Trade Policy with Endogenous Entry Revisited*

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Abstract

This paper revisits the effects of tariffs and quotas in a competitive setting where three results are thought to hold. These are: that quotas are equivalent to specific tariffs, the form of tariffs—specific or ad valorem—does not matter, and that the way in which a quota is allocated has no real effects as it only affects the allocation of rents, not their size. We show that *all three of these results are false* when entry/exit is endogenous. Equivalence holds only if the initial level of entry is set at the long run level under the quota.

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1 Introduction

This paper revisits the effects of conventional trade policy instruments such as tariffs and quotas in a competitive model of supply. It shows that when firm entry/exit is taken into account and "equivalent" trade policies are examined, the effects of quotas and tariffs may differ from what is conventionally understood.

There are two ways to model competitive supply. The first way is to think of supply as coming from identical foreign firms that export to the home country. This is the standard competitive framework. Each exporting firm can be thought of as making an initial investment of one unit of capital, and a later decision on its employment level. At given factor prices, this results in an upward-sloping supply (marginal cost) curve for the firm: the higher the market price of the good, the greater the firm's quasi-rents. Foreign firms enter the home market until quasi-rents per unit of capital equal the (given) price per unit of capital. This defines the cutoff price of the good. Below this cutoff price, quasi-rents are not enough to cover the cost of capital so there is no entry and zero supply. Above this cutoff price, quasi-rents exceed the price of capital so that there is infinite entry. As a result, we get an industry supply curve that is infinitely elastic at the cutoff price, i.e., the standard competitive supply curve, in the long run.

The second way is to think of supply as coming from profit-maximizing competitive traders (import distributors or agents) who bring a good from abroad into the home country for distribution and resale. There is free entry into and exit from the import industry. Anyone can become a trader by paying a fixed cost which allows him to buy a good from the world market at a random price and sell it in the integrated domestic market at the market-clearing price, making profits equal to the difference in the buying and selling price. Thus, traders are homogeneous ex ante but heterogeneous ex post. Traders face capacity constraints, so no one trader can dominate the market and there is perfect competition.[1] The long-run supply curve looks the same as the one in the standard competitive framework above. We will couch our discussion in this setting as it is the less familiar one, though the analysis

[1]In some ways, this can be seen as a competitive analogue of the monopolistically competitive heterogeneous-firm setting common in the international trade/industrial organization literature. In those models, it is much harder to obtain insights into the effects of trade policy; see for example, Melitz and Ottaviano (2008), and Baldwin and Forslid (2006).

could just as well be done in terms of the standard competitive framework; it is free entry that is the critical component of the model, not firm/trader heterogeneity.

Under these conditions, three results are commonly thought to hold. First, quotas are equivalent to tariffs.[2] Second, the form of tariffs—specific or ad valorem—does not matter. Third, the way in which a quota is allocated has no real effects as it does not affect the size of the quota rents, only who gets them. We show that *all three of these results are false* when entry/exit is endogenous. Our model considers the short-run impact of trade policy (when there is no entry/exit) and the long-run impact (after entry/exit has taken place); we also consider the implications of different methods of allocating quota licenses. Thus, the fundamental contribution of this paper lies in its analysis of how firms' entry/exit decisions affect the outcome of trade policy in a standard competitive setting.

In our model, the ranking of equivalent policies depends on the level of entry at the point of comparison. Only if the initial level of entry is set at the long-run level under a quota does the equivalence of specific tariffs and quotas hold. If the initial level of entry is above the long-run entry level under a quota, and equivalence is defined at this point, then a quota reduces entry and welfare the least, followed by an equivalent specific tariff, and finally, an equivalent ad valorem tariff.[3] Furthermore, the way in which quota licenses are distributed makes a difference. In our model, entry is (constrained) optimal if importers have to pay for the quota licenses but not if they are given the licenses for free according to some rationing rule. Therefore welfare is higher whenever the quota rent is captured by some domestic agent(s) other than the traders themselves. The way in which quotas are allocated thus affects aggregate welfare, and not just its distribution across domestic agents.

Why revisit the effects of tariffs and quotas now when they are no longer the most important instruments of trade policy? Because tariffs and quotas have not completely disappeared from the trade policy landscape—quotas are most common these days for agricultural goods and our results are clearly relevant there. More importantly, they arise in other contexts besides trade

[2]There is an enormous literature on the ranking of "equivalent" policies in trade. See Krishna (1990) for a survey of the older literature. More recently, Jørgensen and Schröder (2005) look at this question in a monopolisitically competitive setting.

[3]This order is reversed if the initial entry level is *below* the long run entry level with the quota.

policy, for example, in the recent debate to control emissions by selling permits to pollute. These pollution caps act just like quotas on an intermediate good and it is worth noting that a prediction of our model that the price of a license should fall over time, seems to be borne out in the data on the value of sulfur dioxide emissions permits in the United States (Schmalansee and others, 1998).

The paper is organized as follows. Section 2 sets up the model. Section 3 characterizes the free trade equilibrium with endogenous entry/exit of traders, and establishes that this equilibrium is socially optimal. Section 4 looks at what happens when, starting from the free trade equilibrium, trade is restricted by a quota set below the free trade level of imports. We also consider the effects of selling the quota rights versus giving them to the traders, and conclude that the former welfare-dominates the latter. Sections 5 and 6 consider the effects of a specific tariff and an ad valorem tariff that (for a given level of entry) generate the same level of imports as the quota. Section 7 concludes.

2 The Model

Assume there is an integrated domestic market for a particular good where a single price, P, prevails. Demand in this market is given by $Q^D(P)$. For simplicity, assume the good is not produced at home.[4] Domestic consumers cannot directly access the world supply of this good. Instead, they are served by traders who import the good from the world market and sell it domestically. This world market is not integrated in the sense that there is no single price that prevails: rather, there is a distribution of prices denoted by $F(c)$ which the home country takes as given.[5]

Suppose there is a continuum of these traders with mass N. Every trader has a fixed entry cost, f_e, that he has to incur to enter the market. Once this is paid, the trader gets a draw from the known distribution of prices, $F(c)$. In other words, paying the entry cost allows a trader to access the

[4] For the positive part of the analysis, we can also interpret $Q^D(P)$ as domestic excess demand as long as domestic production is fixed.

[5] Alternatively, we could assume that the traders do not know their productivity (or costs) prior to entry. After entry, each trader draws a productivity, and hence a cost; he is then able to import one unit at the world price plus his cost. High productivity traders would thus be willing to supply at a lower price.

world market at a random price and to sell in the domestic market at the domestic market-clearing price. There are limits to the scale at which the traders can operate as each trader has limited resources at his disposal. For simplicity, assume that each trader has the capacity to import one unit.[6]

The setup is as follows. First, the trader decides whether to pay f_e and enter the market or not. If he enters, he is matched with a seller in the world market and gets a draw of c from $F(c)$. Depending on the draw, the trader decides whether to buy the good or not, keeping in mind that he receives no direct utility from the good, only the profit from selling the good domestically at the market clearing price. If the domestic price is P, only those traders who draw a cost of $c \leq P$ will choose to import the good. Thus, supply from a unit mass of traders is $F(P)$. As usual, the mass of traders in equilibrium is determined so that their expected profit at the time of entry is zero. In what follows, we work with a static setting to keep things simple.[7]

3 Equilibrium Under Free Trade

If a mass of N traders enters the market, supply will be equal to $NF(P)$, and the free trade market clearing price, $P^F(N)$, will be determined by the intersection of demand and supply:

$$Q^D\left(P^F(N)\right) = NF\left(P^F(N)\right). \tag{1}$$

$P^F(N)$ is decreasing in N.

