The Impact of Trade on
Plant Scale, Production-Run Length and Diversification

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Abstract

We develop a model of trade in differentiated products with multi-product plants. The model predicts that plants in a smaller and less competitive market have shorter production runs and tend to be smaller and less productive than those in a larger market. A decline in tariff rates leads to a reduction in the number of products supplied by plants, and the rate of decline is smaller for larger and exporting plants. It increases the production run of exporters but has no effect on that of non-exporters. It also reduces the size of non-exporters. The empirical evidence from a sample of Canadian manufacturing plants in the 1980s and 1990s provides broad support for the model's prediction about the impact of tariff cuts on product diversification and plant size.

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1 Introduction

This paper examines the impact of trade on product diversification and plant size. The issue has dominated discussions on potential benefits of trade liberalization in Canada. Operating behind tariff barriers and limited market size, Canadian plants have been described as having production runs that were too short to exploit economies of large-scale production. Tariff reductions were predicted to reduce product diversification at the plant level and to improve the length of production runs. However, there is little empirical evidence on the link between tariff reductions and increases in product specialization. This paper attempts to fill this research gap.

Shorter production runs can arise either from suboptimal plant size or excessive product line diversity. Earlier studies by Daly et al. (1968) and Caves (1975) focused on the argument that Canadian plants suffered from excessive levels of diversity. A number of Canadian studies have attributed lower productivity to shorter production runs. For example, Safarian's survey on the relative costs of foreign multinationals operating in Canada (1966, ch. 7) reported that most foreign affiliates operating in Canada had higher unit costs than parent companies' plants located in the U.S. These higher costs were attributed by the firms to a variety of sources; but shorter production runs was the most common response for those reporting higher unit costs.

In the same vein, a study by Scherer et al. (1975) reported that Canadian textile makers claimed that their unit costs on style-sensitive dress goods and decorative fabrics were 20 to 30 percent higher than the costs of comparable U.S. manufacturers, primarily because of a ten-fold difference in market size and the attenuated but still substantial differences in lot sizes. Paint manufacturers reported that average batch sizes in Canada were one-fifth to one-half those experienced in the United States.

Both the Canadian Economic Council (1967, 1975) and the Royal Commission on Corporate Concentration (1978) predicted that the lowering of Canadian tariff barriers would increase Canadian average plant size and that it would reduce product diversity at the plant level and improve the length of production runs.

We have two main objectives in the paper. First we develop a model of trade in differentiated goods with multi-product plants. The model contributes to the recent development of firm-based models that highlights differences in the responses of individual firms to trade policies (Bernard et al. 2003; Melitz, 2003; and Yeaple 2002). Second, we provide empirical evidence for the model's prediction regarding the impact of tariff reductions on product diversification and plant size.

Our model adapts Melitz's model of international trade with heterogeneous firms to multi-product plants (Melitz, 2003). We assume that production exhibits economies of scale within product varieties and economies of scope across varieties. The model predicts that plants in a smaller and less competitive market have shorter production runs and tend to be smaller and less productive than those in a larger and more competitive market. These predictions have been confirmed in a number of previous empirical studies (Scherer et al., 1975; Caves, 1975; Syverson, 2003).

Our model has a number of predictions about the impact of tariff reductions on product diversification and plant size. A decline in tariff rates will lead to a reduction in the number of products supplied by plants, and the rate of decline is smaller for larger and exporting plants. It will increase the production run of exporters and have no effect on that of non-exporters. It will also reduce the plant size of non-exporters.

Our trade model of multi-product plants also generates a set of results that are reported in Melitz's model of single-product plants (Melitz, 2003). Tariff barriers induce only the most productive plants to enter the export market. As trade costs fall, the least productive plants exit and the most productive of non-exporters enter the export market and expand their output.

To investigate the model's prediction about the impact of tariff changes, we use a sample of Canadian manufacturing plants in the 1980s and 1990s. The Canadian experience with tariff reductions as a result of the 1989 Canada-U.S. Free Trade Agreement (FTA) and its extension to Mexico provides us with an opportunity to examine how the plants in a market of limited size respond to trade liberalization. Our empirical evidence provides broad support for the model's prediction about the impact of tariff changes about product diversification and plant size.

2 A Model of Closed Economy

In this section, we will develop a model of a closed economy to examine the effect of market size on product diversification and plant size. The model also serves a building block for the open-economy model that will be developed in the next section.

2.1 Demand

Consider an economy with L identical consumers. The consumer's preferences are described by a quasi-linear utility function that is defined over a continuum of differentiated varieties, and a homogeneous good chosen numéraire:

$$(1) \qquad U = \alpha\int_{\omega\in\Omega} q(\omega)d\omega - \frac{1}{2}\gamma\int_{\omega\in\Omega} q(\omega)^2 d\omega - \frac{1}{2}\beta\left(\int_{\omega\in\Omega} q(\omega)d\omega\right)^2 + q_o,$$

where q_o and $q(\omega)$ represent the individual consumption levels of the numeraire good and variety ω. Ω is the set of varieties supplied by firms. The demand parameters α, γ, and β are all positive. The parameter γ indexes the degree of product differentiation between the varieties. The degree of product differentiation increases with γ as consumers give increasing weights to the dispersed consumption of the varieties. An increase in γ implies a decline in substitutability between the varieties, thus limiting the response of a consumer's consumption pattern over the varieties to changes in the price of particular variety. In the limit when $\gamma = 0$, the varieties are perfect substitute and the consumers care only about their total consumption level over the varieties $\int_{\omega\in\Omega} q(\omega)d\omega$. The parameters α and β indexes the substitution between the differentiated varieties and the numeraire. Increases in α and decreases in β increases the demand for the differentiated varieties relative to the numeraire.

Each consumer is endowed with one unit of labour. The budget constraint for the consumer can be written as:

$$(2) \qquad \int_{\omega\in\Omega} p(\omega)q(\omega)d\omega + q_o = w,$$

where w is the wage and $p(\omega)$ is the price of variety ω.

