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THE STATE OF NORTH AMERICAN AND JAPANESE MOTOR VEHICLE INDUSTRIES: A PARTIALLY CALIBRATED MODEL TO EXAMINE THE IMPACTS OF TRADE POLICY CHANGES

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ABSTRACT

In this paper we utilize a three component model of the automotive industry to simulate the impacts of various trade policy scenarios, such as changes in tariffs and quotas, on the U.S. and Canadian motor vehicle sectors as compared to their Japanese competitors. The three components are a cost module, a mark-up module and a demand module. These models contain the features stressed by the "new" international trade literature: (1) economies of scale in production, (2) imperfect competition, and (3) product differentiation. As a result of these modelling details we are able to capture quantitatively a number of outcome characteristics stressed in the strategic trade literature. Scenarios which expand a country's output reduce unit costs of production, both in the short and long-run. Protectionist policies adopted by North American governments result in rent transfers to these countries. The price and output effects of scenarios which favour North American producers at the expense of Japanese producers however are moderated by the Japanese practices of partial pass-through and pricing-to-market. The welfare implications of the various scenarios are in accordance with the strategic trade literature, in the sense the protectionist policies can in some cases increase aggregate welfare in North America at the expense of Japan.

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1. INTRODUCTION

In this paper we utilize a novel three component model of the automotive industry to simulate the impacts of various trade policy scenarios, such as changes in tariffs and quotas, on the U.S. and Canadian motor vehicle sectors (the aggregate of motor vehicle assembly and parts production) as compared to their Japanese competitors. The three components are a cost module, a mark-up module, and a demand module; each of which is "calibrated" to actual 1988 industry data. These modules contain the features stressed by the "new" international trade literature: (1) economies of scale in production, (2) imperfect competition, and (3) product differentiation.[1] What distinguishes this model from other partial equilibrium calibrated models (see Baldwin and Krugman (1988) for the 16K RAM market, or Dixit (1988) for U.S. and Japanese auto markets) is the use of an econometric cost function to specify the cost and production sectors of the industries, rather than the ad hoc "guestimates" of costs found in these other analyses.[2]

The first component of the model consists of a complex econometric cost function module[3] which is based on a study by two of the authors (Fuss and Waverman (1990)). In that paper a capacity utilization model was derived from short-run equilibrium analysis to analyze production decisions in the auto sector. In the short-run, capacity is fixed and in the long-run,

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[1] As this literature has demonstrated, (see Brander and Spencer (1984)) when economies of scale, imperfect competition and product differentiation are present, it is possible for an increase in tariff protection to be welfare-improving. In fact, our empirical results contain just such an example.

[2] A recent paper which is related to our paper conceptually is Lopes-de-Silanes, Markusen and Rutherford (1992), which analyses the effect of the North American Free Trade Agreement on the auto industry. This paper is a fully calibrated partial equilibrium study in which important cost parameters are obtained by a combination of literature searches and guesses.

[3] The cost function module consists of a cost function and input demand functions (in the form of cost share equations) for labour, capital and materials.

capacity is variable. This distinction is crucial in statistically analyzing cost conditions in automobile assembly and parts production because of the substantial short-run cyclical elements which can be induced by policy changes and can lead to large variations in capacity utilization.

This econometric cost function allows for a very rich set of results when trade policies are modelled. When a shock increases sales in one country versus another, firms move down their average cost curves (and up in countries where sales fall). In the short-run, capacity utilization is changed and employment gains (and losses) occur. In the long-run, movements are made to return to normal capacity utilization with plants built in the countries gaining sales and plants closed in countries losing sales. Moving from the short-run with capacity fixed, to the long-run when capacity is altered, involves different employment implications since in the long-run, capital is considerably more substitutable for labour. In all these movements, technical efficiency (total factor productivity (TFP)) is being affected.

The second module consists of a set of "mark-up" equations, detailing how the costs established in the first module are converted into wholesale and retail prices. These mark-up equations incorporate the degree of oligopolistic interdependence implicit in the reactions of producers (in one country) to producers from another country.[4] There is a separate mark-up equation for each (country aggregate) producer selling in each country; hence there are nine mark-up equations. Unlike the econometric cost function, which is estimated using data for the periods 1961-1984 and 1987-88, the mark-up equations are calibrated to a single year's data - the 1988 data.

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[4] Reactions are modelled as firm-specific and include interaction among firms producing in the same country.

The mark-up module incorporates the 'industrial organization' knowledge about competition in the industry. In our model the mark-ups are empirical indicators of how the 'conjectures' of one group of producers' output decisions influence the output decisions of another group of producers. While we assume that the conjecture parameters are constant and do not change between scenarios, they are not limited in value to those implied by Cournot-Nash conjectures. Instead the degree of interdependence among producers is determined empirically as a byproduct of the calibration process.

In the short-run (defining the short-run as the period when capacity is unchanged), the mark-up model leads to the interesting phenomenon that a producer protects market share by lowering its margin when its market share is threatened. Thus, when the dollar/yen exchange rate appreciates, or a tariff barrier is raised in North America, the Japanese market share in North America is threatened if Japanese producers maintain a constant mark-up. However, in our mark-up model, the Japanese producers' margin drops to partially offset this threatened market loss.[5] Alternatively, when a quota is imposed in North America, we assume there is no incentive for the Japanese producers to lower margins, and the model is altered to reflect this assumption.[6]

In the long-term we assume free entry and exit, resulting in normal profits for producers.

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[5] This phenomenon is what Krugman (1987) calls "pricing to market". If all producers act symmetrically then US producers, for example, would lower their mark-ups in the U.S. market if the yen depreciated. However, as a result of calibrating the model to 1988 data, we found that only Japanese margins move if markets are threatened. The 1988 data do not corroborate the story that North American producers change margins. This may be a flaw of the calibration technique which uses one year's data to pinpoint many contemporaneous effects. However, it is consistent with the view that Japanese producers are less likely to "pass through" exchange rate effects than are US producers (Marston (1990)).

[6] There is then an asymmetry for a tariff as compared to a quota. In the case of a North American tariff, Japanese producers are assumed not to know the target market share that governments are aiming for and thus they lower their margins to protect market share.

In the case where a scenario leads to an increase in a cost of production (e.g. exchange rate appreciation), this cost must be passed through to consumers to maintain these normal profit levels. This is equivalent to assuming constant mark-ups in the long-run. Similarly, in the case of a tariff increase, while foreign producers may react to lower their margins in the short-run to maintain sales levels, margins are assumed to be restored in the long-run, through a decline in production capacity in the foreign country.

The third module represents the consumer side of the model. The demand module is structured as a two-stage budgeting process. In the first stage, consumers' total expenditures on automobiles are determined. In the second stage, automobile expenditures are allocated among U.S., Japanese and Canadian produced vehicles. This second stage is a set of consumer demand functions where in, say the US, the demand by U.S. consumers for cars produced in the US is a function of the aggregate demand for cars and also of the prices of U.S. made cars, relative to the prices of cars produced in Canada and in Japan.

The complete model used for the scenarios consists of 43 equations in the short-run and 25 in the long-run. The output from this model consists of percentage changes in various activity variables from the base case - actual 1988 performance. We obtain results for both the short-run (production capacity fixed) and the long-run (capacity is changed so that capacity utilization is at a normal rate). The activities which are traced include (among others): constant dollar production, wholesale and retail prices, sales, unit costs, capacity utilization, employment, and total factor productivity.

We also estimate the impacts on 'welfare' - consumers' welfare (the change in consumer surplus), producers' welfare (the change in profits), the welfare of employees (the change in the wage bill), government welfare (the change in revenue from tariffs), and total national welfare

(the sum of the four sources) for the two North American countries and Japan.[7]

Sections 2 and 3 provide the details on the mathematical structure of the model and of the calibration to the data. Section 4 presents simulations of the effects of policy changes on the motor vehicle industries in the three countries. Section 5 concludes the paper.

2. THE MODEL

2.1 The Cost Function

This module was estimated econometrically for the aggregate motor vehicle assembly and parts production industry (U.S. SIC code 371 and its analogues in Japan and Canada). The econometric cost function allows the disaggregation of various influences on unit costs - factor price effects (the changes in the prices of labour, capital and materials (all raw materials as well as purchased semi-finished components)), and efficiency effects. Efficiency effects themselves are functions of economies of scale, the degree to which capacity utilization differs from normal, and other forces which drive efficiency - the stock of 'knowledge' (derived from R&D expenditures and the efficiency of R&D in lowering unit costs) and a country-specific effect (the residual - the extent to which efficiency differs for reasons not specified in our model).

