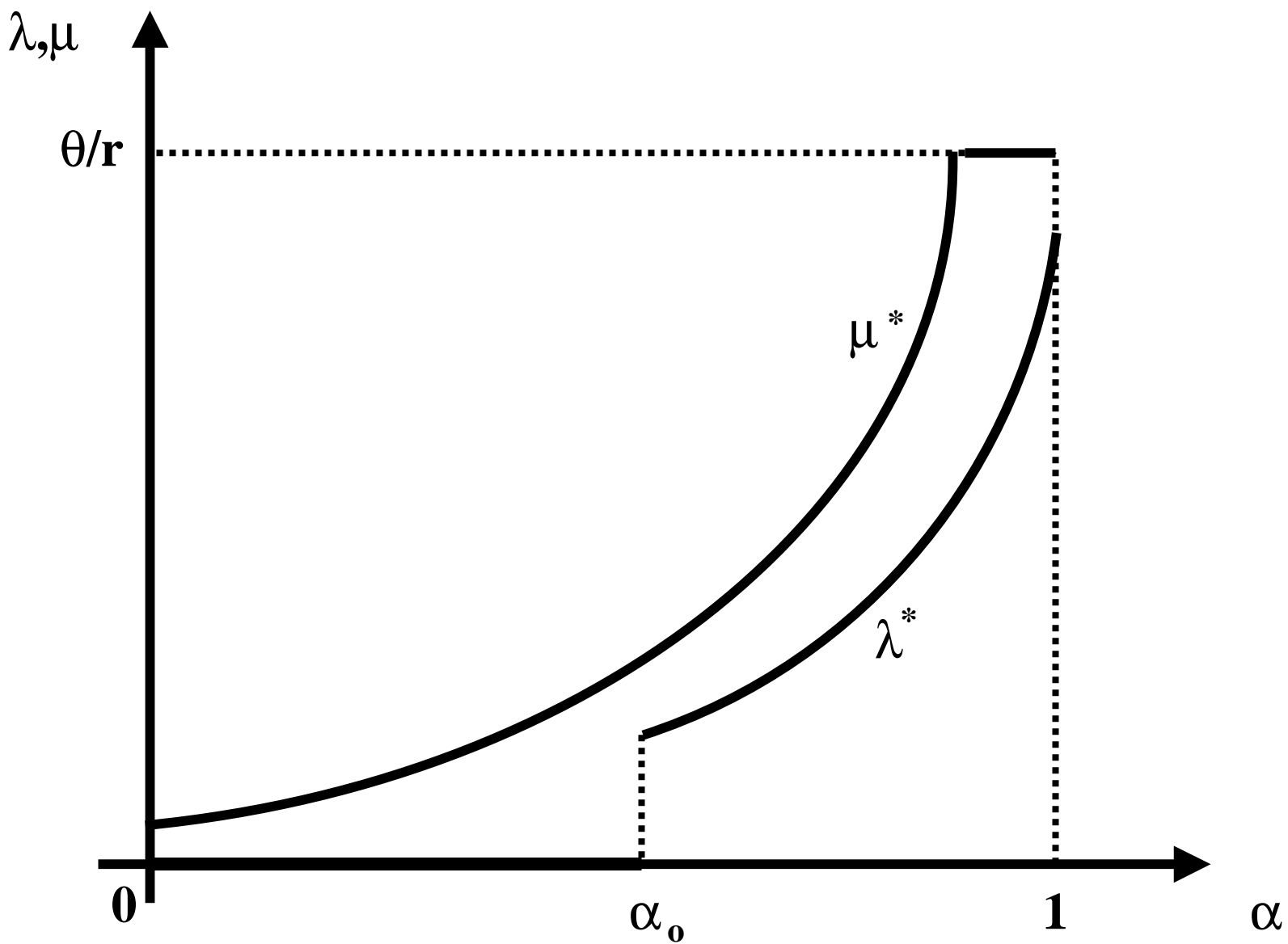


Figure 4

