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

John Baldwin and Wulong Gu

15.1 Introduction

This chapter 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 chapter 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, Keys, and Spence (1968) and Caves (1975) argued that Canadian plants suffered from excessive levels of diversity. And 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 United

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States. 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.

Starting in 1989, two major changes occurred in the trading environment that faced Canadian manufacturers that should have influenced the length of production runs. First, the Canada-United States Free Trade Agreement (FTA) guaranteed a new type of open-border arrangement between these two countries. Then the North American Free Trade Agreement (NAFTA) in 1994 brought together Canada, Mexico, and the United States. These agreements continued a process that extended back to the post-World War II commitments to reduce tariffs and expand international trade. The average tariff collected continued its downward trend during the 1990s—from 3.3 percent in 1989 to 1.1 percent in 1996. But the FTA and NAFTA changes marked a turning point in that they set a timetable for the elimination of tariffs and a framework for the resolution of trade disputes that was intended to give companies greater certainty for foreign direct investment.

The result was an increase during the 1990s in both the export intensity and the import intensity of the Canadian manufacturing sector. Both export intensity and import intensity increased from around 31 percent in 1990 to 47 percent in 1997. The FTA allowed a process that had begun in the 1970s and 1980s to continue into the 1990s. Manufacturing activity shifted from primarily facing import competition to being more export-oriented; this transition provided the link between trade liberalization and the expected impact of increased market size on diversity. The import-competing segments of Canadian manufacturing may also have responded to trade liberalization, as there would be increased competition in an enlarged domestic market.

Previous empirical work suggests that trade liberalization in the early 1990s might have been expected to increase plant specialization. Earlier studies by Baldwin and Gorecki (1983b, 1986) made use of data for the 1970s to study whether the reduction in tariffs that occurred following the

Kennedy round was associated with an increase in plant specialization. During this period of gradual tariff reductions, plant specialization increased slightly, as did the length of the production run. Increases in the latter, though not the former, were greater in those industries where tariffs declined the most. Baldwin, Beckstead, and Caves (2001) examined longer-run trends in both firm and plant specialization.

This chapter extends our work that examines trends in specialization in the Canadian manufacturing sector. We have two objectives. First we develop a model of trade in differentiated goods with multi-product plants to structure our analysis. 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; Yeaple 2002). Second, we provide empirical evidence on the model's prediction regarding the impact of tariff reductions on product diversification, production-run length, and plant size using Canadian experience over the 1980s and the 1990s.

Melitz (2003) has developed a model of trade in differentiated products with producer heterogeneity to examine the effect of trade on firm/plant turnover (entry, exit, and output reallocation) in domestic and export markets. Melitz and Ottaviano (2005) examine the effect of market size on firm size, firm productivity, and firm turnover. In this chapter, we develop a model of trade with multi-product firm/plants to examine the effect of market size and trade on product specialization and production-run length.

Our model generates a number of predictions on the effect of market size and trade integration on product specialization, production-run length, plant size, and plant turnover in domestic and export markets. The most novel finding relates to the effect of market size and trade on product diversification, production-run length and plant size. Our model predicts that plants in a smaller market tend to be more diversified and have shorter production runs. Bilateral trade liberalization reduces the number of products supplied by plants, and the rate of decline is smaller for larger and exporting plants. It increases the production-run length of exporters while having no effect on the production-run length of nonexporters. The effect of bilateral tariff reductions on plant size depends on the export status of a plant. Bilateral tariff cuts reduce the plant size of nonexporters as nonexporters reduces the number of products while keeping the production-run length unchanged. The effect of tariff cuts on the plant size of exporters is ambiguous. On the one hand, tariff cuts increase the plant size of exporters by increasing the production-run length of the portion of the product line that is exported. One the other hand, tariff cuts reduce the plant size of exporters by reducing the total number of products produced. The net effect of bilateral tariff cuts on plant size depends on the size of those two offsetting factors.

The predictions of our model on the effect of trade and market size on plant size, plant productivity, and plant turnover are similar to those in Melitz (2003) and Melitz and Ottaviano (2005). First, plants in a smaller and less competitive market tend to be smaller and less productive than those in a larger and more competitive market. These predictions are similar to those in Melitz and Ottaviano (2005) and have been confirmed in a number of previous empirical studies (Scherer et al. 1975; Caves 1975; Syverson 2003).

Second, 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 nonexporters enter the export market and expand their output.

In our empirical analysis, we focus on the model's prediction on the effect of bilateral tariff cuts on product diversification, production-run length and plant size. To this end, 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. The Canada–U.S. Free Trade Agreement (FTA) committed two countries to gradually eliminate all manufacturing tariff rates over a ten-year period beginning in 1989. The tariff reductions in the two countries are highly correlated (Head and Ries 1999). In addition, the political economy that governed tariff reductions has produced similar cross-industry reductions in the two countries that make it difficult to separate out the effect of each set of tariff reductions. As such, the Canada–U.S. tariff cuts resemble the case of bilateral trade liberalization examined in the model.

15.2 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 firm size. The model also serves as a building block for the open-economy model that will be developed in the next section. It is similar to the one in Melitz and Ottaviano (2005) with one distinction. Here we assume multi-product firms while Melitz and Ottaviano (2005) assume single-product firms.

15.2.1 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 as numéraire:

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

where q_o and $q(\omega)$ represent the individual consumption levels of the numéraire good and variety ω. The set of varieties supplied by firms is Ω. 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 substitutes 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 numéraire. Increases in α and decreases in β increase the demand for the differentiated varieties relative to the numéraire.

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

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

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:

$$p_i(\omega) = \alpha - \gamma q_i(\omega) - \beta Q \tag{3}$$

where $Q = \int_{\omega \in M} \int_{\omega \in \Omega_i} q_i(\omega) d\omega di$ 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:

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

The quasi-linear utility function (1) we choose in our model has a desirable feature that 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) leads to increases in the elasticity of demand.

In contrast, 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, Norman, and Hung 1987; Roberts and Tybout 1996; Syverson 2003; Tybout 2003).

15.2.2 Production and Firm Behavior

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 those models, production exhibits economies of scale within varieties but no economies of scope across varieties. As such, each firm supplies 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 $[0,c_M]$ 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

$$C_i = \int_{\omega \in \Omega_i} [c_i q_i(\omega) + F] d\omega \tag{5}$$

and the total revenue is

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

Firm i maximizes its profit

$$\Pi_i = \int_{\omega \in \Omega_i} [p_i(\omega) q_i(\omega) - c_i q_i(\omega) - F] d\omega \tag{7}$$

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.

The strategic behavior of surviving multi-product firms has been studied in Ottaviano and Thisse (1999). The rest of this section follows closely the analysis in that paper.[1] Ottaviano and Thisse (1999) argue that firms should behave like oligopolists as those firms are large actors and control a nonnegligible set of varieties. 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.[2] 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_{-1}). These discussions suggest that the total market demand is:

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

and the profit of firm i can be rewritten as:

$$(9) \qquad \Pi_i = (p_i q_i - c_i q_i - F)\Omega_i,$$

and the inverse demand (4) becomes:

$$(10) \qquad p_i = \alpha - \frac{\gamma}{L} q_i - \frac{\beta}{L} Q,\ Q = q_i\Omega_i + Q_{-1}.$$

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:

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

and

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

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:

1. But there is a difference. Ottaviano and Thisse (1999) assume that firms are identical and have the same marginal cost. We introduce firm heterogeneity and assume that the marginal cost of producing a product is drawn from a common distribution.

2. 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.

