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Linda Hunter

James R. Markusen

Thomas F. Rutherford

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ABSTRACT

A theoretical model is developed and applied to the North American auto industry, motivated by the possibility of US-Mexico free trade. Special features of the model include (1) significant scale economies at the plant level, (2) imperfect competition among firms, (3) joint ownership of plants and production coordination across plants by each firm, (4) an (initial) ability of firms to segment markets, (5) a separate treatment of non-resident firms in determining oligopolistic markups. Using an applied GE model, we find that (A) the gains to Mexico are significant and the effects on the US and Canada are essentially zero following North American free trade if firms can continue to segment markets; (B) Because of the way that the North American multinationals determine markups, increased imports from Mexico do not result in a rationalization of US and Canadian production in the way it should if firms were strictly national. (C) Genuinely free trade for consumers (integrated markets) results in large gains for Mexico as the Mexican industry is forced to rationalize, while losses to the US and Canada are very small.

Linda Hunter
Department of Economics
San Diego State University

James R. Markusen
Department of Economics
University of Colorado

Thomas F. Rutherford
Department of Economics
University of Western Ontario

1. Introduction

International trade theory now includes, as one of its principal positive and normative branches, a substantial theoretical literature on trade and trade policy under conditions of increasing returns to scale and imperfect competition. Several of the many possible approaches to modelling increasing-returns technologies and imperfectly competitive behavior have in turn been embedded in applied general-equilibrium models (e.g., Harris (1984), Harris and Cox (1984), Smith and Venables (1988), Brown (1989), Brown and Stern (1989), Markusen and Wigle (1989), and Wigle (1988)). A cynical view of both the theoretical and the applied literature is that "anything can happen" depending on the assumptions one chooses. A more constructive statement is that we must be careful to choose the empirically-relevant assumptions if we are to get the policy conclusions correct. Among these choices are the nature of conjectures (Eaton and Grossman (1985)), free entry versus fixed numbers of firms (Venables (1985) and Horstmann and Markusen (1986)), and segmented versus integrated markets (Markusen and Venables (1988)).

One key feature of increasing-returns, imperfectly-competitive industries that has received little attention is the joint ownership of production plants in different countries by multinational firms (the Canadian manufacturing sector is about 60% foreign owed). Models have been constructed to endogenize the existence of multinationals (e.g., Markusen (1984)), but little is known about how multinational ownership affects trade liberalization scenarios. To the best of our knowledge, this issue has not been touched in applied GE analysis.

The purpose of this paper is to develop an analysis of trade liberalization in the presence of trans-border price and output coordination by multinational firms. This analysis is then embedded in an applied general-equilibrium model of the North American auto industry, motivated by the possible reorganization that US-Mexican free trade might bring to that industry. The model will attempt to capture key industrial-organization and institutional features of that industry, and will numerically solve for the impact of alternative trade-liberalization schemes on the pattern of production and trade within North American, and between North America and the rest of the world (ROW).

The applied general-equilibrium model consist of four regions: Canada (CAN), the United States (USA), Mexico (MEX), the rest of the world (ROW). The level of aggregation in non-auto sectors is very high in order that our modelling efforts can be concentrated on the details of the auto industry. There are two goods in the model, each homogeneous across regions. Good Y is produced with constant returns to scale by a competitive industry. Good X is autos, produced in each region by an imperfectly competitive industry with increasing returns to scale. Factor markets are similarly highly simplified, with one factor mobile between sectors and one factor specific to the Y sector.

Autos (X) are produced with a constant marginal cost (for given factor prices) and a fixed cost. This technology yields a downward sloping average cost curve that closely resembles actual engineering estimates. The cost function can be calibrated by picking the ratio of average to marginal cost consistent with the engineering data given the level of firm outputs in each country.

Selecting assumptions regarding oligopolistic behavior among firms is difficult, particularly since economic theory gives us little guide in this matter. One alternative is to pick a conjectural variation (e.g., Cournot) and then calibrate the cost function to the resulting markups. Our modelling framework allows for both this alternative and for the converse procedure just mentioned: calibrating the conjecture from the cost function. In general, we have more confidence in the latter procedure since engineering science gives us reliable estimates of costs while economic science gives us little guide as to small-numbers behavior.

An important feature of the auto industry is the pattern of plant ownership. Plants producing in Canada and Mexico and exporting to the United States are owned by the same firms that produce and sell in the US. We assume that these firms jointly optimize within North America, so that markups on export sales from Mexico and Canada to the US are set jointly with the US markup. In summary, North American producers compete among themselves, but an individual firm jointly optimizes production and exports across plants in the three North American regions.

Imports into North America from ROW are more of a problem, since some are from firms also producing in North America while much of that trade is by firms which do not have North American plants. We assume that these ROW imports are entirely from the latter type of firms and hence compete with North American production.

A final important institutional aspect relates to the nature of trade liberalization. One possibility, adopted in the original US-Canada Auto Pact, is that producers are permitted free trade in autos but consumers are not. This allows producers to continue to price discriminate across borders even with zero tariffs and transport costs. A second option, genuinely free trade for consumers, places arbitrage constraints (which may or may not bind) on firms such that the price plus transport cost in one country cannot exceed the price in its free-trade partner. We have designed our model to calculate both possibilities; that is, to calculate free-trade scenarios with and without the arbitrage constraints imposed.