Solving (2) for the numéraire consumption, substituting the corresponding expression into (1) and solving the first order conditions with respect to $q(\omega)$ yields the inverse demand for variety ω supplied by firm i:

(3) $$p_i(\omega) = \alpha - \gamma q_i(\omega) - \beta Q,$$

where $Q = \int_{i \in M} \int_{\omega \in \Omega_i} q_i(\omega) d\omega di$ is the total market demand of the differentiated product.

The total market demand for variety ω of firm i can be expressed by the inverse demand function:

(4) $$p_i(\omega) = \alpha - \gamma \frac{q_i(\omega)}{L} - \beta \frac{Q}{L}.$$

A word about the choice of quasi-linear utility function (1) for our analysis is in order. In contrast to the C.E.S. demand, the elasticity of demand is not fixed. Instead, it is related to the intensity or "toughness" of competition. Increases in the "toughness" of competition due to a larger market (*L*), a lower degree of product differentiation (γ) lead to increases in the elasticity of demand.

The C.E.S. preferences used in previous studies (e.g, Melitz, 2003) yield a demand system in which the price elasticity of demand is constant. Though convenient from the analytical point of view, such a result is at odds with empirical findings that more intensive competition is associated with a higher elasticity of demand (Campbell and Hopenhayn, 2002; Greenhut et al., 1987; Roberts and Tybout, 1996; Syverson, 2003; Tybout 2002).

2.2 Production and Firm Behaviour

To examine the impact of trade and market size on product diversification, we depart from previous monopolistic competition models of trade in differentiated products.

In all these models, production exhibits economies of scale within varieties but no economies of scope across varieties. As such, each firm supplies one and only one variety, and there is a one-to-one relationship between firms and varieties.

In our model, we assume that production exhibits economies of scale within varieties but economies of scope across varieties. To enter the differentiated product sector, a firm must bear fixed costs of entry *E* regardless of the size of its product range, thus implying that economies of scope are present. An entrant then learns about the marginal cost of the production of a variety. We assume that this is drawn from a common distribution *G(c)* with support on $\left[0, c_M\right]$ and it is the same across varieties within a firm. The production technology of a variety requires fixed overhead costs *F* in order to produce any amount of a variety, thus implying economies of scale within varieties. We assume that this overhead cost is known and it is the same across all varieties.

As the entry cost is sunk, an entering firm would immediately exit if its profit gross of entry costs were negative. The surviving firm, first chooses its product range, then, the quantity and price of each variety it supplies.

Let *M* be a given number of multiproduct firms. Let $\Omega_i \subseteq R_+$ denote the set of varieties ω produced by firm i ($=1,...,M$) and $q_i(\omega)$ the quantity of variety ω. The total production cost of firm i is given by

(5) $$C_i = \int_{\omega\in\Omega_i} \left(c_i q_i(\omega) + F\right) d\omega,$$

and the total revenue is

(6) $$R_i = \int_{\omega\in\Omega_i} p_i(\omega) q_i(\omega) d\omega.$$

Firm i maximizes its profit

(7) $$\Pi_i = \int_{\omega \in \Omega_i} \left(p_i(\omega) q_i(\omega) - c_i q_i(\omega) - F \right) d\omega ,$$

where the demand for variety ω is defined in equation (4).

Because we have symmetry among varieties with each firm's product line, the quantity and price that a firm chooses is the same across its varieties. In other words, we have $p_i(\omega) = p_i$ and $q_i(\omega) = q_i$ for the varieties supplied by firm i.

We have a finite number of multiproduct firms and each firm controls a non-negligible set of varieties (see Ottaviano and Thisse, 1999 for a similar model of multiproduct firms). As such, firms behave like oligopolists. When choosing its product range and the length of production runs, a firm no longer neglects its impact on the market as in monopolistic competition models of trade.[1] The firm must account for the impact of its choice on the demand for its varieties through its effect on total market demand Q, which is the sum of the demand for the varieties of firm i and those of its competitors (Q_{-i}). These discussions suggest that the total market demand is:

(8) $$Q = q_i \Omega_i + Q_{-i} ,$$

and the profit of firm i can be rewritten as:

(9) $\Pi_i = \left(p_i q_i - c_i q_i - F \right) \Omega_i$, and the inverse demand (4) becomes:

(10) $$p_i = \alpha - \frac{\gamma}{L} q_i - \frac{\beta}{L} Q, \quad Q = q_i \Omega_i + Q_{-i} .$$

[1] In monopolistic competition models of trade in differentiated products, each firm produce one variety as there is no economies of scope across varieties. In these models, each firm correctly neglects its impact on the market.

This is a two-stage game. A firm chooses its product range Ω_i in the first stage, and then the quantity and price of its varieties p_i and q_i in the second stage. The solution of the second stage subgame is obtained from the differentiation of the profit function with respect to q_i. Solving for these first-order conditions, we have the optimum output and price of each variety provided by firm i:

(11) $$q_i = \frac{(\alpha - c_i)L - \beta Q_{-i}}{2(\gamma + \beta\Omega_i)}, \text{ and}$$

(12) $$p_i = \frac{(\alpha + c_i)L - \beta Q_{-i}}{2L}.$$

These results show that the firms in a larger market choose longer production runs and set lower prices for their products, as a result of higher demand elasticity for their products.

Substituting (11) and (12) into (9) yields the second-stage equilibrium profit of firm i:

(13) $$\Pi_i = \frac{\left[(\alpha - c_i)L - \beta Q_{-i}\right]^2}{4L\left(\gamma + \beta\Omega_i\right)}\Omega_i - F\Omega_i.$$

The expression (13) describes the payoff of firm i in the first stage game. To find the solution of the second stage subgame, we differentiate (13) with respect to Ω_i and obtain the first order conditions for the equilibrium product range Ω_i:[2]

(14) $$(\gamma + \beta\Omega_i) = \frac{\left((\alpha - c_i)L - \beta Q_{-i}\right)}{2}\sqrt{\frac{\gamma}{FL}}.$$

[2] The payoff function (13) is concave in Ω_i. Therefore, the equilibrium product range implicit in (14) is aunique maximum.

Equations (11), (12) and (13) provide a unique solution $\left(p_i, q_i, \Omega_i\right)$ for M firms. For the rest of section, we will attempt to obtain an analytical solution. The results will be used to conduct a comparative analysis on the impact of market on firm size and product diversification.