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

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.[3]

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

Equations (11), (12), and (13) provide a unique solution (p_i, q_i, Ω_i) for M firms. For the rest of the section, we will obtain an analytical solution for (p_i, q_i, Ω_i). 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) $$q_i^* = \sqrt{\frac{FL}{\gamma}} \equiv q^*.$$

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 $q^*(\Omega - \Omega_i)$, where $\Omega = \Sigma_{i=1}^{M}\Omega_i$ is the total number of varieties in the market. The first order condition (14) can be rewritten as:

(16) $$(\gamma + \beta\Omega_i) = \frac{[(\alpha - c_i)L - \beta q^*(\Omega - \Omega_i)]}{2}\sqrt{\frac{\gamma}{FL}}.$$

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

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

where $\bar{c} = \Sigma_i c_i/M$ 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) $$\Omega_i^* = \Omega^*(c_i) = \frac{[(\alpha - c_i) + M(\bar{c} - c_i)]\sqrt{\dfrac{\gamma L}{F}} - 2\gamma}{\beta(M + 1)}.$$

3. The payoff function (13) is concave in Ω_i. Therefore, the equilibrium product range implicit in (14) is unique maximum.

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

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

Finally, solving (14) for Q_{-1} and substituting the resulting expression into (12), we obtain the equilibrium price of each variety supplied by firm i:

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

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 (a) firms in a larger market have longer production runs for individual products; (b) product diversification declines with the economies of scale within individual products (or increases in fixed overhead costs F); (c) firms with lower costs set lower price, earn higher profits, and are larger.

15.2.3 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 above the cutoff cost c_D would make negative profits and choose to exit. All firms with cost level below c_D earn positive profits and remain in the market. The cutoff cost c_D is determined by the zero profit condition:

$$(21) \qquad \Pi^*(c_D) = 0, \text{ or } [\alpha + M\bar{c} - (M+1)c_D]\sqrt{\frac{\gamma L}{F}} - 2\gamma = 0$$

where $\bar{c} = \int_0^{c_D} c dG(c)/G(c_D)$ 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:

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

For the rest of the chapter, 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:[4]

4. The logarithm of labor productivity $log(1/c)$ follows an exponential distribution with a standard deviation equal to $1/k$.

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

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

These 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 – $G(c_D)$) is 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) $$\Omega^*(c_i) = \frac{(c_D - c_i)}{\beta}\sqrt{\frac{\gamma L}{F}},$$

$$p_i^* = c_D + \sqrt{\frac{F\gamma}{L}}, \quad q_i^* = \sqrt{\frac{FL}{\gamma}},$$

$$\Pi^*(c_i) = \frac{L}{\beta}(c_D - c_i)^2.$$

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

(27) $$\overline{\Omega}^* = \frac{c_D}{\beta(k+1)}\sqrt{\frac{\gamma L}{F}},$$

$$\overline{p}^* = c_D + \sqrt{\frac{F\gamma}{L}}, \overline{q}^* = \sqrt{\frac{FL}{\gamma}},$$

$$\overline{\Pi}^* = \frac{2c_D^2}{(k+1)(k+2)}\frac{L}{\beta}$$

The total number of product varieties is:

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

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.[5] There are more product varieties and more firms in a larger market.

Equations (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.

15.3 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. We assume that two economies are integrated through trade with positive trade cost. 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 15.2.1.

15.3.1 Model

We now consider two economies h and f where there are trade costs. To simplify our analysis, 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 15.2. 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 ex-

5. Firm size is defined as the real output of the firm that is equal to the number of varieties times the output of each variety.

port 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 15.2.1 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:

$$\text{(29)} \qquad \Omega_D(c) = \frac{[(\alpha - c) + M(\bar{c} - c)]\sqrt{\dfrac{\gamma L}{F}} - 2\gamma}{\beta(M+1)},$$

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

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

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:

$$\text{(30)} \qquad \Omega_X(c) = \frac{[(\alpha - \tau c) + M(\bar{c} - \tau c)]\sqrt{\dfrac{\gamma L}{F}} - 2\gamma}{\beta(M+1)},$$

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

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

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:

$$(31)\ \Pi_D(c_D) = 0: \frac{F}{\beta\gamma(M+1)^2}\left\{[\alpha + M\bar{c} - (M+1)c_D]\sqrt{\frac{\gamma L}{F}} - 2\gamma\right\}^2 = 0,$$

$$\Pi_X(c_X) = 0: \frac{F}{\beta\gamma(M+1)^2}\left\{[\alpha + M\bar{c} - (M+1)\tau c_X]\sqrt{\frac{\gamma L}{F}} - 2\gamma\right\}^2 = 0.$$

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

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

As $\tau > 1$, we have $c_X < c_D$. The two cutoff cost levels provide a portioning of firms into exiting, nonexporting, 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 $c \in [0, c_D]$ and the delivered cost of exporting firms $\tau c \in [0, c_X]$ have identical distributions. The average cost of all firms that sell in a market (that includes domestic firms and foreign exporters) is:

$$(33)\qquad \bar{c} = \int_0^{c_D} c_D G(c).$$

Free entry drives the expected profit to zero:

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

Solving for c_D and c_X, we have:

$$(35)\qquad c_D = \left[c_M^k(k+1)(k+2)\frac{E\beta}{2L(1+\tau^{-k})}\right]^{1/(k+2)},$$

$$c_X = \frac{c_D}{\tau} = \left[c_M^k(k+1)(k+2)\frac{E\beta}{2L(\tau^{k+2}+\tau^2)}\right]^{1/(k+2)}.$$

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 nonexporters, 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)
$$\Omega_D(c) = \frac{(c_D - c)}{\beta}\sqrt{\frac{\gamma L}{F}},$$

$$q_D(c) = \sqrt{\frac{FL}{\gamma}}, p_D(c) = c_D + \sqrt{\frac{F\gamma}{L}}.$$

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)
$$\Omega_X(c) = \frac{(c_D - \tau c)}{\beta}\sqrt{\frac{\gamma L}{F}},$$

$$q_X(c) = \sqrt{\frac{FL}{\gamma}}, p_X(c) = c_D + \sqrt{\frac{F\gamma}{L}}.$$

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.

15.3.2 The Comparative Statistics of Bilateral Trade Liberalization

Our model generates a number of testable implications on firm size and product diversification of bilateral trade liberalization, or the decline in common trade cost τ in the two countries. We will focus on the case of bilateral trade liberalization as the Canada-U.S. FTA tariff cuts should be more appropriately modeled as a case of bilateral liberalization.[6] The Canada-U.S. FTA committed the two countries to eliminate manufacturing tariffs in a ten-year period beginning in 1989. The tariff rates are similar in level and their changes over time are highly correlated in the two countries. In addition, the political economy that governed tariff reductions has produced similar cross-industry reductions in the two countries that make it difficult to separate out the effect of each set of tariff reductions.

The Effect on the Number of Products

The total number of products that a firm produces is given by (36). The expression (36) for a firm's product range shows that the number of products is a negative function of tariff rates. A lower tariff rate τ reduces the number of products supplied by firms. In addition, the marginal effect of tariff cuts 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

6. An important extension of the model is to examine the implications of unilateral trade liberalization. The effect of unilateral liberalization and other industrial and trade policy has been the focus of an extensive literature (see, e.g., Helpman and Krugman 1989).

for firms 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 firms. The decline is smaller at exporting and larger firms than at nonexporting and smaller firms.*

The Effect on 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 $E = \Sigma_{i=1}^{\Omega} s_i \log(1/s_i)$, where Ω is the number of products and s_i is the share of a product. The index of product diversification of nonexporters is $\ln(\Omega_D)$—the number of products in log, where Ω_D is given by (36). This will decline as tariff rates fall.