Several interesting results emerge. First, Mexican auto production and exports get a substantial boost from bilateral (US-Mexico) free trade (23% and 62% respectively) despite the initial low level of US protection (3.8%). Relative to this small tariff, the Mexican welfare increase is significant at 4.0% of initial auto production (at factor cost) or 0.13% of GNP. Losses of auto production and in welfare in Canada and the US are far smaller: both countries reducing auto production by less than 1%, and welfare losses negligible (.003% of GNP) Second, trilateral (US-Mexico-Canada) free trade produces no changes; that is, the Canadian import tariff on Mexican autos is non-binding.

Third, increased US imports from Mexico are slightly more at the expense of ROW imports (-1.2%) than at the expense of US (-0.7%) or Canadian (-0.7%) production.

Fourth, the fact that increased imports from Mexico are products of the same firms that produce in the US, these imports do not lead the North American firms to perceive an increased demand elasticity as they would if they were strictly national firms. In the latter case the firms lose market share while in the multinational case considered here they do not. The theoretical implication of this result is that the increased imports have no rationalization effect on US production (as suggested by the Trade-IO literature), and indeed numerical results verify that US output per firm falls slightly.

Fifth, in the bilateral and trilateral scenarios, the Mexican relative price of autos to the composite Y is significantly higher than the corresponding price ratio in the US and so the arbitrage constraint is binding (independent price data corresponds closely to the calibrated relative prices as we shall note below). When this constraint is imposed in an alternative integrated markets scenario (consumers are free to arbitrage cars), some very interesting results occur. No imports into Mexico actually occur, but the Mexican industry is forced into significant rationalization when the domestic markup is lowered to meet the arbitrage constraint. There is next exit from the Mexican auto industry together with a significant increase in total Mexican auto production (45%) over the benchmark. Together these results imply an even stronger increase in output per firm (154%) and a significant lowering of average cost. Mexican exports to the US increase by a large percentage (106%), and Mexican welfare rises by 24.6% of initial production (0.80% of GDP) percent over the benchmark, which is an extremely high number for such a small sector (recall that we are not considering liberalization in any other sectors). US and Canadian losses remain quite small, about 1.9% of auto production and about 0.01% of welfare.

We thus have the very interesting result than the lowering of Mexican protection for consumers results in (A) no imports, (B) an increase in production, (C) a large increase in exports, and (D) a large (given the size of the sector) increase in welfare.

Finally, the common ownership of plants in the three North American countries reduces and indeed eliminates the rationalization effect on US industry predicted by the Trade-IO literature when markets become integrated. The multinationals price to avoid arbitrage, and this involves a combination of raising the US markup and lowering the Mexican markup. This actually leads to a fall in the output per firm in the US relative to both the segmented markets case and the benchmark.

2. The General Equilibrium Model

The Y sector in each of the four regions (CAN, USA, MEX, and ROW) produces a composite commodity, homogenous across regions, from "labor" (L) and a sector-specific factor "resources" (R). Both factors bear no relationship to empirical entities of the same name. Y is specified as Cobb-Douglas, but calibration of the factor shares permits us to specify any arbitrary (local) elasticity of factor supply to X.

(1) $$Y = G(L_y, R) = L_y^{\alpha} R^{1-\alpha}$$

Production of X, the auto sector, requires a fixed cost in units of labor F and a constant marginal cost in units of labor c. The labor required by the ith firm in the X sector is given by

(2) $$L_{ix} = c*X_i + F$$

Let n denote the number of firms active in a country, and assume identical cost functions across firms. Total labor requirements for the X sector are simply

(3) $$L_x = n(c*X_i + F) \qquad \bar{L} = L_x + L_y + L_t$$

The second equation of (3) gives the labor supply adding up constraint, with L_t denoting the labor used in transportation services (discussed below).

Let w denote the wage rate in terms of the composite good Y. The elasticity of scale (ϵ) is given by the ratio of the average to the marginal cost of producing X. ϵ decreases with plant scale.

(4) $$\epsilon \equiv AC/MC = w(c + F/X_i)/(w*c) = 1 + F/(c*X_i)$$

Good engineering estimates, along with data on outputs by model type and by firm, allow us to estimate ϵ for the three North American regions. We also have reasonably good data giving the relative price of cars to the composite price index in the three North American countries. We unfortunately do not have data on marginal cost. The procedure that we follow is to arbitrarily set marginal cost for the US (and ROW), make guesses as to the marginal cost in Mexico and Canada, and then proceed according to the following steps. When we get to equation (19) below, we will see that consumer price ratios for Mexico and Canada are implied. The initial estimates of marginal cost are then adjusted until the resulting domestic price ratios in (19) match the price data.

Given ϵ, estimates of marginal cost, and data on outputs, we then calibrate back to solve for the level of fixed costs, F.

(5) $$F = (\epsilon - 1)(c * X_i)$$

The wage rate in terms of Y in a country is given by the marginal product of labor in the production of Y.