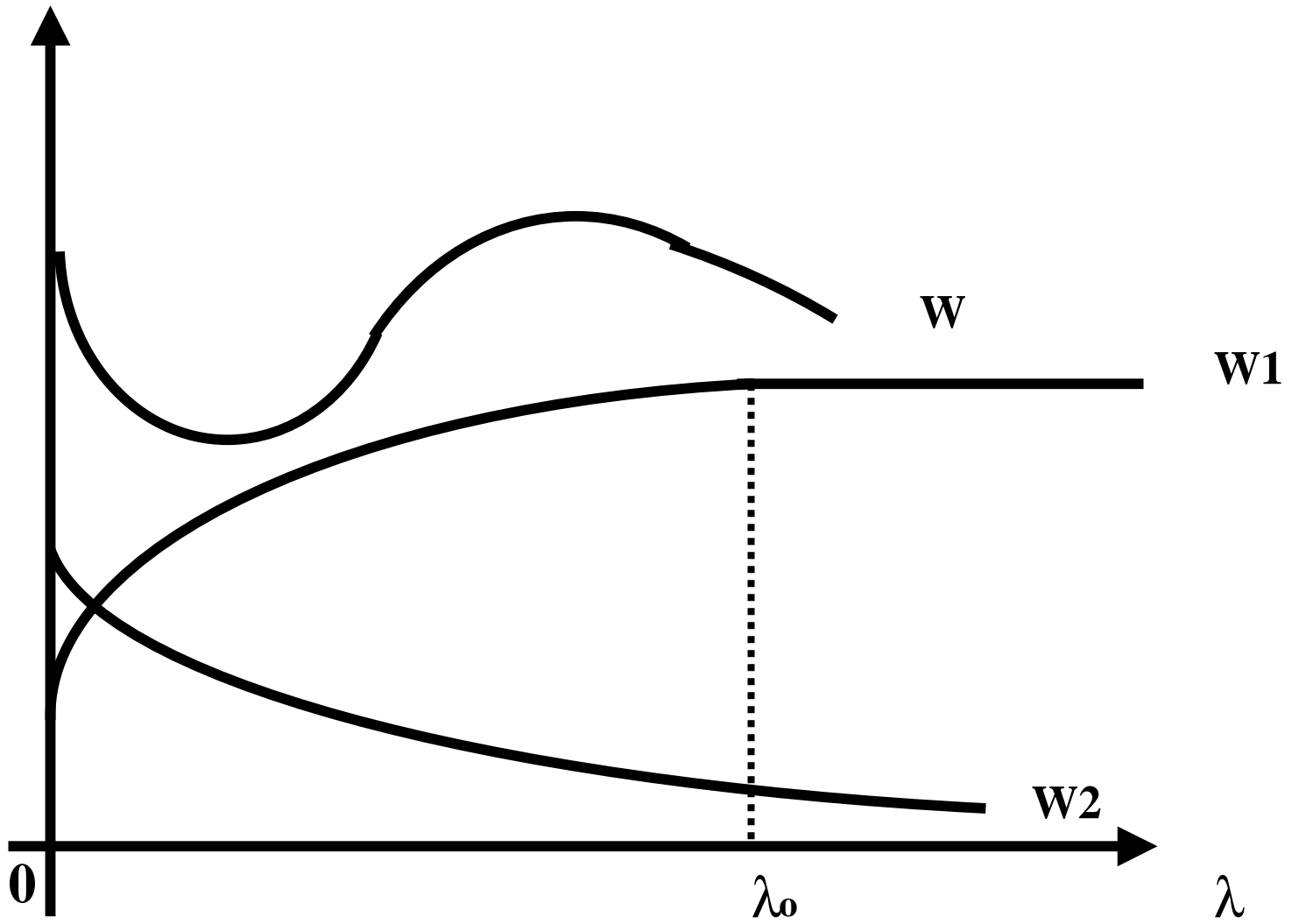


Figure 5