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Abstract

This paper develops a multi-period, general equilibrium model of the impact of the North American Free Trade Agreement (NAFTA) on Mexico. The model has 9 consumption goods sectors and 3 capital goods sectors. At current real interest rates of 10%, the long-run effect of NAFTA is a 3.4% increase in Mexican net domestic product at world prices. These benefits are substantially higher if NAFTA reduces real interest rates: if the real rate falls to 9%, then net domestic product increases by 9.2% in the long run.

The results in this paper are preliminary and should not be cited

1. INTRODUCTION

This paper uses a multi-period, general equilibrium model of the Mexican economy to estimate the effects of the proposed North American Free Trade Agreement (NAFTA). In line with the classification in the Sistema de Cuentas Nacionales de Mexico, the model has three capital goods sectors (machines, buildings and vehicles) and nine consumption/intermediate goods sectors. In each period, production using labor, capital and intermediate goods. The capital in each sector depreciates at the empirically-observed rates, while investment is determined endogenously by profit maximization as part of the general equilibrium conditions of the dynamic model. We find that, at the current real interest rates of 10%, the long run effect of NAFTA is a 3.4% increase in Mexican net domestic product at world prices. The gains are significantly greater if NAFTA reduces real interest rates. If these fall to 9%, then net domestic product increases by 9.2% in the long run.

Our estimates of the benefits from NAFTA are higher than estimates from existing static models. The reason could be as follows. The recent economic liberalization of Mexico has already led to a substantial reduction in tariffs. Since existing nominal rates of protection are quite low, removing these distortions leads only to minor gains in a model where both consumption and production losses from tariffs are essentially proportional to nominal rates of protection. In our model, the consumption losses from tariffs are likewise quite small (of the order of 0.25% of NDP). However, the richer structure of inter-sectoral flows in our model captures more of the distortionary impact of the existing tariff structure on the value added in various sectors. We therefore obtain higher estimates of the production losses arising from inter-sectoral discrepancies in effective rates of protection (Corden (1966, 1975)). As explained in Section 9, the high real interest rates prevailing in Mexico imply that tariffs on capital goods lead to particularly severe inter-sectoral discrepancies in effective rates of protection. Our model also captures additional gains from the NAFTA from improved efficiency in input use within sectors and in the intertemporal allocation of resources within and across sectors.

2. THE DUAL APPROACH TO POLICY MODELLING

The key innovation in our modelling technique is the consistent use of duality in a dynamic open economy model which extends the model of Young and Romero (1990). The monograph of Dixit and Norman (1980) established the dual approach as the standard method of presenting theoretical issues in international economics because of the clarity and economy that results when the first-order conditions for consumer and producer choice are impounded in the dual functions specifying their behavior. Duality also facilitates clarity and economy in empirical modelling of international issues. The dual approach to estimating a sector's production function and determining its factor demands via the cost function is well-known (see the Peat Marwick study). We go further by stating all the equilibrium conditions of the model in terms of the estimated cost functions. Since these cost functions build in the optimal intra-period input choices of firms, this obviates the first-order conditions for these choices. In calculating the steady growth path of the economy, we also bypass the first-order conditions for output and investment by exploiting the intertemporal relationship between the price of capital and the stream of future rentals from the capital. In calculating the transition to steady growth, we can again bypass the first-order conditions for output and investment by using the Second Fundamental Theorem of Welfare Economics and the maximization procedures built into the GAMS computational package to duplicate market outcomes.

These techniques mean that our dynamic general equilibrium model does not require explicit computation of any first-order conditions. This sharply reduces the number of equations, yielding a compact, yet transparent, model which is readily computable.

3. Estimation of Cost Functions

For each sector, we have price indices both for the broad categories of labor, capital and intermediate goods and for the outputs of each of the 12 sectors, including individual intermediate and capital goods. Labor and intermediate inputs are used up in one period, but capital goods depreciate over time, while receiving a rental from the profits of that sector. Of course, there is no way to impute rentals separately to the individual capital goods: machines m, buildings b (which includes all construction) and vehicles v. Nor do we have individual depreciation rates for these goods.

Given the form in which the data is available, it is natural to view production as taking place in two stages. In stage I, the representative sector i firm produces :

(a) a composite capital good K_i using machines, buildings and vehicles;

(b) a composite intermediate good M_i using various intermediate goods.