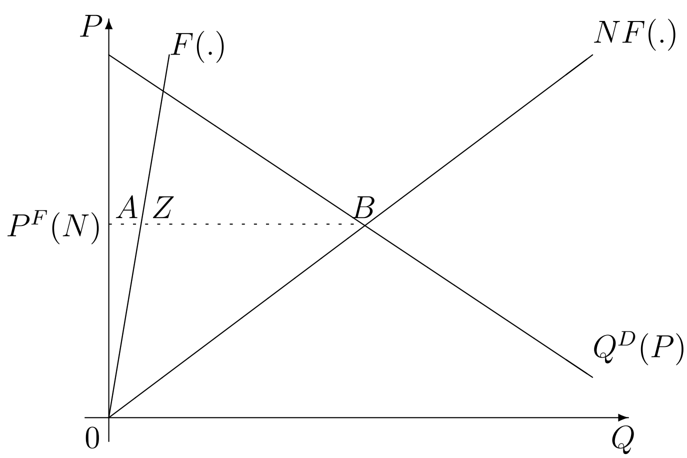
A trader, in deciding whether to enter the market or not, will expect to earn $P^F(N) - c$ if he draws a cost below $P^F(N)$, and zero otherwise. Hence, his expected profit or quasi-rent is:

$$r^F(N) = \int_0^{P^F(N)} \left(P^F(N) - c\right) f(c)\, dc = \int_0^{P^F(N)} F(c)\, dc \tag{2}$$

[6] Capacity constraints of some sort are necessary for internal consistency of a model with cost heterogeneity and perfect competition. Our assumption can be seen as an extreme form of the span of control of a firm a la Lucas (1978).

[7] It is easy to convert this into its dynamic analogue in steady state (à la Melitz (2003)) by assuming a constant exogenous death rate for all firms, and setting the mass of entrants in each time period to exactly compensate for these deaths.

Figure 1: Competitive Equilibrium



(where the second equality follows from integration by parts). Total quasi-rent earned in the economy, $Nr^F(N)$, is thus equal to the area between the supply curve and the equilibrium price, that is, the area OAB in Figure 1. Thus, quasi rents look just like producer surplus. In Figure 1, the area OAZ corresponds to $r^F(N)$. Since $P^F(N)$ is decreasing in N, so is $r^F(N)$.

Entry will occur until each trader's expected quasi-rent equals the fixed cost of entry.

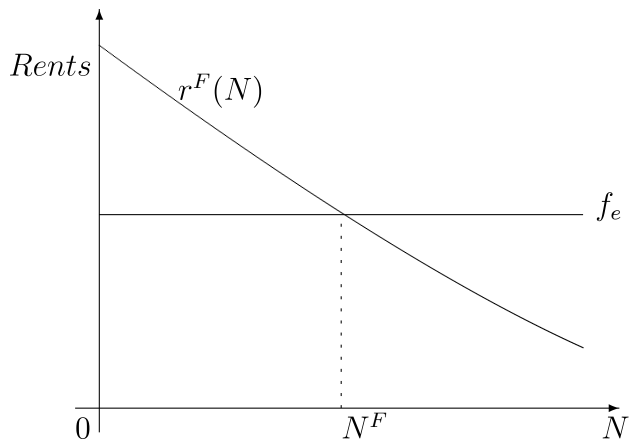
$$r^F\left(N^F\right) = \int_0^{P^F\left(N^F\right)} F(c)\,dc = f_e. \tag{3}$$

This is depicted in Figure 2.

Assumption 1 $f_e < \int_0^{\bar{P}} F(c)\,dc$ where $\bar{P}$ is the price at which demand becomes zero.

Assumption 1 ensures that $r^F(N)$ has a vertical intercept above f_e in Figure 2 so that there is a unique free entry equilibrium with $N^F > 0$. In Figure 3, the equilibrium level of entry under free trade, N^F, is found by setting area OAB equal to $N^F f_e$ or, equivalently, by setting area OAZ equal to f_e.

Figure 2: The Free Entry Condition



3.1 Welfare

For any N, welfare is the sum of consumer surplus and producer surplus (quasi-rent) less entry costs:

$$W^F(N) = \int_{P^F(N)}^{\bar{P}} Q^D(P)dP + N \int_0^{P^F(N)} F(c)\, dc - Nf_e. \tag{4}$$

It is well understood that in the case of differentiated products and monopolistic competition (Dixit and Stiglitz, 1977) there may be too much entry or too little entry relative to the social optimum. We also know that in the case of homogeneous goods and market power (Mankiw and Whinston, 1986) there is too much entry due to the "business stealing effect": firms do not internalize the fact that their entry dissipates the profits of other firms and as a result, more of them enter the market than is socially optimal. However, with homogeneous goods and the absence of market power, the level of entry is optimal. Thus, it should come as no surprise that entry is also optimal in our setting.[8] This result is depicted in Figure 5 below.

[8] We are relatively informal in the proofs of some our results here. More formal proofs for these results can be found in the working paper version (NBER Working Paper No.

Proposition 1 *The free trade equilibrium results in a level of entry that is socially optimal, i.e.,* $dW^F(N)/dN = 0$ *at* $N = N^F$*.*

Proof. In the Appendix. ■

4 Restricted Trade: Quotas

Suppose that we are at the free trade equilibrium with N^F traders in the market and a binding quota of $\bar{Q}$ is imposed, where $\bar{Q}$ is less than the free trade level of imports. Traders now have to purchase a quota license from the government in order to sell the imported good in the domestic market. We assume that quota licenses are transferable. Traders can buy/sell their quota licenses after realizing their draws from $F(c)$.[9] What happens to entry?

The equilibrium is depicted in Figure 3. The price consumers pay (the demand price) is $P^D\left(\bar{Q}\right)$. For the given mass of traders, N^F, the value of a quota license, $L\left(N^F, \bar{Q}\right)$, is equal to DF, the difference between the demand price $P^D\left(\bar{Q}\right)$ and the supply price $P^S\left(N^F, \bar{Q}\right)$, where the latter is defined by:

$$NF\left(P^S\left(N^F, \bar{Q}\right)\right) = \bar{Q}. \tag{5}$$

Note that $P^S\left(N, \bar{Q}\right)$ is decreasing in N and increasing in $\bar{Q}$.

The quasi-rent function facing each trader is now:

$$r^Q\left(N, \bar{Q}\right) = \int_0^{P^S\left(N,\bar{Q}\right)} F(c)\,dc \tag{6}$$

as long as the quota is binding. Like $P^S\left(N, \bar{Q}\right)$, $r^Q(N, \bar{Q})$ is decreasing in N and increasing in $\bar{Q}$. The area OCD in Figure 3 corresponds to the quasi-rent earned by all traders in the market under the quota $\bar{Q}$, so $r^Q(N, \bar{Q})$ is equal to $(1/N)$ of the area OCD or area OCI.

How does $r^Q(N, \bar{Q})$ compare with $r^F(N)$? Define $N_0\left(\bar{Q}\right)$ to be the level of N where the supply curve intersects demand at $P^D\left(\bar{Q}\right)$. In other words,

13040).

[9] As there are no frictions in the license market and no aggregate uncertainty, the license price will be nonstochastic. A trader will be indifferent between buying the license before he knows his cost (and selling it at the market price if his cost exceeds the supply price) and buying it after he knows his cost (as long as his cost is below the supply price).