Substituting the expression for $(\gamma + \beta\Omega_i)$ in (14) into (11) gives the equilibrium output of each variety supplied by firm i:

$$(15) \qquad q_i^* = \sqrt{\frac{FL}{\gamma}} \equiv q^* .$$

This shows that the lengths of production runs are the same across individual products within a firm. Furthermore, it is the same across all firms. This implies that the sum of the output Q_{-i} for the varieties of firm i's competitors can be written as $q^*\left(\Omega - \Omega_i\right)$, where $\Omega = \sum_{i=1}^{M} \Omega_i$ is the total number of varieties in the market. The first order condition (14) can be rewritten as:

$$(16) \qquad (\gamma + \beta\Omega_i) = \frac{\left((\alpha - c_i)L - \beta q^*\left(\Omega - \Omega_i\right)\right)}{2}\sqrt{\frac{\gamma}{FL}} ,$$

Summarizing (16) over all firms and solving for the total number of varieties Ω:

$$(17) \qquad \Omega^* = \frac{(\alpha - \bar{c})M\sqrt{\frac{\gamma L}{F}} - 2\gamma M}{\beta(M+1)} ,$$

where $\bar{c} = \sum_i c_i \big/ M$ is the average cost of M firms. Substituting (17) into (16) and solving for Ω_i yields the equilibrium product range supplied by firm i:

$$(18) \qquad \Omega_i^* = \Omega^*(c_i) = \frac{\left((\alpha - c_i) + M(\bar{c} - c_i)\right)\sqrt{\frac{\gamma L}{F}} - 2\gamma}{\beta(M+1)} .$$

Substituting the expressions (15), (17) and (18) for q_i^*, Ω^* and Ω_i^* into (13) gives the maximum profit of firm i:

(19) $$\Pi^*(c_i) = \frac{F}{\beta\gamma(M+1)^2}\left(\left(\alpha + M\bar{c} - (M+1)c_i\right)\sqrt{\frac{\gamma L}{F}} - 2\gamma\right)^2 .$$

Finally, solving (14) for Q_{-i} and substituting the resulting expression into (12), we obtain the equilibrium price of each variety supplied by firm i:

(20) $$p_i^* = c_i + \frac{\gamma + \beta\Omega_i^*}{L}\sqrt{\frac{FL}{\gamma}} .$$

This implies that firms use an absolute markup instead of relative markup when choosing prices.

In sum, we have derived the analytical solutions for the number of varieties $\Omega^*(c_i)$, the quantity q_i^* and price p_i^* of each variety, the maximum profit $\Pi^*(c_i)$ for each of the *M* firms. These results show that (1) firms in a larger market have longer production runs for individual products; (2) product diversification declines with the economies of scale within individual products (or increases in fixed overhead costs *F*); (3) firms with lower costs set lower price, earn higher profits, and are larger.

2.3 Free Entry Equilibrium in a Closed Economy

After entering a market by making an initial investment *E*, a firm learns about the marginal cost of the production of variety. Let c_D denote the cost of a firm who earns zero profits. All firms with costs below the cutoff cost c_D would make negative profits and choose to exit. All firms with cost level above c_D earn positive profits and remain in the market. The cutoff cost c_D is determined by the zero profit condition:

(21) $\Pi^*(c_D) = 0$, or $\left(\alpha + M\overline{c} - (M+1)c_D\right)\sqrt{\frac{\gamma L}{F}} - 2\gamma = 0$,

where $\overline{c} = \int_0^{c_D} c dG(c) / G(c_D)$ is the average cost of surviving firms, and $G(c_D)$ is the survival rate of entering firms.

We can now determine the number of firms M in equilibrium. Before entering the market, the expected profit is $\int_0^{c_D} \Pi^*(c) dG(c) - E$, where $\Pi^*(c)$ is given in(19). If this profit were positive, more firms would enter. Therefore, the number of firms in equilibrium must satisfy the following condition:

(22) $\int_0^{c_D} \Pi^*(c) dG(c) - E = 0$

For the rest of the paper, we will assume that productivity draws $1/c$ follow a Pareto distribution with lower productivity bound $1/c_M$ and shape parameter $k \geq 1$. This implies a distribution of cost c:[3]

(23) $G(c) = \left(\frac{c}{c_M}\right)^k, c \in [0, c_M]$.

When $k = 1$, costs follow a uniform distribution. An increase in k implies a decline in the dispersion of the costs. Solving the zero profit and free entry conditions (21) and (22) yields the solutions for c_D and M:

(24) $c_D = \left(c_M^k (k+1)(k+2)\frac{E\beta}{2L}\right)^{\frac{1}{k+2}}$, and

[3] The logarithm of labour productivity *log(1/c)* follows a exponential distribution with a standard deviation equal to *1/k*.

$$(25)\qquad M=\left(k+1\right)\frac{\alpha-c_D-2\sqrt{\frac{F\gamma}{L}}}{c_D}.$$

Theses results show that there are more firms in a larger market. The cutoff cost in a larger market is lower and the exit rate for entrants (equals $1-G(c_D)$) higher as competition is more intense in the larger market.

Given these expressions for c_D and M, the performance measures of firm i in (15), (18), (19) and (20) can be rewritten as:

$$(26)\qquad \begin{aligned} &\Omega^*(c_i)=\frac{(c_D-c_i)}{\beta}\sqrt{\frac{\gamma L}{F}},\\ &p_i^*=c_D+\sqrt{\frac{F\gamma}{L}},\ \ q_i^*=\sqrt{\frac{FL}{\gamma}},.\\ &\Pi^*(c_i)=\frac{L}{\beta}(c_D-c_i)^2 \end{aligned}$$

And the average performance measures across all firms can be written as:

$$(27)\qquad \begin{aligned} &\bar{\Omega}^*=\frac{c_D}{\beta(k+1)}\sqrt{\frac{\gamma L}{F}},\\ &\bar{p}^*=c_D+\sqrt{\frac{F\gamma}{L}},\ \ \bar{q}^*=\sqrt{\frac{FL}{\gamma}},.\\ &\bar{\Pi}^*=\frac{2c_D^2}{(k+1)(k+2)}\frac{L}{\beta} \end{aligned}$$

The total number of product varieties is:

$$(28)\qquad \Omega^*=\frac{1}{\beta}\left(\left(\alpha-c_D\right)\sqrt{\frac{\gamma L}{F}}-2\gamma\right).$$

Compared with an average firm in a smaller market, the one in a larger market supplies a larger number of varieties (with a higher degree of product diversification). It has a longer production run and sets a lower price for its product varieties. It is larger and more productive, and has higher profits.[4] There are more product varieties and more firms in a larger market.