In stage II, the firm produces good i using K_i, M_i and labor L_i. The time t mix of capital goods m,b,v used to produce K_i is that minimizing the cost of production, given the time t prices p_{mt}, p_{bt}, p_{vt} of the three capital goods. The depreciation rate d_i of K_i comes directly from the data. The time t rental r_{it} on a unit of K_i equals the time t profits in sector i, divided by the amount of K_i — which equals the time t value of sector i capital, divided by its price p_{iKt}. Thus:

$$(1) \qquad r_{it} = \frac{\text{time t profits} \,.\, p_{iKt}}{\text{time t value of capital}}$$

All production functions are assumed to exhibit constant returns to scale.

The unit cost function for K_i is assumed to be a translog function $C_{iK}(p_m, p_b, p_v)$ of the prices of the individual capital goods. The production function for M_i is assumed to be Cobb-Douglas, so that its unit cost is a Cobb-Douglas function of the vector $p = (p_1,..,p_n)$ of intermediate goods prices:

(2) $$C_{iM}(p) = \gamma_i p_1^{s_{i1}} p_2^{s_{i2}} \ldots p_n^{s_{in}}$$

where s_{ij} is the share of intermediate good j in the total cost of the intermediate good used in the production of good i. These shares are obtained from the Social Accounting Matrix. The constant γ_i is chosen so that the price that emerges from (2) equals the price of the composite intermediate good q_i observed in 1988. Finally, the stage II production function of sector i is estimated indirectly from its cost function $C_i(w_i,r_i,q_i)$, which is assumed to be a translog function of the wage w_i, the rental r_i and the price q_i of M_i.

4. Input Demands

The unit cost function for good i as a function of the sector i wage and rental rate and the prices of individual intermediate goods can be obtained by substituting the unit cost function for intermediates estimated in stage Ib for the intermediate goods price q_i in the cost function $C_i(w_i,r_i,q_i)$ estimated in stage II:

$$c_i(w_i,r_i,p) = C_i(w_i,r_i,C_{iM}(p))$$

By the Shephard-Samuelson relations, the sector i demand for labor a_{iL}, the composite capital good a_{iK} and the individual intermediate goodsis obtained by differentiating c_i with respect to the corresponding price (or rental in the case of the capital good). The demand A_{ik} for capital good k (= m,b,v) per unit of the composite capital good K_i is obtained by differentiating C_{iK} with respect to p_{ik}. Thus, the sector i demand for capital good k per unit of output is:

$$a_{ik}(w_i,r_i,p) = a_{iK}(w_i,r_i,p)A_{ik}(p_m,p_b,p_v).$$

5. Steady Growth

All models with a finite horizon T encounter the problem of modelling investment in capital goods which would be fully depreciated only beyond T. Our approach is to suppose that the time T capital stock and investment rates are at the levels corresponding to a steady growth path, where goods prices are steady but every sector's output, labor force and capital stock expands at a fixed rate g, so that factor returns and capital goods prices are steady also.

The steady growth rental r_i on a unit of capital in sector i satisfies:

(1) $$p_i = c_i(w_i,r_i,p) \qquad i = 1,..,12$$

In equilibrium, the price of new sector i capital equals the unit cost of capital $c_{iK}(p_m,p_b,p_v)$; it also equals the present value of the rentals from that unit, future rentals being discounted at the real rate of interest i plus the empirically-observed depreciation rate d_i:

(2) $$c_{iK}(p_m,p_b,p_v) = \sum_{t=1}^{\infty} r_i \frac{(1-d_i)^{t-1}}{(1+i)^t} = \frac{r_i}{i+d_i}$$

The equilibrium condition for sector i labor is:

(3) $$a_{iL}(w_i,r_i,c_{iI}(p))y_i = L_i$$

All goods except buildings are traded and therefore have their prices determined internationally, once the trade policy is specified. The price of buildings, however, is determined by internal market-clearing conditions. Buildings are demanded by industry, by individuals and by the government. In principle, it would be desirable to estimate private demand for buildings as a function of private income and to include this in the market-clearing conditions. However, there are insurmountable data problems since private housing demand responds to considerations which have fluctuated widely over the estimation period, such as the anticipated rate of inflation, the availability and the terms of finance and the desire to hold wealth in a nontaxable form. Moreover, the government provides a significant portion of the housing stock, as well as all infrastructure — which is included in the category "buildings". Since industrial demand for construction has been a relatively stable proportion of the output of the construction industry, we shall suppose that, as a matter of social policy, the government targets the proportion of construction available to meet private and government demands. Our simulation sets this equal to the proportion that obtained in 1988, when the value of output in the construction industry was 82,481 million pesos while industrial usage was 51,337 million pesos. Thus, we set total demand for construction equal to industry demand multiplied by F = 82,481/51,337 = 1.61. Of course, we can easily explore the implications of other values of F.