Figure 3: Import Equivalent Policies

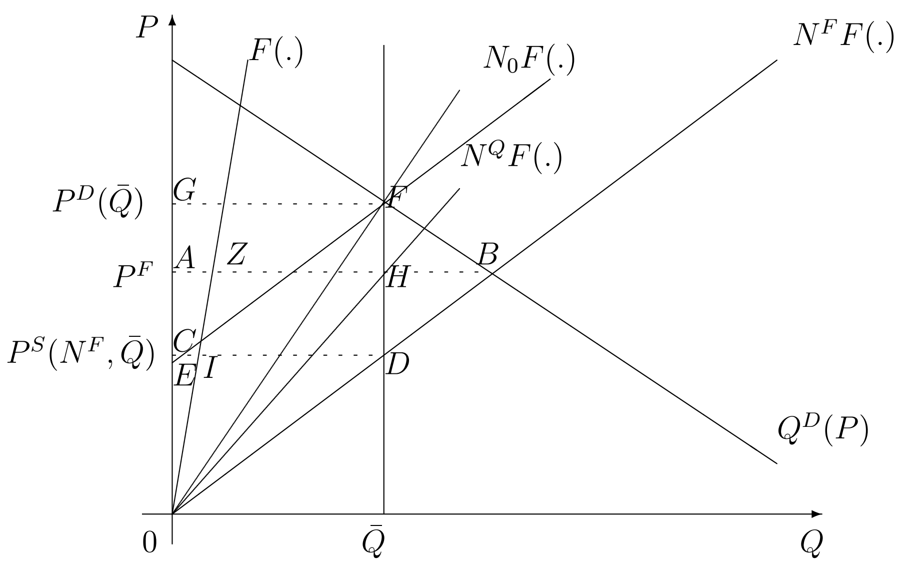
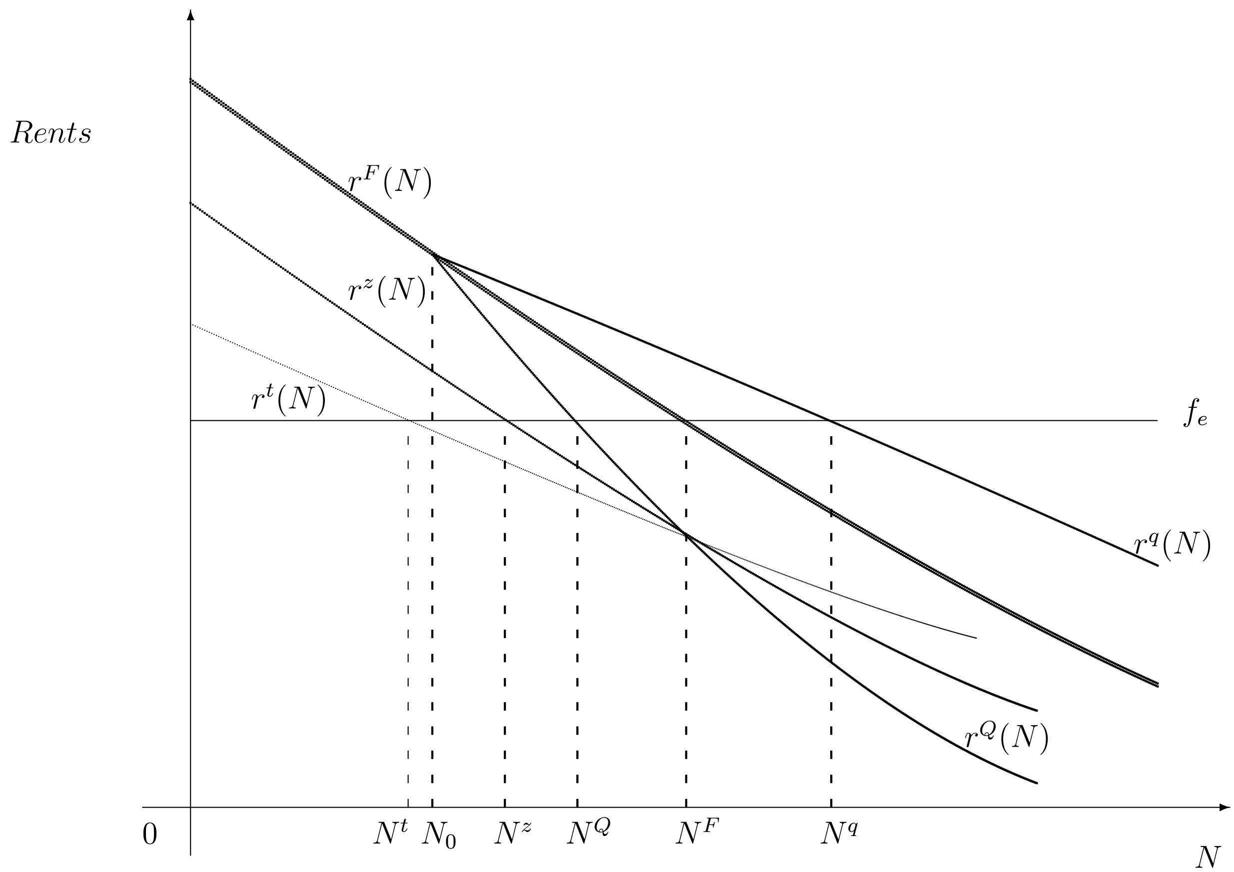


Figure 4: Comparing Rents: Quotas, Specific and Ad-valorem Tariffs



$N_0\left(\bar{Q}\right)$ is the level of entry at which the quota is just binding. Since $\bar{Q}$ is less than the free trade level of imports, $N_0\left(\bar{Q}\right)$ must be below N^F as shown in Figure 3. Once N falls below $N_0\left(\bar{Q}\right)$, the quota will no longer be binding. Therefore, for a given $\bar{Q}$, $r^Q\left(N, \bar{Q}\right)$ will be identical to $r^F(N)$ when $N \leq N_0\left(\bar{Q}\right)$.[10] When $N > N_0\left(\bar{Q}\right)$, $r^Q\left(N, \bar{Q}\right) < r^F(N)$; this follows from Equations (2) and (6) since $P^S\left(N^F, \bar{Q}\right) < P^F\left(N^F\right)$. This is depicted in Figure 4.

Equilibrium entry under the quota, which we will denote by $N^Q\left(\bar{Q}\right)$, is determined by the intersection of $r^Q\left(N, \bar{Q}\right)$ and f_e:

[10]We will use N_0, rather than $N_0(\bar{Q})$, and so on, when there is no danger of confusion.

$$\int_{0}^{P^S\left(N^Q\left(\bar{Q}\right),\bar{Q}\right)} F\left(c\right)dc = f_e. \tag{7}$$

Comparing equations (3) and (7), it is clear that since the right-hand side is the same in both equations, the left-hand side must also be the same. Thus, the supply price in the free entry equilibrium with a quota must equal the free trade price under free entry without a quota, or $P^S\left(N^Q\left(\bar{Q}\right),\bar{Q}\right) = P^F\left(N^F\right)$. In Figure 3, this means that the mass of firms in the free entry equilibrium with a quota must be such that the supply curve goes through point H ensuring that that no matter what the level of the quota, the equilibrium supply price under free entry must equal the free trade price. Hence, we have the following.

Lemma 1 *The equilibrium supply price is invariant with respect to $\bar{Q}$. In other words, for all $\bar{Q}$, $P^S\left(N^Q\left(\bar{Q}\right),\bar{Q}\right) = P^F\left(N^F\right)$.*

We can trace out what will happen as a quota is imposed starting from the free entry equilibrium under free trade. With the mass of firms fixed at N^F, the quota reduces the supply price from P^F to $P^S(N^F,\bar{Q})$. As a result, traders will only import if the cost is less than $P^S(N^F,\bar{Q})$. Thus, in the short run (where entry is fixed at N^F), average cost will fall or productivity will rise. From Figure 3, it is clear that at this lower supply price, quasi-rents are not enough to cover entry costs (as OCI is less than OAZ which equals f_e). Thus, traders will exit until the supply price returns to P^F. As this happens, the average cost will rise (average productivity will fall) returning to its free trade level in the long-run equilibrium under the quota. The mass of traders in the long run under the quota, $N^Q\left(\bar{Q}\right)$, (which pins down the position of the line $N^QF(.)$ in Figure 3) will be smaller than N^F but larger than $N_0\left(\bar{Q}\right)$ so that the license price remains positive.

Proposition 2 *A binding quota will initially raise average productivity as the supply price falls and traders change their import decisions in response to the quota. In the longer run, firms will exit as they cannot cover their fixed cost. As firms exit in response to the quota, average productivity falls returning to its pre-quota equilibrium level. The price of a quota license will fall as the number of traders shrinks, but it will remain positive in the new long-run equilibrium.*

Thus, our model provides some stark but interesting and potentially testable predictions for short-run and long-run cost, productivity, and license prices in an industry in response to a quantitative restriction. Our prediction for license prices seems to be borne out in the case of sulfur dioxide emissions permits in the United States when trading of such permits was tried out.[11] In Section 4.2, we show that the license price also depends on the way in which the quota rights are distributed.