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

HYPOTHESIS 2. *A decline in tariff rates reduces the product diversification index of nonexporting firms. It has an ambiguous effect on the product diversification index of exporting firms.*

The Effect on Firm Size

We define firm size as real output calculated as the number of products times the output of each product. The size of nonexporters is $\Omega_D q_D$, where Ω_D and q_D are given by (36). The size of nonexporters declines with lower tariff rates.

The size of 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 at exporters. This suggests that tariff reductions increase export sales and lowers domestic sales at existing exporters. The overall effect of tariff cuts on the size of exporters depends on the relative magnitude of those two offsetting factors. These discussions provide a third testable implication from our model:

HYPOTHESIS 3. *A decline in tariff rates reduces the size of nonexporters. It has an ambiguous effect on the size of exporters.*

The Effect on Production-Run Length

The production-run length of individual products for nonexporters is q_D in (36), which is independent of tariff changes. The 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 length of exporters and has no effect on the production-run length of nonexporters.*

In addition to its prediction on the effect of tariff cuts on product diversification, plant size and production-run length of existing exporters relative to nonexporters, our model has implications for the entrants to the export market. Tariff cuts will reduce the product diversification index and increase the production-run length of entrants to the export market compared with nonentrants to the export market. The effect of tariff cuts on the size of entrants to the export market depends on the magnitude of two offsetting factors: increased export sales and the reduced product ranges. A proof of these results is similar to the one for our results on the responses of exporters versus nonexporters as a result of tariff cuts.

The implication of bilateral tariff cuts on firm turnover in domestic and export markets are similar to those in the Melitz model of trade (Melitz 2003). As tariff rates fall, the least productive firms exit and the most productive of nonexporters 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; Bernard et al. 2003).[7]

15.4 Data

The empirical analysis will be carried out at the plant level. The data used for the analysis come from a longitudinal data file on all plants in the Canadian manufacturing industry over the period 1973 to 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,

7. 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)

nationality of control, age of plant, exports, the SIC of the industry to which the plant is classified, and whether the 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 chapter, 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 Ω products, the plant's entropy is maximized at $E(s) = \log(\Omega)$.

Production-run length is defined as plant production divided by number of products. We also experimented with an alternative—production divided by the numbers equivalent derived from the entropy diversification measure.[8] The results were similar.

In our model, we have considered the case of symmetric bilateral trade liberalization where tariff reductions are symmetric in the two countries. Our previous discussion suggests that tariff cuts in Canada and the United States resemble symmetric bilateral trade liberalization, particularly during the FTA period. In our 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. The coefficient on the combined tariff cuts should capture the model's prediction on the effect of bilateral tariff cuts.

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. The 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

8. This is derived from the entropy measure of diversification by taking its antilog, which is referred to as the *numbers-equivalent* entropy. Its values are bounded between one and K: it equals one when 100 percent of a plant's activity is in one commodity and it equals K when a plant's production is spread equally across K products.

concordance table used for Canadian commodity duties, and then aggregated to industries based on U.S. import weights.[9]

15.5 Empirical Results

In this section, we provide empirical evidence on the effect of tariff rates on product diversification, production-run length, and plant size as summarized in the four hypotheses in section 15.3.

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

$$(38) \quad \Delta Y_{pt} = \alpha_i + \gamma_i + \beta_1 \Delta\tau_{it} + \beta_2 E_{pt-1} + \beta_3 S_{pt-1} + \beta_4 [E_{pt-1} \times \Delta\tau_{it}] + \beta_5 [S_{pt-1} \times \Delta\tau_{it}] + \beta_6 X_{pt} + \varepsilon_{pt}$$

where Δ denotes the change between periods $t-1$ and t, Y_{pt} is the dependent variable denoting 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-1} is a variable indicating whether the plant is an exporter in period $t-1$; S_{pt-1} is relative plant size; X_{pt} is a set of plant characteristics that includes the value of the dependent variable in period $t-1$ (Y_{pt-1}), a variable indicating whether a plant entered the export market between $t-1$ and t, and a dummy variable indicating whether a plant is a young plant (less than five years old) in period $t-1$. The relative size of a plant is defined as the log difference between the plant and the mean plant in the SIC four-digit industry to which the plant belongs.

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

Our choice of sample for estimating (38) 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 to 1996. As such, we use two panels of continuing long form plants, one over the period 1984 to 1990 and the other over the period 1990 to 1996. We further restrict the sample to those plants that produce more than one product at the start of each period. We have a

9. 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).

total of 7,074 plants for the period 1984 to 1990 and 5,966 plants for the period 1990 to 1996.[10]

We ask whether plants in industries with larger tariff changes had larger changes in product diversification, production-run length, 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, production-run length, and product diversification took place in subsets of plants and thereby to infer what the basic underlying forces behind changes might have been. The initial value of plant size, production-run length, and product diversification is included to control for the natural process of the regression to mean.

There are two empirical issues in estimating equation (39). First, the estimated equation includes a lagged dependent variable to control for the regression to the mean. This may introduce a bias in the estimates. Second, the sample for estimation consists of all plants that produce more than one product in the initial period. This may introduce a sample selection bias due to the exclusion of single-product plants. We will address those issues in our estimation.

We begin with summary statistics on the extent and trend of product diversification for Canadian manufacturing plants. In figure 15.1, we plot the average number of products per plant both for multiproduct plants and then for all plants, including those producing just a single product. The two curves exhibit the same pattern. Plant-level diversification is relatively constant from the early 1970s to 1987, but then begins to decline.[11] Over the period 1987 to 1997, the number of products per plant at multi-product plants falls by 16 percent. The number of products per plant among all plants falls by about 28 percent over the same period. The decline in plant diversification among all plants is a result both of a decline in the share of plants that produce more than one product and a decline in the diversification of the multi-product plants.[12]

In figures 15.2 and 15.3, we plot the average number of products at exporters and nonexporters.[13] Figure 15.2 includes all plants, and figure 15.3

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

11. As with the number of plants per firm, the number of products per plant starts to decline two years before the FTA with the United States.

12. For more detail, see Baldwin, Beckstead, and Caves (2001).

13. As data on exports are only available for the following years, 1974, 1979, 1984, 1990, 1993, 1996, and 1997, we compare exporters and nonexporters in those years in figures 15.2 and 15.3.