The results in (27) also provide intuitive results on the impact of scale and scope economies on product diversification, production run length, firm size and firm profits. The existence of strong scale economies within individual products (high F) is related to higher product specialization, longer production run length, and higher profits. However, it has no effect on firm size and productivity.

The existence of strong scope economies at the firm level (high E) is related to higher product diversification, larger firm size, lower productivity and higher profits. But it has no effect on the lengths of production runs for individual products.

The result relating to the degree of product differentiation (γ) is straightforward. A low degree of product differentiation leads to narrow product lines, long production runs, low price and low profits. It has no effect on firm size and productivity.

3 A Model of Open Economy

In this section, we examine the impact of trade on product diversification and firm size. We will consider two economies of the type that was examined in the last section. If the two economies are perfectly integrated and there are no trade costs, trade allows individual countries to replicate the outcome of an integrated world as in the model of Section 2.1.

[4] Firm size is defined as the real output of the firm which is equal to the number of varieties times the output of each variety.

3.1 Model

We now consider two economies h and f where there are trade costs. To simplify our analysis of the impact of declining trade costs, we assume that the two countries are symmetric. Each country has L consumers. Trade costs are modeled in the standard iceberg formulation, where $\tau > 1$ units of a good must be shipped in order for one unit to arrive at destination.

The firms in the two markets are of the type modeled in section 2. To enter, a firm must first make an irreversible investment *E.* The firm then learns about the cost of the production of a variety that is drawn from a common distribution. After learning about the cost, the least productive firms choose to exit. The more productive firms choose to remain in the domestic market. These firms will also have to decide whether to serve the export market at the same time. All these remaining firms will then choose their product range, the price and quantity of a variety for the domestic market and for the export market if they also decide to serve the export market. As in Melitz (2003), we assume that there is no additional uncertainty for the decision to enter the export market.

The firms maximize the sum of profits earned from domestic and export sales. As the markets are segmented, the firms must maximize the profits from domestic sales and from export sales. The results in the section 2.1.2 show that the number of varieties $\Omega_D(c)$, the quantity and price of each variety $q_D(c)$ and $p_D(c)$, and profits $\Pi_D(c)$ for a firm that produces for the domestic market can be written as:

$$\Omega_D(c)=\frac{\left((\alpha-c)+M(\overline{c}-c)\right)\sqrt{\frac{\gamma L}{F}}-2\gamma}{\beta(M+1)},$$

(29) $$q_D(c)=\sqrt{\frac{FL}{\gamma}},\;\; p_D(c)=c+\frac{\gamma+\beta\Omega_D(c)}{L}\sqrt{\frac{FL}{\gamma}}$$

$$\Pi_D(c)=\frac{F}{\beta\gamma(M+1)^2}\left(\left(\alpha+M\overline{c}-(M+1)c\right)\sqrt{\frac{\gamma L}{F}}-2\gamma\right)^2,$$

where M is the total number of firms that sells in an economy that includes both domestic firms and foreign exporters that sell in the country.

For the firms that sell in a foreign market, number of varieties $\Omega_X(c)$ supplied for the export market, the quantity and price of each variety $q_X(c)$ and $p_X(c)$, and the profits $\Pi_X(c)$ can be rewritten as:

$$\Omega_X(c)=\frac{\left((\alpha-\tau c)+M(\overline{c}-\tau c)\right)\sqrt{\frac{\gamma L}{F}}-2\gamma}{\beta(M+1)},$$

(30) $$q_X(c)=\sqrt{\frac{FL}{\gamma}},\;\; p_X(c)=\tau c+\frac{\gamma+\beta\Omega_X(c)}{L}\sqrt{\frac{FL}{\gamma}}$$

$$\Pi_X(c)=\frac{F}{\beta\gamma(M+1)^2}\left(\left(\alpha+M\overline{c}-(M+1)\tau c\right)\sqrt{\frac{\gamma L}{F}}-2\gamma\right)^2,$$

where τc is the delivered cost of exporters.

Upon entry and learning about its cost, a firm with cost below c_D makes positive profits and stays in the market. Otherwise the firm will exit. The firm with cost below c_X will enter the export market. The cutoff cost levels c_D and c_X are determined from zero profit conditions for domestic sales and export sales:

$$\text{(31)}\quad \begin{aligned} &\Pi_D(c_D)=0: \quad \frac{F}{\beta\gamma(M+1)^2}\left(\left(\alpha+M\overline{c}-(M+1)c_D\right)\sqrt{\frac{\gamma L}{F}}-2\gamma\right)^2=0; \\ &\Pi_X(c_X)=0: \quad \frac{F}{\beta\gamma(M+1)^2}\left(\left(\alpha+M\overline{c}-(M+1)\tau c_X\right)\sqrt{\frac{\gamma L}{F}}-2\gamma\right)^2=0. \end{aligned}$$

Equations in (18) show that the two cutoff cost levels satisfy the condition:

$$\text{(32)}\quad c_X=\frac{c_D}{\tau}.$$

As $\tau>1$, we have $c_X<\mathrm{c_D}$. The two cutoff cost levels provide a portioning of firms into exiting, non-exporting and exporting firms. The least productive firms, those firms with cost above c_D exit the market. The firms with cost between c_X and c_D produce exclusively for the domestic market. The most productive firms with the cost below c_X enter the export market and produce for both domestic and export markets.

