Trade Agreements with Heterogeneous Firms*

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Abstract

Since Melitz (2003), how trade restrictions affect firms within an industry differently has become an important consideration. This paper takes the prediction that a subset of firms actually gain from bilateral trade liberalization and apply it to a lobbying framework. Where conventional wisdom states that the entire import competing industry would lobby against trade agreements, we show that this is no longer the case when firms are heterogeneous. In this instance, because large productive firms gain enough profits in the foreign market to more than offset losses in the domestic market from increased competition, they would support bilateral trade liberalization while small firms that are not productive enough to export prefer autarky. This logic is in line with Henry Ford coming out against the Fordney-McCumber tariff of 1922. We allow for two possible trade barriers (ad valorem tariff and iceberg transport cost) and determine the set of circumstances under which a trade agreement will be reached when firms can lobby the government for the policy that they would prefer.

Keywords: Firm heterogeneity, lobby, non-tariff barriers, tariffs, trade agreement.
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1 Introduction

This paper develops a theoretical model of trade agreements based on an underlying economic structure that features heterogeneous firms due to Melitz (2003). One of the main predictions of Melitz (2003) is that larger firms tend to export while smaller firms tend only to serve the domestic market. Therefore, in the context of negotiations to reach a trade agreement, larger firms' interests will tend to conflict with those of smaller firms. Larger firms will tend to favor trade liberalization because they have the potential to make higher profits overall by gaining access to foreign markets, even though they would lose domestic market share. Smaller firms would tend to be against trade liberalization because they only face the prospect of losing domestic market share in the process. This paper determines the set of circumstances under which a trade agreement will be reached in this environment when firms can lobby the government for the policy that they would prefer.

The economic model is essentially that of Melitz (2003); in each of two countries, a continuum of monopolistically competitive firms produces a horizontally differentiated product at varying degrees of productivity. Throughout the analysis, we make the standard assumption that the variation in productivity across firms is approximated by the Pareto distribution. Trade restrictions are captured by one of two possible instruments: iceberg transport costs or ad valorem tariffs. Starting from autarky, a trade agreement is reached according to the following simple procedure. The two governments announce a proposed agreement to lower trade restrictions, to the same level, across the two countries. The proposed level can lie anywhere below autarky and is bounded from below at free trade. Each firm then has one of two options with regard to lobbying. It can pledge an amount in support of the proposed trade agreement, payable if and only if the agreement is adopted. Or it can pledge an amount in support of the status quo at autarky, payable if and only if the status quo is maintained. The government will then adopt the policy option for which it garners the greatest financial support. We will adopt the tie-breaking rule that if a proposed trade agreement attracts the same level of revenue as autarky then the trade agreement goes ahead. This way to model

lobbying is attractive because it means that the outcome of trade negotiations can be determined from whether the change in aggregate profits across all firms that results from the proposed trade agreement is positive or negative. Our framework abstracts entirely from the role of consumers in order to focus on interactions between firms and their national government in lobbying over trade policy. This approach is reasonably tractable and approximates a more general framework that incorporates consumers but where there is a relatively large weight on contributions made by firms to the government.

We begin our analysis of trade agreement outcomes by focusing on the case where trade restrictions are approximated by iceberg transport costs. This reflects the standard approach in the literature, and is the most tractable approach to the modeling of trade restrictions in this setting. We will refer to iceberg transport costs as 'non-tariff barriers' (NTBs) to clarify that they are determined by the government (as opposed to being determined by geography) but raise no revenue. Our key result for this type of trade agreement is that the level of lobbying for each trade and autarky is identical for each possible level of NTB from autarky down to free trade and results in free trade being the chosen policy. This result rests on a feature of the model with NTBs that, moving between autarky and any given trade restriction that allows trade, the change in aggregate profits sums to zero. That is, for each firm that exports and gains profit by obtaining cheaper access to the foreign market, there are a set of firms that lose an equivalent amount of profit by losing domestic market share to foreign firms and cannot be compensated enough from export profits (which maybe zero). This outcome rests in turn on the assumptions that productivity is distributed according to the Pareto distribution and that NTBs are of iceberg form. Because any proposed trade agreement receives the same support through lobbying as autarky, the government's optimization problem reduces to that which maximizes either the gain to trade supporters or the losses to trade opponents; which is free trade.

We then redo the analysis of trade agreement formation but instead of NTBs we assume that trade restrictions are modelled as (ad valorem) tariffs. Tariffs alter the analysis from

NTBs in two ways. Tariffs generate revenue for the government and, as Besedeš and Cole (2013), Cole (2011), Schröder and Sørensen (2011), and others have shown, ad valorem tariffs affect the extensive margin differently than iceberg transport costs in models of monopolistic competition. With this set-up, starting from autarky, unlike for NTBs a move toward (but not including) free trade from autarky would yield lower aggregate profits. However, with tariffs, the variation in the level of openness across possible agreements also implies variation in the level of tariff revenue. Hence, when combined with lobbying revenues, one possible agreement may be more attractive to the government than others. In this setting, we are able to show that when the fixed costs of exporting are relatively high, the outcome of the trade agreement is more likely to be free trade, despite the fact that under free trade there are no tariff revenues. The contributions by firms in support of a trade agreement are maximized when they must compete most aggressively against those who support autarky. Those lobbying in support of autarky would be prepared to make the largest contributions when they would suffer the biggest losses from a move to free trade. And they suffer the biggest losses from a move to free trade when the fixed costs of exporting are too high for them to be able to export.

As far as we are aware, heterogeneous firms have not featured previously in the literature on trade agreements. In a standard model of trade agreements there are two sectors, as opposed to the single sector of our model, where one sector produces an exportable while the other produces an import-competing good. Each sector is characterized by perfect competition. Those who own factors specific to the exporting sector have an interest in trade liberalization while those who own factors specific to the import competing sector seek protection from foreign competition. Therefore, a difference between the standard model and ours is that those in favor of and those opposed to trade liberalization come from different sectors whereas in our model they originate from the same sector. Focusing on this distinction in more detail, in our model there may be firms who export if the economy is opened to trade but may also oppose the trade liberalization because they would face greater com-

petition from more productive foreign firms. It is this feature that underpins our result that overall support for trade liberalization does not change with a reduction in NTBs.

Broadly, there are three strands to the literature on trade agreements. One strand of the literature, associated with Bagwell and Staiger (1999), focuses on trade agreements under the institutional arrangements of the General Agreement on Tariffs and Trade (GATT)/World Trade Organization (TWO). Bagwell and Staiger show that a trade agreement is motivated by the terms-of-trade externality that arises when countries have power on world markets. When setting tariffs, each country fails to internalize the negative externality that its tariff imposes. The two GATT/WTO pillars of reciprocity and nondiscrimination allow countries to escape the terms-of-trade externality and reach an efficient agreement.

The second branch of the literature is the 'political economy approach,' based around the idea that politicians set trade policy based on their own political imperatives and those of lobbyists making political contributions rather than on the imperatives of citizens at large (Hillman 1982, Hillman and Ursprung 1988, Magee, Brock and Young 1989, Grossman and Helpman 1994). Through their formalization of the problem Bagwell and Staiger are able to show that the political economy approach is nevertheless fundamentally terms-of-trade driven. It is through a manipulation of terms-of-trade that politically motivated ends are achieved. Our paper fits into the political economy approach in the sense that politicians set trade policy based on their own political imperatives and those of lobbyists. But in contrast to the prior literature it is not driven by changes in the terms of trade so much as by gains that arise from variation in firm productivity.

The third branch of the literature highlights a commitment problem faced by governments that wish to liberalize (Staiger and Tabellini 1987, Staiger 1995, Maggi and Rodriguez-Clare 1998). Under this view, terms of trade losses through trade liberalization are small relative to efficiency gains, and the case for trade liberalization is essentially a unilateral one. The argument is that trade agreements can serve as a means through which a government can commit to trade liberalization in the face of opposition from protectionist forces, say

industrial interest groups, within its own nation. There is a sense in which this motivation for a trade agreement exists within our framework as well. In our model no firm would agree to unilateral trade liberalization as they would lose domestic market share without gaining share of export markets. Hence trade liberalization must be reciprocated in order for it to take place at all. However, reciprocal trade liberalization is an assumption in our framework and we do not explore the role of trade agreement as a commitment device in this paper.

The paper proceeds as follows. Section 2 sets out the model. It begins with a brief recapitulation of the Melitz model and then goes on to explain how lobbying works and how the trade agreement is determined. Section 3 then examines the scope for reaching a trade agreement, first for NTBs and then for tariffs. It is here that we characterize the trade agreements that may arise under each of the two trade policy instruments. Conclusions are drawn in Section 4.