The steady growth stock of buildings in sector i is that implied by steady growth output:

$$a_{ib}(w_i,r_i,p)y_i$$

Steady growth investment in sector i buildings is that required to ensure that the stock of buildings grows at a rate g after depreciation d_i:

$$(g+d_i)a_{ib}(w_i,r_i,p)y_i$$

Thus, industry demand is $\sum_i (g+d_i)a_{ib}(w_i,r_i,p)y_i$, while total demand for buildings is assumed to be larger by a factor F. Thus, equilibrium in the market for new buildings requires that:

(4) $$F\sum_i (g+d_i)a_{ib}(w_i,r_i,p)y_i = y_b$$

There is no corresponding constraint on machines or vehicles since they are traded.

This model can be solved for steady growth outputs and factor returns. There are 12 sectors, including three capital goods sectors. We assume that all goods (apart from buildings) are traded so that (1) and (2) comprise 24 equations in 25 unknowns (w_i, r_i for i = 1,..,12, plus p_b, which is endogenously determined since buildings are nontraded). (3) comprises 12 equations and (4) comprises 1 equation, so we have 37 equations in 37 unknowns.

6. Optimization of the Sectoral Labor Forces Under Steady Growth.

Instead of requiring the sectoral labor forces to grow exogenously at the rate g of ...pulation growth up to the beginning T of the steady growth phase, we allow deviations v... in some specified bounds $(g-f_i, g+h_i)$ while forcing the total labor force to grow at the rat... Thus, in solving for the steady growth path starting at time T, we impose the constraints:

$$(1+g-f_i)^T < L_{iT}/L_{i0} < (1+g+h_i)^T \text{ and } \Sigma_i L_{iT} = (1+g)^T L_{i0}$$

and choose the L_{iT} to maximize steady growth net domestic output (i.e., domestic output net of capital depreciation and input costs) valued at domestic prices in order to duplicate the effect of market choices in face of domestic prices. We then compare the steady growth value of net domestic output (NDP) at world prices under free trade and under current tariffs. The next section provides a rigorous welfare interpretation of our empirical results.

7. Production and Consumption Gains from NAFTA

If a country practices free trade at world prices π and its NDP is $r(\pi)$, then its welfare u^f is given by the income-expenditure identity:

(1) $$e(\pi, u^f) = r(\pi)$$

where e(.,.) is the country's expenditure function (Dixit and Norman (1980)). If the country imposes a vector T of ad valorem tariffs and therefore faces internal prices $p_i = \pi_i(1+T_i)$ for good i, and its NDP at these prices is $r(p)$ while its tariff revenue is R, then its welfare u^T is given by the income-expenditure identity:

(2) $$e(p, u^T) = r(p) + R.$$

Suppose that the expenditure function is multiplicatively separable (i.e., consumer preferences are homothetic) with the form:

$$e(p,u) = I(p)f(u)$$

where I(p) is the exact consumer price index and f(u) is "real income". Then the expenditure required to ensure free trade utility u^f at internal prices p is:

(3) $$e(p,u^f) = e(\pi,u^f)I(p)/I(\pi) = r(\pi)I(p)/I(\pi) \text{ by (1)}$$

Thus, a NDP of $r(\pi)$ in face of world prices π yields the same welfare as a NDP of $r(\pi)I(p)/I(\pi)$ in face of tariff-ridden prices p. Thus, NAFTA increases domestic real income by the factor:

(4) $$\frac{f(u^f)}{f(u^T)} = \frac{e(p,u^f)}{e(p,u^T)} = \frac{r(\pi)}{r(p)+R}\,\frac{I(p)}{I(\pi)} = \frac{r(\pi)}{\Sigma_i \pi_i y_i(p)}\,\frac{\Sigma_i \pi_i y_i(p)}{r(p)+R}\,\frac{I(p)}{I(\pi)}$$

For example, if this equals 1.09, then without NAFTA, a 9% increase in income would be needed to achieve the welfare level attainable under NAFTA.

