11

Toward a Dynamic General Equilibrium Model of North American Trade*

Timothy J. Kehoe
University of Minnesota and
Federal Reserve Bank of Minneapolis

I. Introduction

The current tool of choice for analyzing the impact of the North American Free Trade Agreement (NAFTA) on the economies of Canada, Mexico, and the United States is the static applied general equilibrium model. Examples of such analyses include Brown, Deardorff, and Stern (1991); Cox and Harris (1991); Hinojosa-Ojeda and Robinson (1991); KPMG Peat-Marwick (1991); Sobarzo (1991); and Yúnez-Naude (1991). They all tend to find small, but favorable, impacts of such an agreement.

Static applied general equilibrium models can do a good job in analyzing, and even in predicting, the impact of trade liberalization or tax reform on relative prices and resource allocation over a short time horizon. Kehoe, Polo, and Sancho (1991), for example, assess the performance of a static general equilibrium model of the Spanish economy that had been constructed to analyze the impact of the tax reform that accompanied Spain's 1986 entry into the European Economic Community. They find that the model was able to account for more than two-thirds of the variation of relative prices that occurred between 1985 and 1987. (It would be interesting to do similar ex post performance evaluations of the analyses of NAFTA.)

Typically, however, this sort of model predicts small changes in economic

* I am grateful to Karine Moe for diligent and energetic research assistance. The views expressed herein are those of the author and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

welfare [see Shoven and Whalley (1984); Whalley (1989)]. One reason for this is that these models do not attempt to capture the impact of government policy on growth rates. For this we need a dynamic model. Anything that can affect the growth rate of a variable like income per capita or output per worker, if only slightly, can have a tremendous impact over time.

Currently, there is no model that analyzes the impact of NAFTA on growth rates. This paper outlines some of the issues that confront a researcher interested in building a dynamic applied general model to assess the potential economic impact of NAFTA, including the impact on growth rates. A dynamic model can capture the effect of government policy on capital flows, and these are very important. Yet, as we argue in the next section, a low capital-labor ratio cannot be the only, or even the most important, factor in explaining the low level of output per worker in Mexico compared to that in a country like the United States. We must look elsewhere for explanations for the differences in levels of output per worker. It is here that the new, endogenous growth literature, which follows Romer (1987) and Lucas (1988) and focuses on endogenous technical change, is able to provide potential answers. This literature is still at a tentative, mostly theoretical level. By developing a disaggregated dynamic general equilibrium model of the three countries of North America, we could go a long way towards making this theory operational. A model could be calibrated, and alternative versions of the theory could be tested by applying them to past experience. The present paper uses preliminary empirical work at an aggregate level to estimate the impact of free trade on growth rates in Mexico.

Although our calculations are fairly crude, they suggest that the dynamic impact of NAFTA could dwarf the static effects found by more conventional applied general equilibrium models. Similar kinds of suggestive calculations are performed to estimate the dynamic gains from the European Economic Community's 1992 Program by Baldwin (1992). Unlike Baldwin's analysis, however, the results presented here are based on theories and empirical estimates that deal with trade directly. Baldwin obtains his numbers by multiplying estimates of static gains from trade obtained by other researchers by a multiplier derived from a highly aggregated growth model with dynamic increasing returns but without any explicit role for trade. It is worth pointing out that the analysis in this paper does not take into account phenomena like unemployment or underutilization of capacity. It is possible that a free trade agreement would provide dynamic gains based on a more traditional macroeconomic analysis; see Fischer (1992) for some suggestive results in this direction.

Although the endogenous growth literature is still at a tentative stage, the intuition behind it is fairly simple. Increased openness can alter the growth rate in clear ways; economic growth is spurred by the development of new products. New product development is the result of learning by doing, where experience in one product line makes it easier to develop the next product in the line, and of direct research and development. On the final product side, increased openness allows a country to specialize more, achieving a larger scale of operations in those industries in which it has a comparative advantage. On the input side, increased openness allows a country to import many technologically specialized inputs to the production process without needing to develop them itself.

It is worth noting that the analysis in this paper pertains to the benefits of free trade in general, not just in the context of NAFTA. Because of their relative sizes and geographical locations, Canada and Mexico do most of their trading with the United States; see Figure 11.1. For them the concepts of free trade and NAFTA are inextricably connected. Although Canada is the United States' largest trading partner and Mexico its third largest, about three-quarters of U.S. trade is with countries outside North America. Nonetheless, NAFTA represents an opportunity for the United States to commit itself to a free trade policy, and for this reason the progress on NAFTA is being closely monitored throughout the world.

II. Capital Flows

A major impact of NAFTA would be on capital flows. One would expect capital to flow from relatively capital-rich Canada and the United States to relatively capital-poor Mexico. Indeed, it is by exogenously imposing a substantial capital flow of this sort that static models such as that of KPMG Peat-Marwick (1991) are able to show a significant welfare gain to Mexico. It is worth stressing two points about capital flows, however. First, differences in capital-labor ratios between Mexico and its northern neighbors cannot be the sole explanation of the large differences in output per worker between these countries. [See Lucas (1990) for a discussion and calculations similar to those below.] Consequently, simply equalizing capital-labor ratios cannot be the solution to the problem of eliminating income differences. Second, when modeling the savings and investment decisions that determine capital flows, we need to take into account the significant differences in age profiles of the population between Mexico and its neighbors. This point is discussed further in the next section.