Given the relationship between the cutoffs for domestic and foreign sales in (31), the cost of surviving domestic firms $c\in\left[0,c_D\right]$ and the delivered cost of exporting firms $\tau c\in\left[0,c_X\right]$ have identical distributions. The average cost of all firms that sell in a market (that includes domestic firms and foreign exporters) is:

$$\text{(33)}\quad \overline{c}=\int_0^{c_D} c\,dG(c).$$

Free entry drives the expected profit to zero:

$$\text{(34)}\quad \int_0^{c_D}\Pi_D(c)dG(c)+\int_0^{c_X}\Pi_X(c)dG(c)-E=0.$$

Solving for c_D and c_X, we have:

$$
(35) \quad
\begin{aligned}
c_D &= \left(c_M^k (k+1)(k+2) \frac{E\beta}{2L\left(1+\tau^{-k}\right)} \right)^{\frac{1}{k+2}}, \\
c_X &= \frac{c_D}{\tau} = \left(c_M^k (k+1)(k+2) \frac{E\beta}{2L\left(\tau^{k+2}+\tau^2\right)} \right)^{\frac{1}{k+2}}.
\end{aligned}
$$

The results show that a reduction in trade costs leads to a decline in c_D and an increase in c_X. As tariff barriers fall, the least productive firms exit. Of the remaining non-exporters, the more productive enter the export market.

Using the zero profit conditions (31), the product range and the price and quantity of each variety supplied by a firm in the domestic market in (29) can be rewritten as:

$$
(36) \quad
\begin{aligned}
&\Omega_D(c) = \frac{(c_D - c)}{\beta}\sqrt{\frac{\gamma L}{F}}, \\
&q_D(c) = \sqrt{\frac{FL}{\gamma}}, \ \ p_D(c) = c_D + \sqrt{\frac{F\gamma}{L}}.
\end{aligned}
$$

Similarly, the product range and the price and quantity of each variety supplied by a firm in the foreign market can be rewritten as:

$$
(37) \quad
\begin{aligned}
&\Omega_X(c) = \frac{(c_D - \tau c)}{\beta}\sqrt{\frac{\gamma L}{F}}, \\
&q_X(c) = \sqrt{\frac{FL}{\gamma}}, \ \ p_X(c) = c_D + \sqrt{\frac{F\gamma}{L}}.
\end{aligned}
$$

We have $\Omega_X(c) < \Omega_D(c)$. For a firm that produces for both domestic and export markets, the product range supplied for the domestic market is wider than the one supplied for the export market. An exporting firm always exports a subset of its product varieties to the foreign market.

3.2 The Comparative Statistics of Tariff Changes

Our model generates a number of testable implications concerning plant size and product diversification.

The Number of Products. The total number of products of a plant is given by (36). If the plant is an exporter, it chooses a portion of the product line to sell in the export market. The number of products that is sold abroad is given in (37). The expression (36) for a plant's product range shows that the number of products is a negative function of tariff rates. Lower tariff rates reduce the number of products of plants. In addition, the marginal effect of tariffs on log changes in the number of products decline with c. As tariff rates fall, the rate of decline in the number of products should be smaller for plants that are larger and exporters. We have the first testable implication for product diversification from our model:

Hypothesis 1 A decline in tariff rates is related to a decline in the number of products supplied by individual plants. The decline is smaller for exporting and larger plants than non-exporting and smaller plants.

The Index of Product Diversification. In our empirical section, we will use an entropy index to measure product diversification. The entropy index of product diversification is defined as $E = \sum_{i=1}^{\Omega} s_i \log(1/s_i)$, where Ω is the number of products and s_i is the share of a product. Our results show that declines in trade barriers affect the index of product diversification. The index of product diversification of non-exporters is $\ln(\Omega_D)$--the number of products in log, where Ω_D is given by (36). This should decline as tariff rates fall.

For entrants to the export market, lower tariffs should reduce the product diversification index. As tariff rates fall, entrants to the export market reduce the total number of products. They also begin to sell a portion of their product lines in the export market. These effects lead to a decline in the product diversification index.

For existing exporters, tariff changes have an ambiguous effect on the product diversification index. On one hand, existing exporters produce a smaller number of products. On the other hand, these exporters expand the range of products that are shipped abroad. The former leads to a decline in the index of plant diversification while the latter leads to an increase in the index of plant diversification. These discussions provide the second testable implication from the model:

Hypothesis 2 A decline in tariff rates reduces the product diversification index of non-exporting plants and new exporters. It has an ambiguous effect on the product diversification index of existing exporters.

Plant Size. We define plant size as real output calculated as the number of products times the output of each product. The size of non-exporters is $\Omega_D q_D$, where $\Omega_D q_D$ is given by (36). The size of non-exporters should decline with lower tariff rates.

The size of new exporters and existing exporters is $\Omega_D q_D + \Omega_X q_X$. The decline in tariff rates reduces Ω_D, increases Ω_X, and has no effect on q_D and q_X for existing exporters. These results suggest that domestic sales decline and foreign sales increase with lower tariffs and tariff reductions have an ambiguous effect on plant size at existing exporters. This is also the case for new exporters. These discussions provide a third testable implication from our model:

Hypothesis 3 A decline in tariff rates reduces the size of non-exporters. It has an ambiguous effect on the size of current and new exporters.

Length of Production Runs. The length of production run of individual products for non-exporters is q_D in (36), which is independent of tariff changes. For new exporters and existing exporters, lower tariff rates should lead to an increase in the average length of production runs of individual products. The entrants to the export market increase the length of production runs for the varieties shipped abroad. The existing exporters improve the production-run length of the products that they begin to export as a result of lower tariffs. We have a fourth implication from our model:

Hypothesis 4 A decline in trade costs increases the production-run lengths of individual products at existing exporters and has no effect on the length of production runs at non-exporters. The production-run length of entrants to the export market increases relative to that of non-exporters.

Our model adapts the Melitz model of trade to multi-product plants. As such, our model also yields a number of implications that are reported in Melitz (2003). As tariff rates fall, the least productive plants exit and the most productive of non-exporters enter the export market. Current exporters increase export/shipment ratios with lower tariff rates. This is a result of a decline in domestic shipments and an increase in foreign shipments at current exporters. These predictions have been confirmed in a number of previous empirical studies (Bernard, Jensen and Schott, 2003; Baldwin and Gu, 2004; Melitz, 2003, Bernard et al, 2003). As such, we will focus on more novel implications from our model that concern plant size and product diversification. [5]

4 Data

The data used for our analysis come from a longitudinal data file on all plants in the Canadian manufacturing industry over the period 1973-1997. This longitudinal file is based on data that are derived from both survey and administrative sources that provide plant-level data for the universe of plants in the manufacturing sector. The survey data are derived from long-form questionnaires (generally filled in by the largest plants) that contain the most detailed information, including commodity data, and short-form questionnaires (generally filled in by smaller plants) that are much less detailed. In addition, for the very smallest plants, administrative data on sales and employment come from tax records.