4.1 Welfare Under a Quota

Let us assume that the quota rights are sold and that these revenues go to the government. For any N and $\bar{Q}$, welfare is the sum of consumer surplus, producer surplus, and license revenue, less entry costs:

$$\begin{aligned} W^Q\left(N, \bar{Q}\right) &= \int_{P^D(\bar{Q})}^{\bar{P}} Q^D(P)dP + N \int_0^{P^S\left(N,\bar{Q}\right)} F\left(c\right)dc \\ &\quad + \left[P^D\left(\bar{Q}\right) - P^S\left(N, \bar{Q}\right)\right]\bar{Q} - Nf_e. \end{aligned} \tag{8}$$

Lemma 2 *The level of entry is socially optimal, given the quota level.*

Proof. In the Appendix. ■

This result is depicted in Figure 5. While welfare under a quota lies below that under free trade whenever the quota is binding (i.e., when $N > N_0\left(\bar{Q}\right)$), it reaches a maximum at $N^Q\left(\bar{Q}\right)$, the equilibrium entry level under the quota. Note that in equilibrium, total quasi-rent exactly equals total entry costs so welfare comprises only consumer surplus and license revenue:

$$W^Q\left(N^Q\left(\bar{Q}\right), \bar{Q}\right) = \int_{P^D(\bar{Q})}^{\bar{P}} Q^D(P)dP + \left[P^D\left(\bar{Q}\right) - P^S(N^Q\left(\bar{Q}\right), \bar{Q})\right]\bar{Q}. \tag{9}$$

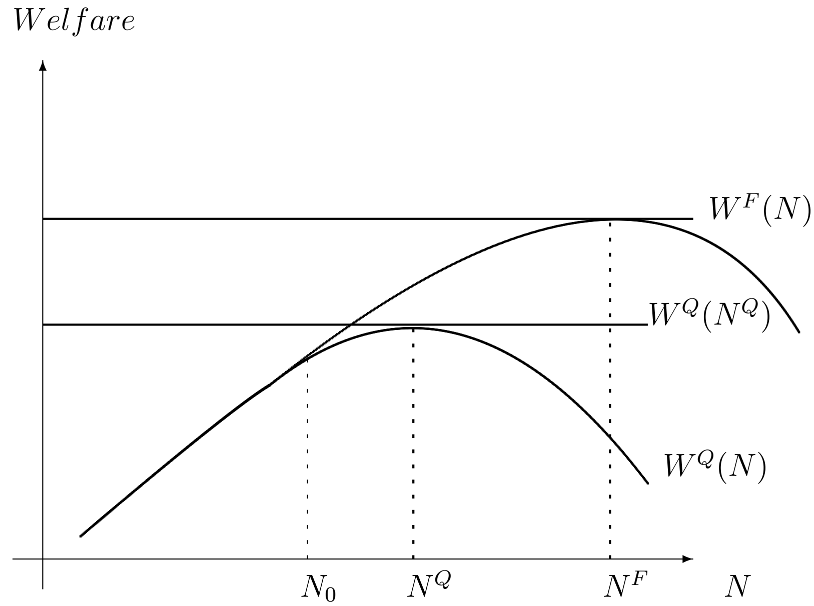
Lemma 3 *An increase in the quota always raises welfare.*

Proof. In the Appendix. ■

This result is easy to understand from Figure 5. An increase in the quota shifts the welfare function $W^Q(N)$ upward, increasing $N_0\left(\bar{Q}\right)$ and also raising the peak of the function.

[11] See Schmalensee and others (1998) for more on this topic.

Figure 5: Welfare Comparisons



4.2 Allocation of Quota Rent

So far we have assumed that quota licenses are sold, with the revenues accruing to the government. But this is often not the case; it is quite common for quota licenses to be awarded to some or all importers based on certain criteria such as past import performance. In this section, we show that the allocation of quota rent has an impact on the entry decision of traders. This means that the details of quota implementation—who receives the licenses and under what conditions—affect not just the distribution of the rents, but the equilibrium size of the import industry.

To illustrate, let us consider the scenario where quota licenses are not sold but rather awarded to the traders free of charge. To avoid confusion, we will refer to such an arrangement as "free" quota to distinguish it from the previous case where traders had to pay for the quota licenses.

We continue to assume that quota licenses are tradeable. When a trader chooses to enter, he pays the fixed cost and upon doing so, he is allocated a license. This allocation is certain if the mass of traders that enter does not exceed the quota, but occurs with a probability $\bar{Q}/N$ if $N > \bar{Q}$. Traders need not import to get a license, they just need to enter (for example, by obtaining a business registration number). Assuming license markets work without friction, we can think of every entering trader selling his license for $L(N,\bar{Q})$ and then buying it back if his cost realization is below the supply price, $P^S(N,\bar{Q})$.

Let $r^q\left(N,\bar{Q}\right)$ denote the expected quasi-rent per trader under the "free" quota.[12] If $N \leq N_0(\bar{Q})$, then $L(N,\bar{Q}) = 0$, $P^S\left(N,\bar{Q}\right) = P^F(N)$, and $r^q(N,\bar{Q}) = r^F(N)$—in other words, the quota is not binding. But if $N > N_0(\bar{Q})$, then $L\left(N,\bar{Q}\right) > 0$ and $P^S\left(N,\bar{Q}\right) < P^F(N)$. Furthermore, $\bar{Q}/N < \bar{Q}/\left(NF(P^S\left(N,\bar{Q}\right))\right) = 1$, thus entrants are not assured of a license. As a result, they obtain $\left(\bar{Q}/N\right)L(N,\bar{Q})$ in expected terms from selling any licenses they are given and $\int_0^{P^S\left(N,\bar{Q}\right)} F(c)\,dc$ from their productive (importing) activities. More compactly, expected earnings of an entrant are:

$$r^q(N,\bar{Q}) = \min\left[1,\frac{\bar{Q}}{N}\right]L(N,\bar{Q}) + \int_0^{P^S\left(N,\bar{Q}\right)} F(c)\,dc. \tag{10}$$

Clearly, $r^q(N,\bar{Q}) > r^Q(N,\bar{Q})$ for any N and $\bar{Q}$, as long as the value of the quota license is positive (i.e., when $N > N_0(\bar{Q})$). In other words, when $N > N_0(\bar{Q})$, entrants must make more in expected terms at any given N and $\bar{Q}$ than when they have to buy licenses. This is why in Figure 4, the quasi-rent curves, $r^Q\left(N,\bar{Q}\right)$, $r^F(N)$, and $r^q\left(N,\bar{Q}\right)$ coincide for entry levels up to $N_0\left(\bar{Q}\right)$ but beyond that point, $r^q\left(N,\bar{Q}\right) > r^Q\left(N,\bar{Q}\right)$.

Lemma 4 *For $N > N_0(\bar{Q})$, $r^q\left(N,\bar{Q}\right)$ lies above $r^Q\left(N,\bar{Q}\right)$.*

Equilibrium entry under the "free" quota, which we will denote by $N^q\left(\bar{Q}\right)$, occurs where $r^q\left(N,\bar{Q}\right)$ equals f_e. As $r^q\left(N,\bar{Q}\right)$ lies above $r^Q\left(N,\bar{Q}\right)$, $N^q\left(\bar{Q}\right)$ exceeds $N^Q\left(\bar{Q}\right)$. Welfare under a quota *at any given* level of N is the same whether quotas are sold or given away (because who owns the quotas does not affect total welfare), and since this welfare reaches a maximum at $N^Q\left(\bar{Q}\right)$ as depicted in Figure 5, it must be that $W(\bar{Q},N^q) < W(\bar{Q},N^Q)$. Welfare is lower with the "free" quota as license rents are frittered away in excessive entry when traders have to do not have to pay for their quota licenses, but are not frittered away when they do have to pay. Consequently, the common

[12] We use the lower case q as the superscript to differentiate the quasi-rent function from $r^Q\left(N,\bar{Q}\right)$, used previously.

practice by many governments of devising rationing rules to distribute quota licenses leads to inferior welfare outcomes compared to simply selling the licenses outright.[13] Thus, we have shown the following.