To illustrate the point that differences in capital-labor ratios cannot explain the differences in output per worker observed in Mexico and the United States, we carry out some simple calculations using aggregate production functions. Suppose that each economy has the same production function

$$Y_j = \gamma N_j^{1-\alpha} K_j^{\alpha}$$

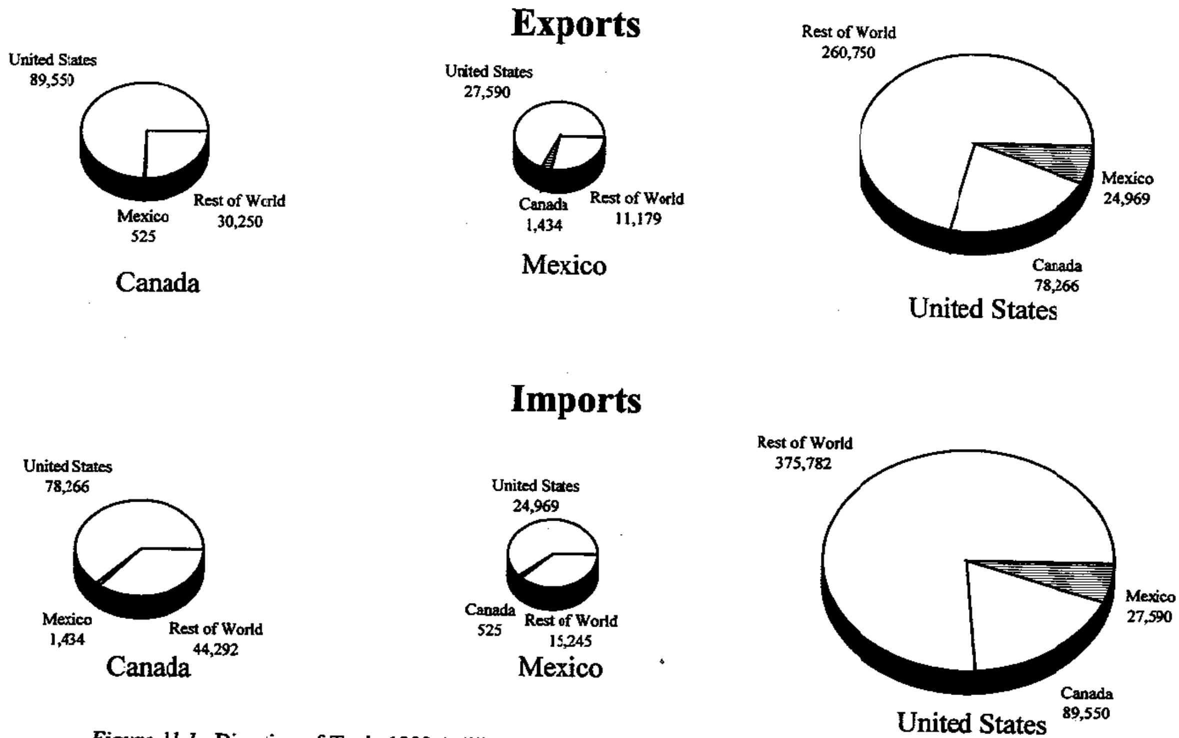

Figure 11.1. Direction of Trade 1989 (millions of 1989 U.S. dollars)
Source: IMP, *Direction of Trade Statistics Yearbook*, 1990.

where Y_j is GDP, N_j is the size of the work force, and K_j is capital. In per capita terms, where $y_j = Y_j/N_j$ and $k_j = K_j/N_j$, this becomes $y_j = \gamma k_j^{\alpha}$. The net return of capital is

$$r_j = \alpha\gamma k_j^{\alpha-1} - \delta$$

where δ is the depreciation rate. In 1988, according to Summers and Heston (1991), real GDP per worker was \$14,581 in Mexico and \$37,608 in the United States. Suppose that $\alpha = 0.3$, which is roughly the capital share of income in the United States. Then, to explain this difference in output per worker, we need capital per worker to be larger than that in Mexico by a factor of 23.5,

$$\frac{k_{us}}{k_{mex}} = \left(\frac{y_{us}}{y_{mex}}\right)^{1/\alpha} = \left(\frac{37{,}608}{14{,}581}\right)^{1/0.3} = 23.5.$$

Suppose that $\delta = 0.05$ and $r_{us} = 0.05$, which are roughly the numbers obtained from calibration. Then the net interest rate in Mexico should be 17.2 times that in the United States,

$$r_{mex} = (r_{us} + \delta)\left(\frac{k_{us}}{k_{mex}}\right)^{1-\alpha} - \delta = 0.10(23.5)^{0.7} - 0.05 = 0.86.$$

During the 1988–90 period, the real return on bank equity in Mexico (and banks are the major source of private capital in Mexico) averaged 28.2 percent per year, as compared to 4.7 percent in the United States [see Garber and Weisbrod (1991)]. Because 28 percent is far less than the 86 percent that we would expect if differences in capital-labor ratios were the principal determinant of the differences in output per worker between Mexico and its neighbors, we must look elsewhere for this determinant.

There are at least two objections that can be raised to the above calculations: First, a comparison based on per capita GDP in U.S. dollars using the exchange rate to convert pesos into dollars would suggest that y_{us}/y_{mex} is much larger, about 7.9. Second, calibrating the capital share parameter α using Mexican GDP data would yield a larger value, about 0.5. These two objections work in opposite directions, however, and our calculations can be defended as being in a sensible middle ground – income comparisons based on exchange rate conversions neglect purchasing power parity differentials; per capita comparisons rather than per worker comparisons neglect demographic differences; much of what is classified as net business income in Mexico is actually returns to labor; and so on.

Moreover, that differences in capital per worker cannot be the sole explanation of differences in output per worker across countries is a more general point. It is supported both by historical evidence, such as that of Clark (1987), and by even more extreme examples of differences in output per worker:

According to Summers and Heston (1991), real GDP per worker in Haiti in 1988 was 4.9 percent of that in the United States. The same sort of calculations as those above would suggest that interest rates in Haiti should be over 11,000 percent per year if differences in the capital-labor ratio were the sole explanation of the differences in output per worker. Furthermore, historical evidence does not indicate that Mexico has always been starved of funds for investment. The problem has often been that investments abroad, particularly in the United States, have been more attractive. Between 1977 and 1982, for example, \$17.8 billion of private investment flowed into Mexico, while \$18.7 billion flowed out [Garcia-Alba and Serra-Puche (1983), p. 45].