2 The Model

There are two countries in the model, Home and Foreign. Variables pertaining to Foreign are denoted with a superscript $*$. There are two goods. Good X comprises a continuum of differentiated varieties, each of which is indexed by i. As is standard in the Melitz model, these varieties are produced by a continuum of monopolistically competitive firms, correspondingly indexed by i, each using an increasing returns to scale technology. There is free entry in sector X, but entry into the sector is costly, so profits are zero in expectation but positive ex post. Each variety of good X may face a trade barrier as it crosses the border between the countries. Good Y is a homogeneous good that is produced under constant returns to scale, perfect competition and free trade. We will choose good Y as the numeraire and, since it is freely traded, world prices and domestic prices of this good can be normalized to 1. Each unit of good Y is produced from just one unit of labor, and so the wage is normalized to 1 as well. The role of good Y in the model is to capture the general

equilibrium effects of trade agreement formation. For this purpose, we will assume that each country is endowed with a sufficient quantity of labor that enough of good Y is produced to clear the trade account in equilibrium. In terms of economic structure, the two countries are identical to one another but will produce different varieties in a trading equilibrium.

There are two time periods. In period 1 there is autarky, with trade restrictions set at prohibitive levels. Producers of good X undertake entry decisions and production. Then markets clear for period 1 and consumption takes place. In period 2, the governments may announce a proposed trade agreement, which entails a symmetrical reduction in trade restrictions to a level that would allow at least some trade, possibly free trade, between the countries. Governments are able to communicate with each other over the proposed trade agreement before announcing it, and each has veto power over the agreement prior to announcement (but not afterwards). Once the proposed trade agreement is announced, each firm predicts the amount of profit it would earn under the alternatives of autarky and the trade agreement. There are two lobbyists, one that supports the status quo of autarky in sector X and one that supports the trade agreement. Each firm pledges a contribution for one of the lobby groups, depending on the regime under which its profits would be maximized. A contribution is only made to a lobby group if the regime it supported is successfully adopted. If the trade agreement goes ahead, the government resets tariffs in accordance with the agreement. Finally, conditional on tariffs, consumption takes place and markets clear.

Although we will undertake separate treatments of trade agreements over NTBs and tariffs, our development of the model will incorporate both instruments simultaneously. This will provide a parsimonious representation of the model and makes it possible to compare the effects of the two restrictions. The remainder of this section specifies the specific details of the model.

2.1 Consumers

Let the utility function for the representative agent in Home take the following form:

$$U = \mu \ln (X) + Y \tag{1}$$

where

$$X = \left(\int_{i \in \Omega} x(i)^{\alpha} di \right)^{\frac{1}{\alpha}},$$

$\varepsilon = 1/(1-\alpha)$ is the elasticity of substitution between varieties of X, and Ω is the set of varieties available to the consumer. Demand for each good by a consumer in Home is

$$x(i) = \frac{p(i)^{-\varepsilon} \mu}{\mathcal{P}^{1-\varepsilon}}$$

where $p(i)$ is the price of variety i sold in home, and

$$\mathcal{P}^{1-\varepsilon} = \int_{i \in \Omega} p(i)^{1-\varepsilon} di$$

is the aggregate price index in Home. An analogous set of equations holds for the foreign country where, by assumption, $\mu^* = \mu$.

2.2 Heterogeneous Firms

Firms considering entry to sector X face a one time sunk market entry cost f_E (measured in units of labor). If this cost is paid, the firm then draws a constant marginal cost coefficient a from the Pareto distribution

$$G(a) = \left(\frac{a}{a_U} \right)^k, \ 0 < a < a_U$$

where the shape parameter $k > (\varepsilon - 1)$.[1] We will denote by a_i the marginal cost drawn by firm i. Once this is observed, a firm decides whether or not to undertake production. If it chooses to produce, it must incur an additional fixed cost f_D paid each period. If trade restrictions are at a level that allows for trade, a firm must pay an additional fixed cost $f_X > f_D$ in order to serve the foreign market. Production exhibits constant returns to scale with labor as the only factor of production.

The decision of whether or not to undertake production and whether to export depends on the associated profits. Fixing the wage equal to 1, the per-period operating profit of firm i facing marginal cost a_i and selling only domestically is

$$\begin{aligned} \pi_D(i) &= [p(i) - a_i]\, Q_D(i) - f_D \\ &= \left[\frac{[p(i) - a_i]\mu}{\mathcal{P}^{1-\varepsilon}}\right] p(i)^{-\varepsilon} - f_D. \end{aligned}$$

A firm selling domestically will charge a price equal to a constant markup over marginal cost, $p(i) = \frac{a_i}{\alpha}$. Therefore, the operating profit function for a purely domestic firm is

$$\pi_D(i) = a_i^{1-\varepsilon} B - f_D \tag{2}$$

where

$$B = \frac{1}{\varepsilon \alpha^{1-\varepsilon}} \left(\frac{\mu}{\mathcal{P}^{1-\varepsilon}}\right).$$

In order to reach the foreign market, in addition to the fixed cost f_X, firm i incurs a per-unit cost arising from either an NTB or a tariff: modelled as an iceberg transport cost, $\tau > 1$, and an ad valorem tariff, $t > 1$, respectively. For tractability we assume that any tariff

[1] The Pareto distribution has the advantage that it has been shown to match the productivity distribution of US firms and allows us to derive closed form solutions. However, there is some loss of generality in the use of a specific distribution. While the Pareto distribution captures the general tradeoffs in decision making over entry by firms, certain results are due to the properties of the specific distribution used; namely for any $a_1 \leq a_2 \leq a_U$:

$$\frac{g(a_2)}{g(a_1)} = g\left(\frac{a_2}{a_1}\right) \qquad \text{and} \qquad \frac{1 - G(a_2)}{1 - G(a_1)} = 1 - G\left(\frac{a_2}{a_1}\right) = \left(\frac{a_2}{a_1}\right)^{-k}.$$

We highlight where this property plays a significant role in our analysis.

revenue is used by the government to consume only the numeraire.[2] Thus the additional operating profit from exporting for a firm that exports is

$$\pi_X = \frac{(t\tau a_i)^{1-\varepsilon} B^*}{t} - f_X, \tag{3}$$

where

$$B^* = \frac{1}{\varepsilon \alpha^{1-\varepsilon}} \left(\frac{\mu}{\mathcal{P}^{*1-\varepsilon}} \right).$$

2.3 Lobbyists

There are two lobbyists in the model named L_A and L_T. While L_A lobbies on behalf of firms that prefer autarky, by pledging a contribution to the government of l_A that will be paid if and only if autarky is adopted, L_T pledges a contribution of l_T which is payable if and only if the proposed trade agreement goes ahead. It will also be helpful to have notation for the greatest feasible contributions to these two lobbies, denoted by $\bar{l}_A$ and $\bar{l}_T$ respectively. We will assume that contributors to these lobbies are able to resolve their collective action problems.

If a firm would make more profits under autarky than under a proposed trade agreement, it would be willing to pay an amount to L_A less than or equal to the profit that it would lose under the agreement, but not more than the current profit made in autarky. Summing across all firms in this position, the maximum aggregate contribution to L_A is therefore given by

$$\bar{l}_A = N_E \int_{\varphi}^{a_A} \left(\pi_A(a) - \pi_T(a) \right) dG(a), \tag{4}$$

where N_E is the number (mass) of entrepreneurs taking a draw from the productivity distri-

[2]Tariff revenue can only affect demand for good X if: (1) The government's preferences are not, in fact, encompassed by the representative consumer and the government demands some of good X; (2) Tariffs are not symmetric across countries and thus income is being shifted from one country to the other (however this is not an issue with quasi-linear utility) or; (3) The government simply throws the revenue away (this is not an issue with quasi-linear utility as long as a positive amount of the numeriare is produced and consumed). We do not allow for these three possibilities in our model.

bution, φ is the firm that is just indifferent between autarky and the trade agreement, a_A is the least efficient firm in autarky, and $\pi_A(a)$ and $\pi_T(a)$ are the respective profit levels of firm $a \in [\varphi, a_A]$ under autarky and the trade agreement respectively.[3] We know that any firm in this position would always be able to meet their contribution to $\bar{l}_A$. The largest contributor would be a firm that would choose to exit the industry in the event of the trade agreement, and it would be willing to forego an amount up to its current profits in autarky to prevent the trade agreement from going ahead.