Proposition 3 *Giving the quota licenses to traders results in more entry and thus lower average cost (higher average productivity) compared to selling the quota licenses to traders. Given the quota level, entry is sub-optimally high and equilibrium welfare is lower when quota licenses are given away than when they are sold.*

We assumed above that it was the government that sold the quota licenses and thereby captured the quota rent, but it could just as well be any other *domestic* public or private agency not affiliated to the traders; it could even be corrupt customs officials that "sell" the quota licenses through bribery.[14] Whether the quota rents are captured by the government or by another domestic agent does not matter for aggregate welfare, only for its distribution—as long as the quota rents go to domestic agents other than the traders, aggregate welfare will be higher than under a "free" quota.

We will now compare the equilibrium effects of "equivalent" trade policies. Equivalent policies are defined relative to the initial level of entry. We will begin by focusing first on one scenario to explain how the model works. In this scenario—call it the trade restriction scenario—we start at the free trade equilibrium with a mass of N^F traders and compare trade policies that restrict imports to $\bar{Q}$ at $N = N^F$. We then allow N to adjust assuming entry is free and compare these "equivalent" policies. This focuses attention on polices that are import-equivalence, starting from free trade, but are far from equivalent once entry is taken into account. This scenario is relevant for a policy maker who is contemplating a new trade restriction where there previously was none; the policy maker would start with the existing free trade level of entry since he would typically lack the information necessary to predict the induced entry effects of different trade policies.

We then build on what we learn from this scenario to present a simple way to look at the problem in general, i.e., when "equivalent" polices are defined

[13] Note that this is different from the question of allowing quota licenses to be traded. Even if trade is allowed, entry will be distorted by not selling the quota to begin with.

[14] This raises the possibility that corruption could have real, rather than simply distributional, effects and society could actually be better off if the quota licenses are "sold" via bribery. Of course, this is an extreme conjecture and, given the well known detrimental effects of corruption, it should not be taken as an endorsement of corruption.

at any N. While the standard equivalence result is not true when evaluated at arbitrary levels of entry, it remains true if equivalence is defined for the long-run entry level of traders under the quota. Using this general approach, we consider a second scenario—call it the quota tariffication scenario—where we start at the quota equilibrium with a mass of $N^Q\left(\bar{Q}\right)$ traders (or the "free" quota equilibrium with a mass of $N^q\left(\bar{Q}\right)$ traders) and compare it to a specific tariff that restricts imports to $\bar{Q}$. This scenario is relevant for a policy maker who is contemplating converting an existing quota into a tariff. We argue that there are major pitfalls in tarrifying "free" quotas.

5 Restricted Trade: Specific Tariffs

Start again from the free trade equilibrium with a mass of N^F traders, and consider now a specific tariff that will reduce imports to the level of the quota, $\bar{Q}$, as depicted in Figure 3. The specific tariff $z(N^F,\bar{Q})$ is thus import-equivalent to the quota $\bar{Q}$ when $N = N^F$, and equal to the quota license price:

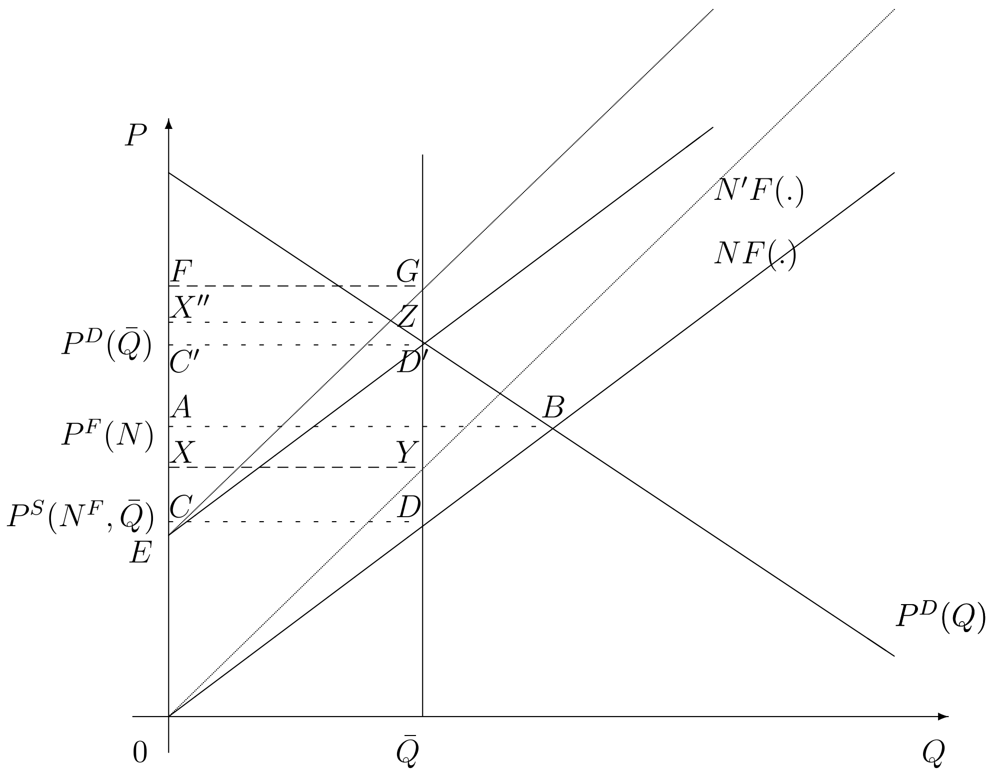
$$z(N^F,\bar{Q}) = L(N^F,\bar{Q}). \tag{11}$$

For notational simplicity, let us denote $z(N^F,\bar{Q})$ by $\bar{z}$. In Figure 6, this is equivalent to shifting the supply curve up by $L(N^F,\bar{Q})$, or the distance $OE = DD'$. Pre-tariff supply is $NF\left(P\right)$ and post-tariff supply is $NF\left(P-\bar{z}\right)$, depicted as the $NF\left(P\right)$ curve shifted up to start at E. The intersection of demand and post-tariff supply determines the quantity imported and the price paid by the consumer, $P^D\left(N,\bar{z}\right)$:

$$NF\left(P^D\left(N,\bar{z}\right)-\bar{z}\right) = Q^D\left(P^D\left(N,\bar{z}\right)\right). \tag{12}$$

Now let us compare expected quasi-rents at a given N. In Figure 6, at $N = N^F$, where $\bar{z}$ is equivalent to the quota, the quasi-rents that accrue to all firms under the specific tariff are given by the area $EC'D'$, which equals the area OCD, the corresponding rents under the quota. As the supply price under the quota and the equivalent specific tariff are the same at $N = N^F$, and falls short of P^F, there will be an exit of traders. As N falls, to say N', the tariff-ridden supply curve swings inward, anchored at E. But this means that the quasi-rents for all N' firms are only $EX''Z$, compared to EFG $(= OXY)$, the total quasi-rents for these N' firms under a quota. By this reasoning, for any $N < N^F$, firms must make less as quasi-rents when

Figure 6: Fall in N: Specific Tariff and Quota



facing the initially equivalent specific tariff than they do under the quota. Of course, by the same logic, for $N > N^F$, quasi-rents under the specific tariff will exceed those under the quota. This is summarized below.

Lemma 5 *$r^z(N, \bar{z})$ lies below $r^Q(N, \bar{Q})$ for $N < N^F$ and above $r^Q(N, \bar{Q})$ for $N > N^F$.*

Equilibrium entry under the specific tariff, which we will denote by $N^z(\bar{z})$, is determined by the intersection of $r^z(N, \bar{z})$ and f_e in Figure 4 and is less than N^Q, that under the quota. Furthermore, it follows from the same argument as Lemma 1 that in equilibrium, the equilibrium supply price is the same as the free trade price, that is: $P^S(N^z(\bar{z}), \bar{z}) = P^F(N^F)$,as only when it receives $P^F(N^F)$ will a firm be able to cover the fixed costs of entry ex ante. Of course, the price that consumers face is even higher due to the tariff. These results are summarized below.