(6) $$w = \alpha L_y^{\alpha-1} R^{1-\alpha}$$

Using (1) and (6), the elasticity of the wage rate with respect to labor demand in the X sector (holding transport demand constant) is then given by

(7) $$\frac{L_x}{w}\frac{\partial w}{\partial L_x} = -\frac{L_x}{L_y}\frac{L_y}{w}\frac{\partial w}{\partial L_y} = \frac{L_x}{L_y}\frac{\alpha(1-\alpha)L_y^{\alpha-2}R^{1-\alpha}}{\alpha L_y^{\alpha-2}R^{1-\alpha}}$$

This simplifies to

(8) $$\frac{L_x}{w}\frac{\partial w}{\partial L_x} = \frac{L_x}{L_y}(1-\alpha) = \frac{L_x}{L_y} * \theta_{ry} \equiv \omega$$

where θ_{ry} is the value share of resources in Y output, and ω denotes the wage elasticity of

X sector labor demand. ω is a general-equilibrium elasticity, that tells how much the "wage" or more appropriately marginal cost (w*c) in the X sector, must rise as output expands. A higher value of ω will tend to choke off expansion of the X sector (or reduce contraction) in a country following trade liberalization. ω is unfortunately a major empirical unknown and will be the subject of sensitivity runs. Choose units such that w = 1 initially. Using (8), (3), and recalling that Y is Cobb-Douglas, (8) can be rewritten as

$$(9) \qquad \omega = \theta_{ry} \frac{(c*X_i + F)n}{(1-\theta_{ry})Y}$$

Inverting this equation gives us θ_{ry} as a function of the other variables.

$$(10) \qquad \theta_{ry} = \frac{\omega * Y}{(c*X_i + F)n + \omega * Y}$$

In our calibrating procedure, Y, X_i, c, ω, ϵ and n are given in the benchmark data set. F is then calculated from these as described above. Equation (10) then allow us to infer back to θ_{ry} which is used to calibrated Y and the factor supplies.

Let superscript n denote a North American owned firm and let r denote a ROW firm, the latter assumed to have no plants in the three North American regions while the former is assumed to have plants in all three North American regions. Let subscripts c, u, m, and r denote the four regions. Let t_{ij} denote the tariff rate on exports from region i to region j and let τ_{ij} denote the transport cost from region i to region j. t is ad valorem while τ is specific (in units of labor). Consider for example the profits earned by a North American firm in the US market. C_u denotes the total sales (not production) by all firms in the US, while C_u^n and C_u^r denote the sales by NA and ROW firms respectively in the US market ($C_u = C_u^n + C_u^r$). X_u^n denotes the sales (i.e., production plus imports from affiliated plants) in the US by an individual NA firm. Finally, X^n_{ij} will denote the shipments of an individual NA firm from region i to region j ($\Sigma_i X^n_{ij} = X^n_j$). Choose units such that w = 1 in all regions initially. Profits from an NA firm derived from US sales are then given by

$$(11) \qquad \pi_{un} = p_u(C_u)X^n_u - \sum_i ((1 + t_{iu})(c_i + \tau_{iu})X^n_{iu}) - F_u \qquad i = (c,u,m)$$

The firm's optimal markup rule for production in the US and sold in the US is given by the partial derivative of (11) with respect to X^n_{uu}.

$$(12) \qquad \frac{\partial \pi_{un}}{\partial X^n_{uu}} = p_u + X^n_u \frac{\partial p_u}{\partial C_u} \frac{\partial C_u}{\partial X^n_{uu}} - c_u = 0 \qquad (t_{ii} = \tau_{ii} = 0)$$

By multiplying and dividing by $p_u * C^n_u * C_u$ we can transform (12) as follows.

$$(13) \qquad p_u + p_u \frac{X^n_u}{C^n_u} \left[\frac{C^n_u}{C_u}\right] \left[\frac{C_u}{p_u} \frac{\partial p_u}{\partial C_u}\right] \frac{\partial C_u}{\partial X^n_{uu}} = p_u(1 + \sigma_u(s^n_u / n^n_u)/\eta_u) = c_u;$$

$$\sigma_u \equiv \frac{\partial C_u}{\partial X^n_{uu}} \qquad \eta_u \equiv \frac{p_u}{C_u}\frac{\partial C_u}{\partial p_u} \qquad s^n_u \equiv \frac{C^n_u}{C_u} \qquad n^n_u = \frac{C^n_u}{X^n_u}$$

σ_u gives the NA firm's "conjecture" as to how much total supply in the US will change in response to its own change in supply. η is the Marshallian market price elasticity of demand, and is negative. s^n_u is the share of NA firms in the total sales in the US, and n^n_u is the number of NA firms producing in the US. The markup formula given in equation (13) is equivalent to Cournot if $\sigma = 1$. Larger values of σ indicate a market that is more collusive than Cournot.

The form of the markup in equation (13) takes the usual form of a quantity subtracted off of the consumer price. For computational purposes, it is more convenient for us to specify the markup as an ad valorem addition to marginal cost. We will denote such markups as m_i^n for NA firms and m_i^r for ROW firms selling in market i. These markups thus take the form $p_i = (1 + m_i^n)c_i$. Our programming converts the price-based markup formulas of equation (13) to these cost-based markups.

Consider serving one market (j) from multiple plants (i,j) under the ownership of a single firm. The first-order conditions for (12) with respect to X_{iu}^n (i=c,m) simply replace c_u with $(1+t_{iu})(c_i+\tau_{iu})$. We assume that σ_u is the same regardless of the source of the firm's supply. The present equivalents of (12) and (13) then show that the optimal plan involves equating the marginal cost in region j to the "CIF" delivered marginal cost from i: $(1 + t_{ij})(c_i + \tau_{ij})$.

$$(14) \qquad p_j = (1 + m_j^n)(1 + t_{ij})(c_i + \tau_{ij}) = (1 + m_j^n)c_j$$

An NA firm's imports from Canada or Mexico into the USA receive the same markup as US production sold in the US.