In this database, a plant's sales are classified to one industry. Each plant is identified as being part of a firm. Detailed information at the plant level includes the 1980 SIC, employment, value of shipments and value added, nationality of control, age of plant, exports, the SIC of the industry to which the plant is classified, and whether the

[5] Tariff reductions have a bigger impact on the export/shipment ratios of exporters for the industries with a larger dispersion of productivity levels (Helpman, Melitz and Yeaple, 2004)

owning firm possess multiple plants. Information on export status is also available for plants that are given a long-form (detailed) questionnaire for the years 1979, 1984, 1990, 1993, 1996 and 1997.

In addition, annual commodity data for all products produced (both primary and secondary) are available for all plants that received a long-form questionnaire. The survey collects data on the value of shipments and quantity of each commodity produced in these “long-form” plants.

We use these commodity data to calculate an index of diversity across commodities for plants. In this paper, we use a diversification measure that takes into account both the number of commodities that a firm produces and the distribution of its activity across commodities. The commodity dimension utilizes over 7,000 commodities.

We use an entropy measure of product diversification that measures how concentrated a plant’s sales are at the product level (see Jacquemin and Berry, 1979). The entropy diversification index takes a value of zero when sales are concentrated within a single product line. At the other extreme, if the plant’s activity is spread evenly across K products, the plant’s entropy is maximised at $E(s) = \log(K)$.

In our model, we have assumed that tariff reductions are symmetric in the two countries. However, in the empirical analysis we will use as independent variable the sum of Canadian tariff reductions against U.S. imports and U.S. tariff reductions against Canadian exports. We find that tariff reductions in the two countries have a similar effect on product diversification and plant size. The differences between them are not significant. Therefore, we combine the two.

The Canadian tariff rates against U.S. imports are based on duties paid that are collected by commodity. These commodities are assigned to industries based on the primary industry of production. Average industry tariffs are then calculated using import values as weights. U.S tariff rates against Canadian imports are once again based on import duties by commodity, which are assigned to an industry using the same Canadian concordance table used for Canadian commodity duties, and then aggregated to industries based on U.S. import weights.[6]

5 Empirical Results

In this section, we examine the relationships between tariff rates and product diversification and plant size as described in Section 3.

We estimate the following specification that expresses changes in product diversification or plant size as a function of tariff changes, export status and a set of plant characteristics:

$$\Delta Y_{pt} = \alpha_i + \gamma_t + \beta_1 \Delta\tau_{it} + \beta_2 E_{pt} + \beta_3 \left[E_{pt} \times \Delta\tau_{it} \right] + \beta_4 X_{pt} + \varepsilon_{pt}, \tag{39}$$

where Y_{pt} denotes the number of products in log for plant p during period t, the index of product diversification, the output of a plant in log, or the average length of production runs for individual products in log; $\Delta\tau_{it}$ is the average annual change in tariff rates; E_{pt} is a dummy variable indicating whether the plant is an exporter, X_{pt} is set of plant characteristics that includes the values of Y_{pt} at the start of period t, the relative size of a plant, plant output growth. The relative size of a plant is defined as the log difference

[6] We are grateful to Professor Dan Trefler for providing us with Canadian and U.S. tariff rates (for details on the sources and construction of the tariff data, see the Appendix in Trefler, 2004).

between the plant and the mean plant in the SIC 4-digit industry to which the plant belongs. The plant growth is defined as the annual change in real output.

Industry fixed-effects α_i are included to control for differences in changes in product ranges across industries. Time fixed-effects γ_t controls for differences over time, which arise from those changes in production technologies, organizational structures, or business conditions.

Our choice of sample for estimating (39) is driven by the availability of data on plant export status and industry tariff rates. The longitudinal ASM plant sample provides data on exports for the plants given "long forms" for the following years, 1979, 1984, 1990, 1993 and 1996 and 1997. Tariffs are available for the period 1980-1996. As such, we use two panels of continuing "long form" plants, one over the period 1984-1990 and the other over the period 1990-1996. We further restrict the sample to those plants that produce more than one product at the start of each period. We have a total of 7074 plants for the period 1984-1990 and 5966 plants for the period 1990-1996.[7]

We ask whether plants in industries with larger tariff changes had larger changes in product diversification and plant size. A positive coefficient on the tariff change variable indicates that the plants in the industries with large tariff cuts have a bigger decline in plant performance variable Y.

The plant characteristics are included to provide us with evidence on the changes that were taking place within industries in terms of product ranges. They allow us to determine whether changes in plant size and product diversification took place in subsets of plants and thereby to infer what the basic underlying forces behind changes might have

[7] The exact number of observations for estimation may differ slightly across specifications as a result of missing values on some variables.

been. The initial value of plant size and product diversification is included to control for the natural process of the regression to mean.

We also recognize that dynamic processes other than changes in tariff rates would have been at work that should be related to changes at the plant level. In particular, the normal growth process should be associated with increases in product ranges; since this is one of the routes used to enable firms to exploit scale economies. Therefore, we include changes in plant size in the regressions for product diversification, all the while recognizing that this introduces a variable that is likely to be simultaneously determined with changing product diversity. Previous efforts have discovered that modeling growth (finding a strong instrument) is difficult (Baldwin, Sabourin and Smith, 2004). However, omitting plant growth offers the equally daunting consequence of specification bias. Our compromise is to provide the reader with two alternatives—one without this variable and one with it included. The results on the effect of tariff changes are similar for regressions with and without the plant-growth variable. In the following sections, we will only report results from regressions that include plant growth as independent variable.