Although capital flows cannot provide all of the answers to Mexico's problems, they are important. If capital flows could lower the net interest rate in Mexico from 28 percent per year to 5 percent, we would estimate that the capital labor ratio in Mexico would increase by a factor of about 5.5:

$$\frac{\hat{k}_{\text{mex}}}{k_{\text{mex}}} = \left(\frac{0.28 + \delta}{0.05 + \delta}\right)^{1/(1-\alpha)} = 5.5.$$

This would increase Mexican output per worker to roughly \$24,300, which would close the current gap with the U.S. level by about 42 percent.

A dynamic applied general equilibrium model would be an ideal tool for analyzing the capital flows that would result from NAFTA. With some sectional disaggregation, such a model could account for differences in total factor productivity in the United States and Mexico that differ widely across sectors. Total factor productivity in some sectors in Mexico is similar to that in the United States, whereas in others it is much lower [see, for example, Blomstrom and Wolf (1989)]. The calculations of the impact of capital inflows reported above are based on aggregate production functions and ignore these differences. A disaggregated model would enable us to capture the various impacts that capital flows would have on different sectors.

If a model is to explain the impact of large capital inflows on the Mexican economy, it should be able to answer this question: If the post-NAFTA interest rate in Mexico is to be so much lower than the pre-NAFTA interest rate, why is the pre-NAFTA rate so high? One possible answer is that a high interest rate in Mexico is the result of closed capital markets and of inefficient, oligopolistic financial intermediaries. If this is the case, we would want to model imperfect competition in the financial services sector and to model explicitly the way in which NAFTA would lower the interest rate.

Another potential answer is that the gap between the pre-NAFTA interest rate in Mexico and the U.S. interest rate represents a risk premium: International investors demand a higher rate of return in Mexico because they fear that a financial collapse and maxidevaluation like that which occurred in 1982 would wipe out much of their investment. By locking Mexico and its two

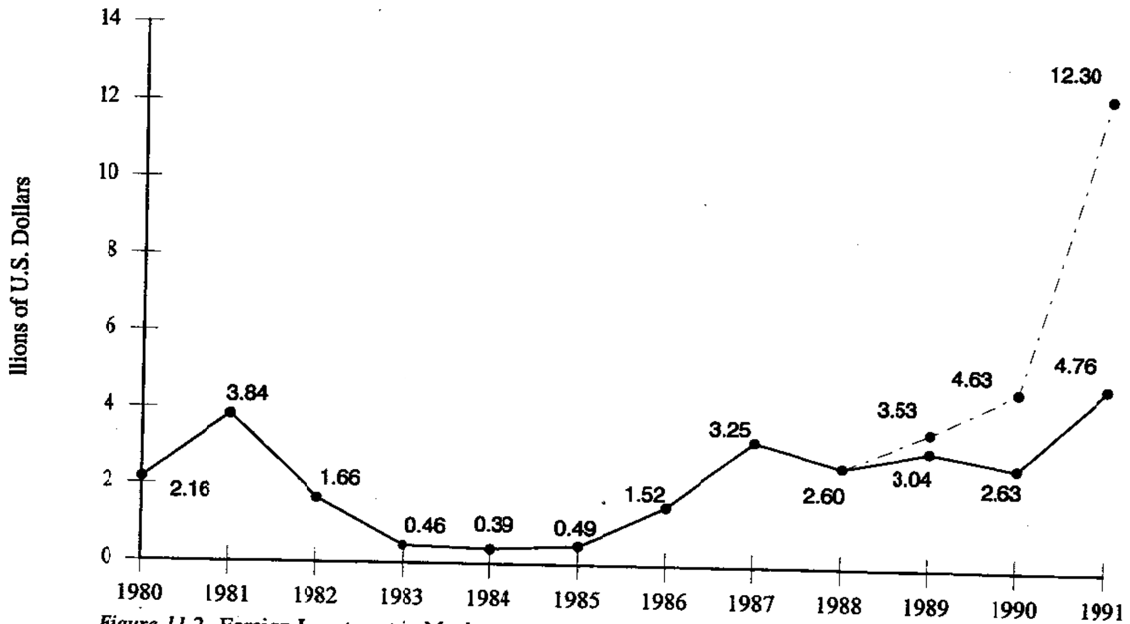

Figure 11.2. Foreign Investment in Mexico
Source: Banco de México.

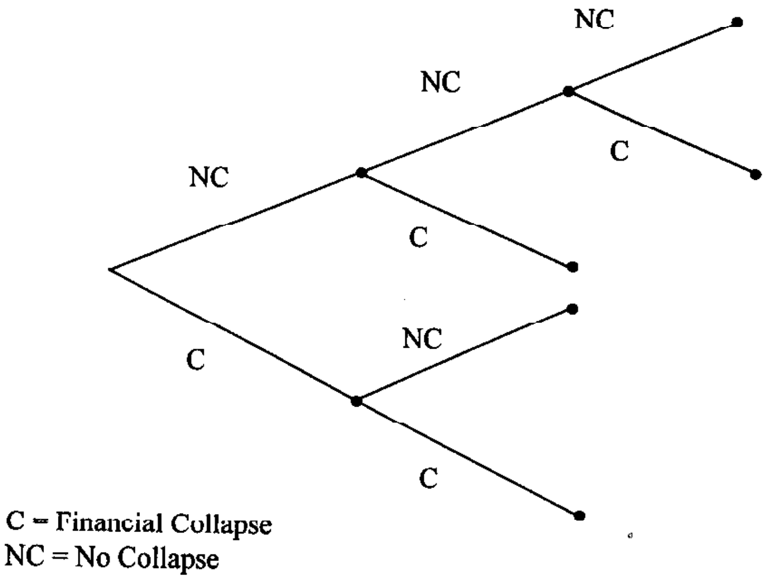

Figure 11.3. Introduction of Uncertainty

northern neighbors into policies that would help guarantee economic stability in Mexico, NAFTA would lower this risk premium and thereby lower the interest rate. Foreign investment in Mexico has increased dramatically in recent years, as seen in Figure 11.2. Some of this increase has been due to the liberalization of Mexican laws regarding such investments, and some has undoubtedly been due to improvements in expectations about Mexico's economic future.