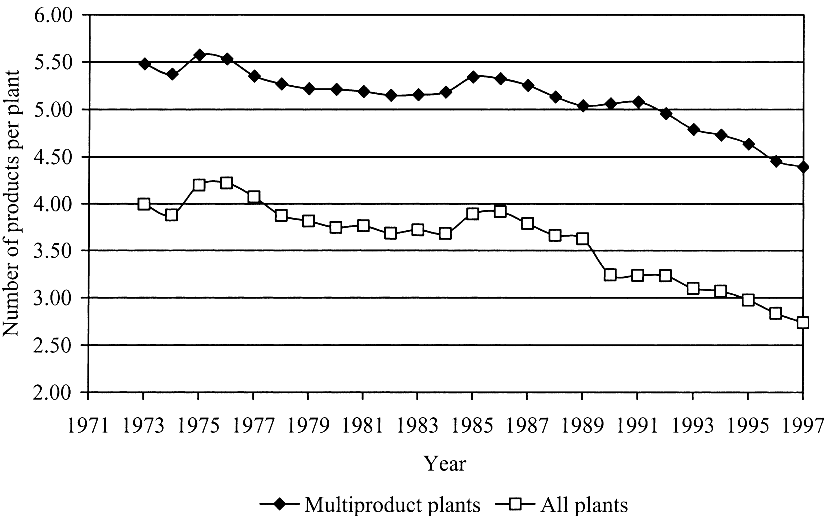

Fig. 15.1 Product diversification of manufacturing plants

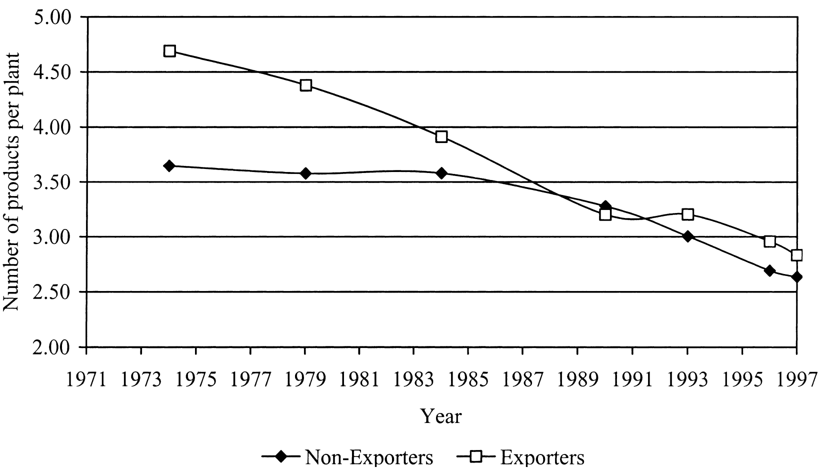

Fig. 15.2 Product diversification of all exporters and nonexporters

includes only multiproduct plants. The number of products declined in both exporters and nonexporters. But the decline was faster at exporters. In 1973, exporters tended to have a higher level of product diversification than nonexporters. In 1997, there was little difference between exporters and nonexporters.

Figure 15.4 shows the average size (real gross output) of Canadian manufacturing plants, normalized to 100 for multi-product plants in 1973. The

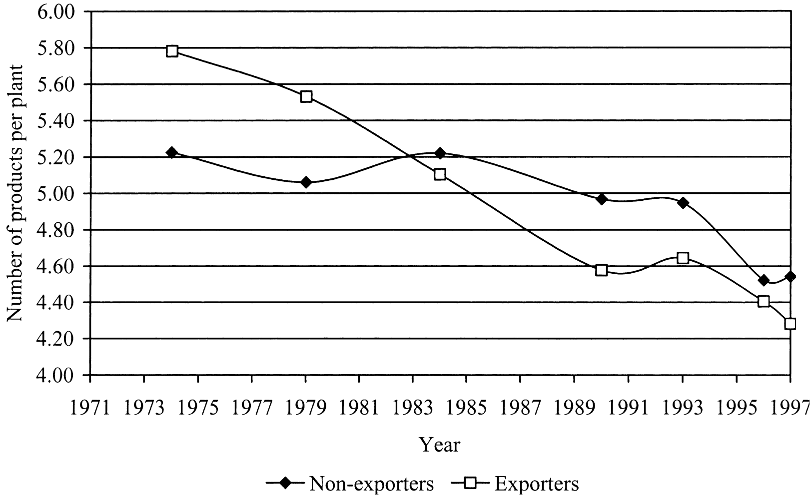

Fig. 15.3 Product diversification of multiproduct exporters and nonexporters

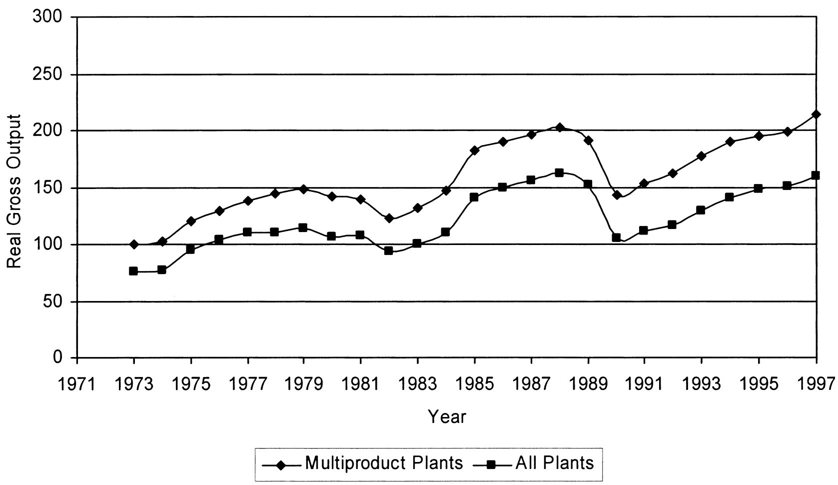

Fig. 15.4 Average size of manufacturing plants

average plant size increased over time and showed large fluctuations over business cycles. It declined during the recessions of the early 1980s and early 1990s.

In figures 15.5 and 15.6, we plot the average size of exporters and nonexporters. Figure 15.5 includes all plants and figure 15.6 includes only multi-product plants. The average size tended to be larger for exporters than for nonexporters. During the 1990s, average plant size increased for

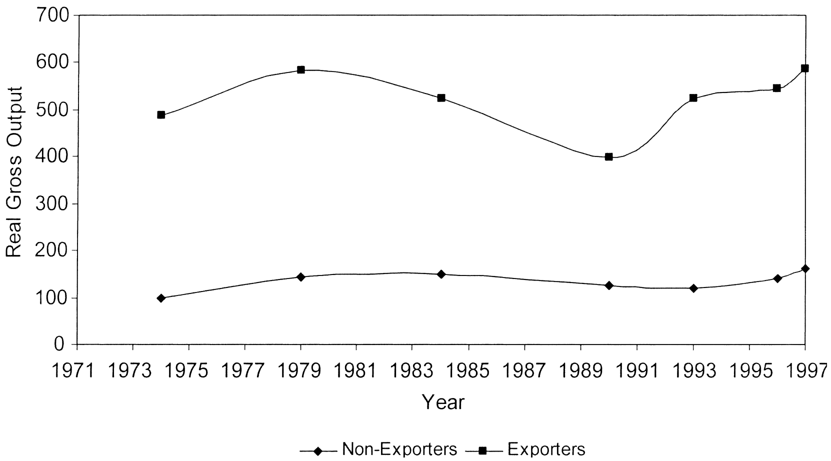

Fig. 15.5 Average size of all exporters and nonexporters

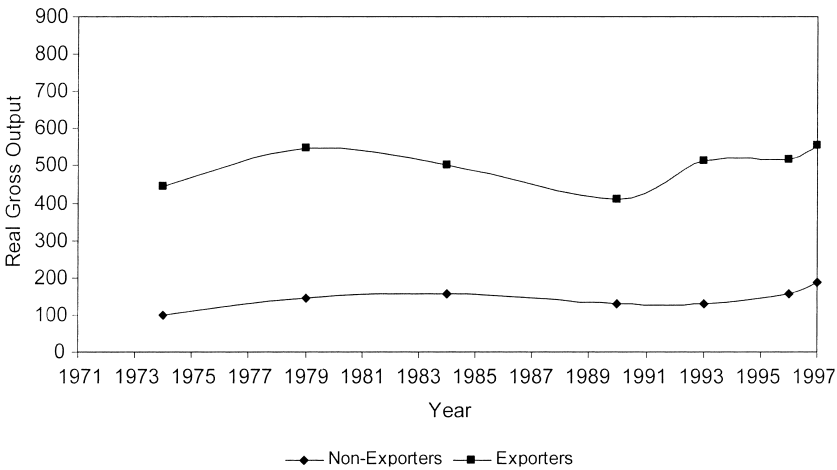

Fig. 15.6 Average size of multiproduct exporters and nonexporters

both exporters and nonexporters. In addition, the growth in the size of exporters increased in the 1990s compared with that of nonexporters.