The cost function module consists of a modified translog cost function and derived factor demand functions (in the form of cost share equations for labour, capital and materials). This model has been described in detail elsewhere (Fuss and Waverman (1990, 1992)), and will not be repeated here. However to render this paper self-contained, a summary of the details of the

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[7] These welfare calculations are partial equilibrium calculations, no macroeconomic effects (e.g, change in demand for cars due to changes in disposable income) occur.

model is contained in an appendix. The particular parameter values used in the simulation are essentially those contained in Fuss and Waverman (1990), but have been modified slightly by the calibration process (see section 3 below).

2.2 THE MARK-UP MODULE

The mark-up module is based on a mixed homogeneous/heterogeneous goods model of oligopolistic behaviour. We assume that vehicles produced by firms in a particular country are close enough substitutes for one another that the interaction of these firms can be approximated by the homogeneous goods oligopoly model. On the other hand, vehicles produced in different countries are assumed to be differentiated products, which leads to the specification of a heterogeneous goods oligopoly model to capture the interaction of U.S., Japanese and Canadian producers.

The jth firm producing in country i has as its short-run profit objective

$$\pi_{ij} = \sum_{k=1}^{3} R^k_{ij} - C^k_{ij} \qquad (1)$$

where R^k_{ij} is the revenue generated by sales in country k for the jth firm producing in country i; and C^k_{ij} is the cost of producing the output sold in country k. For our purposes, the short-run is defined as that period during which firms do not change capacity output, but vary actual output in response to perturbations in the economic environment. In particular, in our short run, it is possible for firms to substitute capital for labour, as long as capacity output remains unchanged. In the long run, capacity output is also a decision variable. Revenue R^k_{ij} is net of tariffs and international transportation costs.

The first order conditions for maximizing π_{ij} are given by the equality of marginal

revenues and marginal costs:

$$\frac{\partial R^k_{ij}}{\partial q^k_{ij}} = \frac{\partial C^k_{ij}}{\partial q^k_{ij}} \qquad \begin{matrix} i = 1, 2, 3 \\ k = 1, 2, 3 \end{matrix} \tag{2}$$

where q^k_{ij} is the output sold in the kth market by the jth firm producing in the ith country.

We begin by deriving the expression for $\frac{\partial R^k_{ij}}{\partial q^k_{ij}}$. Let the US be indexed by 1, Japan by 2, and Canada by 3. To be concrete, we will analyze in detail the expression for sales by U.S. producers in the U.S. market $(\frac{\partial R^1_{1j}}{\partial q^1_{1j}})$. The other expressions are completely analogous. Revenue R^1_{1j} is given by the expression

$$R^1_{1j} = [p^1_1 (q^1_1, q^1_2, q^1_3)] \cdot q^1_{1j} \tag{3}$$

where p^1_1 is the wholesale price of U.S. produced autos sold in the US, which depends on the total quantities of U.S. produced autos sold in the US (q^1_1), Japanese produced autos sold in the US (q^1_2) and Canadian produced autos sold in the US (q^1_3). Expanding marginal revenue $\partial R^1_{1j}/\partial q^1_{1j}$ we obtain

$$\begin{aligned} \frac{\partial R^1_{1j}}{\partial q^1_{1j}} &= p^1_1 + q^1_{1j}\left[\frac{\partial p^1_1}{\partial q^1_1}\cdot\frac{\partial q^1_1}{\partial q^1_{1j}} + \frac{\partial p^1_1}{\partial q^1_2}\cdot\frac{\partial q^1_2}{\partial q^1_{1j}} + \frac{\partial p^1_1}{\partial q^1_3}\cdot\frac{\partial q^1_3}{\partial q^1_{1j}}\right] \\ &= p^1_1\{1 + \frac{\partial p^1_1}{\partial q^1_1}\cdot\frac{\partial q^1_1}{\partial q^1_{1j}}\cdot\frac{q^1_{1j}}{p^1_1} + \frac{\partial p^1_1}{\partial q^1_2}\cdot\frac{\partial q^1_2}{\partial q^1_{1j}}\cdot\frac{q^1_{1j}}{p^1_1} \\ &\quad + \frac{\partial p^1_1}{\partial q^1_3}\cdot\frac{\partial q^1_3}{\partial q^1_{1j}}\cdot\frac{q^1_{1j}}{p^1_1}\ \} \end{aligned} \tag{4}$$

The first term (after the 1) inside the { } brackets in (4) can be rewritten as

$$\frac{\partial p^1_1}{\partial q^1_1}\cdot\frac{\partial q^1_1}{\partial q^1_{1j}}\cdot\frac{q^1_{1j}}{p^1_1} = \left[\frac{\partial p^1_1}{\partial q^1_1}\cdot\frac{q^1_1}{p^1_1}\right]\left[\frac{\partial q^1_1}{\partial q^1_{1j}}\cdot\frac{q^1_{1j}}{q^1_1}\right]$$

$$= E^{1}_{11} \cdot \left[\frac{\partial q^{1}_{1}}{\partial q^{1}_{1j}}\right] \left[\frac{q^{1}_{1j}}{q^{1}_{1}}\right] \tag{5}$$

E^{1}_{11} is the inverse of the aggregate own price elasticity of U.S. autos sold in the US market. The expression $\frac{\partial q^{1}_{1}}{\partial q^{1}_{ij}}$ is the conjecture of the jth U.S. producer about the effect of its supply decision on total sales of U.S. produced cars in the U.S. market. The expression $\frac{q^{1}_{1j}}{q^{1}_{ij}}$ is the market share of the jth U.S. producer as a proportion of total sales of U.S. produced autos in the US. Of these three terms, the first will be obtained from the consumer demand module, the third will be calculated from data[8], and the second - the conjecture - will be obtained by calibration (see section 3 below).

The second term in (4) can be rewritten as

$$\frac{\partial p^{1}_{1}}{\partial q^{1}_{2}} \cdot \frac{\partial q^{1}_{2}}{\partial q^{1}_{1j}} \cdot \frac{q^{1}_{1j}}{p^{1}_{1}} = \left[\frac{\partial p^{1}_{1}}{\partial q^{1}_{2}} \cdot \frac{q^{1}_{2}}{p^{1}_{1}}\right] \left[\frac{\partial q^{1}_{2}}{\partial q^{1}_{1j}} \cdot \frac{q^{1}_{1j}}{q^{1}_{2}}\right]$$

$$= E^{1}_{21} \cdot \left[\frac{\partial q^{1}_{2}}{\partial q^{1}_{1j}}\right] \left[\frac{q^{1}_{1j}}{q^{1}_{1}}\right] \left[\frac{q^{1}_{1}}{q^{1}_{2}}\right] \tag{6}$$

The first term in (6) is the inverse of the aggregate cross price elasticity in the U.S. market of Japanese produced autos with respect to price changes of U.S. produced autos. The second term is the conjecture of the jth U.S. producer about the effect of its supply decision on total sales of Japanese cars in the U.S. market. The third term is the market share of the jth U.S. producer as a proportion of total sales of U.S. produced autos in the US. The fourth term is

[8] Due to data limitations, in the calibration this share is calculated as the share of the "average" sized firm.

the relative market shares (in the U.S. market) of U.S. and Japanese produced autos. Once the cross-elasticity of demand has been specified, the conjecture can be obtained by calibration.

Finally, in an analogous manner we can rewrite the third term of (4) as

$$\frac{\partial p^1_1}{\partial q^1_3} \cdot \frac{\partial q^1_3}{\partial q^1_{1j}} \cdot \frac{q^1_{1j}}{p^1_1} = E^1_{31} \cdot \left[\frac{\partial q^1_3}{\partial q^1_{1j}}\right]\left[\frac{q^1_{1j}}{q^1_1}\right]\left[\frac{q^1_1}{q^1_3}\right] \tag{7}$$

The interpretation of the terms in (7) is the same as above, with "Canadian" replacing "Japanese" in the explanation.

Using equations (4)-(7), equation (2), applied to U.S. producers selling in the U.S. market, can be written compactly as

$$p^1_1 \cdot \lambda^1_1 = \frac{\partial C^1_{ij}}{\partial q^1_{ij}} \tag{8}$$

where λ^1_1 = the inverse of the producer's mark-up over marginal cost by U.S. producers in the U.S. market and is defined as

$$\lambda^1_1 = 1 + S^1_{1j}[E^1_{11} \cdot v^1_{11} + E^1_{21} \cdot v^1_{21} \cdot (S^1_1/S^1_2) + E^1_{31} \cdot v^1_{31} \cdot (S^1_1/S^1_3)] \tag{9}$$

with

v^1_{11}, v^1_{21}, v^1_{31}, as the U.S. producer's conjectures (discussed above),

$S^1_{1j} = q^1_{1j}/q^1_1$ and

$S^1_1/S^1_\ell = q^1_1/q^1_\ell$, $\ell = 2,3$.