It may be possible to model the process by which NAFTA would lower the risk premium in a simple way. Figure 11.3 depicts an event tree for a dynamic, stochastic general equilibrium model in which there is a probability π_{ct} of a financial collapse in period t and a probability $1 - \pi_{ct}$ of no financial collapse. In simulations, we could concentrate on the path in which no financial collapse actually occurs. Even so, in principle, we would have to model what would occur at every node of this event tree. This would subject us to the "curse of dimensionality" associated with an expanding-state space typical in this type of model. To simplify the analysis, however, we could model what happens if a financial collapse occurs in a simple enough way so that we do not have to move further out on branches in which a financial collapse occurs to compute the equilibrium outcomes. Even though we would not need to model in great detail what happens if a financial collapse occurs, lowering its probability

π_{ct} could have a significant impact on equilibrium outcomes along the branch of the tree where there is no collapse. To make this approach useful, we would need to model the interaction of π_{ct} and NAFTA in a way that is tractable but also captures the impact of NAFTA on economic stability in Mexico.

III. Demographics

To successfully account for capital flows, a dynamic general equilibrium analysis of NAFTA would have to model consumers' savings decisions. In modeling savings decisions in Canada, the United States, and Mexico, we must take into account demographic differences among the countries. Figure 11.4 illustrates the stark contrast in the population growth experiences of the United States and Mexico. These differences in population growth manifest themselves in differences in age structures of population; while the populations of Canada and the United States are currently aging as the postwar baby boom generation reaches middle age, half the population of Mexico is currently age 19 or younger.

These differences would be very important in an overlapping generations context in which life-cycle consumers dissave when young and build up their human capital, save during the middle of their lives, and dissave again when old during retirement. An example of an applied general equilibrium model with overlapping generations is Auerbach and Kotlikoff (1987). This model has a single country with a single production sector. A model with a similar dynamic structure but with several countries and multiple production sectors could be used to capture the impacts of NAFTA on capital flows in North America.

Modeling demographic differences in an overlapping generations framework would be especially important in a model in which the accumulation of human capital, as well as that of physical capital, plays an important role. The alternative modeling strategy is to assume that a bequest motive links generations in such a way as to produce families that act as if they were infinitely lived consumers. Empirical evidence does not seem to clearly favor one approach over the other: On one hand, a large percentage of wealth seems to be the result of bequests [see, for example, Kotlikoff and Summers (1981)]. It would be essential to account for this phenomenon in Mexico where wealth is very concentrated. On the other hand, while bequests may be important in some families, they are not important in others [see Altonji, Hayashi, and Kotlikoff (1992)]. Consequently, an applied dynamic model should be able to incorporate both families linked by bequests and other families who engage in life-cycle savings. A theoretical version of such a model has been developed by Escolano (1992); it should be possible to implement an applied version of this model.

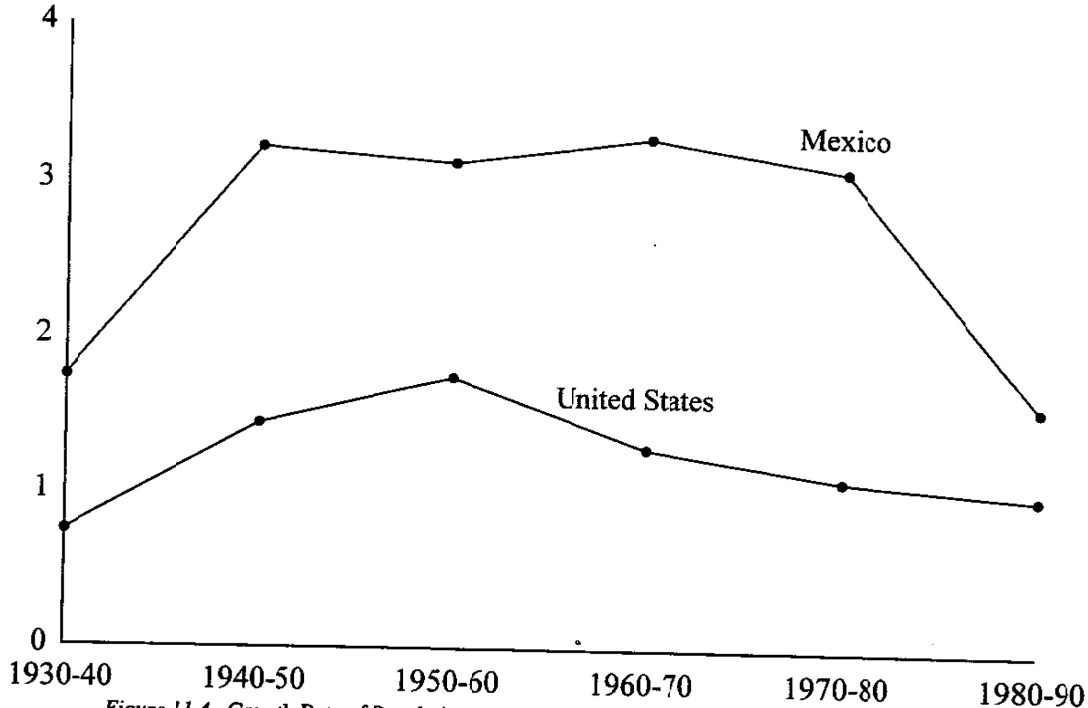

Figure 11.4. Growth Rate of Population
Source: NAFINSA and USDC, Bureau of the Census.