Figure 15.7 shows the average production-run length of Canadian manufacturing plants, normalized to 100 for multiproduct plants in 1973. The average production-run length increased over time. The average production-run length of manufacturing plants showed large fluctuations over business cycles. It declined during the recessions in the early 1980s and early 1990s. This is in contrast to the pattern of change for product diversification, which shows little cyclical change.

In figures 15.8 and 15.9, we plot the average production-run length of exporters and nonexporters. Figure 15.8 includes all plants and figure 15.9 includes only multiproduct plants. The average production-run length tended to be longer for exporters than for nonexporters. The length of production run increased over time, but the increase was much faster in the 1990s following the Canada–U.S. FTA. The increase in production-run length was faster at exporters than at nonexporters.

Table 15.1 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 to 1990 and 1990 to 1996. Product diversification showed a much larger decline in the 1990 to 1996 period

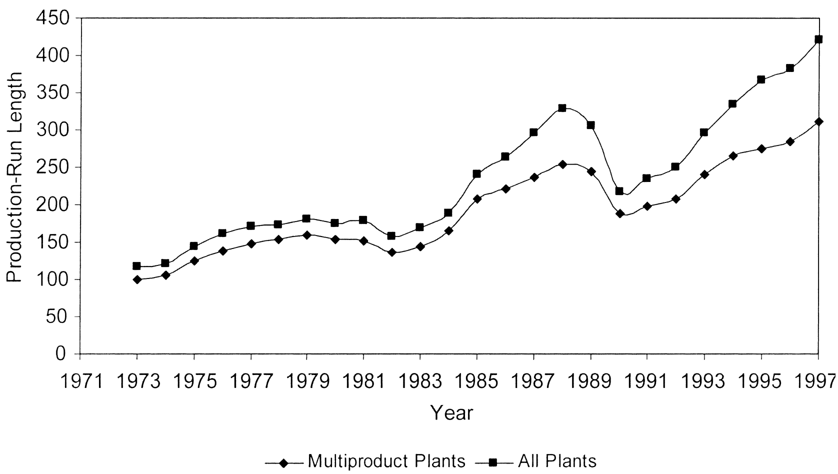

Fig. 15.7 Production-run length of manufacturing plants

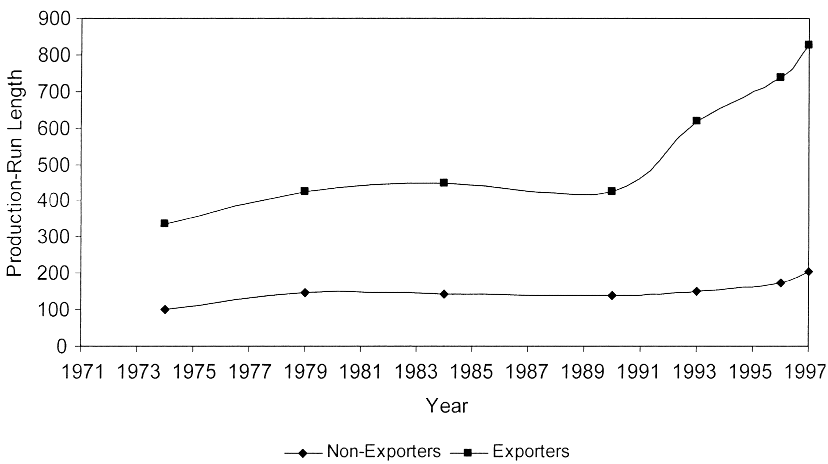

Fig. 15.8 Production-run length of all exporters and nonexporters

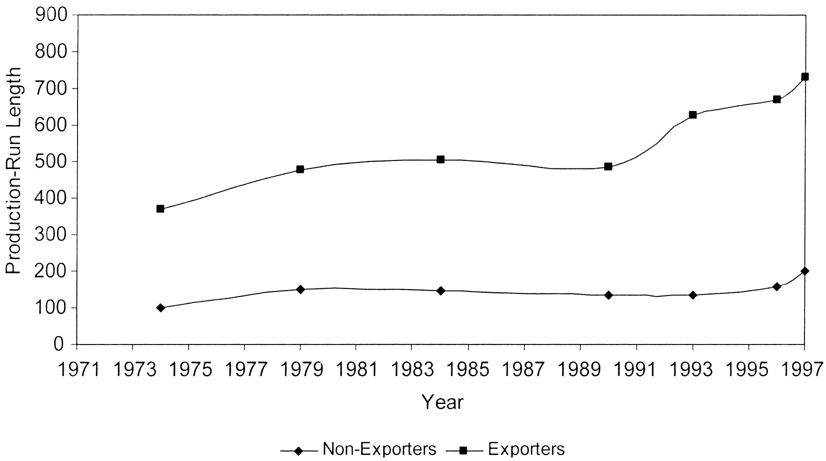

Fig. 15.9 Production-run length of multiproduct exporters and nonexporters

Table 15.1 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 length	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 length	0.0561	0.0667
Nonexporters		
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 length	0.0467	0.0551

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

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 to 1990 to 1990 to 1996 period. The rate of decline in product diversification index increased from 0.8 to 1.3 percent 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 15.1 also shows that product diversification (product counts and product diversification) declined at both exporters and nonexporters during the 1980s and 1990s. The rate of decline became much larger at nonexporters in the 1990s as tariff cuts deepened. There were increases in production-run length and plant size among both exporters and nonexporters, and the rate of growth showed a 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 nonexporters.

15.5.1 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 evidence in table 15.2 shows that the effect of tariff cuts on the number of products is different between exporters and nonexporters and be-

Table 15.2 Changes in the number of products

	(1)	(2)	(3)
Tariff changes	0.5737***	0.2650	0.5611***
	(2.95)	(1.52)	(2.90)
# of products in log	–0.0674***	–0.0676***	–0.0675***
	(–33.83)	(–33.92)	(–33.86)
Exporter	–0.0108***	–0.0044	–0.0103***
	(–3.37)	(–1.66)	(–3.22)
× tariff changes	–0.7451***	—	–0.6889***
	(–3.39)	—	(–3.07)
Relative plant size	0.0112***	0.0098***	0.0103***
	(12.59)	(8.88)	(9.24)
× tariff changes	—	–0.1721	–0.1130
	—	(–1.79)	(–1.16)
New exporter	0.0015	0.0013	0.0014
	(0.53)	(0.46)	(0.51)
Young plants	–0.0032	–0.0030	–0.0030
	(–1.11)	(–1.03)	(–1.03)
Dummy for period 1990–1996	–0.0085***	–0.0089***	–0.0086***
	(–4.10)	(–4.27)	(–4.12)
Observations	12,034	12,034	12,034
R^2	0.16	0.16	0.16

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 percent level.

tween large and smaller plants. The results in column (1) suggest that lower tariffs reduce the number of products produced by nonexporters. A one-percentage-point decline in tariffs is associated with a 0.6 percent decline in the number of products at nonexporters. But tariff cuts have little effect on the number of products at 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).

In column (2), we examine the difference in the effect of tariff cuts on the number of products produced between large and small plants. We find that tariff cuts reduce the number of products that a large plant produces. Our evidence suggests a 1 percentage point tariff cut is associated with a 5 percent decline in the number of products at the plants that are 1 standard deviation smaller than an average plant. But it does not have statistically significant effect on the number of products at the plants that are that are 1 standard deviation larger than an average plant.

The results in column (3) show that tariff cuts are associated with a larger rate of decline in the number of products at smaller nonexporters than at larger nonexporters. Overall, the evidence from nonexporting plants in table 15.2 is consistent with the prediction of our model.