Both production and consumption gains are included in this calculation. In (4), the term $\frac{r(\pi)}{\Sigma_i \pi_i y_i(p)}$ is the factor by which NDP increases as a result of NAFTA, when output is evaluated at world prices. This measures the production gain from NAFTA, i.e., the increased value at world prices π of the country's output when internal producer choices are made facing world prices rather than the distorted prices obtaining under a tariff. The term $\frac{\Sigma_i \pi_i y_i(p)}{r(p)+R} \frac{I(p)}{I(\pi)}$ in (4) measures the consumption gain from NAFTA, i.e., the gain arising when internal consumer choices are made facing world prices rather than the distorted prices obtaining under a tariff, so that consumer needs are met at a lower foreign exchange cost. Exploiting the homotheticity of consumer preferences, an elementary calculation (Appendix A) shows that:

(5) $$\frac{\Sigma_i \pi_i y_i(p)}{r(p)+R} = 1 - \Sigma_i \frac{s_i T_i}{1+T_i}$$

where s_i is the share of consumer expenditure on good i. (5) gives the impact of a unit increase in domestic expenditure on the foreign exchange cost of the goods consumed. This is less than 1 because some the expenditure increase is returned to the domestic economy as tariff revenue. Thus, the consumption gain from NAFTA increases welfare by the factor:

$$\left\{ 1 - \Sigma_i \frac{s_i T_i}{1+T_i} \right\} \frac{I(p)}{I(\pi)}$$

i.e., the percentage consumption gain from NAFTA equals the percentage increase in the cost of living due to the tariffs minus the percentage of domestic expenditure that would be returned to the domestic economy as tariff revenue.

Cobb-Douglas preferences imply that the expenditure share s_i on each good i is fixed and that the expenditure function has the form:

$$e(p,u) = u p_1^{s_1} p_2^{s_2} \ldots p_n^{s_n}$$

so the tariffs T_i increase the consumer price index by the factor:

$$\frac{I(p)}{I(\pi)} = (1+T_1)^{s_1} (1+T_1)^{s_2} \ldots (1+T_n)^{s_n}$$

Estimating Mexican demand parameters assuming Cobb-Douglas preferences, we find that NAFTA would reduce the cost of living by 3.59% while 3.36% of domestic expenditure is returned to the Mexican economy as tariff revenue. Thus, the consumption gain from NAFTA is about 0.23%. This is very small compared to the production gains reported below, indicating that it is hardly worthwhile making more sophisticated estimates, e.g., with more flexible functional forms or non-homothetic preferences. Thus, we henceforth focus on production gains.

8. Steady Growth Outcomes

The following results were obtained for steady growth net domestic product at world prices.

A: Tariffs i = 10%	B:Free Trade i = 10%	C:Free Trade i = 9%	$\frac{B-A}{A}$	$\frac{C-A}{A}$	$\frac{C-B}{B}$
411,969,600	426,114,800	450,019,100	3.4%	9.2%	5.6%

Thus, the long-run effect of NAFTA is a substantial increase in Mexican net domestic product, even at current real interest rates. The gains are even greater if NAFTA reduces Mexican real interest rates, as we would expect for the reasons given below in Section 9.4. Our analysis indicates that this could well be one of the most significant benefits of NAFTA to Mexico.

The above results assume that each sector's share of the labor force can deviate from its current share by 20% either way. Earlier models assumed perfect labor mobility, yet estimated much smaller gains from NAFTA. In general, we found that the gains from NAFTA are greater, the greater the deviations allowed in the structure of employment. Thus, the benefits from NAFTA to Mexico would be substantially enhanced by government policies which facilitate labor mobility, such as an expansion of educational opportunities.

In ongoing work, we are solving the model for the transition path of the Mexican economy toward steady growth. This will enable us to determine the behavior of Mexico's balance of trade and capital flows along this path. Our approach to analyzing the transition is set out in Appendix B.

9. The Economic Gains from NAFTA

This section provides an intuitive idea of the economic gains from NAFTA that are captured in our model, contrasting them with the gains captured in earlier models.