IV. Specialization in Final Products

Incorporating capital flows and demographics would be essential in any analysis of the dynamic impact of NAFTA. Even more essential would be to account for the impact of NAFTA on growth rates in the three countries. Studying the recent economic performances of the Philippines and South Korea, Lucas (1992) concludes that the key to understanding growth is what economists call *learning by doing*. The potential of learning by doing to account for economic growth has been recognized since the pioneering work of Arrow (1962). The microevidence has a long history going back to Wright (1936), who found that productivity in airframe manufacturing increased with cumulative output at the firm level. Later studies have confirmed this relationship at the firm level and industry level. Recent research that incorporate learning by doing into models of trade and growth include Stokey (1988) and Young (1991).

Consider the following simple framework, as presented by Backus, Kehoe, and Kehoe (1992): Output in an industry in some country depends on inputs of labor and capital, country- and industry-specific factors, and an experience factor that depends, in turn, on previous experience and output of that industry in the previous period. Keeping constant the rates of growth of inputs, the crucial factor in determining the rate of growth of output per worker is the rate of growth of the experience factor. Output per worker grows faster in industries in which this experience factor is higher. The level of growth of output per worker nationwide is a weighted average of the rates of growth across industries. One way increased openness promotes growth is that it allows a country to specialize in certain product lines and attain more experience in these industries.

Modeling dynamic increasing returns as the result of learning by doing is a reduced form specification for a very complex microeconomic process. It captures the effects of the learning curve documented by industrial engineers. It also captures, to some extent, the adoption of more efficient production techniques from abroad and from other domestic industry. The learning that takes place is not solely related to physical production techniques but also to the development of complex financial and economic arrangements between producers of primary and intermediate goods and producers of final goods. The ability of a country to benefit from learning by doing depends on the educational level of the work force. It also depends on whether a country is at the frontier of development of new products and production techniques or if it can import these from abroad; it is easier to play catch-up than to be the technological leader.

The challenge that lies ahead is to build the concepts sketched out above into a calibrated model of North American trade. To appreciate some of the issues involved, consider a simple analytical model in which value added in industry i, $i = 1, \ldots, I$, is produced according to the function

$$Y_{it} = \gamma_i A_{it} N_{it}^{1-\alpha_i} K_{it}^{\alpha_i}$$

Here Y_{it} is real value added of industry i in period t, N_{it} is labor input, and K_{it} is capital services. The variable A_{it} measures the external effects of learning by doing. We assume that

$$A_{it+1} = A_{it}\,(1+\beta_i Y_{it})^{\eta},$$

where β_i and η are positive constants. Thus, the rate of increase in learning is proportional to total output. This is slightly different from the standard experience curve, in which productivity is an increasing function of cumulative output, but has the same flavor: Current production raises future productivity. Defining $y_{it} = Y_{it}/N_t$ to be real output per capita and similarly defining n_{it} and k_{it}, we obtain

$$y_{it} = \gamma_i A_{it} n_{it}^{1-\alpha_i} k_{it}^{\alpha_i}$$

which implies that the growth rate in per capita output is

$$g(y_{it}) = \frac{y_{it+1}}{y_{it}} - 1 = (1+\beta_i Y_{it})^{\eta}\left(\frac{n_{it+1}}{n_{it}}\right)^{1-\alpha_i}\left(\frac{k_{it+1}}{k_{it}}\right)^{\alpha_i} - 1$$

If we consider a balanced growth path in which the capital stock in each industry grows at the same rate as output and the fraction of the labor force in each industry is constant, then we can calculate

$$g(y_{it}) = (1+\beta_i Y_{it})^{\delta_i} - 1$$

where $\delta_i = \eta/(1-\alpha_i)$.

The aggregate growth rate is the weighted average of growth rates of individual industries, with weights given by shares in aggregate output:

$$1 + g(y_t) = \sum_{i=1}^{I} (Y_{it}/Y_t)[1 + g(y_{it})] = \sum_{i=1}^{I} (Y_{it}/Y_t)(1+\beta_i Y_{it})^{\delta_i}$$

If, in addition, $\beta_i = \beta$ and $\delta_i = 1$ for all i, aggregate growth is

$$g(y_t) = \beta Y_t \sum_{i=1}^{I} (Y_{it}/Y_t)^2$$

We refer to the summation in the above expression, a number between zero and one, as a *specialization index*. Its product with aggregate output operates as a scale effect on growth. In general, that is, with $\delta_i \neq 1$, the appropriate specialization index is based on other powers of the output shares Y_{it}/Y_t, but this simple measure captures the dispersion of production across industries that the theory suggests is important.

V. Imports of Specialized Inputs

Increased openness allows a country to import more specialized inputs to the production process. Stokey (1988) and Young (1991) have proposed models in which new product development is still the result of learning by doing but where the primary impact of learning by doing is in the development of new, more specialized inputs. Trade allows a country to import these inputs without developing them itself. Aghion and Howitt (1989), Grossman and Helpman (1989), Rivera-Batiz and Romer (1989), and others have proposed similar models where it is research and development that leads to the development of new products. (Here, of course, the relationship of trade and growth is more complicated if one country can reap the benefits of technological progress in another country by importing the technology itself without importing the products that embody it.)

Suppose, as in Stokey (1988) and Young (1991), that learning by doing leads to the development of new or improved products. Final output is produced according to the production function

$$Y_t = \gamma N_t^{1-\alpha} \left(\int_0^\infty X_t(i)^\rho di \right)^{\alpha/\rho}.$$

There is a continuum of differentiated capital goods (or intermediate goods), with $X_t(i)$ denoting the quantity of capital goods of type i, $0 \leq i \leq \infty$. The parameter ρ is positive, allowing output even if there is no input of some capital goods. This type of production function embodies the idea that an increase in the variety of inputs leads to an increase in measured output.