Our model assumes free entry of firms or plants until profits are zero. For the NA firms (possibly) operating plants in all three NA regions, the sum of markup revenues must then be equal to fixed costs. This is given in matrix form by

$$(15) \qquad [\ (1 + t_{ij})(c_i + \tau_{ij})X_{ij}^n\ ] \begin{bmatrix} m_c^n \\ m_u^n \\ m_m^n \end{bmatrix} = \begin{bmatrix} F_c \\ F_u \\ F_m \end{bmatrix} \qquad (i,j) = (c,u,m)$$

But the joint maximization by plants across NA borders just discussed implies that (15) simplifies to

$$(16) \qquad [\ c_j * X_{ij}^n\ ] \begin{bmatrix} m_c^n \\ m_u^n \\ m_m^n \end{bmatrix} = \begin{bmatrix} F_c \\ F_u \\ F_m \end{bmatrix}$$

Our preliminary program that calibrates the model solves this system of three simultaneous equations in order to obtain the values of m_i^n consistent with the benchmark data. Since it is difficult to say how many ROW firms are relevant, ROW firms are simply assumed to be Cournot ($\sigma = 1$) and fixed costs in ROW are inferred from this markup rule. Given that we have solve for m_i^n for the NA firms from the cost and output data, we then work backwards using the markup formula in (13) to calibrate σ. From (13) and the definition of m_i we have

$$(17) \qquad 1 + \sigma_i (s_i^n / n_i^n) / \eta_i = (1 + m_i^n)^{-1}$$

Cobb-Douglas utility functions give us $\eta = -1$, and all the other variable in (17) are known at this point. The conjecture parameter is thus calculated by rearranging (17).

$$(18) \qquad \sigma_i = -\frac{\eta_i (n_i^n / s_i^n) m_i^n}{1 + m_i^n}$$

Given that we have the marginal costs in each region and the markups by both ROW and NA firm in all regions where they are active, consumer prices in each region are given simply as

$$(19) \qquad p_i = (1 + m_i^n) c_i$$

At this point, the relative consumer prices in the US, Mexico, and Canada are compared to our data on these prices. The initial marginal costs in Canada an Mexico are then adjusted, the entire model recalibrated, and a new set of consumer prices generated until the data and the values obtained by the benchmarking procedure converge. Once this is completed, (19) allows us to calculate transport costs on the active trade links using (14).

$$(20) \qquad \tau_{ij} = p_j[(1 + t_{ij})(1 + m_j^n)]^{-1} - c_i$$

This completes the discussion of the theory and the calibration proceedure for calculating a world general-equilibrium solution when firms can price discriminate among markets. But whether or not this is the proper approach depends on the nature of a free-trade agreement as discussed in the introduction. It may be that in a free-trade solution, some arbitrage constraint is not satisfied, and thus genuinely free trade for consumers will lead to a different outcome. This is precisely the case in out empirical work developed below, in that Mexico, in spite of being an exporter of cars, actually has a relatively high consumer price for cars in (discriminating) free trade.

There exists some theoretical uncertainty or rather arbitrariness as to how we should model market integration (arbitrage constraints), a problem that confronted Horstmann and Markusen (1986) and Markusen and Venables (1988). In our case it is more difficult with firms jointly optimizing across plants. For example, if firms "correctly" endogenize the effect of arbitrage on prices, they will be contradicting the assumption of Nash behavior used in other aspects of the model.

In this paper, we will essentially take the an approach similar to Horstmann and Markusen (1986) and Markusen and Venables (1988), which will be described in the context of US-Mexican trade when the arbitrage constraint from the US to Mexico is binding. We assume that a Mexican plant views the responses of the outputs of other firms according to the parameter σ_m, but correctly endogenizes arbitrage by consumers: i.e., if the plant reduces Mexican sales by one unit, consumers will import from the US until the arbitrage constraint is again satisfied. The key result is intuitive: the multinational firm does not want US production supplied to Mexico, because that results in some of the Mexican sales originating from high cost US production rather than from low cost Mexican production. It is optimal to expand Mexican output and sales (and/or reduce US output and sales) up to the point where the arbitrage constraint is just binding and no imports from the US occur.

For clarity, assume that tariffs are zero and that a firm has plants only in the US and Mexico. Assume also that an arbitrage constraint is binding: $p_u + \tau_{um} = p_m$. Using the notation developed above, the firm's programming problem is given by

$$(21) \qquad Maximize\ \pi_n = p_u(C_u)X_u^n - \sum_i (c_i + \tau_{iu})X_{iu}^n + p_m(C_m)X_m^n - \sum_i (c_i + \tau_{im})X_{im}^n - (F_u + F_m) + \lambda(p_u + \tau_{um} - p_m) \qquad i = u, m$$

The first order conditions for X_{uu}^n, X_{um}^n, X_{mm}^n, X_{mu}^n respectively are as follows.