There are nine equations analogous to each of (8) and (9) (one for each of the three countries' producers selling in each country). These equations take the general form

$$p^k_i \cdot \lambda^k_i = \frac{\partial C^k_{ij}}{\partial q^k_{ij}} \tag{10}$$

and

$$\lambda^k_i = 1 + S^k_{ij} \cdot [E^k_{ii} \cdot v^k_{ii} + \sum_{\ell \neq i} E^k_{\ell i} \cdot v^k_{\ell i} \, (S^k_i / S^k_\ell)] \qquad i, j, \ell = 1, 2, 3 \tag{11}$$

From equations (11) it can be seen how market share protection occurs in this model. Suppose there is an increase in the tariff against Japanese imports to the U.S. market. Consider the Japanese mark-up equation for sales in the US (k=1, i=3). The initial impact is to increase the retail price of Japanese produced vehicles relative to U.S. and Canadian produced vehicles, which reduces relative sales and hence the relative market shares of Japanese produced vehicles (S^1_3/S^1_ℓ). Since, as can be shown, the conjectures $v^1_{\ell 3}$ are positive and the inverse cross-price elasticities of demand $E^1_{\ell 3}$ are negative, the initial impact of the tariff increase has the effect of increasing the inverse mark-up λ^1_3, hence reducing the mark-up. The reduction in the mark-up moderates the price increase so that it is lower than it would have been in a constant mark-up regime, and this lower price in turn moderates the Japanese share loss. The extent of this reduced "pass-through" depends on the degree of substitutability of the differentiated products (cross-price elasticities of demand) and the extent of oligopolistic interdependence (values of the conjecture parameters).

We now turn to the cost side of the mark-up module. Given the lack of individual firm cost data, we assume that the cost function for each firm in country i is equivalent to country i's aggregate cost function (cost per plant) from the cost module. Thus

$$C^k_{ij} = C_i \, (q^k_{ij}) \tag{12}$$

and

$$\frac{\partial C^k_{ij}}{\partial q^k_{ij}} = \frac{\partial C_i}{\partial q^k_i} = \frac{\partial C_i}{\partial q_i} \tag{13}$$

with $q_i = \sum_{k=1}^{4} q^k_i$

where $\frac{\partial C}{\partial q_i}$ is the marginal cost of producing the total output of country i. The output q^k_i is the output sold by the ith country's producers in "the rest of the world" (outside of the US, Japan and Canada).

Combining (10) and (13) we obtain

$$p^k_i \quad \lambda^k_i = \frac{\partial C_i}{\partial q_i} \tag{14}$$

Equations (14) can be manipulated into the form

$$p^k_i \cdot \lambda^k_i = \left[\frac{\partial \log C_i}{\partial \log T_i}\right] \cdot \left[\frac{C_i}{q_i}\right] \qquad \begin{matrix} k = 1, 2, 3 \\ i = 1, 2, 3 \end{matrix} \tag{15}$$

where T_i = the capacity utilization rate (q_i/Q_i, where Q_i is capacity output),

$\frac{\partial \log C_i}{\partial \log T_i}$ = the elasticity of cost with respect to the capacity utilization rate, obtainable from the cost module.

Equations (15) are used to solve for the mark-ups λ^k_i which in turn are used to obtain the conjectures v^k_{ii}, $v^k_{\ell i}$.

The above specification was developed for the short-run model. In the long-run (the period of time when capacity can be altered), we assume that freedom of entry and exit reduces

producers' excess profits to zero, i.e., firms earn their cost of capital.[9] In this case, the wholesale price equals the average cost of production, i.e,

$$p^k_i = \frac{C_i(Q_i)}{Q_i} \tag{16}$$

where Q_i is the capacity output (size) of the average plant of producers in country i. In the base case, this average cost is the average cost which would have occurred had 1988 been a year of long-run equilibrium (obtainable from the cost function module with the capacity utilization rate set to unity).[10]

2.3 THE DEMAND MODULE

As noted in the introduction, the demand module is structured as a two-stage budgeting process. In the first stage, consumers' total expenditures on automobiles are determined. In the second stage, automobile expenditures are allocated among U.S., Japanese and Canadian produced vehicles. The second stage system of demand equations takes the double- logarithm form[11] (again the US is indexed by 1, Japan by 2 and Canada by 3):

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[9] This is the normal long-run assumption for models of the type developed in this paper. For further elaboration and interpretation see the excellent survey article by Harris (1989).

[10] Note that in this case the wholesale price (fob) is the same in all countries k in which county i's producers sell. Retail prices will not necessarily be the same since they depend on transportation costs, tariffs, and wholesale-retail mark-ups (see the demand module below). Note also that conjectures play no role in the long-run model. As discussed by Shapiro (1989), the use of conjectural variations, which is essentially a static concept, in oligopoly modelling is not sensible in the long run where capacity decision-making imparts a dynamic nature to the game being played.

[11] This functional form implies constant price elasticities of demand. Without this constraint, calibration of the mark-up and demand modules would be extremely difficult.

$$\log q^k_i = \alpha^k_i + \beta^k_i \log r^k_1 + \delta^k_i \log r^k_2 + \gamma^k_i \log r^k_3 + \theta_{ik} \log (y^k/P^k) \quad (17)$$

where q^k_i is the quantity of motor vehicles (and parts) produced in country i demanded in country k; r^k_ℓ, $\ell = 1,2,3$, is the *retail* price, in country k, of autos produced in the US, Japan and Canada, respectively; y^k is total consumer expenditure on automobiles in country k, and P^k is an aggregate retail price index of autos in country k, assumed computed as:

$$\log P^k = \sum_\ell s^k_\ell \log r^k_\ell \quad (18)$$

where s^k_ℓ is the 1988 expenditure share in country k of autos produced in country ℓ.

The retail prices of autos (r^k_ℓ) are linked to the wholesale prices p^k_ℓ by the equation

$$r^k_\ell = p^k_\ell(1+Z^k_\ell)(1+t^k_\ell)(1 + M^k_\ell) \quad (19)$$

where Z^k_ℓ is the percentage transportation cost of transporting autos from country ℓ to country k.

t^k_ℓ is the percentage tariff applied by country k to autos originating in country ℓ.

M^k_ℓ is the wholesale-retail mark-up in country k for autos produced in country ℓ.

The first stage demand for autos in the aggregate is specified to be of the form

$$\log q^k_A = a^k + b^k \log P^k + c^k \log P^k_0 + d^k \log I^k \quad (20)$$

where $q^k_A = y^k/P^k$ = real aggregate quantity of autos demanded in country k.

P^k_0 is the price index of goods and services other than autos (in country k).

I^k is the aggregate income in country k.

In the appendix we demonstrate how the parameters of the demand module are calculated. These parameters depend importantly on estimates of demand elasticities. Unfortunately, there is not a vast literature detailing the own and cross-price elasticities of demand for automobiles that we require (for example the cross-price elasticity of demand between U.S.-made cars and Japanese-made cars). We adopt two scenarios - high and low cross elasticity cases, distinguished mainly by the cross-price elasticity of demand. In both cases, the aggregate elasticity of demand for motor vehicles is assumed to be -0.5. The two cases are given in table 1. The estimates for the U.S. and Canadian markets correspond reasonably closely to Levinsohn's (1988) econometric estimates for the U.S. market (years 1983-85) which were based on individual model-specific data. Our low and high elasticity cases correspond to Levinsohn's δ=-1 and δ=-6 cases respectively.

To our knowledge there exist no estimates of elasticities for the Japanese market in the form we require. We have chosen own price elasticities which approximate (but are somewhat lower than) Levinsohn's U.S. estimates. We have specified very low cross price elasticities between Japanese produced and US produced, and Japanese produced and Canadian produced cars respectively, to reflect the non-tariff barriers in the Japanese market and the culturally oriented preference of Japanese consumers for Japanese produced vehicles. These estimates also appear in table 1.

3. CALIBRATION

Calibrations of the mark-up and demand modules were performed in ways which have become standard in the computational general equilibrium (CGE) modelling literature. These calibrations are discussed in previous sections of this paper and in the appendix.[12] In this section we discuss calibration of the cost function module to the 1988 data, since our procedure is non-standard. However it does take advantage of the econometric nature of the module.

The cost function and share equations had previously been estimated by Fuss and Waverman (1990) using data only through 1984. Calibration to the 1988 data was obtained by adding the 1988 data to the data through 1984 and re-estimating the cost system.[13] The model was respecified to incorporate any changes in efficiency differences among the three countries' production processes that may have occurred between 1984 and 1988. This was accomplished by adding dummy variables which take on the value unity in 1988 and zero otherwise to the appropriate shift terms in the cost and cost share equations. This procedure is similar to the standard calibration methodology as applied to non-econometric CGE models if the addition of the 1988 data does not change the parameter estimates. In our case the parameter estimates changed slightly, but not significantly.