9.1. Equalization of Effective Rates of Protection: Static Gains

Consider three sectors A, B and C, each protected by a nominal 5% tariff. If each sector used only Mexican inputs which are themselves unprotected, then their effective rates of protection would be the same and there would be no misallocation of resources across the three sectors, although there would be a misallocation between these sectors and sectors producing nontraded goods. The latter misallocation would be small because of the low level of the nominal tariffs. By contrast, suppose that the free trade percentage of the final product price representing value added from Mexican sources is 90% in A, 50% in B and 50% in C. Suppose also that A and B use inputs which are imported freely, while C uses inputs which are subject to a 20% tariff. The standard formula for effective protection then implies that the tariff structure has increased the value added from Mexican sources by +5.55% in A, +10% in B and - 5% in C, severely distorting the allocation of these resources between these sectors, even though all enjoy the same nominal protection. Moreover, relative to nontradeables, the value added in sector B has increased by 10% while that in sector C has fallen by 5%, suggesting that NAFTA would move resources from B into nontradeables and from nontradeables into C. Thus, removing modest nominal tariffs can significantly improve the efficiency of resource use. The gains from eliminating a complex tariff structure can be estimated only within a CGE which captures all inter-sectoral resource flows: there can be no presumption that low nominal tariff rates imply low gains. Indeed, as the above examples illustrate, *low* nominal rates of protection of a final good sector tends to imply *high* negative effective protection when combined with moderate tariffs on inputs. Thus, models with highly aggregated input structures which fail to capture the impact of NAFTA on traded input prices could bypass important efficiency gains.

9.2. Equalization of Effective Rates of Protection: Dynamic Effects

Machinery and other capital goods are currently subject to substantial nominal tariffs of the order of 16% - 20%. We pointed out above that a sector whose inputs are highly protected suffers negative effective protection and ends up too small relative to sectors enjoying positive effective protection. This effect is stronger, the greater the share of the final product price absorbed by inputs which are subject to tariffs. For goods whose production requires substantial investment, the relevant "final product price" is the present value of the future revenue generated. The very high real rates of interest currently obtaining in Mexico imply that, in highly capital-intensive sectors, the cost of capital goods is particularly high relative to the present value of the revenue stream generated from investment in those goods. Thus, highly capital-intensive sectors suffer particularly high negative levels of effective protection. The tariffs on capital inputs act like a tax on capital accumulation, slowing economic growth by raising the perceived cost of producing for future periods and cutting off investment projects which would enhance labor productivity. The efficiency losses imposed by the tariffs on capital inputs are cumulative, reducing the rate of economic growth.

9.3. Efficient Input Use Within a Sector

Tariffs not only misallocate resources across sectors, but also prevent each sector from using the input combination with the lowest foreign exchange cost. Models with highly aggregated input structures could bypass the potential gains from NAFTA arising from the more efficient use of inputs within a sector. For example, within a broad category such as "materials", the removal of tariffs on different types of materials will lead sectors to choose combinations of materials which cost the country less foreign exchange, but these cost savings will not be captured in a model which treats all "materials" as an aggregate. Indeed, unless the model captures the full impact of the removal of tariffs on the internal prices of the aggregative inputs, it will not even fully capture the gains from the use of more efficient combinations of these inputs.

The detailed modelling of intersectoral flows in our model should capture more of the gains from more efficient input use within each sector. The prevailing high interest real rates imply that these gains will be particularly great since they exacerbate the inefficiencies in input use within a sector that result from tariffs on capital goods. Faced with high rates, an entrepreneur will economize sharply on capital goods whose prices have been raised by tariffs, resulting in production techniques which are inefficient for the country as a whole, given their actual opportunity cost.

9.4. A Fall in Real Interest Rates

If the current high real rates in Mexico arise from a high degree of uncertainty about future monetary policy and about the economy generally, and such uncertainty would be substantially reduced by NAFTA, then significant reductions in the real interest rates can be expected. Static models cannot take account of the impact of the fall in Mexican real interest rates that is likely to accompany NAFTA. Our analysis indicates that this will be one of its most important benefits, contributing a 5.6% increase in net domestic product. As real interest rates fall, industries switch to more capital intensive techniques, increasing the productivity of the existing labor force and raising NDP.

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Appendix A. Derivation of Equation (7.5).