$$(22) \qquad p_u + X_u^n p_u' \sigma_u - c_u + \lambda p_u' \sigma_u \leq 0 \qquad (X_{uu}^n)$$

$$(23) \qquad p_m + X_m^n p_m' \sigma_m - (c_u + \tau_{um}) - \lambda p_m' \sigma_m \leq 0 \qquad (X_{um}^n)$$

$$(24) \qquad p_m + X_m^n p_m' \sigma_m - c_m - \lambda p_m' \sigma_m \leq 0 \qquad (X_{mm}^n)$$

$$(25) \qquad p_u + X_u^n p_u' \sigma_u - (c_m + \tau_{mu}) + \lambda p_u' \sigma_u \leq 0 \qquad (X_{mu}^n)$$

From equations (23) and (24), we see the result just asserted: $X_{um}^n = 0$ given that $c_m < c_u$ at the equilibrium. The firm does not want to supply Mexico from the US. From equations (22) and (23), we again get the result that $c_u = c_m + \tau_{mu}$, or alternatively that

Mexican exports to the US market carry the US markup.

Multiply (24) through by $(p_u'\sigma_u)/(p_m'\sigma_m)$. (24) becomes

$$(26)\qquad [p_m + X^n_m p_m' \sigma_m - c_m]ß - \lambda p_u' \sigma_u = 0 \qquad ß \equiv \frac{(p_u'\sigma_u)}{(p_m'\sigma_m)} = \frac{\sigma_u p_u C_m \eta_m}{\sigma_m p_m C_u \eta_u} = \frac{\sigma_u p_u C_m}{\sigma_m p_m C_u}$$

ß is interpreted as the increase in X^n_{mm} necessary following a unit increase in X^n_{uu} in order to prevent arbitrage: $dX^n_{mm} = ßdX^n_{uu}$. The final equation of (26) exploits Cobb-Douglas demand, and gives a very simple formula for computing ß.

Denote the quantity in brackets times ß in (26) as γ, and note from our previous definition of m^n in (13) and (17) that we can write this as

$$(27)\qquad \gamma \equiv [p_m + X^n_m p_m' \sigma_m - c_m]ß = [p_m(1 + m^n_m)^{-1} - c_m]ß$$

Equation (27) is interpreted as the change in profits from the Mexican operation, following a unit change in supply to the US market (since Mexican supply must increase to preserve zero arbitrage). The firm's optimal US supply must take this change into account. Note that we expect γ to be negative. With Mexican supply increased to prevent arbitrage, marginal revenue (with zero imports) is less than marginal cost. Now substitute (26) into (22).

$$(28)\qquad p_u + X^n_u p_u' \sigma_u + \gamma - c_u = 0$$

With $\gamma < 0$, the US markup will be larger, ceteris paribus, than when the firm can discriminate. The burden of preventing arbitrage is shared between a US price increase and a Mexican price decrease (i.e., the negative effect of increased US output on Mexican profits is endogenized). Note from the formula for ß in (26) that γ becomes small as the size of the Mexican market becomes small relative to the US market.

Using the notation of (13) and (17), (28) gives us the new US markup equation.

(29) $$(1 + \sigma_u(s_u^n/n_u^n)/\eta_u + \gamma/p_u) = (1 + m_u^n)^{-1}$$

To compute the integrated markets solution, five equations are solved simultaneously with the rest of the general equilibrium system. Two equations are added for ß (defined in (26)), and γ (27), while (17) is retain for defining m_m^n, the latter used in computing γ in (27). Benchmark values of σ_m and σ_u are also retained. A fourth equation (29) gives the US markup rule as just noted. The final additional equation (inequality) bounds the markup of NA firms in Mexico such that the Mexican price does not exceed the US price plus the transport cost. Letting m_m^k refer to the actual Mexican markup, this constraint is given by

(30) $$(1 + m_m^k)c_m \leq (1 + m_u^n)c_u + \tau_{um}$$

If this constraint is not binding, then the markup m_m^n continues to be calculated from (17). Regardless of whether or not the arbitrage constraint in (21) is binding, the markup rule ensures that no US cars are arbitraged to Mexico. Note that this is intuitively optimal for the firm because, as noted above, arbitrage would imply that the Mexican market was being supplied by costly US production rather than by inexpensive Mexican production. The intuition behind the increased (ceteris paribus) US markup is that part of the optimal response to the "threat" of arbitrage from the US to Mexico is to raise the US price as well as to lower the Mexican price.

3. The Applied General-Equilibrium Model

The model of the previous section appears to be very simple, with two homogeneous goods, four countries, two factors, no taxes other than tariffs on cars, and a single consumer in each country. In fact, the industrial-organization aspects of the model make its specification considerably more complicated than a simple counting of these dimensions would suggest. A second problem relates to the need for a robust solution algorithm in light of the many side constraints, including inequality constraints. Some activities such as certain trade links are slack in the benchmark, but may not be in the counterfactual experiments, so we need to be able to calculate corner solutions for some variables. This latter set of difficulties is easily handled using Rutherford's software, MPS/GE (mathematical programming system, general equilibrium). The non-linear complementarity formulation of MPS/GE easily handles the side constraints, inequalities, and corner solutions.