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[12] There is one aspect of the calibration of the mark-up module which needs to be noted. The mark-up module contains 27 conjecture parameters and there are only 9 equations containing these parameters. Hence, 18 a priori restrictions must be imposed. There are two sources of our restrictions. First, since the producers in Canada and the US are essentially the same firms, we assumed that the conjectures held by Canadian and U.S. producers would be symmetric with respect to Japanese producers in the three markets. Second, we assumed that Japanese firms would hold zero (Cournot-Nash) conjectures with respect to North American producers in the Japanese market. This is a reasonable assumption since North American producers held less than 1 % of the Japanese market in 1988.

[13] Data for 1987 was also required since the model as originally estimated incorporated a first order autocorrelation adjustment.

4. THE SIMULATIONS

A set of simulations were undertaken aimed at understanding the potential impacts of changes in exchange rates and trade policies on motor vehicle assembly and parts production and demand.

The simulations were as follows:

(1) an exchange rate effect *(What are the impacts on North American and Japanese auto producers of shifts in exchange rates?)*

a. - impacts of a 110 yen/US dollar ratio (a 14% appreciation of the yen over its 1988 value of 128 yen/US dollar),

b. - impacts of a 150 yen/US dollar ratio (a 17% depreciation of the yen over its 1988 value of 128 yen/US dollar).

(2) a tariff effect (*What are the impacts of increased protection in North America?)*

- a common tariff of 15% is modelled for North America (up from an average of 4.5% in the US (autos, trucks, parts) and 9.2% in Canada).

(3) a market share effect *(What will returning to the Voluntary Export Restraints (VER) of 1981 do?*

- the Japanese market share in North America (in both assembly and parts) is reduced by one-third.

Scenarios (2) and (3) can be linked directly to trade policies that governments might adopt, since tariffs and quotas are the usual instruments of protection. The first scenario, the exchange rate effect, is somewhat different since one does not normally think of exchange rate variation as the result of government policy directed at a specific industry. The exchange rate scenarios are designed to indicate the sensitivity of various aspects of industry performance to exogenous changes in exchange rates.

4.1 SUMMARY OF MAJOR IMPACTS

We highlight the major impacts for the three scenarios for both the short-run and the long-run for the low and high cross-price elasticity cases (see tables 2 and 3). Indicated on these tables are percentage changes in sales by North American producers in the US and Canada, sales by Japanese producers in the US and Canada, total sales in the United States, Canada and Japan, unit costs in the United States, Canada and Japan, total factor productivity (TFP) in the US, Canada and Japan, and finally, percentage changes in employment in the US, Canada and Japan. More detail is contained in an appendix available from the authors.

i) Exchange Rate Scenarios

The first row provides the results from the exchange rate scenario where the actual exchange rate in 1988 of 128 yen/US dollar is changed to 110 yen/US dollar. This is a significant appreciation of the yen relative to the North American currencies and thus raises the prices of Japanese producers in North America. As noted earlier, not all the yen appreciation is "passed through" by the Japanese producers so that mark-ups fall.[14] In addition, because competition is imperfect, the North American producers increase prices. The major results of this yen appreciation are as follows (for the low cross price-elasticity case): Japanese sales (of vehicles and parts) fall 10% in the short-run (the short-run is defined as that period before capacity reacts to the appreciation) and 12.3% in the long-run.[15] Sales of U.S. producers

[14] The "pass-through" elasticities associated with the yen appreciation is -0.77 (low elasticity case) and -0.72 (high elasticity case). These impacts are close to Marston's (1990) estimate of -0.68 for the Japanese transportation equipment industry. On the other hand, our "pricing to market" elasticity of 0.11 (both low and high elasticity cases) is substantially below Marston's estimate of 0.41.

[15] These sales changes are substantial, but it must be remembered that in 1988 Japanese producers held 14% of the North American vehicles and parts market. Thus a 10% fall reduces this market share to 12.6%.

in the U.S. market (note this does not include sales of 'Canadian' producers in the U.S. market) increase 1.4% in the short-run (on a base of 72% of the market of vehicles and parts) and 2.7% in the long-run (when scale (capacity) is increased). Total sales in the US fall 1.6% in the short-run and 1.4% in the long-run, because U.S. built cars are not perfect substitutes for Japanese built cars. Total sales in Canada decrease 1.5% in the short-run and 1.1% in the long-run. Note that unit costs rise in the US and Canada and fall in Japan. This is due to the fact that the unit cost implications of the foreign content of inputs in the industry (parts, materials and equipment denominated in the foreign currency - yen or dollars respectively) outweigh the unit cost implications associated with changes in capacity utilization (short run) and scale (long run).[16]

Of significance is the fact that TFP is not altered much, increasing by .1% in the US and .3% in Canada, and falling by .1% in Japan (all in the long-run). Our estimate of the efficiency gap between the US and Japan in 1988 is 17%; a .1% improvement in favour of the US created by the assumed yen appreciation is not significant. Employment rises in the US and Canada, in the long-run by 2.7% and 2.2% respectively (or a gain of some 24,000 jobs in North America). Employment falls in Japan by 2.6% in the long-run, or by some 18,000 jobs. It is clear that exchange rate movements shift sales and have important impacts on employment. Exchange rate movements however are not important in affecting efficiency. The richness of the above results in terms of detail is due in large part to the existence of an econometric model (the cost function) as a component of the simulation model, as was discussed in the introduction.

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[16] Our model contains the production characteristics emphasized in the international trade/industrial organization literature - increasing returns to utilization in the short run and increasing returns to scale in the long run. However, our model also contains a subtlety not normally found in this literature - an effect on costs when exchange rates change associated with the foreign/domestic split of the sourcing of intermediate goods.

The high elasticity case amplifies the results (table 3), since this case involves a greater degree of substitution of North American produced cars for Japanese produced cars (cross-price elasticity of 0.5 instead of 0.25), and a more elastic own-price elasticity (-1.5 instead of -1.0). Thus, an appreciation of the yen/$ rate from 128 to 110 lowers Japanese sales in North America 18% in the long-run at the higher elasticity values versus 12.4%, as was the case with the lower cross-price elasticity. The change in elasticities means that the increase in U.S. sales more than doubles (a 5.9% gain instead of 2.7%) in the long-run, while employment effects are about twice as high (a 5.4% gain instead of 2.7% for the low elasticity case). In the long-run, in the high elasticity case, TFP increases 0.1% in the USA and 0.7% in Canada, and falls 0.2% in Japan, still an insignificant closing of the efficiency gaps.

The second row in tables 2 and 3 (scenario 1b) shows the effects of a devaluation of the yen to 150 yen/US dollar. Here the results are the reverse of scenario 1a and Japanese sales in the US and Canada increase markedly, 11.3% in the short-run and 14.6% in the long-run (low elasticity case). Unit costs fall slightly in the US and Canada because the materials and equipment which are purchased from Japan become less expensive, and this effect outweighs the unit cost increasing effects of lower capacity utilization rates (short-run) and lower scale (long-run) on the part of the North American producers. The impacts on TFP are small. The impacts on employment are more substantial, with employment in the US falling by 2.7% and in Japan rising by 3.1% in the long-run. In the high elasticity case, the substantial yen appreciation results in Japan gaining 22.9% greater sales in the US (versus 14.6% in table 2). Similarly, the impact on U.S. producers' sales in the US is greater - falling 5.9% in the long-run. The employment swings are very pronounced - employment in the U.S. motor vehicle and parts

industry falls 5.3% (39,000 employees); in Canada it falls 4.9% (7,000 employees); and in Japan it increases 4.6% (33,000 employees).

2) Tariffs

In scenario 2, the existing tariffs in Canada and the US are raised to a common 15% tariff.[17] This is a more substantial increase for the US than for Canada, since the weighted tariff is 4.5% in the US (including the tariffs of 2.5% on cars, 3.1% on parts, and 25% on light trucks) as compared with 9.2% in Canada. The significant difference in the tariff increase leads to differential impacts in the Canadian and U.S. markets. For the low elasticity case, in the short-run (long-run) the increased protection reduces Japanese sales in the U.S. by 7.7% (9.2%) and in Canada by 3.9% (5.2%). In the US market sales by U.S. producers increase by 1.4% (2.4%) but the total market falls by 1% (0.6%). Similar effects occur in the Canadian market.

The tariff increase lowers unit costs of North American producers very slightly, since the increase in the costs of inputs which are imported from Japan tends to be outweighed by the unit cost-reducing impact of increased capacity utilization and scale. TFP impacts are marginal as are all changes in the Japanese market. U.S. employment increases by 1% (1.9%).

Raising the degree of substitutability between North America and Japanese products (the high elasticity case) increases the benefits of protection for domestic North American producers. Japanese sales fall 10.1% (13.7%) and 4.7% (7.9%) respectively in U.S. and Canadian markets (see table 3). TFP improvements are somewhat larger (but still small). On the other hand, North American employment gains are substantially greater.

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[17] The Canada-US Free trade Agreement and the proposed North American Free Trade Agreement create pressures which make the imposition of a common external tariff in the motor vehicle industry more likely.