A firm that would make more profits under the trade agreement will be willing to contribute to L_T an amount up to, but not more than, the extra profit it would make under the agreement. Therefore, maximum aggregate contributions to L_T can be formalized as

$$\bar{l}_T = N_E \int_0^{\varphi} \left(\pi_T(a) - \pi_A(a)\right) dG(a). \tag{5}$$

Given our setup, each firm's contribution towards $\bar{l}_T$ would never exceed its current profit, so we know that the firm will be willing and able to meet any such commitment that it makes in support of the trade agreement.

2.4 Government

The government's objective is to maximize income, which is derived entirely from tariff revenue and contributions by lobbyists. It consumes only the numeraire good. Therefore, the only effect of government policy on sector X comes through the distortions created by t and τ. In period 1 where there is autarky the government earns no income. In period 2 where governments may propose a trade agreement the Home government's problem is formalized as follows:

$$\max_{t,\tau} \{l_A(t,\tau), l_T(t,\tau) + TR(t,\tau)\}, \tag{6}$$

[3]These terms will be defined explicitly when we characterize the equilibrium.

where $TR(\cdot)$ represents tariff revenue. The Foreign government's problem is analogous. The government chooses whichever level of trade restriction maximizes its revenue from lobbying and tariffs combined. If $l_A(t,\tau) = l_T(t,\tau) + TR(t,\tau)$ then we will assume that the trade agreement goes ahead. This assumption will serve to focus attention on a limitation of our model to predict the outcome of trade agreements over NTBs, which will then be resolved when considering trade agreements over tariffs.

Although the problem here is defined over NTBs and tariffs, t and τ, by assumption governments will make an agreement over only one instrument. That is, in the next section tariffs will be set to zero ($t = 1$) while we first consider an agreement over NTBs, and after that NTBs will be set to unity ($\tau = 1$) while we consider an agreement over tariffs. Until we consider each type of agreement in turn, we will continue to develop the model in terms of both t and τ together.

3 Equilibrium

Now we calculate whether or not the governments of Home and Foreign would reach an agreement to move away from autarky and, if so, whether or not it would be characterized by free trade. We begin with an examination of autarky equilibrium and then proceed to characterize a trade agreement.

3.1 Autarky

Use subscript-A to denote autarky. There exists a cutoff marginal cost a_A which represents the productivity of the firm that is indifferent, under autarky, between supplying the domestic market and exiting. Using equation (2), this is characterized by:

$$f_D = \frac{\mu}{\varepsilon}\left(\frac{a_A}{\alpha \mathcal{P}_A}\right)^{1-\varepsilon}. \tag{7}$$

There is free entry, so that an entrepreneur will pay to take a draw from the productivity distribution as long as the present value of average profits $\bar{\pi}$ is positive. We assume that firms fully discount profits in period 2, and so take into account only the expected profit in the current period when making their entry decision.[4] The free entry condition is

$$V(a_A)B_A - G(a_A)f_D = f_E \tag{8}$$

where

$$V(z) = \int_0^z a^{1-\varepsilon} dG(a) = \frac{k}{k-\varepsilon+1}\left(\frac{z}{a_U}\right)^k z^{1-\varepsilon}.$$

Conditions (7) and (8) close the model and pin down a_A and the number (mass) of entrepreneurs taking a draw from the productivity distribution, N_E.

We restrict entry to period 1 only, and our only equilibrium conditions are the non-negative profit conditions. This set of assumptions would only be restrictive if more entrepreneurs wanted to take a productivity draw under the trade agreement than under autarky. In that case we would need to account for these new entrants and how they might lobby.[5] Our approach of fixing the mass of entrants is not unlike others in the literature such as Do and Levchenko (2009), Eaton and Kortum (2005), Chaney (2008), and Arkolakis (2008). Since we have assumed firm productivity is distributed Pareto, we can find closed form solutions for these two variables:

$$a_A = \left[\frac{\psi f_E}{f_D}\right]^{\frac{1}{k}} a_U,$$
$$N_E = \frac{\alpha\mu}{k f_E},$$

[4]This assumption does not affect the qualitative results, but affects the level of firms taking a draw, N_E.

[5]Since productivity is distributed Pareto, this is not an issue as it can be shown that

$$V(a_D)B_T - G(a_D)f_D + \frac{V(a_X)(t\tau)^{1-\varepsilon}B_T}{t} - G(a_X)f_X \leq f_E.$$

where

$$\psi \equiv \frac{[k-(\varepsilon-1)]}{(\varepsilon-1)} > 0.$$

Note that all parameters are identical across countries, so it follows that $a_A = a_A^*$. Furthermore, in order to rule out corner solutions ($a_A \leq a_U$), we make the simplifying assumption that the shape parameter k is bounded from above as well; i.e.

$$k \leq \frac{(\varepsilon-1)[f_E+f_D]}{f_D}.$$

Finally, we are left with ex post aggregate per period industry profits in autarky equal to

$$\begin{aligned} \Pi_A &= N_E \int_0^{a_A} \pi_A(a)\, dG(a) \\ &= N_E \left[V(a_A)B_A - G(a_A)f_D\right] = \frac{\alpha\mu}{k}. \end{aligned} \tag{9}$$

3.2 Trade Agreement

The concept of equilibrium that we will use to consider the trade agreement is that of Nash equilibrium. This will be applied to period 2 only, as there is no attempt to reach an agreement in period 1. Let r be the trade restriction, either τ or t, over which agreement is being reached. Then the agreement will consist of a triple, $\left(\hat{l}_A, \hat{l}_T, \hat{r}\right)$, where $\hat{l}_A$ and $\hat{l}_T$ are best-response aggregate contributions made by L_A and L_T respectively, and $\hat{r}$ is the best-response level of the trade restriction given the aggregate contribution levels: $\hat{\tau}$ in the case of an agreement over NTBs; $\hat{t}$ in the case of an agreement over tariffs.

To develop the framework needed to analyze equilibrium under a trade agreement, begin by assuming that a trade agreement proposed by the two governments has been adopted. We can now derive the expressions we need to evaluate the payoffs entailed. Under the trade agreement, a given firm will continue to produce domestically if it makes nonnegative profits from doing so. There exists a cutoff productivity level a_D which represents the productivity of the firm that is indifferent under the trade agreement between supplying the domestic

market and exiting:

$$\frac{\mu}{\varepsilon}\left(\frac{a_D}{\alpha \mathcal{P}_T}\right)^{1-\varepsilon} = f_D. \tag{10}$$

A firm will export if the profits from doing so are positive. The cutoff productivity level for becoming an exporter is given by the following condition:

$$\frac{\mu}{\varepsilon t}\left(\frac{\tau t a_X}{\alpha \mathcal{P}_T^*}\right)^{1-\varepsilon} = f_X. \tag{11}$$

Since we are considering a symmetric trade agreement in which trade restrictions are at the same level in both countries, with aggregate expenditure on good X identical across both countries and equal to μ, we will have a symmetric equilibrium under an agreement and henceforth drop the $*$ superscripts. Thus, these two conditions close the model under the trade agreement. Since firm productivity is distributed Pareto, we can find closed form solutions for the two cutoffs:

$$a_D = \left[\frac{f_X^{\psi}\tau^k t^{\frac{k}{\alpha}}}{f_X^{\psi}\tau^k t^{\frac{k}{\alpha}} + t f_D^{\psi}} \frac{\psi f_E}{f_D}\right]^{\frac{1}{k}} a_U;$$

$$a_X = \left[\frac{f_D^{\psi}}{f_X^{\psi}\tau^k t^{\frac{k}{\alpha}} + t f_D^{\psi}} \frac{\psi f_E}{f_X}\right]^{\frac{1}{k}} a_U.$$

Using these cut-offs, we are able to calculate ex-post aggregate industry profits in an equilibrium under the trade agreement, Π_T:

$$\begin{aligned} \Pi_T &= N_E \int_0^{a_D} \pi_T(a)\, dG(a) \\ &= \frac{\alpha\mu}{k}\left[\frac{f_X^{\psi}\tau^k t^{\frac{k}{\alpha}} + f_D^{\psi}}{f_X^{\psi}\tau^k t^{\frac{k}{\alpha}} + t f_D^{\psi}}\right] = \Pi_A\left[\frac{f_X^{\psi}\tau^k t^{\frac{k}{\alpha}} + f_D^{\psi}}{f_X^{\psi}\tau^k t^{\frac{k}{\alpha}} + t f_D^{\psi}}\right]. \end{aligned} \tag{12}$$