Tariff revenue R satisfies:

(a1) $$R = \sum_i \frac{p_i T_i}{1+T_i}\{d_i(p, r(p)+R) - y_i(p)\}$$

Given homothetic preferences, the share s_i of expenditure on good i is independent of income so:

$$d_i(p, r(p)+R) = \frac{\{r(p)+R\}s_i}{p_i}$$

and (a1) becomes:

$$R = \sum_i \frac{p_i T_i}{1+T_i} \frac{\{r(p)+R\}s_i}{p_i} - \sum_i \frac{T_i p_i y_i(p)}{1+T_i}$$

Therefore:

$$r(p) + R = r(p) + \{r(p)+R\}\sum_i \frac{s_i T_i}{1+T_i} - \sum_i \frac{T_i p_i y_i(p)}{1+T_i}$$

and:

$$\{r(p)+R\}\left\{1 - \sum_i \frac{s_i T_i}{1+T_i}\right\} = r(p) - \sum_i \frac{T_i p_i y_i(p)}{1+T_i}$$

$$= \sum_i \pi_i(1+T_i)y_i(p) - \sum_i \pi_i T_i y_i(p)$$

$$= \sum_i \pi_i y_i(p)$$

(7.5) follows immediately.

APPENDIX B: TRANSITION TO THE STEADY GROWTH PATH

B.1 Steady Growth Quantities Needed to Calculate the Transition Path.

Let L_{iT} be the labor force at time T, the end of the transition phase and the beginning of steady growth phase. It will be convenient to set this equal to the starting labor force in sector i (i.e., set T = 0). Calculate the steady growth values of:

(a) sector i capital K_{is};

(b) the price of capital in each sector;

(c) domestic income at world prices = the value of output at world prices less the depreciation on capital.

(d) The present value of the stream of domestic income, discounted at the world rate of interest. This equals steady growth domestic income divided by i.

Steady growth with a labor force larger by a factor A could proceed if the values of capital in sector i are AK_{is}. All steady growth quantities would then be multiplied by A, while steady growth prices would be unchanged.

B.2 Transition Time to Steady Growth

To determine whether an economy starting with specified capital stocks can move to the steady state solution within just one period, compare the depreciated capital stocks at the end of the first period with the capital stocks that would prevail under steady growth, given a labor force equal to the time 0 labor force plus one period's populaton growth. If the latter capital stocks are larger in all sectors, then steady growth is possible after just one period. If not, then the steady state can be attained in two periods if the starting capital stocks, depreciated over two periods, are all less than the steady growth capital stocks corresponding to a population equal to the time 0 population plus two period's population growth. Extending this reasoning, the transition phase requires at least T periods where T is the smallest integer such that for all sectors i:

$$K_{i0}(1-d_i)^T < K_{is}(1+g_i)^T$$

where K_{i0} is the value of sector i at time 0 and K_{is} is the steady growth value of sector i capital associated with sectoral labor forces equal to their time 0 levels.

Suppose that the transition takes one period. In the fastest transition path, time 0 investment in sector i equals the difference between the depreciated time 0 capital stock and the time 1 steady growth capital stock. The sum across sectors of the investments in new buildings then gives the output of the building sector required at time 0. However, this fastest path might result in too low domestic income in the early transition periods as excessive resources are devoted to the investment needed to achieve the steady state capital stocks. The present value of domestic income might be higher under a slower transition which attains steady growth only after $T > 1$ periods.

B.3 Equilibrium Conditions for the Transition to Steady Growth with Exogenous Sectoral Labor Forces and Investment

At transition times $t = 0,..T-1$, the rental r_{it} on sector i capital satisfies:

(1) $$p_{it} = c_i(w_{it}, r_{it}, p_t)$$

The equilibrium condition for sector i labor is:

(2) $$a_{iL}(w_{it}, r_{it}, p_t)y_{it} = L_{it}$$

The equilibrium condition for sector i physical capital is:

(3) $$a_{iK}(w_{it}, r_{it}, p_t)y_{it} = K_{it}$$

The equilibrium condition for buildings is:

(4) $$\Sigma_i\, a_{ib}(w_i, r_i, p)I_{it} = y_{bt}$$

where I_{it} is the time t physical investment in sector i .