Proposition 4 *If we start at the free trade equilibrium and impose a specific tariff that is initially import-equivalent to the quota, there will be a net exit of traders and the new long-run equilibrium will be characterized by a lower level of entry and imports compared with the quota. Average cost will fall (average productivity will rise) in the short run as traders change their import decisions in response to the tariff. But average cost will rise (average productivity will fall) in the long run as traders change their entry decisions—after entry adjusts, average cost and average productivity will return to their free trade levels in the new long-run equilibrium. Imports will fall as the number of traders shrinks, so imports will be lower than the quota level in the new long-run equilibrium.*

5.1 Specific Tariffs, Quotas, and Equivalence in General

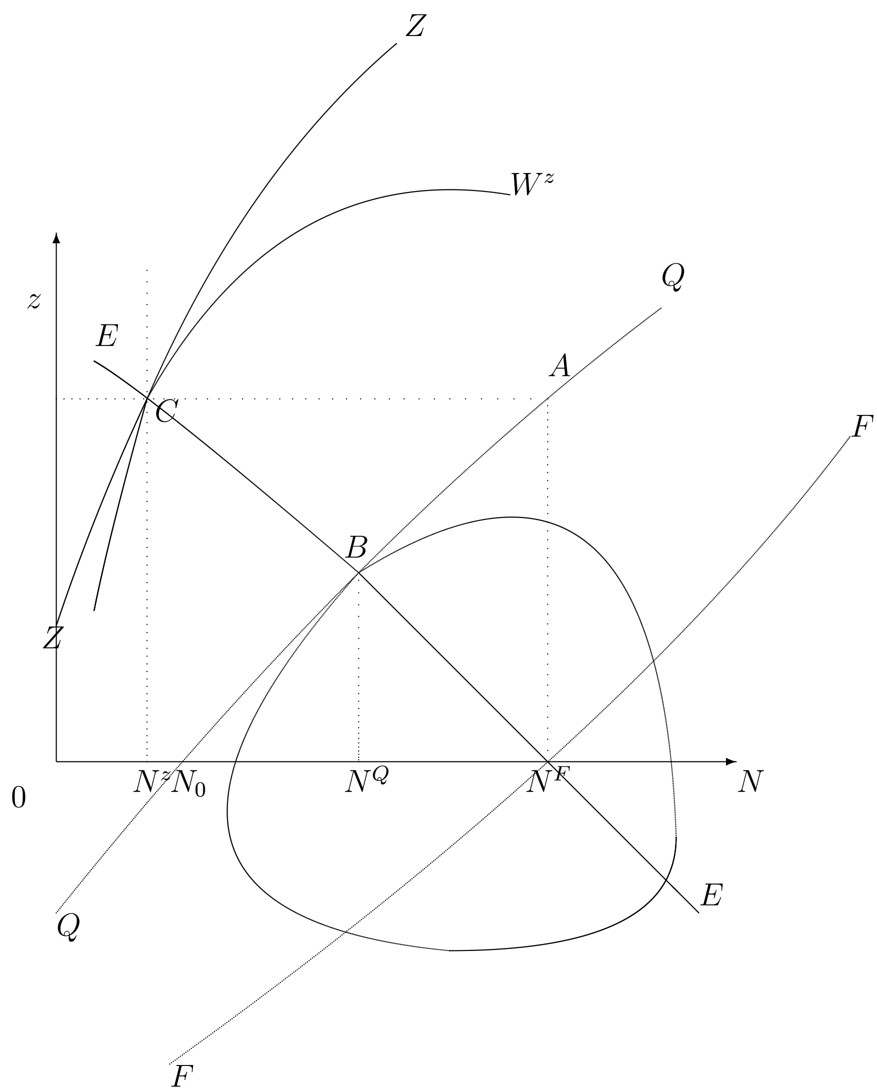
So far we have only considered the trade restriction scenario, i.e., we have used the free trade equilibrium with N^F traders as our starting point for analyzing the effects of "equivalent" policies. But in practice, the starting point for policy analysis need not be the free trade equilibrium: if there are trade policies already in place, the number of traders in the market could be greater or less than the free trade number. In this section, we develop a general way to show how different starting points can lead to different policy rankings. Then we consider the quota tariffication scenario(s) in more detail using this approach.

To see how the different notions of equivalence affect our results, it is useful to look at Figure 7. This has the tariff z on the vertical axis and the mass of traders N on the horizontal axis. The line FF depicts combinations of z and N that are consistent with the free trade level of imports, Q^F:

$$Q^D\left(P^D\left(N,z\right)\right) = Q^F. \tag{13}$$

Since $P^D\left(N,z\right)$ is decreasing in N and increasing in z, the FF line has to be upward-sloping as depicted: an increase in z (for a given N) raises the price paid by consumers and reduces imports while an increase in N (for a given z) lowers the price paid by consumers and increases imports, so an increase in z must be accompanied by an increase in N in order to keep imports constant along FF. By definition, FF intersects the horizontal axis at N^F, since $P^D\left(N^F,0\right) = P^F\left(N^F\right)$.

Figure 7: Quotas Versus Specific Tariffs



Similarly, the upward-sloping line QQ depicts combinations of z and N that are consistent with the quota, $\bar{Q}$:

$$Q^D \left(P^D (N, z)\right) = \bar{Q}. \tag{14}$$

As the quota is set below the free trade level of imports, the QQ line must lie above and to the left of the FF line. Moreover, its intersection with the horizontal axis occurs at $N_0 \left(\bar{Q}\right)$, the level of entry in the absence of tariffs that makes the quota just binding.

Likewise, the upward-sloping line ZZ depicts combinations of z and N that are consistent with the free entry equilibrium output level under the specific tariff, $\bar{z}$:

$$Q^D \left(P^D (N, z)\right) = Q^z (\bar{z}) \tag{15}$$

where $Q^z (\bar{z}) = Q^D \left(P^D (N^z (\bar{z}), \bar{z})\right)$. Since we know that $Q^z (\bar{z})$ is less than $\bar{Q}$, the ZZ line must lie above and to the left of QQ.

The fourth component of the diagram is the free entry line, EE. The EE line depicts combinations of z and N such that the quasi-rent per trader exactly offsets the cost of entry:

$$r^z(N, z) = f_e. \tag{16}$$

$r^z (N, z)$ is decreasing in both its arguments. Hence the EE line must slope downwards as depicted in Figure 7. Also, the EE line must cut the horizontal axis at $N = N^F$ since that point represents the free trade equilibrium.

The intersection of the QQ line and the EE line gives the free entry equilibrium with a quota of $\bar{Q}$ (when the quota licenses are sold). This occurs at point B on the line EE, where z and N are such that the free entry condition is met and imports are equal to $\bar{Q}$. At point B, z is exactly equal to the license price $L \left(N^Q \left(\bar{Q}\right), \bar{Q}\right)$ due to tariff-quota equivalence. Since the EE line is downward-sloping, $N_0 \left(\bar{Q}\right) < N^Q \left(\bar{Q}\right) < N^F$ as was shown earlier.

We can use Figure 7 to depict the import-equivalent specific tariff at any initial N. Let us start with $N = N^F$. From N^F on the horizontal axis, go up to the QQ curve to point A: the vertical distance gives $z \left(N^F, \bar{Q}\right)$, the level of z needed to get imports of $\bar{Q}$, which is also the license price under the quota $\bar{Q}$ when $N = N^F$. Set the specific tariff at this level and find the number of traders that enter using the EE line: the horizontal coordinate of point C on the EE line will give the equilibrium entry, $N^z\left(z\left(N^F, \bar{Q}\right)\right)$, with this tariff. A quota at this level of imports is depicted by the curve ZZ going through C. As C is to the left and above B, ZZ corresponds to a lower level of imports than QQ.

The same thing can be done for any N, not just $N = N^F$. In Figure 7, start from $N = N^Q$. Go up vertically to the QQ curve to point B; the vertical distance gives the level of z needed to get imports of $\bar{Q}$. Set the specific tariff at this level and find the equilibrium level of entry using the EE line: since the EE line and the QQ line intersect at point B, equilibrium entry under the specific tariff is the same as equilibrium entry under the initially import-equivalent quota. Hence tariffs and quotas are equivalent in the quota tariffication scenario when $N = N^Q$ to begin with.

If $N > N^Q$, say we start at the "free" quota equilibrium with $N = N^q$, following the same procedure as above leads us in Figure 7 to a point on the QQ line above and to the right of point B. Hence entry under the specific tariff equivalent to the quota $\bar{Q}$ at $N = N^q$ will be lower than entry under the (initially) import-equivalent quota.