But, the evidence from exporting plants appears to be at odds with our model. The evidence in table 15.2 shows that while exporters reduce product ranges relative to nonexporters, the decline in the number of products is not related to tariff cuts. For exporters, the effect of tariff cuts on the number of products is not significant at the 5 percent level. This suggests that once in the export markets, plants respond to forces other than tariff cuts, such as learning-by-exporting, the competitive force in the export market, and opportunities afforded with an access to larger markets (Baldwin and Gu 2004). For those exporting plants, additional tariff cuts may not be an important factor in the choice of product ranges.

Baldwin and Gu (2004) also find that exporters increase product specialization relative to nonexporters and interpret this as evidence that exporting raises productivity growth through increased product specification. Nevertheless, it should be noted that the sign on plant size is opposite to that on exporters and about the same magnitude, which implies that the effect of being an exporter exists for smaller plants but is unimportant for large plants.

The results in table 15.2 also show that larger plants also add new products in order to expand their market for their products.

15.5.2 Product Diversification

Our model predicts that lower tariff rates reduce the product diversification index of nonexporters. It has an ambiguous effect on the diversification index of existing and new exporters. For the 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 generate an ambiguous effect of tariff cuts on the product diversification index of exporters.

Table 15.3 presents empirical evidence on the effects of tariff cuts on the product diversification index of a plant. The results in column (1) suggest that the reduction in tariff rates is associated with a decline in the product diversification index of nonexporting plants. The effect of lower tariff rates on the product diversification index of exporting plants, which is 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 have little effect on the product diversification of exporters.

In column (2), 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. A 1 percentage point decline in tariff rates is associated with 0.2 percent decline in the plant diversification index for plants that are 1 standard deviation smaller than an average plant. The

Table 15.3 **Changes in product diversification index**

	(1)	(2)	(3)
Tariff changes	0.1281	0.0457	0.1189
	(1.88)	(0.76)	(1.75)
Product diversification index	–0.0725***	–0.0726***	–0.0726***
	(–38.72)	(–38.79)	(–38.77)
Exporter	–0.0029***	–0.0011	–0.0026**
	(–2.67)	(–1.24)	(–2.36)
× tariff changes	–0.2120***	—	–0.1704**
	(–2.80)	—	(–2.22)
Relative plant size	0.0034***	0.0027***	0.0028***
	(11.60)	(7.25)	(7.51)
× tariff changes	—	–0.0984***	–0.0838**
	—	(–2.98)	(–2.49)
New exporter	0.0005	0.0004	0.0005
	(0.53)	(0.45)	(0.48)
Young plants	–0.0007	–0.0005	–0.0006
	(–0.71)	(–0.54)	(–0.55)
Dummy for period 1990–1996	–0.0049***	–0.0050***	–0.0049***
	(–6.98)	(–7.13)	(–7.02)
Observations	12,037	12,037	12,037
R^2	0.20	0.20	0.20

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 percent level.

**Significant at the 5 percent level.

effect is significant at the 5 percent level. In contrast, the effect of the tariff cuts on the product diversification of plants that are 1 standard deviation larger is not statistically significant at the 5 percent level. 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 results in column (3) show that tariff cuts are associated with a larger rate of decline in the product diversification index at small nonexporters than at larger nonexporters. Overall, the results in table 15.3 are consistent with the prediction of our model regarding the effect of tariff cuts on product diversification.

The coefficient estimates on the export status variable suggest that exporters reduce product diversification relative to nonexporters, a finding that is consistent with the one in Baldwin and Gu (2004). Once more, this impact exists primarily for small exporters.

To examine the effect of tariff cuts on the product diversification of new exporters, we have introduced an interaction term of the variables for new exporters and tariff changes. The evidence suggests that the effect of tariff cuts on the product diversification of entrants to the export market is not significant at the 5 percent level. This is consistent with the model's prediction that tariff cuts have an ambiguous effect on the product diversification of the entrants to the export market relative to nonexporters.

15.5.3 Plant Size

Our model has implications for plant size. The decline in tariff barriers will reduce the size of nonexporting plants as these plants reduce the range of their product lines. But it has an ambiguous effect on the size of existing and new exporters. For those plants, the tariff reduction leads to an increase in export sales and an offsetting decline in domestic sales.

The results in table 15.4 provide empirical evidence that is consistent with our model's prediction about plant size. The coefficient on tariff changes in column (1) is positive and significant at the 1 percent level. Lower tariffs lead to a decline in the size of nonexporters. The effect of tariff changes on the 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 does not have a significant effect on the size of exporters.[14]

To examine the effect of tariff cuts on the size of new exporters, we have introduced an interaction term of the variables for tariff cuts and new exporters. We find that the tariff reduction does not have an effect on the size of new exporters.

14. 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.

Table 15.4 **Changes in plant size**

	(1)	(2)	(3)
Tariff changes	0.4688**	0.3706**	0.4984**
	(2.29)	(1.97)	(2.44)
Exporter	0.0185***	0.0199***	0.0174***
	(5.58)	(7.49)	(5.24)
× tariff changes	–0.1637	—	–0.2975
	(–0.70)	—	(–1.26)
Relative plant size	–0.0171***	–0.0153***	–0.0150***
	(–17.74)	(–12.15)	(–11.87)
× tariff changes	—	0.2445**	0.2699**
	—	(2.33)	(2.54)
New exporter	0.0195***	0.0196***	0.0196***
	(7.32)	(7.36)	(7.37)
Young plants	0.0175***	0.0170***	0.0170***
	(5.75)	(5.58)	(5.58)
Dummy for period 1990–1996	0.0033	0.0032	0.0034
	(1.53)	(1.51)	(1.57)
Observations	12,034	12,034	12,034
R^2	0.09	0.09	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 percent level.

**Significant at the 5 percent level.

The evidence in column (2) suggests that tariff cuts have more of a negative effect on the size of larger plants than on that of smaller plants. A 1 percentage point decline in tariff rates is associated with a 0.6 percent decline in the size of plants that are one standard deviation larger than an average plant. But the effect of tariff cuts on plant size is not significant at the 5 percent level for plants that are 1 standard deviation smaller than an average plant.

The evidence in column (3) suggests that the negative effect of tariff cuts on the size of nonexporters increase with plant size. The rate of decline in plant size as a result of tariff cuts is larger for larger nonexporters that for smaller nonexporters. While the tariff cut does not have a significant effect on the size of average exporters, the evidence in column (3) shows that it reduces the size of larger exporters.

The coefficients on the exporters and new exporter variables are positive and significant at the 5 percent level. The exporting plants increase their size relative to nonexporters. 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. A number of previous studies have examined the relationship between tariff barriers and plant size and found little evidence that tariff cuts increased plant size (Head and Ries

1999). The firm-based approach to models of trade used in this chapter 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 nonexporters.

15.5.4 Production-Run Length

Our model has implications for the length of production runs within individual producers. As tariff rates fall, the length of production runs will increase for existing and new exporters as a result of declines in product ranges and increases in the foreign sales of their products. For nonexporters, the length of production run will remain the same.

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.

Consistent with the model, the evidence in column (1) of table 15.5 suggests that tariff cuts do not have statistically significant effects on the production-run length of nonexporters. However, the evidence on the effect of tariff cuts on the production-run length of exporters is at odds with the model's prediction. The effect of tariff cuts on the production-run length of exporters, as calculated as the sum of the coefficients on the tariff change and exporter variables, is not significant at the 5 percent level. In addition, the effect of tariff cuts on the production-run length of new exporters is not found to be statistically significant. This suggests that the tariff cuts do not increase the production-run length of exporters as the model predicts.

While tariff reductions do not increase the production-run length of exporters and entrants to the export market, the evidence shows that those exporting plants increased the production-run length compared with nonexporters. We interpret this evidence as suggesting that plants, once in the export markets, do not consider additional tariff cuts as an important determinant in the choice of production-run length. For exporters and entrants to the export market, learning-by-exporting, competition in the export market and continued access to the export market are much more important factors in their production decision.