Growth arises from an increase in the number of available capital goods. In period t, only capital goods in the interval $0 \leq i \leq A_t$ can be produced. Production experience results in the expansion of the interval, the development of new products,

$$A_{t+1} = A_t(1 + \beta Y_t)$$

The resource constraint on capital goods is

$$\int_0^{A_t} X_t(i)\, di = K_t$$

If the production functions for capital goods are identical, then the most efficient allocation of resources results in equal production of all goods that are actually produced. Let us assume that all goods in the interval $0 \leq i \leq A_t$ are produced in equal amounts. Under suitable assumptions, this is the equilibrium outcome [see, for example, Romer (1990)]. Letting $X_t\,(i)\;\bar{X}_t, 0 \le i \le A_t$, we obtain

$$\bar{X}_t = K_t/A_t$$

which implies

$$Y_t = \gamma N_t^{1-\alpha} K_t^{\alpha} A_t^{\alpha(1-\rho)/\rho}$$

The growth rate of output per worker is

$$g(y_t) = (1+\beta Y_t)^{\alpha(1-\rho)/\rho} \left(\frac{k_{t+1}}{k_t}\right)^{\alpha} - 1$$

If we assume, in addition, that the capital stock grows at the same rate as output, then growth is simply a function of the scale of production:

$$g(y_t) = (1+\beta Y_t)^{\delta} - 1$$

where $\delta = \alpha(1-\rho)/[\rho(1-\alpha)]$. Again, there is a scale effect at the country level: Countries with larger outputs grow faster.

The most interesting aspect of this theory is the perspective it gives us on trade and growth. In the previous section, the natural interpretation is that technology is embodied in people and is not tradeable. Trade may influence the pattern of production, including both the scale of production and the pattern of specialization, and in this way affect growth. In this model, technology is embodied in product variety, and there is a more subtle interaction between trade and growth. Recall that increases in the number of varieties of intermediate goods raise output. If these varieties are freely traded, a country can either produce them itself or purchase them from other countries. By importing these products, a small country can grow as fast as a large one. When there is less than perfectly free trade in differentiated products, we might expect to find that both scale and trade in differentiated products are positively related to growth.

A commonly used measure of the extent to which a country engages in trade of specialized products in the Grubel-Lloyd (1975) index. The Grubel-Lloyd index for country j is

$$\mathrm{GL}^j = \frac{\sum_{i=1}^{I} (X_i^j + M_i^j - |X_i^j - M_i^j|)}{X^j + M^j}$$

Here X_i^j is exports of industry i; M_i^j is imports of industry i; X^j is total exports; and M^j is total imports. Backus, Kehoe, and Kehoe (1992) find a strong positive relation between the Grubel-Lloyd index for all products at the three-digit

S.I.T.C. level and growth in GDP per capita for a large sample of countries. They also find a strong positive relationship between the Grubel-Lloyd index for manufactured products and growth in manufacturing output per worker. Trade in category 711, nonelectrical machinery, might consist of imports of steam engines (7,113) and exports of domestically produced jet engines (7,114). Simultaneous imports and exports of these goods provide the country with both and leads to more efficient production.

VI. Some Empirical Estimates and Illustrative Calculations

Using cross-country data from a large number of countries over the 1970–85 period, Backus, Kehoe, and Kehoe (1992) analyze the determinants of growth. Various other researchers have used similar cross-country data sets to estimate the parameters of endogenous growth models; see Levine and Renelt (1992) for a survey. Typically, researchers in this area find that their results are very sensitive to the exact specification of the model and the inclusion or exclusion of seemingly irrelevant variables. Backus et al. (1992) find, however, that, in explaining rates of growth of output per worker in manufacturing, results related to the theory sketched out in the previous two sections are remarkably robust. Using their methodology, we can estimate some parameters for a model in which both specialization in final output and the ability to import specialized inputs foster growth. Details concerning the data sources and methodology can be found in Backus et al. (1992).

Consider a relationship of the form

$$g(\bar{y}^j) = \alpha + \beta_1 \log \bar{Y}^j + \beta_2 \log \sum_{i=1}^{I} (\bar{X}_i^j/\bar{Y}^j)^2 + \beta_3 \log \bar{GL}^j + \beta_4 \log y^j + \beta_5 \, \mathrm{PRIM}^j + \varepsilon^j$$

Here $g(\bar{y}^j)$ is average yearly growth of manufacturing output per worker in percent form from 1970–85; $\bar{Y}^j$ is 1970 manufacturing output; $\sum_{i=1}^{I} (\bar{X}_i^j/\bar{Y}^j)^2$ is a specialization index based on exports at the three digit S.I.T.C. level; $\bar{GL}^j$ is the 1970 Grubel-Lloyd index of intraindustry trade; y^j is 1970 per capita income; and PRIM^j is 1970 primary school enrollment rate. Bars above the variables indicate that the variable deals with the manufacturing sector only; the specialization index and the Grubel-Lloyd index, for example, are computed for manufacturing industries only.

We include total manufacturing output and the specialization index to account for the impact of specialization in production of final goods. One motivation for using export data is that specialization is most important in the export sector. Another motivation is purely practical. The trade data permits a more detailed breakdown of commodities, and the export specialization index can be thought of as a proxy for the total production specialization index; if exports are proportional to outputs, then $\bar{X}^i_i = \varepsilon \bar{Y}^i_i$ and $\Sigma^I_{i=1} (\bar{X}^i_i/\bar{Y}^i)^2 = \varepsilon^2 \Sigma^I_{i=1}(\bar{Y}^i_i/\bar{Y}^i)^2$ and the two indices are proportional. The Grubel-Lloyd index is included, as we have explained, because it captures, in a loose way, the ability of a country to trade in finely differentiated products, which our theory implies is important for growth. We include initial per capita income and the primary enrollment rate partly because they are widely used by other researchers in this area, such as Barro (1991) and partly because they may be relevant to our theory; the inclusion of per capita income allows for less-developed countries, which are playing catch-up, to face different technological constraints. The inclusion of the enrollment rate allows for differences in countries' ability to profit from learning by doing because of differences in levels of basic education.