If $N < N^Q$ but above N_0 where the quota becomes nonbinding, then the import-equivalent specific tariff will be less than the vertical coordinate of B and equilibrium entry will be more than N^Q. The closer N is to N_0, the lower the import-equivalent specific tariff and the closer the equilibrium level of entry will be to the free trade equilibrium, N^F.

Proposition 5 *Equilibrium entry under a quota $\bar{Q}$ (when licenses are sold) equals equilibrium entry under a specific tariff that is initially import-equivalent to the quota at $N = N^Q\left(\bar{Q}\right)$. It is higher than equilibrium entry under a specific tariff that is initially import-equivalent to the quota at $N > N^Q\left(\bar{Q}\right)$; and lower than equilibrium entry under a specific tariff that is initially import-equivalent to the quota at $N < N^Q\left(\bar{Q}\right)$.*

Now we can turn to welfare comparisons. If we start at $N^Q\left(\bar{Q}\right)$ and impose an import-equivalent specific tariff, there will be no change in N, and welfare will stay at $W^Q\left(N^Q\left(\bar{Q}\right), \bar{Q}\right)$. But if we start at $N > N^Q\left(\bar{Q}\right)$, then welfare under the initially import-equivalent specific tariff will be lower than in the quota equilibrium. For example, if we start at $N = N^F$ (the trade restriction scenario), equilibrium welfare with the specific tariff (at point C) is equal to $W^z\left(N^z\left(\bar{z}\right), \bar{z}\right)$. Note that $\bar{z}$ (represented by the height of point C) is greater than the equilibrium license price under the quota, $L\left(N^Q\left(\bar{Q}\right), \bar{Q}\right)$

(represented by the height of point B). Since $N^z(\bar{z})$ is less than $N^Q\left(\bar{Q}\right)$, it follows that the quota that is import-equivalent to $\bar{z}$ at $N = N^z(\bar{z})$ has to be smaller than $\bar{Q}$. From Lemma 3, we know that welfare is lower the smaller the quota. Therefore: $W^z\left(N^z(\bar{z}), \bar{z}\right) < W^Q\left(N^Q\left(\bar{Q}\right), \bar{Q}\right) < W^F\left(N^F\right)$. The same argument holds for $N = N^q\left(\bar{Q}\right)$ (the "free" quota tariffication scenario), as $N^q\left(\bar{Q}\right) > N^Q\left(\bar{Q}\right)$.

In other words, as entry is optimal given the quota level, the iso-welfare contour going through C must be tangent to ZZ as drawn in Figure 7 and the one going through B must be tangent to QQ at B. As C is further away from the optimum along EE, our construction shows that welfare under free entry with the quota is less than that under free trade, but more than that under the specific tariff that is import equivalent to the quota at $N = N^F$. It is easy to verify that this ordering holds for equivalence defined at all $N > N^Q$. By an analogous argument, it can be seen that equilibrium welfare under the specific tariff is higher than under the equivalent quota (when licenses are sold) when equivalence is defined at $N < N^Q\left(\bar{Q}\right)$ (but free trade welfare is still the highest).

Proposition 6 *Equilibrium welfare under a quota $\bar{Q}$ (when licenses are sold) is equal to equilibrium welfare under a specific tariff that is initially import-equivalent to the quota at $N = N^Q\left(\bar{Q}\right)$; higher than equilibrium welfare under a specific tariff that is initially import-equivalent to the quota at $N > N^Q\left(\bar{Q}\right)$; and lower than equilibrium welfare under a specific tariff that is initially import-equivalent to the quota at $N < N^Q\left(\bar{Q}\right)$.*

The above results argue for caution when tariffying quotas as a means to liberalize trade. A common strategy to convert quotas to tariffs is for the government to auction the quota rights and use the realized license prices as guides to setting tariffs. Proposition 5 shows that in computing the tariff equivalent of a quota, one has to make sure that z is exactly equal to $L\left(N^Q\left(\bar{Q}\right), \bar{Q}\right)$; a tariff equivalent calculated at any other level of N will not be equivalent and hence may not have the desired result. Specifically, the allocation of quota licenses needs to be considered in defining the "equivalent" specific tariff. Recall that both entry and the implicit license price are higher when the quota licenses are given to the traders than when they are sold. In Figure 7, it is easy to see that tariffying the quota at $N^q\left(\bar{Q}\right)$ rather than at $N^Q\left(\bar{Q}\right)$ would lead to a net exit of traders.

We can now return to welfare under a specific tariff under free entry.[15] It is clear from Figure 7 that as z rises, welfare falls. A higher z moves the free entry equilibrium to the left and upwards along EE. This corresponds to lower welfare and lower imports. Thus we have the following result.

Lemma 6 *A reduction in the specific tariff always raises welfare.*

5.2 Restricted Trade: Ad Valorem Tariffs

Now let us once again return to the free trade equilibrium and impose an ad valorem tariff that is import-equivalent to the quota $\bar{Q}$. The tariff is set at $t\left(N^F, \bar{Q}\right)$ so that imports are equal to $\bar{Q}$ with $N = N^F$, hence:

$$1 + t(N^F, \bar{Q}) = \frac{P^D(\bar{Q})}{P^S(N^F, \bar{Q})}. \tag{17}$$

For notational simplicity, denote $t\left(N^F, \bar{Q}\right)$ by $\bar{t}$.

Since we assume a single price for the good in the domestic market, and the ad valorem tariff is levied on the domestic market price, all traders will pay the same tariff amount in dollar terms (as with the specific tariff earlier). Thus, the ad valorem tariff equals the import-equivalent specific tariff at $N = N^F$ in nominal terms. However, as the ad valorem rate is fixed, the total payment depends on the supply price in the market, which of course, depends on the mass of traders entering the market—as more traders enter, the supply price drops and as a result, the dollar amount of the tariff also drops. *Thus, an ad valorem tariff is like a specific tariff that declines with N.* Once we realize this, the rest is obvious. As N falls, the effects of an ad valorem tariff are the same as those of the specific tariff that rises with the fall in N. As increases in the specific tariff further reduce quasi-rents, this means that for $N < N^F$, the total quasi-rents earned by firms at any such N must lie below those under the initially equivalent specific tariff as depicted in Figure 4. Similarly, for $N > N^F$, the opposite holds. This is why $r^t\left(N, \bar{t}\right)$ is drawn to be flatter than flatter than $r^z\left(N, \bar{z}\right)$ in Figure 4.

Lemma 7 $r^t\left(N, \bar{t}\right)$ *lies below* $r^z(N, \bar{z})$ *for* $N < N^F$ *and above* $r^z(N, \bar{z})$ *for* $N > N^F$.

[15] In equilibrium under free entry with any specific tariff (when $N = N^z\left(\bar{z}\right)$), all quasi-rents are competed away so welfare consists of consumer surplus plus tariff revenue only.

From this it follows that the equilibrium level of entry under the initially equivalent ad valorem tariff is less than that under the specific tariff. Furthermore, it follows from the same argument as Lemma 1 that the equilibrium supply price is the same as the free trade price: $P^S\left(N^t\left(\bar{t}\right), \bar{t}\right) = P^F\left(N^F\right)$. We also have the same kind of response to the initially import equivalent ad-valorem tariff as to the quota and specific tariff as stated below.

Proposition 7 *If we start at the free trade equilibrium and impose an ad valorem tariff that is initially import-equivalent to the quota $\bar{Q}$ and the specific tariff $\bar{z}$, there will be a net exit of traders and the new long-run equilibrium will be characterized by a lower level of entry compared with the specific tariff. Average cost will fall (average productivity will rise) in the short run as traders change their import decisions in response to the tariff. But average cost will rise (average productivity will fall) in the long run as traders change their entry decisions—after entry adjusts, average cost and average productivity will return to their free trade levels in the new long-run equilibrium. Imports will fall as the number of traders shrinks, so imports will be less than what they were under the specific tariff and the nominal tariff will be higher than $\bar{z}$ in the new long-run equilibrium.*

Since the ad valorem tariff is like a specific tariff set at a higher level than the import equivalent one, this higher specific tariff will be above point A in Figure 7. Thus, the equilibrium entry point will lie somewhere to the left of point C along the EE line and $N^t\left(\bar{t}\right)$ will be less than $N^z\left(\bar{z}\right)$. The import level corresponding to the free entry equilibrium will be less than that along the ZZ line so after accounting for entry/exit, welfare will be even lower under the initially equivalent ad valorem tariff than under the initially equivalent specific tariff.