The dimensionality of the model is much greater than it appears at first glance for several reasons. First, MPS/GE requires the specification of constant returns in all activities, so the production of cars in each region requires two activities: one produces fixed costs, and the other produces actual output. Second, two side constraints are needed in each country to determine the markup rule, and there are different markups for NA and ROW firms. The markup is then specified as an endogenous "tax" on inputs (marginal cost). Third, a dummy consumer called ENTRE is specified in each country; this consumer receives the markup revenues and "demands" fixed costs. The level of the fixed-cost activity corresponds to the number of firms in free-entry equilibrium. Fourth, since sales to different countries carry different markups, different trade activities to each country must be specified from a given country. Thus whereas in a competitive, constant-returns model we might specify a sector by a single activity, here a sector is specified by two activities, two side constraints, an endogenous tax rate, an additional consumer, and up to three additional trade activities. Three more inequality side constraints are needed to compute the integrated markets solution. All together, the model has 32 sectors, 25 commodities, 15 side constraints, and 8 consumers. The fully calibrated model thus specifies 32 activity levels, 25 commodity prices, the values of 15 constraint variables, and 8 income levels: 80 separate non-linear inequalities constitute the model.

Table 1 gives the protection levels in the four regions, while BILAT and TRILAT liberalize US-Mexico, and US-Canada-Mexico trade respectively. All data are 1988 values. The integrated markets scenarios use the same protection levels as BILAT or TRILAT (we note below that these are the same outcomes because the Canadian tariff is non-binding). The US protection levels is a weighted average of the tariff on cars and light trucks (substitutes in production), but consistent data could only be obtained for passenger cars. The Mexican tariff was 20%, but non-tariff barriers discriminated against imports by non-NA producers, so we have rather arbitrarily set the Mexican tariff against ROW at 33%. ROW tariffs are arbitrary but immaterial since they are not being adjusted (i.e., lower ROW tariffs would just raise calibrated transport costs by the same amount).

Table 2 gives some of the key data for the four regions. The model is calibrated so that all producer prices are one initially. The level of Y is then inferred from the percentage share of passenger cars in GNP in each region. ω is unfortunately quite arbitrary: the 20% values implies that a doubling of the auto sector in a given country raises

TABLE 1: PROTECTION LEVELS IN ALTERNATIVE SCENARIOS

	CAN.BENCH	USA.BENCH	MEX.BENCH	ROW.BENCH
CAN	0	0	0.020	0.333
USA	0	0	0.020	0.333
MEX	0.095	0.038	0	0.333
ROW	0.095	0.038	0.333	0
+	CAN.BILAT	USA.BILAT	MEX.BILAT	ROW.BILAT
CAN	0	0	0.020	0.333
USA	0	0	0	0.333
MEX	0.095	0	0	0.333
ROW	0.095	0.038	0.333	0
+	CAN.TRILAT	USA.TRILAT	MEX.TRILAT	ROW.TRILAT
CAN	0	0	0	0.333
USA	0	0	0	0.333
MEX	0	0	0	0.333
ROW	0.095	0.038	0.333	0 ;

TABLE 2: BENCHMARK DATA

	Y	ω	c	ϵ	n	P_{xi}/P_{xu}
CAN	44.301	0.20	0.95	1.200000	5	1.1
USA	470.873	0.20	1.00	1.100000	8	1.0
MEX	12.842	0.20	0.70	1.750000	5	1.4
ROW	1152.663	0.20	0.90	1.100000	10	-

TABLE 3: BENCHMARK NET TRADE PATTERN FOR AUTOS (MILLIONS OF CARS)

		Destination			
		CAN	USA	MEX	ROW
Origin	CAN	.632	.573	0	0
	USA	0	7.113	0	0
	MEX	0	.148	.206	0
	ROW	.359	3.111	0	22.281

the "wage" (marginal cost of production) in terms of good Y by 20%. ϵ is calculated from engineering studies together with the outputs per firm and model line in each country for the three North American regions. ϵ for ROW is set equal to that for the US. n denotes the number of auto producers in each country. P_{xi}/P_{xu} denotes the approximate relative consumer prices (each in terms of Y) in country i relative to the US. As described in the previous section, these data are then used to infer a marginal cost (c) in the three North American regions which is consistent with ϵ and the consumer price ratio. Marginal cost for Row is set rather arbitrarily between that of Canada and that of Mexico. Sensitivity analysis suggests that this is of little important to the experiments conducted.

4. Results and Interpretations

Table 4 give results for four experiments. BILAT and TRILAT are as described above. INT1 assumes that US cars can be supplied (abritraged) to Mexico at the US consumer price. INT2 adds a transactions or transportation cost of 5% of the US consumer price when a car is shipped to Mexico.

The first set of results are for changes in welfare, measured as a percentage of the value of auto production at factor cost (average cost per car). We see that the effects on Canada and the US are almost negligible, never reaching even one percent of production, although the integrated markets cases produce changes that are about triple those of BILAT and TRILAT. The latter two scenarios are identical because Canadian protection on Mexican autos is non-binding. The effects on ROW in all scenarios are negligible.