A regression of the above relationship yields

$$g(\bar{y}^i) = \underset{(5.686)}{2.602} + \underset{(0.259)}{0.743} \log \bar{Y}^i + \underset{(0.113)}{0.309} \log \sum_{i=1}^{I} (\bar{X}^i_i/\bar{Y}^i)^2$$
$$+ \underset{(0.410)}{0.890} \log \bar{GL}^i + \underset{(0.799)}{-0.172} \log y^i + \underset{(2.271)}{2.421} \text{PRIM}^i$$
$$\text{NOBS} = 49 \qquad R^2 = 0.479.$$

(The numbers in parentheses are heteroskedasticity-consistent standard errors.) Notice that in this regression the coefficients all have the expected signs and that the first three variables, total manufacturing output, the specialization index, and the Grubel-Lloyd index, are all statistically significant.

To illustrate the dramatic impact of trade liberalization possible in a dynamic model that contains the endogenous growth features discussed in the previous two sections, let us suppose that NAFTA allowed Mexico to increase its level of specialization in production of final manufactured goods and imports of specialized inputs. The average values over 1970–85 of the specialization indices and Grubel-Lloyd indices for the three North American countries are listed below. The values of the same indices for South Korea, a country with about the same output per worker as Mexico, are also included for comparison.

	$\Sigma^I_{i=1}(\bar{X}^i_i/\bar{Y}^i)^2$	$\bar{GL}^i$
Canada	7.10×10^{-2}	0.638
Mexico	5.93×10^{-4}	0.321
U.S.	1.92×10^{-3}	0.597
Korea	5.43×10^{-2}	0.362

Suppose that free trade allows Mexico to increase its specialization index to 0.1×10^{-2} and its Grubel-Lloyd index to 0.6. Dramatic increases of this sort are possible: In 1970, for example, Ireland had a Grubel-Lloyd index for manufactured goods of 0.150; in 1980, after having joined the European Economic Community in 1973, this index was 0.642. Over the same 1970–80 period, earnings per worker in Ireland rose at a 4.1 percent annual rate.

Using the above regression results, we would estimate the increase in the growth rate of manufacturing output per worker of 1.430 percent per year:

$$1.430 = 0.309 \log \left(\frac{1.00 \times 10^{-2}}{5.93 \times 10^{-4}}\right) + 0.890 \log \left(\frac{0.600}{0.321}\right)$$

$$= 0.873 + 0.557.$$

It is clear that much is at stake in the issues discussed here. Suppose that Mexico is able to increase its growth rate of output per worker by an additional 1.430 percent per year by taking advantage of both specialization and increased imports of specialized intermediate and capital goods. Then, after 30 years, its level of output per worker would be more than 50 percent higher than it would have otherwise been. By way of comparison, if Mexico's output per worker were 50 percent higher in 1988 than it was, then output per worker in Mexico would be about the same as that in Spain (again, this comparison uses Summers' and Heston's 1991 data). Our earlier calculations suggested that Mexico could increase its output per worker by roughly 66 percent by increasing its capital per worker until the rate of return on capital is equal to that in the United States. Admittedly, these calculations are very crude, but they suggest that there is a significant impact of increased openness on growth through dynamic increasing returns. Furthermore, the dynamic benefits of increased openness dwarf the static benefits found by more conventional applied general equilibrium models.

Obviously, this is an area that requires more research, and even a crude disaggregated dynamic general equilibrium model of North American economic integration would make a substantial contribution. More empirical work also needs to be done. Notice, for example, that the Grubel-Lloyd indices reported above fail to capture the observation that Korea is fairly closed in final goods markets but open to imports of intermediate and capital goods.

Our analysis suggests that Mexico has more to gain from free trade than do Canada or the United States. Both are already fairly open economies, and the United States is big enough to exploit its dynamic scale economies. Mexico, however, has a smaller internal market. To follow an export-led growth strategy, Mexico must look to the United States, as the trade statistics in Figure 11.1 indicate.

Endogenous growth theories can be used to support industrial policies that target investment towards certain industries and trade policies that protect some final-goods industries. At the level of aggregation used here, our results have little to say directly about such policies. Two warnings about such policies are worth making, however. First, with regard to industrial policies, the learning-by-doing process discussed in this paper, and innovation in general, is something that needs to be modeled at a more advanced microlevel. Whether the government can do a better job than market forces in directing investment in the presence of this kind of external effect is an important question that is left open by our analysis. Second, with regard to trade policies, open access to U.S. markets for Mexico means open access to Mexican markets for the United States in the context of NAFTA. It would be politically difficult, if not impossible, for Mexico to pursue selective protectionist policies like those of Korea.

VII. Aggregation Issues

One problem that confronts a researcher interested in constructing a dynamic general equilibrium model to analyze the impact of NAFTA is what level of aggregation to use. There is evidence that some disaggregation is necessary: Echevarria (1992), for example, finds that although changes in total factor productivity in the OECD has been negligible in recent decades in agriculture, it has been significantly positive in services but less than in manufacturing. Simple regressions of growth in income per capita on the initial composition of output – that is, on percentages of output in industry, agriculture, and services – account for more than 22 percent of the variation in growth rates. Furthermore, differences in total factor productivity between Mexico and the United States differ substantially across industries. The growth effects of NAFTA are, therefore, apt to vary across industries. The empirical results of Backus, Kehoe, and Kehoe (1992), which finds that the simple endogenous growth models presented in this paper do well in explaining productivity growth in manufacturing but not growth in total output per capita, further suggest that some disaggregation is necessary if endogenous growth theory is to be successfully incorporated into an applied general equilibrium model. Yet disaggregation has its costs in terms of data requirements and potential computational difficulties.

A further problem in applied modeling of trade and growth at a disaggregate level is that the objects in theoretical models that stress the development of new products do not have obvious empirical counterparts in the data. [We should note that work such as that of Brown (1987) and Watson (1991) indicate that the disaggregation of goods typically used in static trade models has problems in terms of capturing the degree of substitutability between imports and domestically produced goods.] Various approaches have been used to reinterpret trade data disaggregated using the S.I.T.C. in terms of these sorts of themes, for example, Feenstra (1990), Havrylyshyn and Civan (1985), and this paper. This is obviously an area that needs more research, particularly research with a high imagination component.