3) Restrict Japanese Sales in North America

There are two direct ways of reducing the market that Japanese producers hold in North America - a quota and a tariff. During the 1980s the governments of Canada and the US opted for a quota system - Voluntary Export Restraints (VER). Earlier we discussed why a quota and a tariff will not lead to exactly the same impacts on the North American industries because of the differential impact that these two policies would have on the margins of Japanese producers in North American markets. The results of a tariff, or alternatively, a quota aimed at reducing Japanese sales of cars and parts by one-third are shown as cases 3a and 3b in tables 2 and 3.[18]

To reduce Japanese sales by one-third in the low elasticity case by the use of a tariff requires an increase in the tariffs in Canada and the US by nearly 60 percentage points (in the US from 4.5% to 64%). In the low elasticity case, in the short-run (long-run) sales of U.S. producers in the US increase by 7% (10.4%), but total sales in the U.S. market fall by 5% (2.5%). This increase in the market share of a smaller market by domestic producers is the expected effect of increased protection. Employment increases 5.4% (8.5%) in the US and 3.4% (7.8%) in Canada while falling 1.9% (3.2%) in Japan.

Raising cross price-elasticities of demand increases domestic producers' gains from any particular tariff. Thus to reduce Japanese sales by one-third requires an increase in the tariff of "only" 43 percentage points in the higher cross-price elasticity case (from a 4.5% tariff to a 48% tariff in the US). This reduction in Japanese sales by one-third increases U.S. domestic producers' sales by 9.4% (13.6%). The total US market falls by 5% (1.5%). Employment increases in the US by 7.2% (11%).

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[18] The reduction of Japanese sales by one-third would return Japanese producers to approximately the share of North American markets they enjoyed in the early 1980s.

In scenario 3b the effects of a quota to reduce Japanese sales in North America by one-third are presented. The effects on the items listed in tables 2 and 3 are virtually identical to the imposition of the required tariff since they are driven by the sales reductions. The major difference in the two policy instruments is the relative welfare effects, which are discussed below. The very large tariffs (64% or 48% in the case of the US) needed to reduce Japanese sales in North American markets by one-third may explain why the use of a quota has been preferred as a political instrument despite the adverse welfare implications (see below).

Welfare Effects

Tables 4-9 report the impacts of the scenarios on welfare in the US, Canada and Japan. We explicitly include a consideration of the welfare effects of North American policy changes on Japan to provide a more complete picture of the total welfare effects. It is unlikely that North American governments would give much weight to the implications of their policies for welfare in Japan.

Welfare effects consist of a number of components. The change in consumers' welfare due to a "shock" (scenario) is the sum of two effects: the change in expenditures on the quantity previously purchased plus the 'consumer surplus' on the change in consumption caused by the shock.[19] The change in producers' welfare is the change in profits. The change in the welfare of labour is the change in total wages. Two cases are considered - the first when the alternative

[19] Our computation of consumers' surplus is based on Marshallian demand functions rather than the theoretically more appropriate income-compensated demand functions. Since any scenario involves a change in three prices rather than a single price, the more exact calculation is quite difficult to obtain.

wage is zero; the second where the alternative wage is the average industrial wage[20]. Government welfare is the change in tariff revenues, if any. Aggregate country welfare is the sum of all four components.[21] Aggregate welfare is the sum of the three countries' aggregate welfare.

For the sake of brevity, in the scenarios which follow we will discuss only the low elasticity case (tables 4-6). The high elasticity case, which is contained in tables 7-9, provides qualitatively similar results.

We first examine the impact of a yen appreciation. U.S. and Canadian aggregate welfare fall, whereas Japan's aggregate welfare increases. The yen appreciation, while benefiting North American producers and labour, reduces consumers' welfare in North America considerably due to the higher prices for cars and parts. The effects are just the opposite in Japan.

The gain in consumers' welfare in Japan from a yen appreciation may seem strange at first, since it would appear that prices denominated in yen would be unaffected by the yen appreciation. But in our model, yen prices of autos in Japan actually fall in this scenario. There are two sources of this decline in price. First, some inputs into Japanese production are denominated in dollars and hence become less expensive in yen, resulting in a decline in the unit cost of production. Second, the loss of sales outside Japan has an adverse effect on capacity utilization, and Japanese producers lower margins in Japan (as well as North America) to

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[20] When a shock is assumed to lead to changes in employment in the economy, the appropriate opportunity cost is a zero wage (ignoring unemployment insurance and welfare payments). However, if the shock leads to changes in employment in the motor vehicle industry but no change in employment in the economy, the relevant opportunity cost is the alternative wage, which we approximate by the average industrial wage.

[21] Note that our welfare function gives equal weight to all four possible sources of surplus. Alternative weights could be used to construct the aggregate welfare function.

maintain production rates. This latter effect is only a short run phenomenon in our model, which explains why the consumers' welfare effect is greater in the short-run than in the long-run ($7.5B versus $4.1B).[22]

A devaluation of the yen to 150 yen/U.S. dollar has, as expected, the opposite effects on welfare compared with a yen appreciation. Welfare in North America increases, while welfare in Japan falls. North American producers and labour lose, whereas Japanese producers and labour gain.

An increase in North American protectionism - the move to a common 15% tariff barrier - also has the expected effects on the North American economies. Consumers lose while producers and labour gain. Note that there is an aggregate welfare gain in North America ($1.0B in the short-run and $0.4B in the long-run). This result suggests that the current North American tariff levels are below optimal levels, as long as Japan does not retaliate in response to an increase.

An interesting further result is that aggregate welfare in North America plus Japan increases ($0.2B in both the short-run and the long-run). This result, which contradicts traditional trade theory, is due to the industrial organization details imbedded in our model. The gains to Japanese consumers, as Japanese producers lower prices in the home market to counteract the adverse effects of production declines, is sufficient to generate a total positive effect.

Scenario 3a simulates large increases in North American tariff barriers (up to a tariff barrier of 64% in the low elasticity case). Not unexpectedly, there are large welfare losses (gains) for

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[22] In the long-run, scale effects on unit costs will be similar to capacity utilization effects but of lower magnitude. However, margin effects will be absent due to our assumption of zero economic profits and hence constant margins.

North American consumers (producers and labour). Because of the large increase in government revenues, aggregate welfare in North America actually increases in the short-run (by $2.2B), but this revenue-generating effect is not sufficiently strong to overcome the adverse effects in the long-run (a welfare loss of $0.9B). The welfare increase for Japanese consumers in the short-run is once again the result of Japanese producers lowering margins and hence prices in the home market to protect production rates in the face of large losses of sales in North America. Aggregate welfare for the three countries declines both in the short-run ($1.2B) and in the long-run ($1.6B). Note that this aggregate welfare result, which is consistent with traditional trade theory, differs from that of the previous case of a much smaller tariff increase.

A quota restricting Japanese market share by one-third (scenario 3b) has the same effects on the welfare of North American consumers, producers and labour as the equivalent tariff (scenario 3a). However, the welfare of North American governments are significantly altered. For example, in the short run the additional revenue accruing to the U.S. government from increased protection declines from $15.2B to -$0.6B. This revenue effect change means that the imposition of the quota results in large welfare losses in North America ($15.2B in the short-run and $17.7B in the long-run).

In Japan, only the position of producers is altered when a quota is imposed, rather than the equivalent tariff. In the short-run, producers' profits change from a decline of $9.1B (tariff) to a gain of $7.4B (quota). The move from a policy instrument of a tariff to one of a quota effectively transfers $16.5B per annum from North American treasuries to Japanese producers in the short-run. Note that in the long-run, given the assumptions of the model, entry eliminates

the increase in profits of Japanese producers, but the use of a quota for protection rather than a tariff still results in substantial government revenue losses.

As an example of how our model fits into the recent strategic trade literature[23], we estimate the rent transfer which may occur due to increased protection (Brander and Spencer (1984)). We define rent generated in any particular country as the sum of producers' profits and wages in excess of opportunity cost (wages calculated using the average industrial wage). Note that rents do not disappear in the long run even though producers' profits go to zero.[24]

Consider the case of tariff increases in Canada and the US sufficient to erect a 15% tariff barrier against Japanese imports. In the short-run, rents increase in the US by $3.1B and in Canada by $0.5B. A large portion of this increase is due to rent transfer since Japanese rents decline by $2.1B. This is just the case where a protectionist policy increases domestic welfare, and it is the rent transfer which tips the balance.

5. SUMMARY

In this paper we have developed a model of the motor vehicle industry in order to investigate quantitatively the impacts of possible trade policy initiatives of North American governments. Our model contains the elements stressed by the international trade/industrial organization literature. Production is characterized by non-constant capacity utilization effects in the short-run and non-constant scale effects in the long-run. Price and output decisions of firms supplying

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[23] This approach to trade theory has also been called the "new protectionism". For a review and evaluation of this literature, see Harris (1989).

