Federal Reserve Bank of Minneapolis
Research Department

MODELING THE DYNAMIC IMPACT OF NORTH AMERICAN FREE TRADE

Timothy J. Kehoe*

Working Paper 491

March 1992

ABSTRACT

The current tool of choice for analyzing the impact of a potential North American Free Trade Agreement on the economies of Canada, Mexico, and the United States is the static applied general equilibrium model. Although this type of model 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, it does not attempt to capture the impact of government policy on growth rates. For this we need a dynamic model. This paper outlines some of the issues that confront a researcher interested in building a dynamic general equilibrium model to assess the potential economic impact of a NAFTA, including the impact on growth rates. Simple calculations based on preliminary empirical work indicate that the dynamic benefits of increased openness could dwarf the static benefits found by more conventional applied general equilibrium models.

*University of Minnesota and Federal Reserve Bank of Minneapolis. I am grateful to Karine Moe for diligent and energetic research assistance.

1. Introduction

The current tool of choice for analyzing the impact of a potential North American Free Trade Agreement 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); Hinojasa-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 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 the NAFTA.)

Typically, however, this sort of model predicts small changes in economic welfare (see Shoven and Whalley 1984 and 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 a 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 a 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. This 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 a NAFTA could dwarf the static effects found by more conventional applied general equilibrium models. Similar kinds of suggestive calculations are done to estimate the dynamic gains from the European 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 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