15.5.5 Discussions of the Results

In this section, we discuss two main empirical issues in our estimation. The first relates to our choice of regression specification and the second relates to possible sample selection bias due to our choice of the sample.

To estimate the effects of tariff cuts on product diversification, production-run length, and plant size, we have used an empirical specification that includes a lagged dependent variable as a control variable. If the lagged de-

Table 15.5 **Changes in production-run length**

	(1)	(2)	(3)
Tariff changes	–0.1415	0.0766	–0.0989
	(–0.53)	(0.32)	(–0.37)
Product run in log	–0.0633***	–0.0637***	–0.0637***
	(–26.30)	(–26.39)	(–26.36)
Exporter	0.0299***	0.0248***	0.0284***
	(7.07)	(7.14)	(6.69)
× tariff changes	0.5997**	—	0.4085
	(2.00)	—	(1.33)
Relative plant size	0.0351***	0.0386***	0.0382***
	(14.61)	(14.59)	(14.34)
× tariff changes	—	0.4203***	0.3854***
	—	(3.10)	(2.77)
New exporter	0.0184***	0.0187***	0.0186***
	(5.14)	(5.22)	(5.19)
Young plants	0.0196***	0.0188***	0.0188***
	(4.94)	(4.75)	(4.75)
Dummy for period 1990–1996	0.0179***	0.0183***	0.0181***
	(6.28)	(6.40)	(6.34)
Observations	12,034	12,034	12,034
R^2	0.15	0.15	0.15

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 percent level.

**Significant at the 5 percent level.

pendent variable is predetermined, the ordinary least squares (OLS) estimators are consistent. However, if the lagged dependent variable is correlated with error terms, the OLS estimation will yield a biased estimate of the coefficient on the lagged dependent variable. But it will yield consistent estimates of the coefficients on the variables of interest, such as tariff changes and plant export status.

To examine the robustness of our findings on the effects of tariff cuts, we have also estimated a specification that excludes the lagged dependent variable. The results are presented in table 15.6. Overall, the results are similar to those obtained using specifications that include the lagged dependent variable.

The sample for the estimation consists of the plants that produce more than one product in the initial period. This may introduce sample selection bias due to the exclusion of single-product plants.

To address the issue of sample selection bias, we have estimated the regression equation using a sample that also includes the single-product plants. As shown in table 15.7, the evidence from the full sample shows that tariff cuts reduce the product diversification and size of nonexporting

Table 15.6 Alternative estimates of the effect of tariff changes on product diversification, plant size, and production-run length

	Dependent variables			
	No. of products	Product div. index	Plant size	PR length
Tariff changes	0.6808***	0.1306	0.4984**	–0.1820
	(3.28)	(1.77)	(2.44)	(–0.66)
Exporter	–0.0093***	–0.0017	0.0174***	0.0266***
	(–2.74)	(–1.46)	(5.24)	(6.09)
× tariff changes	–0.8322***	–0.1844**	–0.2975	0.5329
	(–3.42)	(–2.21)	(–1.26)	(1.67)
Relative plant size	0.0054***	0.0016***	–0.0150***	–0.0204***
	(4.59)	(3.92)	(–11.87)	(–12.48)
× tariff changes	0.0355	–0.0382	0.2699**	0.2340
	(0.34)	(–1.06)	(2.54)	(1.63)
New exporter	0.0043	0.0009	0.0196***	0.0152***
	(1.48)	(0.89)	(7.37)	(4.09)
Young plants	0.0020	0.0003	0.0170***	0.0149***
	(0.66)	(0.31)	(5.58)	(3.66)
Dummy for period 1990–1996	–0.0055**	–0.0048***	0.0034	0.0089***
	(–2.50)	(–6.36)	(1.57)	(3.01)
Observations	12,034	12,034	12,034	12,034
R^2	0.05	0.05	0.09	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 percent level.

**Significant at the 5 percent level.

plants, and has no effect on the production-run length of those plants. Exporting plants reduce product diversification and increase production-run length and plant size, but those changes do not appear to be related to tariff cuts. Overall, these results are qualitatively similar to those obtained using the multi-product plant sample. But as the changes in product diversification are left-censored for single-product plants, the estimated effect of tariff changes on product diversification is lower than the estimated effect using the multi-product plant sample.

15.6 Conclusions

Microdata on business populations provide a rich picture of heterogeneity within firm populations. They provide new information on the variety of change going on within industries.

Initially, studies of change focused primarily on describing the nature of different groups—those that were gaining and losing market share, those that entered and exited versus incumbents, and those that gained and lost

Table 15.7 **The effect of tariff changes on product diversification, plant size and production-run length from a sample of all continuing plants**

	Dependent variables			
	No. of products	Product div. index	Plant size	PR length
Tariff changes	0.4743**	0.0875	0.7379***	0.2638
	(2.50)	(1.35)	(3.96)	(1.05)
Exporter	–0.0068**	–0.0015	0.0206**	0.0274***
	(–2.30)	(–1.47)	(7.16)	(7.10)
× tariff changes	–0.6165***	–0.1221	–0.4186	0.1970
	(–2.73)	(–1.63)	(–1.95)	(0.67)
Relative plant size	–0.0032***	–0.0010***	–0.0187***	–0.0155***
	(–3.30)	(–2.97)	(–14.58)	(–10.38)
× tariff changes	–0.0007	–0.0246	0.1402	0.1412
	(–0.01)	(–0.80)	(1.43)	(1.12)
New exporter	0.0047	0.0011	0.0238***	0.0190***
	(1.87)	(1.29)	(10.11)	(5.84)
Young plants	0.0143***	0.0039***	0.0206***	0.0063**
	(5.91)	(4.78)	(8.52)	(1.96)
Dummy for period 1990–1996	–0.0061***	–0.0042***	0.0027	0.0088***
	(–3.19)	(–6.73)	(1.44)	(3.45)
Observations	17,211	17,211	17,205	17,205
R^2	0.03	0.04	0.11	0.06

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 percent level.

**Significant at the 5 percent level.

relative productivity. The picture that these studies provided is one of heterogeneous populations, with different types of producers existing side by side.

Studies using business microdata have begun to outline the ramifications of heterogeneity in producer characteristics. For example, some members contribute more to productivity growth than others. Equally important, heterogeneous producers might be expected to respond differently to exogenous shocks.

This chapter has focused on one such response to outside shocks—the response of different manufacturers to trade liberalization. Others have focused on the reaction of industries as a whole to trade liberalization, treating industries as a homogeneous set of producers. In contrast, the approach adopted here has focused on developing a model of heterogeneous producers that differ in terms of costs and asking whether the reaction of producers to trade liberalization might be expected to differ in a systematic way.

To do so, we present a model that suggests that two groups of firms, distinguished here as nonexporters and exporters, would be expected to differ substantially in terms of their reaction to trade liberalization with respect to the number of products produced, product specialization, plant size, and, finally, the length of production-run. The stylized model predicts that tariff reductions should increase product specialization and decrease plant size in nonexporters. Its effect on specialization of existing exporters is ambiguous—though it is expected to have a positive effect on the length of production runs in exporters.

The empirical evidence on nonexporting plants provides broad support for the model. The evidence on exporting plants shows that exporters reduce product diversification, and increase production-run length and plant size, but those changes do not appear to be related to tariff cuts. Once in the export markets, plants respond to forces other than tariff cuts. Baldwin and Gu (2004) identified learning by exporting, competition in the export market, and access to the larger market as important factors in the production decision of exporters.

These findings support the need to think of producer populations as heterogeneous units whose reactions are likely to be diverse. They also stress the need to be cautious about generalizations based on representative plants or firms.