[24] We undoubtedly underestimate rent transfers in the long run since we assume no change in the wage rate occurs as a result of a shock. For example, a union's monopsony power may allow it to increase the wage rate in the long run in response to an increase in the tariff barrier.

differentiated products are influenced by oligopolistic interdependence among these producers.

As a result of these modelling details we are able to capture quantitatively a number of outcome characteristics stressed in the strategic trade literature. Scenarios which expand a country's output reduce unit costs of production, both in the short and long-run. Protectionist policies adopted by North American governments can result in rent transfers to these countries. The price and output effects of scenarios which favour North American producers at the expense of Japanese producers however are moderated by the Japanese practices of partial pass-through and pricing-to-market. The welfare implications of the various scenarios are in accordance with the strategic trade literature. Protectionist policies can increase aggregate welfare in North America at the expense of Japan. This comes about due to the combination of rent transfer and an improvement in North American production efficiency at the expense of Japanese production efficiency.

REFERENCES

Baldwin R. and P. Krugman (1988), "Market Access and International Competition: A Simulation Study", in R. Feenstra (ed.), Empirical Methods for International Trade, Cambridge: MIT Press.

Brander, J. and B. Spencer (1984), "Trade Warfare, Tariffs and Cartels", Journal of International Economics, 16, pp. 227-42.

Dixit, A. (1988), "Optimal Trade and Industrial Policies for the US Automobile Industry", in R. Feenstra (ed.), Empirical Methods for International Trade, Cambridge: MIT Press.

Fuss M. and L. Waverman (1990), "The Extent and Sources of Cost and Efficiency Differences Between U.S. and Japanese Motor Vehicle Producers", Journal of the Japanese and International Economies, September, pp. 219-256.

Fuss, M. and L. Waverman (1992), Costs and Productivity in Automobile Production: The Challenge of Japanese Efficiency, Cambridge: Cambridge University Press.

Harris, R.G. (1989), "The New Protectionism Revisited", Canadian Journal of Economics, 22, pp. 751-778.

Krugman, P. (1987), "Pricing to Market When the Exchange Rate Changes", in S.W. Arndt and J.D. Richardson (eds.), Real-Financial Linkages among Open Economies, Cambridge: MIT Press, pp. 49-70.

Levinsohn, J. (1988), "Empirics of Taxes on Differentiated Products: The Case of Tariffs in the U.S. Automobile Industry", in R.E. Baldwin (ed.), Trade Policy Issues and Empirical Analysis", Chicago: Chicago University Press pp. 11-40.

Lopez-de-Silanes, F., J. Markusen, and T. Rutherford (1992), "The Auto Industry and the North American Free Trade Agreement: Employment, Production and Welfare Effects", University of Colorado, Boulder, mimeographed, September.

Marston, R. (1990), "Price Behavior in Japanese and U.S. Manufacturing", National Bureau of Economic Research Working Paper No. 3364, Cambridge, MA, May.

Shapiro, C. (1989), "Theories of Oligopoly Behavior", in R.Schmalensee and R. Willig (eds.), Handbook of Industrial Organization, North Holland: Amsterdam, volume 1, pp. 330-414.

APPENDIX

The Cost Function Module

The modified translog cost function can be written out in detail for the ith country as

$$\log C_{it} = G(\log w_{it}, \log Q_{it}, \log T_{it}, D)$$

$$= \alpha_o + \alpha_{oi}D_i + \sum_k (\alpha_k + \alpha_{ki}D_i)\log w_{kit}$$

$$+ (\beta_l + \beta_{li}D_i)\log Q_{it}$$

$$+ \sum_l (\theta_l + \theta_{li}D_i)\log T_{lit}$$

$$+ \tfrac{1}{2}[\sum_k \delta_{kk}(\log w_{kit})^2 + \mu_{ll}(\log Q_{it})^2 + \sum_l \phi_{ll}(\log T_{lit})^2]$$

$$+ \sum_k \sum_{\substack{m \\ k<m}} \delta_{km} \log w_{kit} \log w_{mit}$$

$$+ \sum_l \sum_{\substack{p \\ l<p}} \phi_{lp} \log T_{lit} \log T_{pit}$$

$$+ \sum_k \lambda_{kl} \log w_{kit} \log Q_{it}$$

$$+ \sum_k \sum_l \Lambda_{kl} \log w_{kit} \log T_{lit}$$

$$+ \sum_l \tau_{1l} \log Q_{it} \log T_{lit} \qquad \text{(A.1)}$$

where w_{it} is the vector of input prices, Q_{it} is capacity output, T_{it} consists of two components - T_{1it} (or q_{it}/Q_{it}) the capacity utilization rate (q_{it} is actual output) and T_{2it}, an index for country specific efficiency - and D is a vector of country specific dummy variables with $D_c = 0$, as Canada is chosen as the reference country. Imposing the envelope theorem (the relationship between short-run and long-run average costs and marginal costs), the

parameters of (A.1) must satisfy the constraints (see Fuss and Waverman (1992, pp. 71-74) for details):

$$\theta_1 = \beta_1$$

$$\theta_1 = \beta_{1i}$$

$$\theta_{1l} = \tau_{1l}, \qquad l \neq 1$$

$$\Lambda_{kl} = \lambda_{kl}$$

$$\tau_{11} = \mu_{11}. \tag{A.2}$$

When the equalities (A.2) are imposed, $ECT_{1it} - ECQ_{it} = (\phi_{11} - \tau_{11})\log T_{1it}$, where ECT_{1it} is the cost-capacity utilization elasticity and ECQ_{it} is the cost-capacity output elasticity . For the envelope inequalities to hold, it must be the case that $\phi_{11} > \tau_{11}$.

Denote long-run equilibrium cost by C^*_{it} and the long-run equilibrium share by S^*_{kit}. Then Shephard's Lemma implies

$$\frac{\partial \log C^*_{it}}{\partial \log w_{kit}} = S^*_{kit}$$

or
$$S^*_{kit} = \alpha_k + \alpha_{ki}D_i + \delta_{kk}\log w_{kit} + \sum_{m \neq k} \delta_{km}\log w_{mit} + \lambda_{kl}\log Q_{it} + \sum_{l \neq 1} \Lambda_{kl}\log T_{lit}, \quad k = 1, \ldots, K. \tag{A.3}$$

The parameters of (A.3) must satisfy the usual adding-up and symmetry constraints

$$\sum_k \alpha_k = 1, \ \sum_k \alpha_{ki} = 0, \ \sum_m \delta_{mk} = 0, \ \delta_{mk} = \delta_{km},$$

$$\sum_k \lambda_{kl} = 0, \ \sum_k \alpha_{ki} = 0, \ \theta_{lp} = \theta_{pl}, \ \sum_k \Lambda_{kl} = 0, \ l \neq 1. \tag{A.4}$$

The unobserved long-run equilibrium share S^*_{kit} is linked to the observed actual

short-run equilibrium share S_{kit} through the capacity utilization rate by assuming:

$$S_{kit} = S^{*}_{kit} + \Lambda_{kl} \log T_{lit} \tag{A.5}$$

which implies,

$$S_{kit} = \alpha_k + \alpha_{ki} D_i + \delta_{kk} \log w_{kit} + \sum_{m \neq k} \delta_{km} \log w_{mit}$$

$$+ \lambda_{kl} \log Q_{it} + \sum_{l} \Lambda_{kl} \log T_{lit} \quad k = 1, \ldots, K \tag{A.6}$$

Since $\Sigma_k S_{kit} = \Sigma_k S^{*}_{kit} = 1$, there exists the following additional adding-up constraint which must be satisfied:

$$\sum_{k} \Lambda_{kl} = 0. \tag{A.7}$$

The capital cost share should decline when capacity utilization increases relative to when capacity increases. A parsimonious, sufficiently flexible specification to capture this characteristic is obtained by adding terms of the form

$$\frac{1}{6} \sum_{k} \sum_{l=1}^{1} \sum_{\rho=1}^{1} \rho_{klp} \log w_{kit} \log T_{lit} \log T_{pit} = \tfrac{1}{2} \sum_{k} \rho_{k11} \log w_{kit} (\log T_{1it})^2 \tag{A.8}$$

to the cost function. As a result of (A.8), a term of the form

$$\tfrac{1}{2} \rho_{k11} (\log T_{1it})^2 \tag{A.9}$$

is added to the kth cost share equation.

Before calibration, the above cost function and factor share equations were estimated using annual pooled three-digit SIC motor vehicle production data (assembly + parts

production) from Canada (1961-1984), the United States (1961-1984) and Japan (1968-1984). The arguments of the cost function are prices of labour, capital, and materials (w_{it}); constant dollar capacity production of vehicles and parts per plant (Q_{it}); capacity utilization rate (T_{1it}); and an index of the real stock of R&D expenditures (T_{2it}). C_{it} is the average cost per plant.