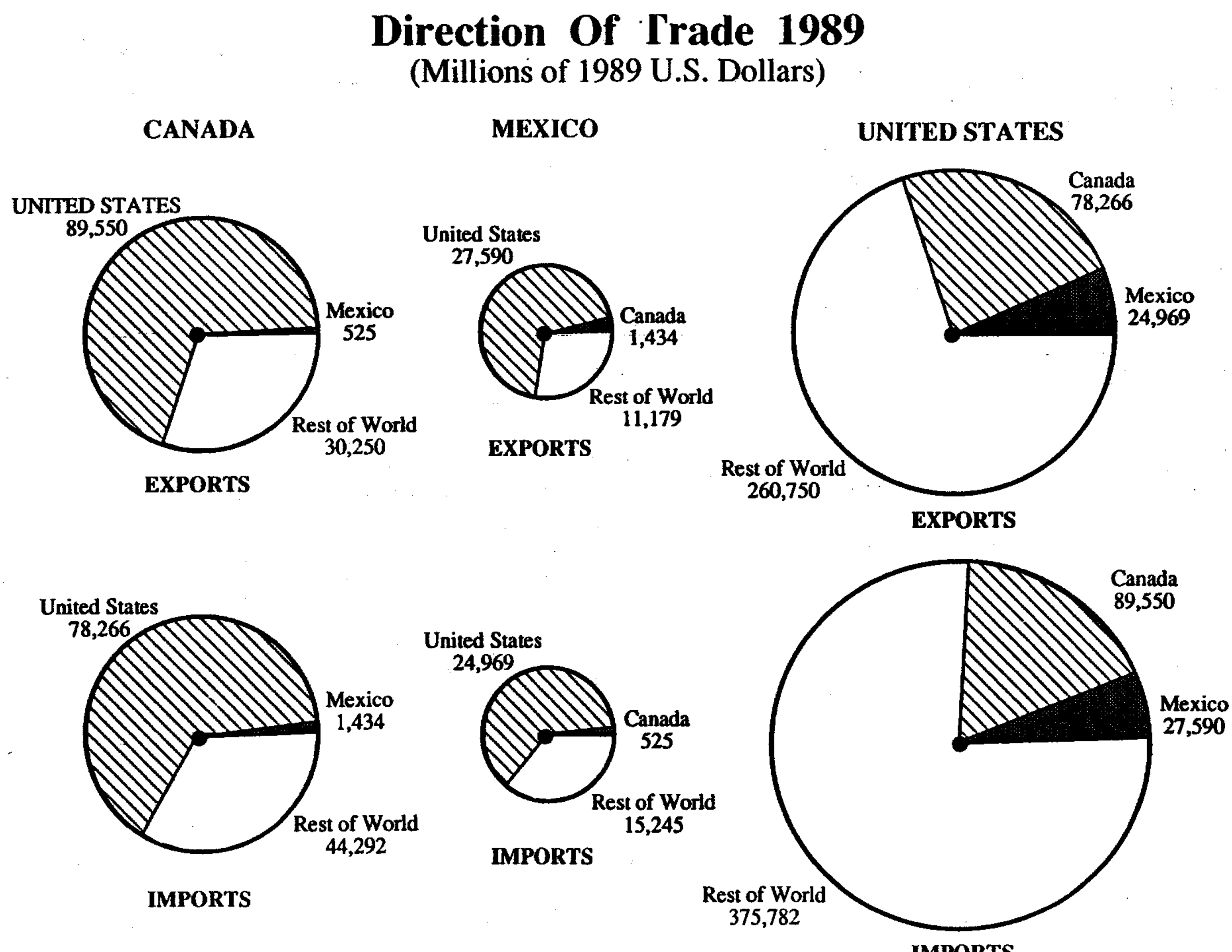

Figure 1

Source: IMF, Direction of Trade Statistics Yearbook, 1990.

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 the NAFTA. Because of their relative sizes and geographical locations, Canada and Mexico do most of their trading with the United States; see Figure 1. For them the concepts of free trade and the 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, the NAFTA represents an opportunity of the U.S. to commit itself to a free trade policy, and for this reason the progress on the NAFTA is being closely monitored throughout the world.

2. 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 U.S. 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 1989 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.

To illustrate the point that differences in capital-labor ratios cannot explain the differences in output per worker, suppose that each economy has the production function

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

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 U.S. Suppose that $\alpha = 0.3$, which is roughly the capital share of income in the U.S. 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 U.S.,

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

During the period 1988–90 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 U.S. (see Garber and Weisbrod 1991). Since 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 capital 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 U.S. 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 U.S., 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

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

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

Some of the current high return on capital in Mexico can be accounted for by an inefficient and oligopolistic financial services sector. A NAFTA might increase the efficiency of this sector. An even more significant impact of a NAFTA would be to create a stable economic environment that would encourage private investment in Mexico. It was do to this in at least two ways: First, it would lock the Mexican government into the free trade policy and the liberal policy towards foreign direct investment that it is currently pursuing unilaterally. Second, it would protect Mexican producers from protectionist tendencies in the U.S., which fluctuate with the business cycle and are sensitive to a variety of special interest groups. Direct foreign investment in Mexico has increased dramatically in recent years, as seen in Figure 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.

A sensible analysis of capital flows must model consumer's savings decisions. In modeling savings decisions in North America, we must take into account demographic differences among these countries. To illustrate the importance of demographic differences, we note that currently half of the population of Mexico is under the age of seventeen, while the populations of Canada and the U.S. are currently aging as the postwar baby boom generation reaches middle age. These differences would be very important in an overlapping generations context in which life-cycle consumers dissave when young and build up human capital, save during the middle of their lives,