The effects on Mexico are non-trivial relative to the size of the sector in the first two

TABLE 4: PRELIMINARY RESULTS

WELFARE INDEX I: CHANGE AS A % OF AUTO PRODUCTION AT COST

	BILAT	TRILAT	INT1	INT2
CAN	-0.100	-0.100	-0.300	-0.266
USA	-0.122	-0.122	-0.367	-0.306
MEX	4.041	4.041	24.610	22.039
ROW	-0.009	-0.009	0.000	0.000

WELFARE INDEX II: CHANGE AS A % OF GDP

	BILAT	TRILAT	INT1	INT2
CAN	-0.003	-0.003	-0.009	-0.008
USA	-0.002	-0.002	-0.006	-0.005
MEX	0.132	0.132	0.804	0.720
ROW	-0.0002	-0.0002	0.0000	0.0000

AUTO PRODUCTION (CAN, USA, MEX), EXPORTS TO USA+CAN (ROW) (% CHANGE)

	BILAT	TRILAT	INT1	INT2
CAN	-0.665	-0.665	-1.954	-1.741
USA	-0.609	-0.609	-1.842	-1.637
MEX	23.400	23.400	44.927	42.241
ROW	-1.167	-1.167	-0.067	-0.292

NUMBER OF FIRMS

	BENCH	BILAT	TRILAT	INT1	INT2
CAN	5.000	5.011	5.011	5.069	5.058
USA	8.000	7.996	7.996	8.124	8.100
MEX	5.000	4.854	4.854	2.847	3.110
ROW	10.000	9.995	9.995	9.999	9.998

DOMESTIC MARKUPS BY NA FIRMS (% OVER MARGINAL COST)

	BENCH	BILAT	TRILAT	INT1	INT2
CAN	0.286	0.287	0.287	0.288	0.288
USA	0.100	0.101	0.101	0.103	0.103
MEX	1.186	1.141	1.141	0.519	0.594

TABLE 4 CONTINUED

OUTPUT PER FIRM (THOUSANDS OF CARS)

	BENCH	BILAT	TRILAT	INT1	INT2
CAN	241	239	239	233	234
USA	889	884	884	859	863
MEX	71	90	90	180	162

IMPORTS (MILLIONS OF CARS)

	BENCH	BILAT	TRILAT	INT1	INT2
CAN	0.358	0.356	0.356	0.347	0.349
USA	3.832	3.875	3.875	3.962	3.948
MEX	0.000	0.010	0.010	0.000	0.000

EXPORTS (MILLIONS OF CARS)

	BENCH	BILAT	TRILAT	INT1	INT2
CAN	0.573	0.562	0.562	0.536	0.541
MEX	0.148	0.240	0.240	0.305	0.296
ROW	3.470	3.429	3.429	3.468	3.460

NORTH AMERICAN FIRMS' SHARE OF THE MARKET (%)

	BENCH	BILAT	TRILAT	INT1	INT2
CAN	63.774	64.048	64.048	65.041	64.863
USA	71.576	71.923	71.923	71.482	70.576
MEX	100.000	95.359	95.359	100.000	100.000

CALIBRATED CONJECTURE PARAMETER FOR AUTO PRODUCERS

CAN 1.743111, USA 1.016084, MEX 2.712926, ROW 1.000000

SHARE OF SPECIFIC FACTOR IN Y IMPLIED BY BENCHMARK PARAMETERS

CAN 0.866, USA 0.923, MEX 0.856, ROW 0.900

scenarios. The welfare effects in the integrated markets scenarios are extremely large for this type of analysis. The contrast between these results and those of liberalization retaining market segmentation is equally dramatic. The two differ by a factor of six. We will see the explanation for this difference shortly. The second set of numbers in Table 4 express the welfare changes as a percentage of GNP.

Percentage changes in auto production are shown in the third set of numbers. Losses to the US and Canada under BILAT and TRILAT are very small, with increased Mexican production and sales in the US coming more at the expense of ROW imports than US or Canadian production. This last result reverses in the integrated scenarios. We believe this is due to the way the North American firms coordinate their markups to prevent arbitrage. As shown in the theory section above, the NA firms raise their US markups, ceteris paribus, to prevent arbitrage, and thus the ROW firms capture more sales (i.e., are hurt less) than when markets are segmented. The most interesting result here is the strong boost in production that Mexico gets from market integration, about double what they get if markets remain segmented. Yet from this alone it is not clear why we get the dramatic welfare effect from market integration.

The first part of the answer is given by the data on the number of firms in Table 4. Reading across the rows we see that BILAT and TRILAT have a negligible influence on rationalizing the number of firms. There is essentially no exit from the US or Mexico, and we actually have a small increase in Canada. There is little effect on ROW since in the data NA sales are only about 12% of its production. The big effect comes with market integration, which forces a large price decrease in Mexico. This in turn forces a large rationalization in Mexico and exit from the industry.

This is also seen in the results on domestic markups of NA firms. The alternative scenarios make almost no difference for the markups in the US and Canada, and the fall in the Mexican markup is small under BILAT and TRILAT. But with market integration, the Mexican markup falls by over half, as the NA firms price to prevent arbitrage.

Finally, the effect of market integration is seen equally clearly in the data on output per firm. Liberalization but maintaining market segmentation has a significant effect on output per firm in Mexico, but the effect of market integration is to more than double the level under BILAT and TRILAT, and to increase output per firms by 154% over the benchmark level. The data on the markup levels, and the output per firm reveal why an industry expansion of 45% translates into such a large welfare gain. First, there is a large consumer surplus gain in Mexico as the consumer price falls significantly (the relative price of autos is 40% higher in the benchmark than in INT1). Second, there is a large efficiency gain with firms increasing outputs by 154%, moving down a steep average cost curve.