Table 1 presents the mean changes in tariff rates, product diversification and plant size from our sample of plants. Tariff rates and product diversification declined in both periods 1984-1990 and 1990-1996. Product diversification showed a much larger decline in the 1990-1996 period as tariff reductions became larger. The rate of decline in the number of products rose from 3.4 to 4.2 percent per year from the 1984-1990 to 1990-1996 period. The rate of decline in product diversification index increased from 0.8 to 1.3 per year.

Average plant size and average production-run length increased in both the 1980s and 1990s. The rate of growth was faster during the 1990s as tariff cuts deepened. These results are encouraging and consistent with the model's predictions about plant size and product diversification.

Table 1 also shows that product diversification (product counts and product diversification) declined at both exporters and non-exporters during the 1980s and 1990s. The rate of decline became much larger at non-exporters in the 1990s as tariff cuts deepened. There were increases in production-run lengths and plant size among both exporters and non-exporters, and the rate of growth showed somewhat larger acceleration in the 1990s among exporters. The evidence is consistent with the model's prediction about the difference in the impact of tariff changes between exporters and non-exporters.

5.1 Number of Products

Our model has a specific implication for the relationship between tariff barriers and the product range of plants. The number of products will decline as tariff rates fall. The rate of decline in the number of products should be smaller for larger and exporting plants.

The results in Table 2 provide support for the model's prediction. Consistent with our model, the reduction in tariff rates is associated with the decline in the number of products across individual plants, and the rate of decline in the number of products is smaller for exporting and larger plants. The results in column (2) suggest that lower tariffs reduce the number of products among non-exporters. It has little effect on the number of products among exporters, as the sum of the coefficient on tariff changes and its interaction with exporter is not significant at the 5 percent level. These results are consistent with those reported in Baldwin, Caves and Gu (2004).

The coefficient on exporter is negative and significant at the 5 percent level. This implies that exporters reduce product ranges and increase product specialization relative to non-exporters. Baldwin and Gu (2004) find similar evidence and interpret this as evidence that exporting raises productivity growth through increased product specification.

The results in Table 2 also show that growing plants tend to add new products in their product lines. Larger plants also add new products in order to expand their market for their products. Young plants are increasing their product specialization relative to older plants.

5.2 Product Diversification

Our model predicts that lower tariff rates reduce the product diversification index of non-exporters and new exporters. It has an ambiguous effect on the diversification index of exporters. For exporters, lower tariff rates leads to decline in the number of products and an increase in the portion of its product line shipped abroad. These two effects are offsetting and lead to an ambiguous effect of tariff cuts on the product diversification index of exporters.

The results in Table 3 confirm the prediction from our model. The results in column (2) show that the coefficient on tariff changes is positive and significant at the 10 percent level. This suggests that reduction in tariffs leads to a decline the product diversification index of non-exporters and new exporters[8]. The effect of lower tariff rates on the product diversification index of exporters, which is calculated as the sum of the coefficients on tariff changes and its interaction with plant export status is not significant at the 10 percent level. This implies that tariff reductions do not have significant effect on the diversification of exporters.

In column (3), we examine the difference in the effect of lower tariffs on product diversification across plant sizes. The results show that tariff reductions have less of an impact on the diversification of larger plants than on that of smaller plants. This is consistent with the finding on the number of products in the previous section, where we find that lower tariffs reduce the number of products of larger plants less than that of smaller plants.

The coefficient on export status in column (2) is negative and significant at the 5 percent level. Compared with non-exporters, exporters are becoming more specialized and reducing product diversification, a finding that is consistent with the one in Baldwin and Gu (2004).

The positive and significant coefficient on plant growth suggests that growing plants are becoming more diversified. This is consistent with the view that plants adopt product diversification as a strategy to growth.

5.3 Plant Size

Our model has implications for plant size. The decline in tariff barriers will reduce the size of non-exporting plants as these plants reduce the range of their product lines. But it has an ambiguous effect on the size of current and new exporters. For those plants,

[8] The coefficients on two dummy variables for non-exporters and new exporters are not statistically different. Therefore we combine the two in the regressions.

the tariff reduction leads to an increase in export sales, which is offset by a decline in their domestic sales.

The results in Table (4) provide empirical evidence that is consistent with our model's prediction about plant size. The coefficient on tariff changes in column (2) is positive and significant at the 1 percent level. Lower tariffs lead to a decline in the size of non-exporters. The effect of tariff changes on plant size of exporters, which is the sum of the coefficients on tariff changes and its interaction with plant export status, is not significant. This suggests that the tariff reduction is not related to changes in the size of current exporters and new exporters.[9]

The results in Table 4 show that exporters (current and new) increase their size relative to non-exporters. Baldwin and Gu (2004) finds a similar result.

One of the predictions of policy advocates for free trade was that plant size would increase as a result of free trade. Yet the 1990s have been characterized as having a decline in average plant size in manufacturing. Increasingly more of total employment became concentrated in smaller plants (Baldwin, Jormin and Tang, 2002). A number of previous studies have examined the relationship between tariff barriers and plant size (Head and Ries, 1999). The firm-based approach to models of trade used in this paper and other papers (Melitz, 2003) highlights the differences in the responses to tariff reductions that should be expected across plants. Our model and that of Melitz (2003) show that tariff reductions have a different effect on the size of exporters and non-exporters.

[9] When we introduce the interaction of tariff changes with the dummies for current and new exporters separately, we find that the difference in the coefficients on the two interactions terms is not significant.

5.4 Production-Run Length

Our model has implications for the lengths of production runs within individual products. As tariff rates fall, the length of production runs will increase for current and new exporters as a result of declines in product ranges and increases in the foreign sales of their products. It will decline for non-exporters as a result of narrower product lines.

We define the length of production run of individual products for a plant as the ratio of the real output of the plant to the number of products of the plant. The estimated length of production runs represents an average across products, as output distribution is not uniform across individual products.

The results, shown in table 5, provide some support for the model's implication for production run lengths. Consistent with the model, the length of production runs at entrants to the export market increased relative to that at non-entrants. Tariff changes have no effect on the length of production runs among non-exporters. Among exporters, the effect of tariff changes on the production-run length depends on plant size. Our evidence suggests that lower tariffs increase the production-run length of large exporters.