Proposition 8 *Equilibrium welfare under the ad valorem tariff is lower than under a specific tariff that is initially import-equivalent at $N = N^F$.*

This can be seen in Figure 7 as points to the northwest of point C (representing combinations of z and N where $z > \bar{z}$ and $N < N^z\left(\bar{z}\right)$) lie outside the iso-welfare contour corresponding to the equilibrium under the specific tariff, $\bar{z}$.

Lemma 8 *An increase in the ad- valorem tariff reduces welfare in the free entry equilibrium.*

This can also be seen from Figure 7. A higher t will move the free entry equilibrium to the left along EE and reduce welfare.

6 Conclusion

The effects of trade policy can be sensitive to the choice of instruments in the short run and the long run when we consider the entry/exit of traders/firms. This is true even in the absence of imperfect competition and product differentiation. When we look more closely at entry/exit decisions, whether couched in a standard specific-factor competitive-firm setting or a slightly less familiar one with heterogeneous competitive traders, the entry and welfare effects of tariffs and quotas differ considerably depending on the level of entry at which we start. If we start from the free trade equilibrium and compare the results of restricting imports to a given amount (in the short run) by means of a quota or a tariff, in the short run the import-equivalent quota and tariff (specific or ad valorem) have equivalent effects but in the long run: (i) the specific tariff will tend to reduce entry, imports, and welfare more than the initially import-equivalent quota, (ii) the ad valorem tariff will reduce entry, imports, and welfare even further; and (iii) giving the quota licenses to the traders/firms ("free" quota) could raise or reduce entry but will reduce welfare by more than if the quota licenses were sold. If we start from the "free" quota equilibrium and tariffy the quota, in the long run results (i) and (ii) will also apply.

The intuition behind our results is simple. Although tariffs and quotas are equivalent given entry, their effects on entry are profoundly different. Trade restrictions by and large discourage entry and thereby reduce the supply of imports. But quotas tend to discourage entry less than tariffs do. The reason is that as traders leave the market in response to the quota, import supply shrinks—this reduces the value of a quota license and hence the restrictiveness of the quota. By contrast, the exit of traders does not change the restrictiveness of a given specific tariff.

The comparison is more nuanced when we consider how the quota is implemented. In most cases, quota licenses are not sold by the government—auction quotas are relatively rare—but given to the traders free of charge on the basis of certain criteria, such as historical import performance, or the level of investment, or even first-come-first-served. Welfare under such a "free" quota may well be lower than welfare under an initially import-equivalent tariff, even though entry is greater. In fact, the most common criticism of quotas is their potential for encouraging rent-seeking behavior. "Free" quota allocation schemes give traders the incentive to expend real resources on things like opening an office in the capital city in order to be close to the license administrator—such expenditures provide no utility to either party and thus represent pure waste. If these expenditures are large, then welfare under a "free" quota will be even lower than our model suggests, and more likely to fall below that associated with an initially import-equivalent tariff. In sum, the method of quota allocation matters—an auction quota is preferable to an (initially) import-equivalent tariff, but a "free" quota, which tends to promote wasteful rent-seeking behavior, need not be preferable to a tariff.

A widely promoted tenet of trade policy reform is to replace quotas with "equivalent" tariffs which can then be lowered in a transparent manner. (See, for example, Thomas, Nash, and associates (1991) and WTO (2005).) But finding the correct "equivalent" tariff (whether specific or ad valorem) for a given quota depends crucially on the details of the quota arrangement in place. If the quota licenses are given rather than sold to traders, as is often the case, then a large number of traders will enter the market and the value of a quota license will be high in equilibrium. Tariffying such a "free" quota will result in an excessively high tariff that will shrink the import market excessively and could lead to a reduction in welfare. The results are worse if the conversion is to an ad valorem tariff instead of a specific tariff.[16]

[16]Moschini (1991) discusses other pitfalls in tariffication.

Appendix

Proof of Proposition 1.

$$\begin{aligned}
\left.\frac{dW^F(N)}{dN}\right|_{N=N^F} &= -Q^D\left(P^F(N)\right)P^{F\prime}(N)+\int\limits_0^{P^F(N)}F(c)\,dc \\
&\quad +NF\left(P^F(N)\right)P^{F\prime}(N)-f_e \\
&= \left[NF\left(P^F(N)\right)-Q^D\left(P^F(N)\right)\right]P^{F\prime}(N) \\
&\quad +\left[\int\limits_0^{P^F(N)}F(c)\,dc-f_e\right] \\
&= 0.
\end{aligned}$$

The first equality above comes differentiating; the second from rearranging terms; and the third from (i) market clearing—demand equals supply at price $P^F(N^F)$ so that the first square bracketed term is zero, and (ii) the free entry condition—at $N = N^F$, the expected level of profits exactly covers fixed cost so that the second square bracketed term is zero. ■

Proof of Lemma 2. Differentiating Equation (8) with respect to N for a given $\bar{Q}$:

$$\begin{aligned}
\left.\frac{\partial W^Q(N,\bar{Q})}{\partial N}\right|_{N=N^Q(\bar{Q})} &= \int\limits_0^{P^S(N,\bar{Q})}F(c)\,dc+NF\left(P^s\left(N,\bar{Q}\right)\right)\frac{\partial P^s\left(N,\bar{Q}\right)}{\partial N} \\
&\quad -\bar{Q}\frac{\partial P^s\left(N,\bar{Q}\right)}{\partial N}-f_e \\
&= \frac{\partial P^S\left(N,\bar{Q}\right)}{\partial N}\left[NF\left(P^s\left(N,\bar{Q}\right)\right)-\bar{Q}\right] \\
&\quad +\left[\int\limits_0^{P^S(N,\bar{Q})}F(c)\,dc-f_e\right] \\
&= 0.
\end{aligned}$$

The first equality comes from differentiation; the second from rearranging terms; and the third from (i) market clearing—supply at $P^s\left(N^Q\left(\bar{Q}\right),\bar{Q}\right)$

equals the quota level, so that the first square-bracketed term is zero, and (ii) the free entry condition—at $N = N^Q\left(\bar{Q}\right)$, the expected level of profits exactly covers fixed cost so that the second square bracketed term is zero. ■

Proof of Lemma 3. Differentiating Equation (9) with respect to $\bar{Q}$:

$$\begin{aligned}
\frac{dW^Q\left(N^Q\left(\bar{Q}\right),\bar{Q}\right)}{d\bar{Q}} &= -Q^D(P^D(\bar{Q}))P^{D\prime}(\bar{Q}) \\
&\quad + \left[P^D\left(\bar{Q}\right) - P^S\left(N^Q\left(\bar{Q}\right),\bar{Q}\right)\right] \\
&\quad + P^{D\prime}\left(\bar{Q}\right)\bar{Q} - \bar{Q}\frac{dP^S\left(N^Q\left(\bar{Q}\right),\bar{Q}\right)}{d\bar{Q}} \\
&= \left[P^D\left(\bar{Q}\right) - P^S\left(N^Q\left(\bar{Q}\right),\bar{Q}\right)\right] \\
&\quad + P^{D\prime}(\bar{Q})\left[\bar{Q} - Q^D(P^D(\bar{Q}))\right] \\
&\quad - \bar{Q}\frac{dP^S\left(N^Q\left(\bar{Q}\right),\bar{Q}\right)}{d\bar{Q}} \\
&= P^D\left(\bar{Q}\right) - P^S\left(N^Q\left(\bar{Q}\right),\bar{Q}\right) \\
&> 0
\end{aligned}$$

where the first equality comes from total differentiation; the second from rearranging terms; and the third from (i) market clearing—demand at $P^D(\bar{Q})$ equals the quota level, so that the second square-bracketed term is zero, and (ii) Lemma 1. The inequality follows from the result that the license price is positive in equilibrium (Proposition 2). ■

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