The Demand Module

In this part of the appendix we demonstrate how the parameters of the demand module are calculated. Homogeneity of degree zero in income (or expenditure) and prices implies the parameter constraints[25]

$$b^k + c^k + d^k = 0 \qquad k=1,2,3 \tag{A.10}$$

$$\beta^k_i + \delta^k_i + \gamma^k_i = 0 \qquad i,k=1,2,3 \tag{A.11}$$

We will assume that the second level demand functions are homothetic in real expenditures on autos (q^k_A),[26] which results in the additional constraints

$$\theta_{ik} = 1 \qquad i,k=1,2,3 \tag{A.12}$$

Given the above structure of demand, own price elasticities of demand for autos produced in country i and sold in country k can be calculated as

$$\epsilon^k_{11} = \beta^k_i + \theta^k_1 b^k s^k_1 \qquad k=1,2,3 \tag{A.13}$$

Similarly,

$$\epsilon^k_{22} = \delta^k_2 + \theta^k_2 b^k s^k_2$$

$$\epsilon^k_{33} = \gamma^k_3 + \theta^k_3 b^k s^k_3 \tag{A.14}$$

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[25] Note that b^k is the aggregate own price elasticity of demand for autos in the kth country.

[26] This implies that there is no bias as total real expenditure increases in the quantity of automobiles purchased by country of origin.

The cross price elasticity of demand ϵ^k_{12} (the effect on demand for the 1st (U.S.) auto type caused by a change in the price of the 2nd auto type (Japan) is given by

$$\epsilon^k_{12} = \delta^k_1 + \theta^k_1 b^k s^k_2 \qquad \text{(A.15)}$$

Similarly,

$$\epsilon^k_{13} = \gamma^k_1 + \theta^k_1 b^k s^k_3$$

$$\epsilon^k_{21} = \beta^k_2 + \theta^k_2 b^k s^k_1$$

$$\epsilon^k_{23} = \delta^k_2 + \theta^k_2 b^k s^k_3 \qquad \text{(A.16)}$$

$$\epsilon^k_{31} = \beta^k_3 + \theta^k_3 b^k s^k_1$$

$$\epsilon^k_{32} = \gamma^k_3 + \theta^k_3 b^k s^k_2$$

Given *a priori* specification of the values of the elasticities ϵ^k_{it} and b_k, equations (A.11)-(A.16) can be solved for the parameters β^k_i, γ^k_i, δ^k_i.[27] In the policy scenarios, we will assume that the policies being considered do not change aggregate income or the price index of all other goods in any country. Hence we do not require estimates of c^k, d^k, and the transformed constant $a^k + c^k \log P^k_0 + d^k \log I^k$ can be obtained by calibration to the 1988 prices and quantities.

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[27] For example, in the low elasticity case (see below and table 1 for the elasticity scenarios), for the U.S. producer selling in the U.S. market, $\beta^1_1 = \epsilon^1_{11} - \theta^1_1 b^1 s^1_1 = 0.64$, where, by assumption, $\epsilon^1_{11} = -1$, $\theta^1_1 = 1$, $b^1 = -0.5$; and for 1988, $s^1_1 = 0.72$. The parameters α^k_i can be obtained by calibration to the 1988 value of prices and quantities.

TABLE 1

Price Elasticities of Demand

US and Canadian Markets	HIGH Cross Elasticity Case			LOW Cross Elasticity Case		
	US Made	Cdn. Made	Japan Made			
US Made	-1.5	0.5	0.5	-1.0	.25	.25
Canadian Made	0.5	-1.5	0.5	.25	-1.0	.25
Japan Made	0.5	0.5	-1.5	.25	.25	-1.0

Japanese Market	HIGH Cross Elasticity Case			LOW Cross Elasticity Case		
	US Made	Cdn. Made	Japan Made			
US Made	-1.01	.5	.01	-.76	.25	.01
Canadian Made	.5	-1.01	.01	.25	-.76	.01
Japan Made	.01	.01	-.52	.01	.01	-.52

Table 2
Scenarios - Summary - Low Cross Elasticity Case
Impacts (% change)

Scenario		US Sales in US	Japan Sales in US & Canada*		Total Sales in US	Total Sales in Canada	Total Sales in Japan	Unit Costs in US	Unit Costs Canada	Unit Costs Japan	TFP US	TFP Canada	TFP Japan	Employment US	Employment Canada	Employment Japan
1. Exchange Rate																
a) 110 yen/US$	SR	1.43	-10.0	-10.2	-1.64	-1.46	1.5	1.05	1.16	-1.53**	0.13	0.32	-0.15	1.6	1.2	-1.7
	LR	2.69	-12.4	-12.4	-1.38	-1.10	0.73	1.07	1.15	-1.62**	0.07	0.27	-0.10	2.7	2.2	-2.6
b) 150 yen/US$	SR	-1.48	11.3	11.6	1.66	1.47	-1.7	-0.91	-0.99	1.42**	-0.15	-0.35	0.14	-1.6	-1.1	2.0
	LR	-2.78	14.6	14.6	1.38	1.09	-0.87	-0.96	-1.00	1.47**	-0.06	-0.31	0.11	-2.7	-2.3	3.1
2. Raise tariffs To 15% in North America	SR	1.4	-7.7	-3.9	-1.0	-0.7	0.3	-0.11	-0.30	0.06	0.11	0.30	-0.06	1.0	.6	-.45
	LR	2.4	-9.2	-5.2	-0.6	-0.2	-.02	-0.05	-0.28	0.04	0.05	0.28	-0.04	1.9	1.7	-.85
3a. Japan Sales in US & Can Reduced by One-Third (Tariff)	SR	7.0	-33.3	-33.3	-5.0	-4.3	1.2	-0.43	-1.5	0.29	0.44	1.5	-0.29	5.4	3.4	-1.93
	LR	10.4	-33.3	-33.3	-2.5	-1.6	-0.1	-0.23	-1.3	0.16	0.23	1.3	-0.16	8.5	7.8	-3.2
3b. Japan Sales in US & Can Reduced by One-Third (Quota)	SR	7.1	-33.3	-33.3	-5.1	-4.3	1.2	-0.44	-1.5	0.29	0.44	1.5	-0.29	5.4	3.4	-1.95
	LR	10.4	-33.3	-33.3	-2.5	-1.6	-0.1	-0.23	-1.3	0.16	0.23	1.3	-0.16	8.5	7.8	-3.2

*Sales in US and Canadian markets respectively.
**Denominated in yen.

Table 3
Scenarios - Summary - High Cross Elasticity Case
Impacts (% change)

Scenario		US Sales in US	Japan Sales in US & Canada*		Total Sales in US	Total Sales in Canada	Total Sales in Japan	Unit Costs in US	Unit Costs Canada	Unit Costs Japan	TFP US	TFP Canada	TFP Japan	Employment US	Employment Canada	Employment Japan
1. Exchange Rate																
a) 110 yen/US$	SR	2.62	-12.5	-12.9	-1.99	-1.84	1.8	0.95	0.89	-1.46**	0.22	0.59	-0.21	2.5	1.7	-2.1
	LR	5.94	-18.0	-18.0	-1.33	-1.00	0.7	0.99	0.71	-1.56**	0.14	0.73	-0.16	5.4	4.8	-3.6
b) 150 yen/US$	SR	-2.61	14.4	14.9	2.00	1.85	-2.1	-0.79	-0.71	1.57**	-0.27	-0.64	0.19	-2.4	-0.7	2.7
	LR	-5.87	22.9	22.9	1.33	1.02	-0.84	-0.89	-0.56	1.41**	-0.14	-0.75	0.18	-5.3	-4.9	4.55
2. Raise tariffs To 15% in North America	SR	2.4	-10.1	-4.7	-1.3	-1.0	0.3	-0.16	-0.51	0.07	0.16	0.51	-0.07	1.6	1.0	-.56
	LR	4.8	-13.7	-7.9	-0.6	-0.1	-.03	-0.10	-0.60	0.06	0.10	0.60	-0.06	3.7	3.6	-1.30
3a. Japan Sales in US & Can Reduced by One-Third (Tariff)	SR	9.4	-33.3	-33.3	-5.0	-4.5	1.2	-0.50	-1.9	0.28	0.50	1.9	-0.28	7.2	4.5	-1.87
	LR	13.6	-33.3	-33.3	-1.5	-0.9	-0.1	-0.30	-1.8	0.16	0.30	1.8	-0.16	11.0	11.0	-3.2
3b. Japan Sales in US & Can Reduced by One-Third (Quota)	SR	9.5	-33.3	-33.3	-5.1	-4.6	1.2	-0.50	-1.9	0.28	0.51	1.9	-0.28	7.3	4.6	-1.89
	LR	13.6	-33.3	-33.3	-1.5	-0.9	-0.1	-0.30	-1.8	0.16	0.30	1.8	-0.16	11.0	11.0	-3.2

*Sales in US and Canadian markets respectively.
**Denominated in yen.