The production-run length of exporters increased relative to that of non-exporters. The coefficient estimate in column (2) suggests that a one percentage-point decline in tariff rates is associated with 3 percentage point increase in annual growth in production runs among exporters..

6 Conclusions

In this paper, we examine the impact of trade and market size on product diversification and plant size. We first develop a model of trade in differentiated goods with multi-product plants. The model yields predictions about the impact of market size on plant performance that are consistent with previous empirical evidence. The firms in a smaller and less competitive market have shorter production runs, and tend to be smaller and less productive than those in a larger and more competitive market.

Our model has a number of predictions about the impact of tariff changes on changes in product diversification and plant size. Our empirical evidence from a sample of Canadian manufacturing plants provides broad support for our model. First, lower tariff rates reduce the product diversification of plants. The rate of decline in product specialization is smaller for larger and exporting plants. Second, lower tariff rates reduce the size of non-exporting plants as these plants become more specialized. Third, entrants to the export market increase the production-run length relative to non-entrants. Fourth, a decline in tariff rates increases the length of production runs of large exporters. It has no effect on the length of production runs of non-exporters.

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Table 1. Annual Average Changes in Tariffs, Product Diversification and Plant Size

	1984-1990	1990-1996
Canadian tariff changes	-0.0036	-0.0076
U.S. tariff changes	-0.0020	-0.0034
Log changes in the number of products	-0.0346	-0.0420
Changes in product diversification index	-0.0083	-0.0130
Changes in real output	0.0157	0.0195
Changes in production run lengths	0.0504	0.0615
Exporters		
Log changes in the number of products	-0.0422	-0.0403
Changes in product diversification index	-0.0105	-0.0123
Changes in real output	0.0139	0.0264
Changes in production run lengths	0.0561	0.0667
Non-Exporters		
Log changes in the number of products	-0.0298	-0.0441
Changes in product diversification index	-0.0070	-0.0140
Changes in real output	0.0168	0.0110
Changes in production run lengths	0.0467	0.0551

Notes: The length of production runs in a plant is defined as plant output divided by the number of products.

Table 2. Changes in the Number of Products

	(1)	(2)	(3)
Tariff changes	0.3247* (1.75)	0.5270*** (2.73)	0.2284 (1.32)
# of products in log		-0.0670*** (-33.75)	-0.0671*** (-33.84)
Exporter		-0.0124*** (-4.33)	-0.0060*** (-2.74)
× tariff changes		-0.7279*** (-3.33)	
Relative plant size		0.0129*** (14.42)	0.0114*** (10.23)
× tariff changes			-0.1951** (-2.04)
Plant growth		0.1022*** (9.64)	0.1028*** (9.72)
Young plants		-0.0049* (-1.72)	-0.0047 (-1.63)
Dummy for period 1990-1996	-0.0064*** (-2.93)	-0.0088*** (-4.26)	-0.0092*** (-4.43)
Observations	12038	12034	12034
R^2	0.05	0.17	0.17

Notes: Numbers in parentheses are robust t-statistics. Regressions cover two panels 1984-1990 and 1990-1996. All specifications include fixed effects for 4-digit industries. *** Significant at the 1% level. ** Significant at the 5% level. *Significant at the 10% level.

Table 3. Changes in Product Diversification Index

	(1)	(2)	(3)
Tariff changes	0.0468 (0.71)	0.1148* (1.68)	0.0356 (0.59)
Product diversification index		-0.0720*** (-38.58)	-0.0722*** (-38.64)
Exporter		-0.0034*** (-3.47)	-0.0016** (-2.12)
× tariff changes		-0.2062*** (-2.73)	
Relative plant size		0.0039*** (13.06)	0.0031*** (8.32)
× tariff changes			-0.1054*** (-3.20)
Plant growth		0.0283*** (8.00)	0.0286*** (8.11)
Young plants		-0.0012 (-1.20)	-0.0010 (-1.02)
Dummy for period 1990-1996	-0.0050*** (-6.62)	-0.0050*** (-7.11)	-0.0051*** (-7.26)
Observations	12038	12034	12034
R^2	0.05	0.21	0.21

Notes: Numbers in parentheses are robust t-statistics. Regressions cover two panels 1984-1990 and 1990-1996. All specifications include fixed effects for 4-digit industries. *** Significant at the 1% level. ** Significant at the 5% level. *Significant at the 10% level.

Table 4. Changes in Plant Size

	(1)	(2)
Tariff changes	0.3043 (1.58)	0.6941*** (2.89)
Plant size in log		-0.0171*** (-17.74)
Current exporter		0.0159*** (4.89)
New exporter		0.0156*** (4.82)
Exporter × tariff changes		-0.4545* (-1.91)
Young plants		0.0176*** (5.78)
Dummy for period 1990-1996	0.0043** (1.99)	0.0033 (1.53)
Observations	12034	12034
R^2	0.05	0.09

Notes: Numbers in parentheses are robust t-statistics. Regressions cover two panels 1984-1990 and 1990-1996. All specifications include fixed effects for 4-digit industries. *** Significant at the 1% level. ** Significant at the 5% level. *Significant at the 10% level.

Table 5. Changes in Product Run Length

	(1)	(2)	(3)
Tariff changes	-0.0212 (-0.08)	-0.1415 (-0.53)	-0.1738 (-0.65)
Product run in log		-0.0633*** (-26.30)	-0.0351*** (-26.37)
Current exporter		0.0299*** (7.07)	0.0363*** (8.51)
× tariff changes		0.5997** (2.00)	0.7827** (2.50)
× tariff changes ×relative plant size			-0.3471* (-1.87)
New exporter		0.0184*** (5.14)	0.0202*** (5.58)
Relative plant size		0.0351*** (14.61)	
Young plants		0.0196*** (4.94)	0.0119*** (3.00)
Dummy for period 1990-1996	0.0107*** (3.61)	0.0179*** (6.28)	0.0130*** (4.53)
Observations	12034	12034	12034
R^2	0.05	0.15	0.13

Notes: Numbers in parentheses are robust t-statistics. Regressions cover two panels 1984-1990 and 1990-1996. All specifications include fixed effects for 4-digit industries. *** Significant at the 1% level. ** Significant at the 5% level. *Significant at the 10% level.