References

Aghion, P., and P. Howitt. 1989. "A model of growth through creative destruction." Unpublished manuscript, Massachusetts Institute of Technology.

Altonji, J.G., F. Hayashi, and L.J. Kotlikoff. 1992. "Is the extended family altruistically linked? Direct tests using micro data." *American Economic Review* 82:1177–98.

Arrow, K.J. 1962. "The economic implications of learning by doing." *Review of Economic Studies* 24:155–73.

Auerbach, A.J., and L.J. Kotlikoff. 1987. *Dynamic Fiscal Policy*. Cambridge: Cambridge University Press.

Backus, D.K., P.J. Kehoe, and T.J. Kehoe. 1992. "In search of scale effects in trade and growth." *Journal of Economic Theory* 58:377–409.

Baldwin, R. 1992. "Measurable dynamic gains from trade." *Journal of Political Economy* 100:162–74.

Barro, R.J. 1991. "Economic growth in a cross section of countries." *Quarterly Journal of Economics* 106:407–44.

Blomstrom, M., and E.N. Wolff. 1989. "Multinational corporations and productivity convergence in Mexico." NBER Working Paper no. 3141.

Brown, D.K. 1987. "Tariffs, the terms of trade, and national product differentiation." *Journal of Policy Modeling* 9:503–26.

Brown, D.K., A.V. Deardorff, R.H. Stern. 1991. "A North American free trade agreement: Analytical issues and a computational assessment." Unpublished manuscript, University of Michigan.

Clark, G. 1987. "Why isn't the whole world developed? Lesson from the cotton mills." *Journal of Economic History* 47:141–73.

Cox, D., and R.G. Harris. 1991. "North American free trade and its implications for Canada: Results from a C.G.E. model of North American trade." Unpublished manuscript, University of Waterloo.

Echevarria, E.C. 1992. "Sectoral composition and its relation to development." Unpublished Ph.D. dissertation, University of Minnesota.

Escolano, J. 1992. "Essays on fiscal policy, intergenerational transfers, and distribution of wealth." Unpublished Ph.D. dissertation, University of Minnesota.

Fischer, S. 1992. "Growth, macroeconomics, and development." *NBER Macroeconomics Annual* 6:329–64.

Garber, P.M., and S.R. Weisbrod. 1991. "Opening the financial services market in Mexico." Unpublished manuscript, Brown University.

Garcia-Alba, P., and J. Serra-Puche. 1985. *Financial Aspects of Macroeconomic Management in Mexico*. El Colegio de México.

Grossman, G.M., and E. Helpman. 1989. "Product development and international trade." *Journal of Political Economy* 97:1261–83.

Grubel, H., and P.J. Lloyd. 1975. *Intra-Industry Trade*. London: Macmillan.

Havrylyshyn, O., and E. Civan. 1985. "Intra-industry trade among developing countries." *Journal of Development Economics* 18:253–71.

Hinojosa-Ojeda, R., and S. Robinson. 1991. "Alternative scenarios of U.S.-Mexico integration:

A computable general equilibrium approach." Discussion Paper 609, University of California at Berkeley.

Kehoe, T.J., C. Polo, and F. Sancho. 1991. "An evaluation of the performance of an applied general equilibrium model of the Spanish economy." Research Department Working Paper 480, Federal Reserve Bank of Minneapolis.

Kotlikoff, L.J., and L.H. Summers. 1981. "The importance of intergenerational transfers in aggregate capital accumulation." *Journal of Political Economy* 84:706–32.

KPMG Peat Marwick/Policy Economics Group. 1991. "Analysis of economic effects of a free trade area between the United States and Mexico: Executive summary." Washington, D.C.: U.S. Council of the Mexico-U.S. Business Committee.

Levine, R., and D. Renelt. 1992. "A sensitivity analysis of cross-country growth regressions." *American Economic Review* 82:942–63.

Lucas, R.E. 1988. "On the mechanics of economic development." *Journal of Monetary Economics* 22:3–42.

———. 1990. "Why doesn't capital flow from rich to poor countries?" *American Economic Review*, Paper and Proceedings 80:92–96.

———. 1992. "Making a miracle." Unpublished manuscript, University of Chicago.

Rivera-Batiz, L., and P.M. Romer. 1989. "International trade with endogenous technological change." Unpublished manuscript, University of Chicago.

Romer, P.M. 1987. "Growth based on increasing returns due to specialization." *American Economic Review*, Papers and Proceedings 77:56–62.

———. 1990. "Endogenous technological change." *Journal of Political Economy* 98:S71–102.

Shoven, J.B., and J. Whalley. 1984. "Applied general equilibrium models of taxation and international trade." *Journal of Economic Literature* 22:1007–51.

Sobarzo, H.E. 1991. "A general equilibrium analysis of gains from trade for the Mexican economy of a North American free trade agreement." Unpublished manuscript, El Colegio de México.

Stokey, N.L. 1988. "Learning by doing and the introduction of new goods." *Journal of Political Economy* 96:701–17.

Summers, R., and A. Heston. 1991. "The Penn world table (Mark 5): An expanded set of international comparisons, 1950–1988." *Quarterly Journal of Economics* 106:327–68.

Watson, W.G. 1991. "Canada's trade with and against Mexico." Unpublished manuscript, McGill University.

Whalley, J. 1989. "General equilibrium trade modelling over the last five years." Unpublished manuscript, University of Western Ontario.

Wright, T.P. 1936. "Factors affecting the cost of airplanes." *Journal of Aeronautical Sciences* 3:122–28.

Young, A. 1991. "Learning by doing and the dynamic effects of international trade." *Quarterly Journal of Economics* 106:369–406.

Yúnez-Naude, A. 1991. "Hacia un tratado de libre comercio norteamericano: Efectos en los sectores agropecuarios y alimenticios de Mexico." Unpublished manuscript, El Colegio de México.