These data in Table 4 also reveal that there is very little rationalization in the US or Canada. As just noted, Canadian and US production, markups, and output per firm move very little. We believe that this is in large part due to the multinational nature of the industry. Refer back to equations (12) and (13), and note that the perceived demand elasticity and therefore the US markup of a NA firm depends not on just its US production, but on its combined supply to the US market from its plants in the US, Canada, and Mexico. Thus if the firm imports one more car from Mexico and produces one less car in the US, the firm's perceived market share, perceived demand elasticity, and markup (ceteris paribus) are unchanged.

This result differs significantly from the more conventional trade-IO approach with strictly national firms. In that type of model with free entry, increased import penetration causes domestic firms to lose market share, their perceived demand elasticities increase, and they respond by increasing outputs and lowering markups. The final result with national ownership should be fewer domestic firms each producing a larger output. With multinational firms, this theoretical result is weakened or reversed and indeed this is confirmed by our results in Table 4 listing output per firm. US output per firm falls very slightly with BILAT and TRILAT, and falls a little over 3% with INT1. Recall in the last case that the US firm raises its markup (reduces output) in order to increase the US price to prevent arbitrage.

Table 4 next lists changes in imports and exports of cars. In BILAT and TRILAT, Mexico increases its exports to the US by 92 thousand cars. Net imports in the US increase by 43 thousand cars. The difference is composed of a reduction of 11 thousand from Canada and 38 thousand from ROW. Diversion from ROW is thus three times larger than the diversion from Canada. In the scenario INT1, Mexican exports to the US are 157 thousand units above the benchmark. Canada's exports fall by 37 thousand units, while ROW's exports to the US actually grow by 3 thousand units. As suggested above, this seems due to the fact that, with integrated markets, NA firms raise their US markup to prevent arbitrage to Mexico.

The "calibrated conjecture parameter" listed in Table 4 is the value of sigma, the formula for which was given in equation (18) above. The value for ROW is set equal to 1, indicating Cournot conjectures. The calibrated value for the US turns out to be very close to the Cournot value. Canada's value is significantly higher at 1.74, indicating a more collusive market. Mexico's is much higher yet at 2.71, indicating that, ceteris paribus, the Mexican domestic markup is 171% higher than the Cournot value. Again, this high value of non-competitive behavior helps explain the high initial consumer price in Mexico despite the low production cost, and it helps explain the powerful rationalization effect of market integration.

The final numbers presented in Table 4 are the calibrated values of θ_{ry}, given in equation (10). These values are quite similar, reflecting the fact that the same values of ω is assume for each country and the fact that auto production is a roughly similar share of national output in all three regions.

5. Summary and Conclusions

The purpose of this paper is to present an analysis of trade liberalization with multinational firms and (initial) market segmentation, motivated by and applied to the effects of US-Mexico free trade on the North American auto industry. The theoretical approach follows the free-entry tradition of Venables (1985), Horstmann and Markusen (1986), and Markusen and Venables (1988) rather than alternative approaches with fixed number of plants because the former seems far more consistent with historical experience in this industry. Both segmented markets (Venables) and integrated markets (Horstmann and Markusen) approaches are jointly considered, and indeed one of the most interesting results is the possible change in regime from the former to the latter as a consequence of trade liberalization. An important theoretical development of the present paper is to add joint decision making (multinational ownership) across plants to the elements of increasing returns and imperfect competition.

The applied general-equilibrium model follows the traditions of Harris (1984), Harris and Cox (1984), Smith and Venables (1988), Wigle (1988), and Markusen and Wigle (1989) in assuming free entry and technologies with fixed costs and constant marginal cost. The model differs from these by adding the elements of multinational decision making and assuming homogeneous products (e.g., consumers cannot tell whether a North American car is made in the US, Canada, or Mexico). We believe that these assumptions are vital to getting the story right for the auto industry. The important role of trade liberalization in possibly breaking market segmentation has been examined by Smith and Venables (1988), Norman (1989), and Venables (1990a), and this paper adds the further element of multinational decision making to that analysis.

The results have been highlighted in the introduction and in the previous section, so we can be brief here. First, trade liberalization that maintains market segmentation has a significant effect on Mexican production and welfare given the initially low level of protection, and almost zero effects on the US and Canada. We argued that the effect of multinational decision making contributes to the lack of rationalization in the US and Canada following increased Mexican imports. This is clearly one point where the explicit treatment of multinationals leads to different results from those predicted by theory which assumes national ownership of all production (e.g., Markusen and Venables) and corresponding numerical results (e.g., Harris and Cox).

Our results indicate that free trade for producers only (market segmentation) leaves the Mexican consumer price of autos significantly higher than in the US despite the fact that Mexico is the low cost producer. Permitting free trade for consumers (market integration) leads to double the effect on Mexican production and increases Mexican welfare by six times the effect when free trade is permitted for producers alone. Arbitrage possibilities force the rationalization of the Mexican industry, leading to exit of firms, but a very large increase in output per firm such that total industry output rises sharply as just noted.

No imports to Mexico actual occur after market integration because the multinationals do not want Mexico supplied by high cost US production. The multinationals follow a combined policy of raising the US markup and lowering the Mexican markup (ceteris paribus) to prevent arbitrage. But this reinforces the effect just noted: trade liberalization does not force the rationalization of production in the US or Canada because of the markup coordination of the multinational firms. Output per firm in the US falls by about 3% following trade liberalization and market integration.

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