For the firm φ that is just indifferent between autarky and the trade agreement,

$$\Delta\pi(\varphi) = \pi_T(\varphi) - \pi_A(\varphi) = 0.$$

Explicitly, φ is determined as follows:

$$\varphi = \left(\frac{f_D}{f_X} \left[(1 + \tau^{1-\varepsilon} t^{-\varepsilon}) - F^{1-\varepsilon} \right] \right)^{\frac{1}{\varepsilon - 1}} a_D = \lambda a_D \tag{13}$$

where

$$F \equiv \left[\frac{f_X^{\psi} \tau^k t^{\frac{k}{\alpha}}}{f_X^{\psi} \tau^k t^{\frac{k}{\alpha}} + t f_D^{\psi}} \right]^{\frac{1}{k}},$$

and

$$\lambda = \left(\frac{f_D}{f_X} \left[(1 + \tau^{1-\varepsilon} t^{-\varepsilon}) - F^{1-\varepsilon} \right] \right)^{\frac{1}{\varepsilon - 1}}.$$

We can use the expressions for aggregate profits and aggregate contributions that we have derived to determine how the outcome of the lobbying process is related to aggregate profits. For given tariff revenue, the greater is $\bar{l}_A$ compared to $\bar{l}_T$, the more likely autarky is to be the outcome. So it will be useful to be able to relate the difference in lobbying revenues to the difference in aggregate profits. Using (4), (5), (9) and (12),[6]

$$\begin{aligned} \bar{l}_A - \bar{l}_T &= N_E \int_0^{a_A} (\pi_A(a) - \pi_T(a)) \, dG(a) \\ &= \Pi_A - \Pi_T. \end{aligned} \tag{14}$$

Therefore, the difference in maximum lobbying revenue between autarky and the trade agreement is determined by the difference in aggregate profits under the two outcomes. This insight will be useful in determining the outcome of a proposed agreement.

3.3 Trade Agreement Over NTBs

We consider an agreement over τ while setting $t = 1$. In this setting any agreement that the governments reach raises no revenue; $TR(1, \tau) = 0$. So the home government's problem (6)

[6]This derivation uses the fact that $\pi_T(a) = 0$ for $a \in [a_D, a_A]$ to rewrite equation (12) as $\Pi_T = N_E \int_0^{a_A} \pi_T(a) \, dG(a)$.

may be simplified to

$$\max_{\tau} \{l_A(1,\tau), l_T(1,\tau)\}.$$

It can be seen by inspection of (12) that if we set tariffs equal to zero in that expression (i.e. $t = 1$) and focus on τ as the only form of trade restriction, ex-post aggregate industry profits in autarky and the trade agreement are always equal for any proposed agreement, i.e. $\Pi_T = \Pi_A = \alpha\mu/k$ for any τ.[7] Therefore, $\bar{l}_A = \bar{l}_T$ and consequently each lobby group will offer the highest amount for any given τ; i.e. $l_A(1,\tau) = \bar{l}_A(1,\tau)$ and $l_T(1,\tau) = \bar{l}_T(1,\tau)$. This means the government's problem reduces to setting an agreed NTB level that maximizes $\bar{l}_A$:[8]

$$\max_{\tau} \ \bar{l}_A(1,\tau) = \max_{\tau} \ N_E \left[\int_{\varphi}^{a_A} \pi_A(a) dG(a) - \int_{\varphi}^{a_X} \pi_X(a) dG(a) - \int_{\varphi}^{a_D} \pi_D(a) dG(a) \right]. \quad (15)$$

In order to maximize the contribution that firms would make to the outcome of autarky, $\bar{l}_A(t,1)$, the government needs to choose τ in such a way that it makes the firms who would lobby for autarky as badly off as possible under the trade agreement. To simplify the problem, first note that when the agreement NTB level changes, the following also change: the indifferent firm between autarky and trade, φ; the least efficient exporter, a_X; the profits of an exporting firm, $\pi_X(a)$; the least efficient purely domestic firm, a_D; and the domestic profits of firms that would prefer autarky to trade. By definition, it follows that $\pi_X(a_X) = 0$, $\pi_D(a_D) = 0$ and $\pi_A(\varphi) - \pi_T(\varphi) = 0$. Therefore, the tension we are concerned with is how the decrease in domestic profits that occur when the government reduces τ weigh against the increase in profits from exporting. In formal terms:

$$\frac{d\bar{l}_A(1,\tau)}{dt} = -N_E \left[\int_{\varphi}^{a_X} \frac{d\pi_X(a)}{d\tau} dG(a) + \int_{\varphi}^{a_D} \frac{d\pi_D(a)}{d\tau} dG(a) \right]. \quad (16)$$

The first term in brackets captures the sum of the export profit $\pi_X(a)$ of the group of firms

[7] Intuitively, this means that the gains to from trade exactly offset the losses. It should be noted that this particular result is driven by the unique properties of both the Pareto distribution and the iceberg transport cost assumptions. However, the tensions described are true in general.

[8] Identically, the government could maximize $\bar{l}_T$ and arrive at the same "optimal" policy.

that export but would be better off in autarky, $a \in (\varphi, a_X)$. The second term in brackets captures the domestic profits of those same firms, plus the domestic profits of the firms that only serve the domestic market. As NTBs are lowered, $\pi_D(a)$ is reduced for all firms. But at the same time, as NTBs are lowered, this increases the return that a given firm would make from exports. Lowering NTBs also changes the set of firms that would find it profitable to export. The lower the NTB in the trade agreement, the more the firms that would prefer the trade agreement to autarky; φ increases. These are the tensions that the government faces in setting τ. Further intuition can be gleaned from the graphical illustration in Figure 1. Governments want to maximize the shaded area. With a lower tariff, domestic profits decrease as illustrated by a decrease in the blue line. However, at the same time profits from exporting increase thereby raising the green line. This brings us to our first proposition. For notational ease, let $f_X = \gamma f_D$ where $\gamma > 1$.

Proposition 1. *The NTB policy that maximizes lobby revenue for the government is free trade; i.e.* $\tau = 1$.

Proof. First note that

$$\frac{d\pi_X(a)}{d\tau} = \frac{(\varepsilon-1)\gamma f_D}{\tau}\left(\frac{a}{a_X}\right)^{1-\varepsilon}\epsilon^{\tau}_{a_X} = \frac{(1-\varepsilon)\gamma f_D}{\tau}\left(\frac{a}{a_X}\right)^{1-\varepsilon}\left(\frac{\gamma^{\psi}\tau^{k}}{\gamma^{\psi}\tau^{k}+1}\right)$$
$$\frac{d\pi_D(a)}{d\tau} = \frac{(\varepsilon-1) f_D}{\tau}\left(\frac{a}{a_D}\right)^{1-\varepsilon}\epsilon^{\tau}_{a_D} = \frac{(\varepsilon-1) f_D}{\tau}\left(\frac{a}{a_D}\right)^{1-\varepsilon}\left(\frac{1}{\gamma^{\psi}\tau^{k}+1}\right),$$

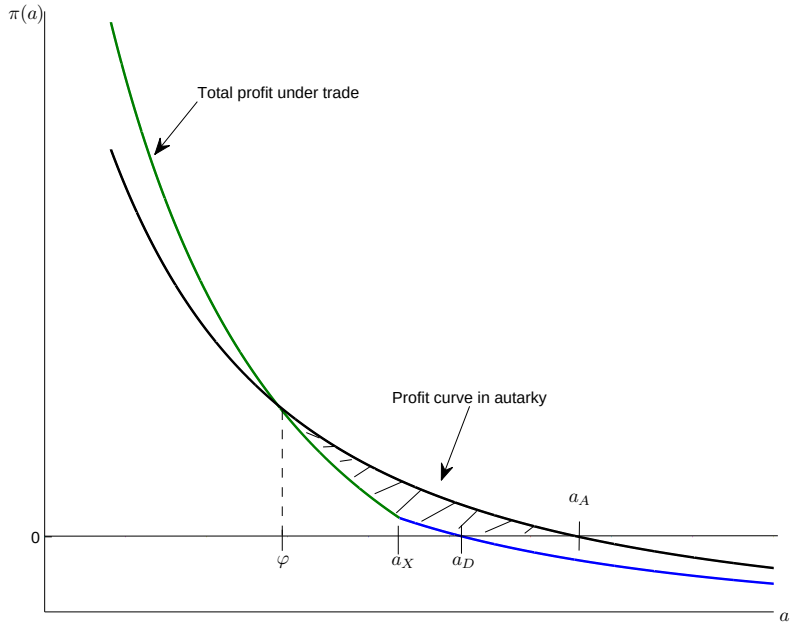
where ϵ refers to elasticity. So the first derivative, equation (16), reduces to:

$$\begin{aligned}\frac{d\bar{l_A}(1,\tau)}{dt} &= \frac{-N_E(\varepsilon-1)f_D}{\tau}\left[\int_{\varphi}^{a_X}\left(\frac{a}{a_X}\right)^{1-\varepsilon}\gamma\epsilon^{\tau}_{a_X}dG(a) + \int_{\varphi}^{a_D}\left(\frac{a}{a_D}\right)^{1-\varepsilon}\epsilon^{\tau}_{a_D}dG(a)\right] \\ &= -\frac{N_E(\varepsilon-1)f_D}{\tau}\left[\frac{\gamma\epsilon^{\tau}_{a_X}}{a_X^{1-\varepsilon}}\left[V(a_X)-V(\varphi)\right] + \frac{\epsilon^{\tau}_{a_D}}{a_D^{1-\varepsilon}}\left[V(a_D)-V(\varphi)\right]\right] \\ &= -\frac{N_E k f_D}{\tau\psi}\left[\gamma^{\psi}\tau^{k+1-\varepsilon}-1\right]\lambda^{k+1-\varepsilon}\left(\frac{a_D}{a_U}\right)^{k}\epsilon^{\tau}_{a_D} < 0 \;\; \forall\, \tau \geq 1.\end{aligned}$$

This is negative because $\gamma > 1$, $\tau \geq 1$, and $k > \varepsilon - 1$. Therefore, the government will choose

free trade. □

Figure 1: Profits Under Two Regimes: Autarky and Trade



3.4 Trade Agreement Over Tariffs

Next we consider an agreement over t while setting $\tau = 1$. Tariff revenue is raised by any outcome other than autarky and free trade, and so equation (6) is the appropriate expression of the Home government's problem. For this we need to calculate explicitly how much tariff revenue the government would receive for any tariff level t in a proposed agreement:

$$\begin{aligned} TR &= (t-1) \times \text{imports value} \\ &= (t-1) N_E \int_0^{a_X} p(a)x(a)dG(a) \\ &= \left[\frac{(t-1) f_D^{\psi}}{f_X^{\psi} t^{\frac{k}{\alpha}} + t f_D^{\psi}} \right] t\mu. \end{aligned}$$

With this expression in hand, we find that the difference between aggregate autarky

ex-post profit and aggregate profit under the trade agreement is

$$0 \leq \Pi_A - \Pi_T = \left[\frac{(t-1)f_D^{\psi}}{f_X^{\psi}t^{\frac{k}{\alpha}} + tf_D^{\psi}}\right]\frac{\alpha\mu}{k} = \left(\frac{\alpha}{tk}\right)TR \leq TR.$$

In other words, the ex post aggregate profit under the trade agreement is less than (or equal to in free trade) aggregate profit in autarky but is greater if tariff revenue is included:

$$\Pi_A \leq \Pi_T + TR. \tag{17}$$

Using equation (14), we have that

$$\bar{l}_A \leq \bar{l}_T + TR.$$

This gives us a result that will be useful in characterizing equilibrium under the trade agreement.

Lemma 1. *In a trade agreement over tariffs, the maximum aggregate contribution by L_T plus tariff revenue is always greater than or equal to the maximum aggregate contribution by L_A.*

This result suggests that, like for the NTB, the equilibrium outcome of an agreement over tariffs will be a trade agreement. However, since tariff revenue varies with the tariff, the result also suggests that tariff revenue will play a decisive role in determining what the level of openness will be in the agreement that is reached in equilibrium.

We will now work through the basic characteristics of equilibrium, before going on to explore exactly what an equilibrium agreement would look like. Begin by assuming that an equilibrium agreement exists at the tariff level $\hat{t}$. Then just as in the equilibrium for an agreement over NTBs, the equilibrium aggregate contribution level by L_A must be $\hat{l}_A = \bar{l}_A$. But the equilibrium aggregate contribution by L_T is $\hat{l}_T = \bar{l}_A - TR(\tau, t) \leq \bar{l}_A$, where the inequality is strict at any level other than free trade. The proof is the same as for the equilibrium over the NTB, except that now L_T's contribution only has to equal L_A's net of

tariff revenue in order for a trade agreement to be adopted. The key difference is that for the agreement over tariffs the government does care about the agreement tariff level $\hat{t}$ because each tariff level will imply a different level of tariff revenue.

It now remains to work out the agreement that would maximize the sum of contributions and tariff revenue. Since in a trade agreement $\hat{l}_A = \bar{l}_A = \hat{l}_T + TR(1, \hat{t})$, the government's problem reduces to setting an agreed tariff level that maximizes $\bar{l}_A$. This is similar to that of the previous section analyzing the government's choice of NTBs and the intuition follows as well.

$$\max_t \ \bar{l}_A(t,1) = \max_t \ N_E \left[\int_{\varphi}^{a_A} \pi_A(a) dG(a) - \int_{\varphi}^{a_X} \pi_X(a) dG(a) - \int_{\varphi}^{a_D} \pi_D(a) dG(a) \right] \quad (18)$$

In order to maximize the contribution that firms would make to the outcome of autarky, $\bar{l}_A(t,1)$, the government needs to choose t in such a way that it makes the firms who would lobby for autarky as badly off as possible under the trade agreement. To simplify the problem, first note that when the agreement tariff level changes, the following also change: the indifferent firm between autarky and trade, φ; the least efficient exporter, a_X; the profits of an exporting firm, $\pi_X(a)$; the least efficient purely domestic firm, a_D; and the domestic profits of firms that would prefer autarky to trade. By definition, it follows that $\pi_X(a_X) = 0,\ \pi_D(a_D) = 0$ and $\pi_A(\varphi) - \pi_T(\varphi) = 0$. Therefore, the tension we are concerned with is how the decrease in domestic profits that occur when the government reduces t weigh against the increase in profits from exporting. In formal terms:

$$\frac{d\bar{l}_A(t,1)}{dt} = -N_E \left[\int_{\varphi}^{a_X} \frac{d\pi_X(a)}{dt} dG(a) + \int_{\varphi}^{a_D} \frac{d\pi_D(a)}{dt} dG(a) \right]. \quad (19)$$

The first term in brackets captures the sum of the export profit $\pi_X(a)$ of the group of firms that export but would be better off in autarky, $a \in (\varphi, a_X)$. The second term in brackets captures the domestic profits of those same firms, plus the domestic profits of the firms that only serve the domestic market. As tariffs are lowered, $\pi_D(a)$ is reduced for all firms. But at

the same time, as tariffs are lowered, this increases the return that a given firm would make from exports. Lowering tariffs also changes the set of firms that would find it profitable to export. The lower the tariff in the trade agreement, the more the firms that would prefer the trade agreement to autarky; φ increases. These are the tensions that the government faces in setting t.

To obtain deeper insight into the problem, we can obtain a reduced form expression for $d\bar{l}_A(t,1)/dt$. Using

$$\frac{d\pi_X(a)}{dt} = \frac{(\varepsilon-1)\gamma f_D}{a_X}\left(\frac{a}{a_X}\right)^{1-\varepsilon}\frac{da_X}{dt} = \frac{(\varepsilon-1)\gamma f_D}{t}\left(\frac{a}{a_X}\right)^{1-\varepsilon}\epsilon^t_{a_X}$$
$$\frac{d\pi_D(a)}{dt} = \frac{(\varepsilon-1) f_D}{a_D}\left(\frac{a}{a_D}\right)^{1-\varepsilon}\frac{da_D}{dt} = \frac{(\varepsilon-1) f_D}{t}\left(\frac{a}{a_D}\right)^{1-\varepsilon}\epsilon^t_{a_D}$$

where ϵ refers to elasticity, equation (19) can be written

$$\frac{d\bar{l}_A(t,1)}{dt} = -N_E(\varepsilon-1)f_D\left[\int_\varphi^{a_X}\left(\frac{a}{a_X}\right)^{1-\varepsilon}\frac{\gamma\epsilon^t_{a_X}}{t}dG(a) + \int_\varphi^{a_D}\left(\frac{a}{a_D}\right)^{1-\varepsilon}\frac{\epsilon^t_{a_D}}{t}dG(a)\right]$$

or, simplifying further,

$$\frac{d\bar{l}_A(t,1)}{dt} = \frac{N_E(1-\varepsilon)f_D}{t}\left[\frac{\gamma\epsilon^t_{a_X}}{a_X^{1-\varepsilon}}\left[V(a_X)-V(\varphi)\right] + \frac{\epsilon^t_{a_D}}{a_D^{1-\varepsilon}}\left[V(a_D)-V(\varphi)\right]\right] \tag{20}$$