Table 4

Scenarios - Welfare Implications for the US ($Cdn Billion) - Low Cross Elasticity Case

Scenario		Consumer	Producer***	Labour*	Labour**	Government	Total*	Total**
1. Exchange Rate								
a) 110 yen/US$	SR	-9.9	2.9	0.7	0.2	0.02	-6.3	-6.7
	LR	-9.3	0.0	1.3	0.45	0.01	-8.0	-8.9
b) 150 yen/US$	SR	9.7	-2.9	-0.7	-0.2	-0.01	6.0	6.5
	LR	9.1	0.0	-1.3	-0.45	-0.01	7.8	8.6
2. Raise tariffs to 15% in North America	SR	-6.0	3.0	0.4	0.1	3.6	1.0	0.8
	LR	-4.0	0.0	0.9	0.3	4.1	0.9	0.35
3a) Japan Sales in US & Can Restricted by One-Third (Tariff)	SR	-31.4	16.8	2.3	0.8	15.2	2.9	1.4
	LR	-17.0	0.0	4.1	1.4	14.7	1.7	-0.9
3b) Japan Sales in US & Can Restricted by One-Third (Quota)	SR	-31.7	17.0	2.3	0.8	-0.6	-13.0	-14.5
	LR	-17.0	0.0	4.1	1.4	-0.7	-13.6	-16.3

* Assumes other wage available to labour = 0
** Assumes other wage available to labour = average industrial wage
*** In the long run, producers are assumed to earn their cost of capital

Table 5

Scenarios - Welfare Implications in Canada ($Cdn Billion) - Low Cross Elasticity Case

Scenario		Consumer	Producer***	Labour*	Labour**	Government	Total*	Total**
1. Exchange Rate								
a) 110 yen/US$	SR	-1.1	0.3	0.07	0.01	0.0	-0.8	-0.85
	LR	-1.0	0.0	0.15	0.03	0.0	-0.8	-0.95
b) 150 yen/US$	SR	1.1	-0.3	-0.07	-0.01	-0.0	0.7	0.8
	LR	0.9	0.0	-0.15	-0.03	-0.0	0.8	0.9
2. Raise tariffs to 15% in North America	SR	-0.5	0.5	0.03	0.01	0.2	0.2	0.2
	LR	-0.2	0.0	0.11	0.02	0.2	0.15	0.06
3a) Japan Sales in US & Can Restricted by One-Third (Tariff)	SR	-3.4	2.8	0.2	0.04	1.3	0.9	0.8
	LR	-1.4	0.0	0.5	0.09	1.3	0.4	-0.0
3b) Japan Sales in US & Can Restricted by One-Third (Quota)	SR	-3.4	2.85	0.2	0.04	-0.1	-0.5	-0.7
	LR	-1.4	0.0	0.5	0.09	-0.1	-1.0	-1.4

* Assumes other wage available to labour = 0
** Assumes other wage available to labour = average industrial wage
*** In the long run, producers are assumed to earn their cost of capital

Table 6

Scenarios - Welfare Implications in Japan ($Cdn Billion) - Low Cross Elasticity Case

Scenario		Consumer	Producer***	Labour*	Labour**	Government	Total*	Total**
1. Exchange Rate								
a) 110 yen/US$	SR	7.5	-5.8	-0.6	-0.1	0.0	1.1	1.6
	LR	4.1	0.0	-1.1	-0.2	0.0	3.0	3.9
b) 150 yen/US$	SR	-8.9	5.1	0.7	0.16	0.0	-3.0	-3.6
	LR	-5.0	0.0	1.25	0.3	0.0	-3.7	-4.7
2. Raise tariffs to 15% in North America	SR	1.3	-2.1	-0.16	-0.04	0.0	-1.0	-0.84
	LR	-0.1	0.0	-0.35	-0.08	0.0	-0.5	-0.2
3a) Japan Sales in US & Can Restricted by One-Third (Tariff)	SR	5.9	-9.1	-0.7	-0.2	0.0	-3.9	-3.4
	LR	-0.45	0.0	-1.3	-0.3	0.0	-1.8	-0.7
3b) Japan Sales in US & Can Restricted by One-Third (Quota)	SR	6.0	7.4	-0.7	-0.2	0.0	12.6	13.2
	LR	-0.45	0.0	-1.3	-0.3	0.0	-1.8	-0.7

* Assumes other wage available to labour = 0
** Assumes other wage available to labour = average industrial wage
*** In the long run, producers are assumed to earn their cost of capital

Table 7

Scenarios - Welfare Implications in the US ($Cdn Billion) - High Cross Elasticity Case

Scenario		Consumer	Producer***	Labour*	Labour**	Government	Total*	Total**
1. Exchange Rate								
a) 110 yen/US$	SR	-12.1	5.8	1.1	0.4	-0.04	-5.2	-5.9
	LR	-9.0	0.0	2.6	0.9	-0.1	-6.5	-8.2
b) 150 yen/US$	SR	11.6	-5.5	-1.0	-0.35	0.04	5.1	5.8
	LR	8.8	0.0	-2.5	-0.9	0.1	6.3	8.0
2. Raise tariffs to 15% in North America	SR	-7.8	5.2	0.7	0.2	3.5	1.6	1.1
	LR	-3.8	0.0	1.8	0.6	3.8	1.8	0.6
3a) Japan Sales in US & Can Restricted by One-Third (Tariff)	SR	-31.3	22.6	3.1	1.1	10.7	5.0	3.0
	LR	-10.3	0.0	5.3	1.8	8.7	3.6	0.15
3b) Japan Sales in US & Can Restricted by One-Third (Quota)	SR	-31.7	22.9	3.1	1.1	-0.6	-6.3	-8.3
	LR	-10.3	0.0	5.3	1.8	-0.7	-5.7	-9.2

* Assumes other wage available to labour = 0
** Assumes other wage available to labour = average industrial wage
*** In the long run, producers are assumed to earn their cost of capital

Table 8

Scenarios - Welfare Implications in Canada ($Cdn Billion) - High Cross Elasticity Case

Scenario		Consumer	Producer***	Labour*	Labour**	Government	Total*	Total**
1. Exchange Rate								
a) 110 yen/US$	SR	-1.4	0.7	0.1	0.02	-0.0	-0.6	-0.69
	LR	-0.9	0.0	0.3	0.06	-0.0	-0.6	-0.87
b) 150 yen/US$	SR	1.4	-0.7	-0.10	-0.02	0.0	0.6	0.7
	LR	0.9	0.0	-0.32	-0.06	0.0	0.6	0.8
2. Raise tariffs to 15% in North America	SR	-0.76	0.85	0.06	0.01	0.2	0.3	0.3
	LR	-0.1	0.0	0.24	0.04	0.2	0.3	0.1
3a) Japan Sales in US & Can Restricted by One-Third (Tariff)	SR	-3.6	3.7	0.3	0.05	0.9	1.3	1.1
	LR	-0.8	0.0	0.7	0.13	0.7	0.7	0.09
3b) Japan Sales in US & Can Restricted by One-Third (Quota)	SR	-3.7	3.8	0.3	0.05	-0.1	0.3	0.07
	LR	-0.8	0.0	0.7	0.13	-0.1	-0.2	-0.8

* Assumes other wage available to labour = 0
** Assumes other wage available to labour = average industrial wage
*** In the long run, producers are assumed to earn their cost of capital

Table 9

Scenarios - Welfare Implications in Japan ($Cdn Billion) - High Cross Elasticity Case

Scenario		Consumer	Producer***	Labour*	Labour**	Government	Total*	Total**
1. Exchange Rate								
a) 110 yen/US$	SR	8.8	-8.0	-0.8	-0.2	0.0	0.1	0.7
	LR	3.9	0.0	-1.5	-0.3	0.0	2.45	3.6
b) 150 yen/US$	SR	-10.5	7.3	0.9	0.2	0.0	-2.2	-2.9
	LR	-4.8	0.0	1.9	0.4	0.0	-2.9	-4.4
2. Raise tariffs to 15% in North America	SR	1.7	-2.7	-0.2	-0.04	0.0	-1.2	-1.1
	LR	-0.2	0.0	-0.5	-0.1	0.0	-0.7	-0.3
3a) Japan Sales in US & Can Restricted by One-Third (Tariff)	SR	5.7	-8.85	-0.7	-0.15	0.0	-3.8	-3.3
	LR	-0.46	0.0	-1.3	-0.3	0.0	-1.8	-0.7
3b) Japan Sales in US & Can Restricted by One-Third (Quota)	SR	5.7	2.9	-0.7	-0.15	0.0	8.0	8.5
	LR	-0.46	0.0	-1.3	-0.3	0.0	-1.8	-0.7

* Assumes other wage available to labour = 0
** Assumes other wage available to labour = average industrial wage
*** In the long run, producers are assumed to earn their cost of capital