Time 0 (=1988) physical capital in sector i, K_{i0}, is obtained from the data. Its time t value for t = 1,..,T-1 equals the depreciated value of time t-1 physical capital plus the time t-1 value of physical investment:

(5) $K_{it} = (1-d_i)K_{it-1} + I_{it-1}$

Thus. if we know sectoral physical investment at $t = 0,...,T-1$, then we can deduce the capital stocks for $t = 0,...,T$. Given also the sectoral labor forces during the transition, at any $t = 0,...,T-1$, (1) - (4) comprise 37 equations in 37 unknowns $(w_{it}, r_{it}, y_{it}, p_{bt})$.

Time t domestic net output comprises:

(i) the time t value of the net output of the consumption/investment goods industries i, i.e., gross output of i less total usage of i as an input)

(ii) the time t value of the output of each capital goods industry $j = m,b,v$ less depreciation on existing capital. The cost of investment to the economy as a whole shows up in these depreciation terms: investment per se (as distinct from the domestic production of machines, buildings and vehicles) does not add to nor detract from domestic output but depreciation of the capital goods acquired detracts from future net output.

B.4 Optimization Over the Transition with Exogenous Sectoral Labor Forces

Let the time t sectoral labor forces L_{it} equal the time 0 labor forces plus t periods' population growth. Set GAMS to choose sectoral physical investments (I_{it}) during the transition (subject to $I_{it} \geq 0$) to solve the following problems:

(a) maximize the time 0 present value of domestic net output over the transition phase (valued at domestic prices) plus the time 0 present value of the time T capital stock, valued at the domestic prices for time T capital determined by the steady growth solution.

(b) maximize the present value of domestic net output over the transition phase (valued at domestic prices), ignoring the terminal value of capital but constraining the time T capital stocks to equal the levels required to begin steady growth at time T with the population exogenously specified for time T.

The Second Fundamental Theorem of Welfare Economics indicates that problem (a) duplicates the market outcome when investors can sell the terminal capital stocks at their steady growth prices. Similarly, optimization (b) duplicates the market outcome when investors can sell the terminal capital stocks at prices equal to the T Kuhn-Tucker multipliers associated with the constraints on the terminal capital stocks. Investment choices at times $t < T$ would then satisfy the following market equilibrium conditions for time t positive investment [with complementary slackness]:

$$c_{iK}(p_{mt}, p_{bt}, p_{vt}) \geq \sum_{\tau=t+1}^{T-1} r_{i\tau} \frac{(1-d_i)^{\tau-t-1}}{(1+i)^{\tau-t}} + c_{iK}(p_{mT}, p_{bT}, p_{vT}) \frac{(1-d_i)^{T-t-1}}{(1+i)^{T-t}} \quad [I_{it} \geq 0]$$

i.e., time t investment in sector i is positive only if the time t price of a unit of new sector i capital equals the time t present value of the rentals which that unit would earn up until time T (when steady growth commences) plus the time T value of the depreciated capital. For problem (a), p_{iKT} equals the steady growth price of sector i capital and for problem (b) p_{iKT} equals the Lagrange multiplier associated with the constraint on the time T capital stock in sector i.

Von Neumann's Theorem on the optimality of balanced growth indicates that if the transition and the steady growth phases comprise an optimal program, then (a) and (b) would yield the same outcomes since the time T prices of sector i capital used in (a) would equal the Kuhn-Tucker multiplier in (b) associated with the constraint on the time T capital stock in sector i. Thus, the discrepancy between the solutions in (a) and (b) measures whether the transition time T has been set far enough into the future that we are close to maximizing the present value of net domestic income at domestic prices - and thus duplicating the restricted market outcome. T should be increased until this discrepancy is small.

The effects of NAFTA can then be evaluated by comparing the present values of net domestic income at world prices under the two policies when this is summed over the transition and the steady growth phases.

B.5 Optimization over the Transition with Endogenous Sectoral Labor Forces

Instead of forcing the sectoral labor forces to grow at the rate of population growth, we could allow deviations in the growth rate each period within specified bounds while forcing the total labor force to grow at the population growth rate g. Thus, during the transition, we impose the constraints:

$$1+g-f_i < L_{it}/L_{it-1} < 1+g+h_i \quad \text{and} \quad \Sigma_i L_{it} = (1+g)L_{it-1}$$

We then set GAMS to choose the L_{it} to maximize value of net domestic output (i.e., domestic output net of capital depreciation and input costs) valued at domestic prices in order to duplicate the effect of market choices. We then compare the steady growth value of net domestic output valued at world prices under free trade and under tariffs.

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