Since $\varepsilon > 1$, the term outside the bracket is negative. Therefore the signs of the terms inside the bracket will determine the sign of the overall expression. If they are negative overall then $d\bar{l}_A(t,1)/dt$ is positive and the government would chose a higher agreed tariff level. However, if the term in the bracket is positive then the the government would choose a lower agreement tariff level. What makes the sign ambiguous is the fact that the elasticity of the least efficient exporter, a_X, is negative but the elasticity of the least efficient purely domestic

firm, a_D, is positive. The elasticities are

$$\epsilon^t_{a_X} = -\frac{k\gamma^\psi t^{\frac{k}{\alpha}} + \alpha t}{\alpha k\left(\gamma^\psi t^{\frac{k}{\alpha}} + t\right)} < 0$$
$$\epsilon^t_{a_D} = \frac{t(k-\alpha)}{\alpha k\left(\gamma^\psi t^{\frac{k}{\alpha}} + t\right)} > 0.$$

It can be seen that since $\gamma > 1$ and $k > \alpha$, the cutoff for the least efficient exporter is more elastic than for the least efficient purely domestic firm. However, this is countered by the fact that

$$[V(a_X) - V(\varphi)] < [V(a_D) - V(\varphi)]$$

and

$$\frac{1}{a_X^{1-\varepsilon}} < \frac{1}{a_D^{1-\varepsilon}}.$$

We now characterize the circumstances under which we can expect free trade to be the outcome of an agreement.

Proposition 2. *Assume $k \geq \alpha+1$ and that $\bar{l}_A(t,1)$ is quasi-concave in t for given parameters. Then there exists a value $\bar{\gamma} > 1$ for which, if $\gamma \geq \bar{\gamma}$, then in equilibrium there will be a trade agreement in which the outcome is free trade: $\hat{t} = 1$. If $\gamma \in [1, \bar{\gamma})$ then free trade will not arise in any trade agreement that forms.*

The interesting feature of this result is that as γ is increased free trade becomes more likely as an equilibrium outcome of the trade agreement. It may seem surprising at first sight that a trade agreement would involve free trade because the government collects no tariff revenue in such an agreement. Recall that the feature of the model that causes the government to set a positive tariff in a trade agreement is the effect on export profits for the set of firms who export ex post, but are worse off under the trade agreement than in autarky; i.e. $a \in (\varphi, a_X)$. For a low value of γ, a firm towards the upper end of this set is at least able to recoup some of the losses it suffers under a lower tariff by exporting, limiting

the amount this firm would be willing to lobby against free trade. However, as γ increases this firm can no longer afford to become an exporter, dropping out of $a \in (\varphi, a_X)$, and so the only effect of the reduction in t is a loss in its domestic profits, thus increasing the amount this firm would be willing to lobby against free trade. Notice that the result only holds for $k \geq \alpha + 1$, leaving out the parameter range for which $\frac{\alpha}{1-\alpha} < k < \alpha + 1$. However, empirical estimates of French firms by Crozet and Koenig (2010) imply that $k - \alpha > 1$. For the 27 sectors that they examine, the average value is $k - \alpha \approx 2.1$.

We were unable to provide a general characterization in Proposition 2 of a trade agreement in equilibrium for $\gamma \in [1, \bar{\gamma})$. However, we can get some idea of what such agreements look like using simulations. In Figures 2 through 9, we graph $d\bar{l}_A(t,1)/dt$ for various parameter values. In all figures, we assume that $f_E = 0.1$, $f_D = 1$, and $\mu = 100$. We are only using values for α that are consistent with our assumptions: $a_A < a_U$ and $k > \varepsilon - 1 = \frac{\alpha}{1-\alpha}$. For now, we focus on two possible values for k; 1.5 and 2. Del Gatto et al. (2008), using Italian firm-level data, find an average (across sectors) shape parameter to be approximately 1.7 with a minimum of 1.12 and a maximum of 2.145. Crozet and Koenig (2010) use French firm-level data and find an average (across sectors) shape parameter to be approximately 3.3 with a minimum of 1.65 and a maximum of 6.93. Therefore, we feel these parameters give some variation while still remaining in line with the empirical literature.

First focus on Figures 2 through 5. Each figure shows $d\bar{l}_A(t,1)/dt$ for four values of γ: $\gamma = 1$, 1.25, 1.5 and 1.75. The value of k is fixed across all these figures at $k = 1.5$. In Figures 2 through 5 the value of α is put at $\alpha = 0.2$, $\alpha = 0.3$, $\alpha = 0.4$ and $\alpha = 0.5$ respectively. In Figure 2 we see that for $\gamma = 1$, the value of $d\bar{l}_A(t,1)/dt$ at $t = 1$ (i.e. free trade) is positive, as predicted by Proposition 2. Therefore, for this parameter value, the agreement tariff level at which $d\bar{l}_A(t,1)/dt = 0$ is positive, and so the equilibrium trade agreement entails a positive tariff level. For the higher values of γ, $\gamma = 1.25$, 1.5 and 1.75, $d\bar{l}_A(t,1)/dt < 0$ for all values of $t \geq 1$ and so free trade will maximize revenue for the government across this range. In these cases there would be no tariff revenue from the agreement but the amount that firms

would be prepared to lobby in favor of free trade would be maximized.

In Figures 3 through 5, we replicate the analysis in Figure 2 but increasing α in steps of 0.1 until 0.5. Here we see that, at $t = 1$, $d\bar{l}_A(t,1)/dt$ is greater for $\gamma = 1$ than for the other values of γ, as was the case in Figure 1. However, in Figure 4, we see that $d\bar{l}_A(t,1)/dt > 0$ at $t = 1$ for $\gamma = 1.25$ as well as at $\gamma = 1$, meaning that the range of values of γ for which the outcome of the agreement is a positive tariff has increased. This pattern is continued for a further increase in α in Figure 5 to $\alpha = 0.5$. For α at that level, $d\bar{l}_A(t,1)/dt > 0$ at $t = 1$ for all the levels of γ reported, meaning that the outcome of the agreement is a positive tariff in all these cases. Taking Figures 2 through 5 together, we see that when the outcome of the agreement is a positive tariff it is decreasing in γ all else equal.

Figures 6 through 9 show the same sequence of exercises to examine the effect of increasing α on the trade agreement, but now for $k = 2$ instead of $k = 1.5$. What we notice from these figures is that, for $k = 2$, $d\bar{l}_A(t,1)/dt$ is everywhere lower at $t = 1$ than its corresponding value for $k = 1.5$. Overall this implies that free trade tends to be the outcome for a wider range of parameter values when $k = 2$ than when $k = 1.5$. And where the outcome of a trade agreement is a positive tariff, the tariff tends to be lower when $k = 2$ then when $k = 1.5$. The intuition for how k affects the revenue maximizing tariff is similar to that of γ. As k increases, the expected productivity level that any firm draws is being shifted towards a_U, the lowest possible productivity, and away from lower values of a. This means that, all else equal, there will be more firms that do not export in the trade equilibrium and these firms lobby the most against free trade.

4 Conclusion

The purpose of this paper has been to examine the scope for a trade agreement in a setting where there is a single industry comprised of heterogeneous firms. We found that if the only trade restriction in the model takes the form of an iceberg transport cost, and there

is no cost to lobbying, then for any possible trade agreement ex post aggregate industry profits are always equal under autarky and the trade agreement, regardless of the level of trade liberalization implied by the agreement. This surprising result rests on the Pareto distribution and serves as a useful benchmark. With this basic set-up the model predicts that free trade would emerge as that would provide the most lobbying revenue by making the trade supporters the best off while making the autarky supporter the worst off.

If the only trade restriction in the model takes the form of a tariff, then some levels of openness are more favorable to the government than others. Here we are able to make a prediction about the unique trade agreement that would emerge in equilibrium. When the fixed costs associated with exporting are relatively high, the outcome is more likely to be free trade. This surprising outcome is driven by the fact that firms are more likely to serve only the domestic market, and these firms' profits more significantly reduced by trade liberalization. Thus they will lobby more aggressively in favor of autarky, and this in turn will increase the amount exporting firms are prepared to contribute when lobbying in favor of free trade.