While the chapter helps to shed light on the reaction to tariff changes, it also suggests that other changes were taking place within the population of manufacturers. Testing stylized models is difficult when those models have difficulty in taking into account changing circumstances. While our findings on the effects of tariff changes accord broadly with expectations, other results suggest the need to expand our research. In particular, the reaction of exporters relative to nonexporters suggests that the underlying technology was not staying constant. Small exporters were more likely to specialize or reduce diversity than large exporters. Similarly, small exporters were more likely to increase their plant size. This suggests that the technology conditions of smaller plants that resulted in increased diversification—possibly to take advantage of scale economies—changed over the time period studied.

One explanation for this is that the attraction of scale changed across plant size classes—that is, the advantages of incremental improvements in size increased for larger plants relative to smaller plants. This suggests a shift in the nature of technologies or capital intensity between small and large plants in favor of large plants that led to increased opportunities to exploit scale economies via diversification in the 1990s.

In related work, we have found evidence of this occurring. Baldwin, Rama, and Sabourin (1999) report that the gap in advanced technology use between small and large plants increased in the 1990s. Baldwin and Dhaliwahl (2001) report that output per worker in larger plants has increased relative to smaller plants throughout the period. Baldwin, Jarmin, and Tang (2002) report the same phenomenon can be found in both Canada and the

United States. These studies suggest that the degree of scope economies that provide the incentive to increase diversification probably increased in large plants at the same time as trade liberalization was occurring.

Our study has also shown that there is a dynamic aspect to the growth of producers that our analytical models have not fully captured. In our models, producers differ at a point in time by their level of unit costs. But this distribution is subject to change. Just as producers grow by increasing their capital intensity, they also do so by learning how to combine more than one product within an establishment to take advantage of scale and scope economies. Both transitions require a learning process that ultimately needs to be incorporated into a more dynamic framework.

References

Baldwin, J. R. 1995. *The dynamics of industrial competition.* Cambridge: Cambridge University Press.

Baldwin, J. R., D. Beckstead, and R. E. Caves. 2001. Changes in diversification of Canadian manufacturing firms and plants (1973–1997): A move to specialization. Analytical Studies Branch Research Paper Series no. 179. Ottawa: Statistics Canada.

Baldwin, J. R., R. E. Caves, and W. Gu. 2004. Responses to trade liberalization: Changes in product diversification in foreign and domestic controlled plants. In *Governance, multinationals and growth*, ed. L. Eden and W. Dobson, 206–46. Northampton, MA: Edward Elgar Publishing.

Baldwin, J. R., and N. Dhaliwal. 2001. Heterogeneity in labour productivity growth in manufacturing: Differences between domestic and foreign-controlled establishments. In *Productivity Growth in Canada*. Ottawa: Statistics Canada.

Baldwin, J. R., and P. K. Gorecki. 1983. Trade, tariffs, relative plant scale in Canadian manufacturing industries, 1976–79. Discussion Paper no. 232. Ottawa: Economic Council of Canada.

———. 1986. *The role of scale in Canada-U.S. productivity differences in the manufacturing sector: 1970–79.* Toronto: University of Toronto Press.

Baldwin, J. R., and W. Gu. 2003. Participation in export markets and productivity performance in Canadian manufacturing. *Canadian Journal of Economics* 36 (3): 634–57.

———. 2004. Trade liberalization: Export-market participation, productivity growth, and innovation. *Oxford Review of Economic Policy* 20 (3): 372–92.

Baldwin, J. R., R. S. Jarmin, and J. Tang. 2002. Small North American producers give ground in the 1990s. *Journal of Small Business Economics* 23 (4): 349–61.

Baldwin, J. R., E. Rama, and D. Sabourin. 1999. Growth of advanced technology use in Canadian manufacturing during the 1990s. Research Paper no. 105, Analytical Studies Branch. Ottawa: Statistics Canada.

Bernard, A. B., J. Eaton, B. J. Jensen, and S. Kortum. 2003. Plants and productivity in international trade. *American Economic Review* 93 (4): 1268–90.

Bernard, A. B., J. B. Jensen, and P. K. Schott. 2003. Falling trade costs, heterogeneous firms, and industry dynamics. NBER Working Paper no. 9639. Cambridge, MA: National Bureau of Economic Research, March.

Campbell, J. R., and H. A. Hopenhayn. 2002. Market size matters. NBER Working Paper no. 9113. Cambridge, MA: National Bureau of Economic Research, July.
Caves, R. E. 1975. *Diversification, foreign investment, and scale in North American manufacturing industries.* Ottawa: Economic Council of Canada.
Daly, D. J., B. A. Keys, and E. J. Spence. 1968. Scale and specialization in Canadian manufacturing. Economic Council Staff Study no. 21. Ottawa: Queen's Printer.
Economic Council of Canada. 1967. *Fourth annual review: The Canadian economy from the 1960s to the 1970s*. Ottawa: Queen's Printer.
———. 1975. *Looking outward.* Ottawa: Information Canada.
Greenhut, M. L., G. Norman, and C.-S. Hung. 1987. *The economics of imperfect competition: A spatial approach.* Cambridge: Cambridge University Press.
Harris, R. 1984. Applied general equilibrium analysis of small open economies with scale economies and imperfect competition. *American Economic Review* 74 (5): 1016–32.
Head, K., and J. Ries. 1999. Rationalization effects of tariff reductions. *Journal of International Economics* 47:295–320.
Helpman, E., and P. Krugman. 1989. *Trade policy and market structure.* Cambridge, MA: MIT Press.
Helpman, E., M. J. Melitz, and S. R. Yeaple. 2004. Export versus FDI with heterogeneous firms. *American Economic Review* 94 (10): 300–16.
Jacquemin, A. P., and C. H. Berry. 1979. Entropy measures of corporate growth. *The Journal of Industrial Economics* 27:359–69.
Melitz, M. J. 2003. The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica* 71 (6): 1695–1725.
Melitz, M. J., and G. I. P. Ottaviano. 2005. Market size, trade, and productivity. NBER Working Paper no. 11393. Cambridge, MA: National Bureau of Economic Research, May.
Ottaviano, G. I. P., T. Tabuchi, and J.-F. Thisse. 2002. Agglomeration and trade revisited. *International Economic Review* 43 (2): 409–35.
Ottaviano, G. I. P., and J.-F. Thisse. 1999. Monopolistic competition, multiproduct firms, and optimum product diversity. CORE Discussion Paper no. 9919.
Roberts, M., and J. Tybout, eds. 1996. *Industrial evolution in developing countries.* New York: Oxford University Press.
Royal Commission on Corporate Concentration. 1978. *Report.* Ottawa: Minister of Supply and Services Canada.
Safarian, E. 1966. *Foreign ownership in Canadian industry.* Toronto: McGraw-Hill of Canada.
Scherer, F. M., A. Beckenstein, E. Kaufer, R. D. Murphy, and F. Bougeon-Maassen. 1975. *The economics of multi-plant operation.* Cambridge, MA: Harvard University Press.
Syverson, C. 2003. Product substitutability and productivity dispersion. NBER Working Paper no. 10049. Cambridge, MA: National Bureau of Economic Research, September.
Trefler, D. 2004. The long and short of the Canada-U.S. Free Trade Agreement. *The American Economic Review* 94 (4): 870–95.
Tybout, J. 2003. Plant and firm-level evidence on new trade theories. In *Handbook of International Trade* ed. J. Harrigan and K. E. Choi, 388–415. Oxford: Basil-Blackwell.
Yeaple, S. R. 2005. A simple model of firm heterogeneity, international trade, and wages. *Journal of International Economics* 65 (1): 1–20.