We have used a highly stylized model to demonstrate this effect, and it would be useful to explore the generalities of these results in a more detailed and realistic simulations model. However, the tension that our model focuses on seems likely to carry over to a more general setting as well. It would be particularly useful to explore the predictions of our model in a setting where consumer welfare could be taken into account in government preferences. Our framework can be thought of as approximating one in which governments place a relatively low weight on the welfare of consumers. An extension to a framework where consumer welfare can be accounted for would make it possible to get a better idea of how much government concern for consumers would be needed to overturn the type of government response to lobbying that our model characterizes.

The framework we have focused on here is one of multilateral trade agreements. The question we pose would carry over to a setting of preferential trade agreements as well.

However, the analysis would be complicated by the fact that not only might firms prefer autarky while exporting, they might prefer a preferential trade agreement to free trade. This might help to provide a new explanation for the dramatic proliferation of preferential trade agreements in recent years.

The prediction of our model that higher fixed costs of exporting are more likely to be associated with trade agreements that support a movement all the way to free trade could be tested against the data. To the extent that fixed costs of penetrating markets for manufactures are higher than for agricultural products, the econometric results of such an investigation may support the observation that trade agreements in manufactures have moved further towards free trade than those for agriculture.

A Appendix

Proof of Proposition 2. Evaluating the first derivative, equation (20), at free trade (i.e. $t = 1$) yields

$$\frac{d\bar{l}_A(1,1)}{dt} = \frac{-(k-\alpha)\mu}{k^2(\gamma^\psi+1)^2}\left[\left(\frac{k[\gamma^\psi-1]+2\alpha}{k-\alpha}\right)\left[2-F^{1-\varepsilon}\right]^\psi - \left(1+\gamma^\psi\right)\alpha\right]. \tag{21}$$

Now set $\gamma = 1$ to yield

$$\left.\frac{d\bar{l}_A(1,1)}{dt}\right|_{\gamma=1} = \frac{-\alpha\mu}{2k^2}\left[\left(2-2^{\frac{\varepsilon-1}{k}}\right)^\psi - (k-\alpha)\right]. \tag{22}$$

If $k \geq \alpha+1$ then equation (22) is strictly positive as $\left[2-2^{\frac{\varepsilon-1}{k}}\right]^\psi < 1$. Therefore, at $\gamma = 1$ $d\bar{l}_A(1,1)/dt > 0$. By inspection of (21) we see that the coefficient on $\left[2-2^{\frac{\varepsilon-1}{k}}\right]^\psi$ is increasing in γ for $\gamma \geq 1$. So by continuity there exists a value of γ, call this $\bar{\gamma}$, for which the term in brackets must equal zero, and for which all further increases in γ would result in the term in brackets being positive and $dl_A(1,1)/dt < 0$. If $dl_A(t,1)/dt < 0$ at $t = 1$ then by the quasi-concavity of $\bar{l}_A(t,1)$ in t it must be the case that $dl_A(t,1)/dt < 0$ for all t. So we know

that a maximum occurs for $\bar{l}_A(t,1)$ at $t=1$. If $\gamma \in [1,\bar{\gamma})$ then there must be a range of t for which $dl_A(t,1)/dt > 0$ and so the maximum value of t must occur at a value other than $t=1$. $\square$

Figure 2: $\frac{dl_A}{dt}$ when $\alpha = 0.2$ and $k = 1.5$

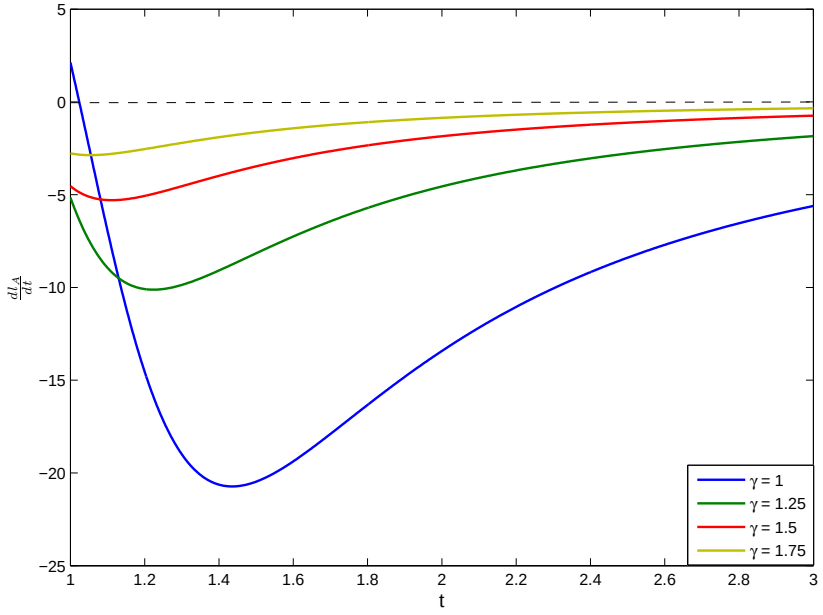


Figure 3: $\frac{dl_A}{dt}$ when $\alpha = 0.3$ and $k = 1.5$

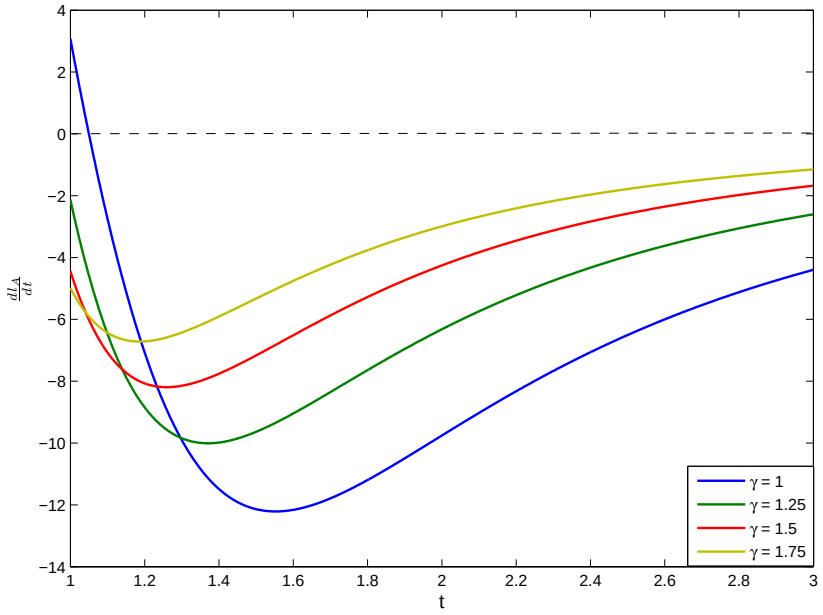


Figure 4: $\frac{dl_A}{dt}$ when $\alpha = 0.4$ and $k = 1.5$

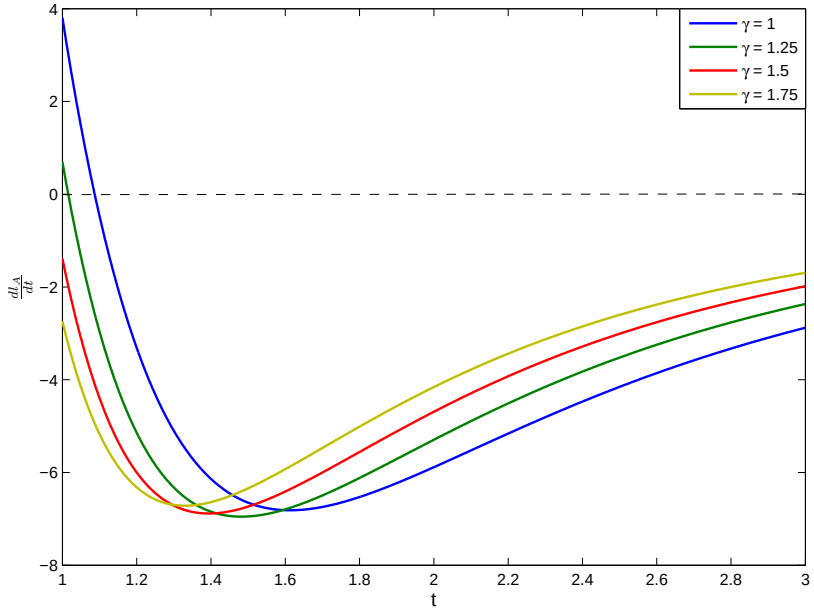


Figure 5: $\frac{dl_A}{dt}$ when $\alpha = 0.5$ and $k = 1.5$

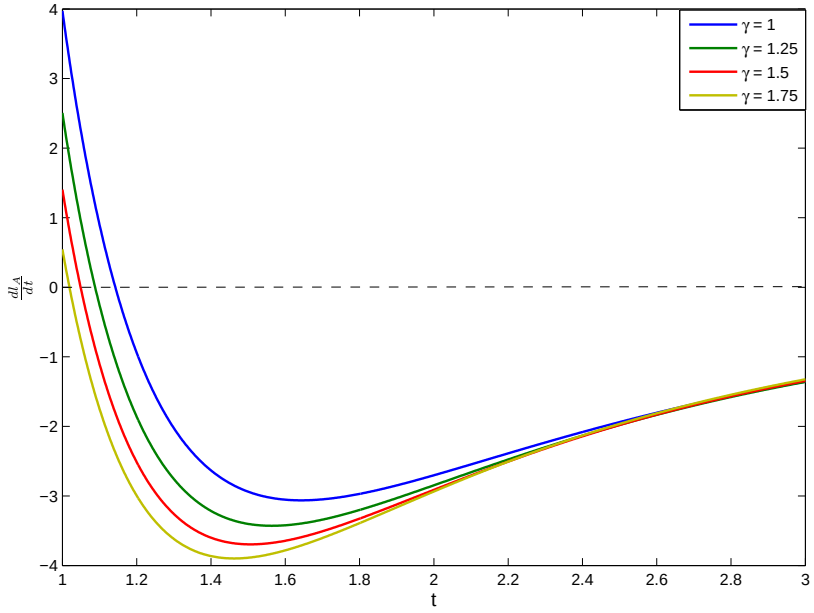


Figure 6: $\frac{dl_A}{dt}$ when $\alpha = 0.2$ and $k = 2$

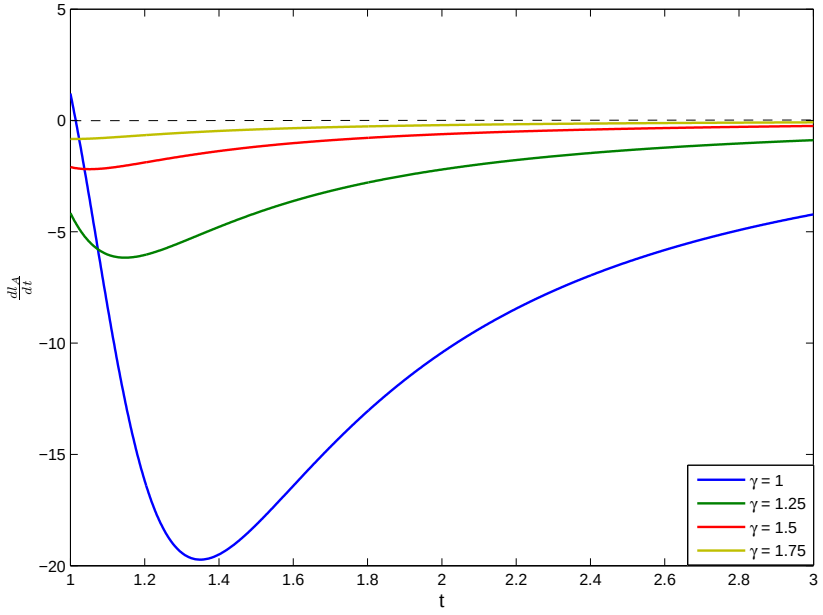


Figure 7: $\frac{dl_A}{dt}$ when $\alpha = 0.3$ and $k = 2$

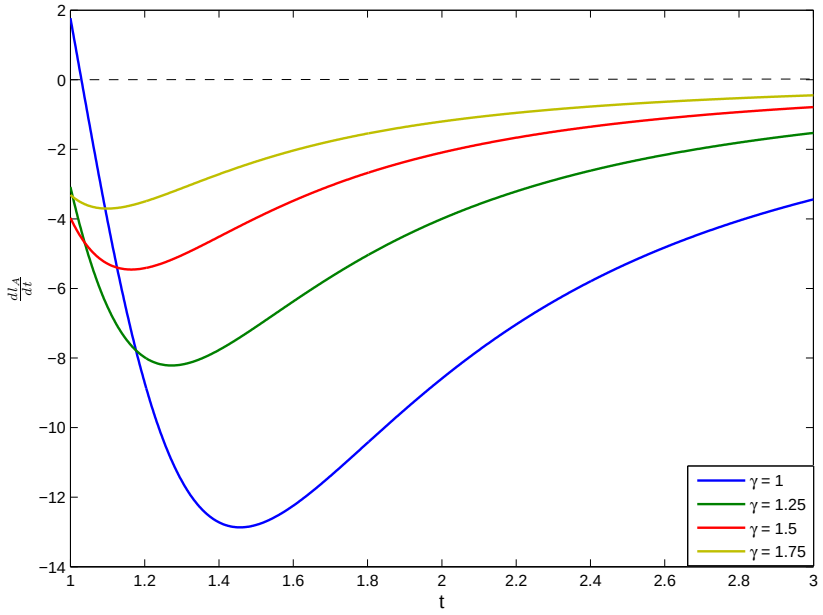


Figure 8: $\frac{dl_A}{dt}$ when $\alpha = 0.4$ and $k = 2$

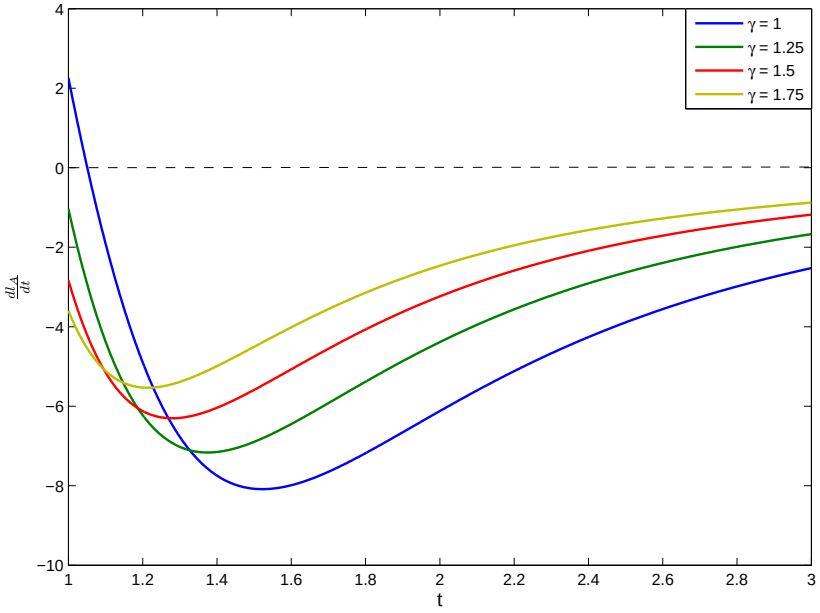
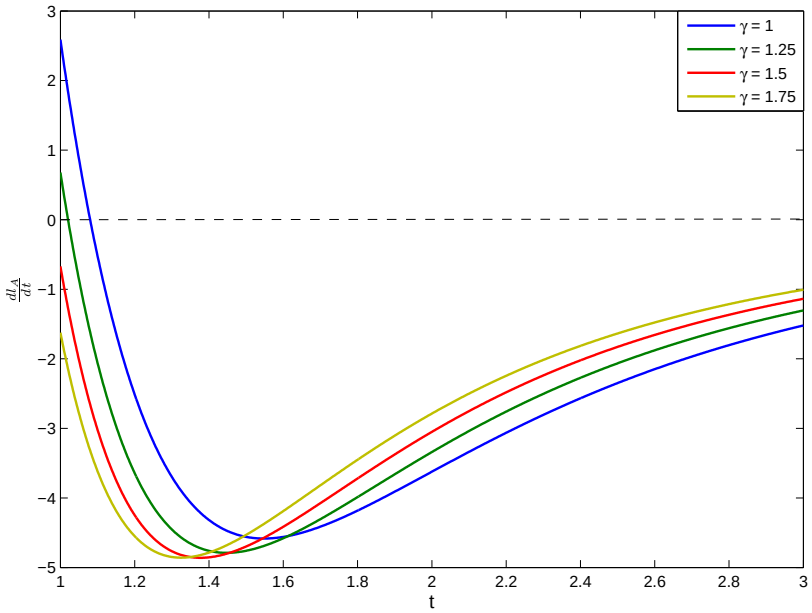


Figure 9: $\frac{dl_A}{dt}$ when $\alpha = 0.5$ and $k = 2$



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