Book Value of Direct Foreign Investment in Mexico

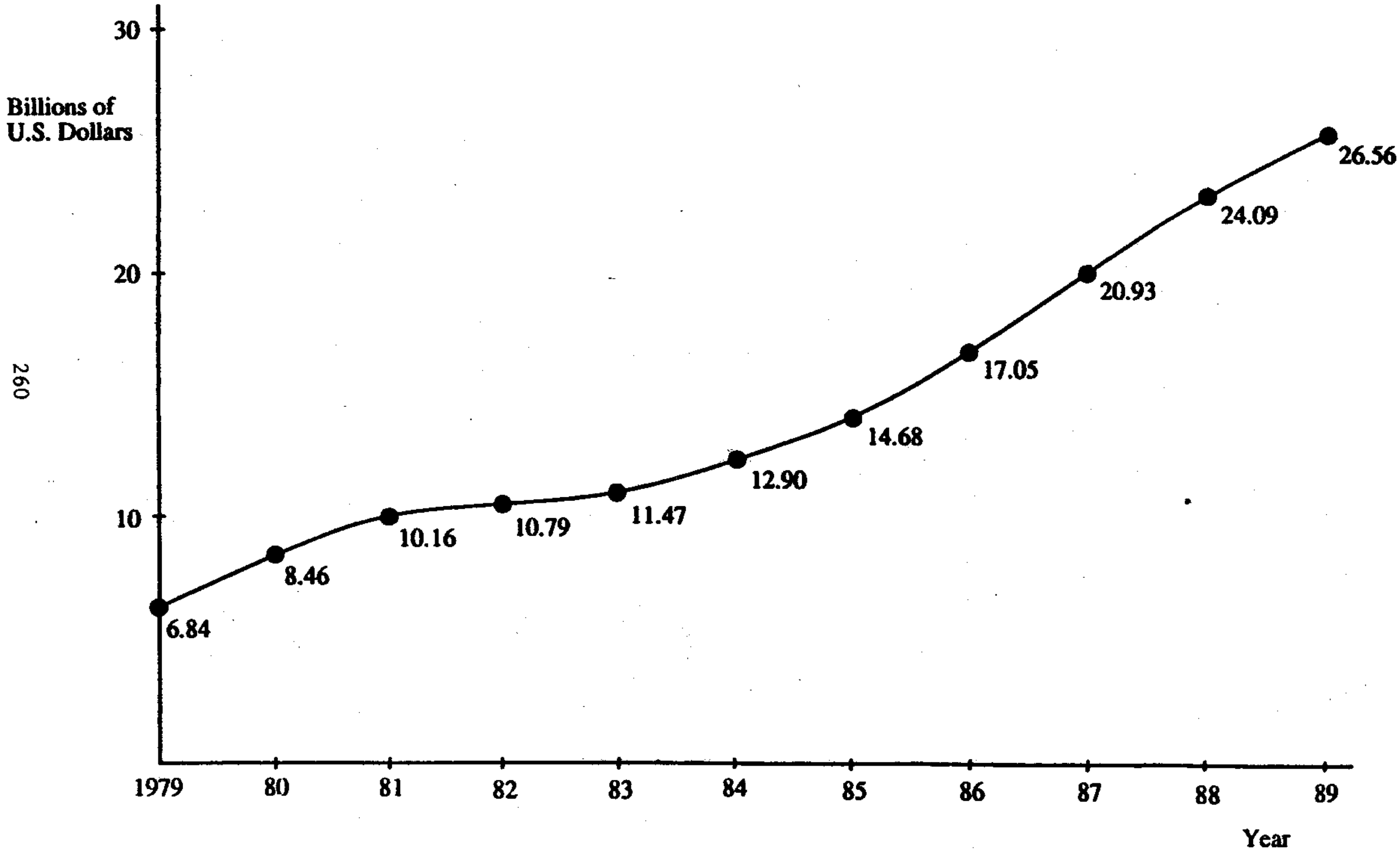

Figure 2

Source: Secretaría de Comercio y Fomento Industrial and dissave again when old during retirement. An example of an applied general equilibrium model with overlapping generations is Auerbach and Kotlikoff (1987). 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.

3. Specialization in Final Products

The potential of learning by doing to account for economic growth has been recognized since the pioneering work of Arrow (1962). The micro evidence 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 (1991): 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.

Consider a 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 ρ 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 suggest is important.

4. 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 $X_t(i) = \bar{X}_t$, $0 \leq i \leq A_t$, 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

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

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 (1991) 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 (7113) and exports of domestically produced jet engines (7114). Simultaneous imports and exports of these goods provide the country with both, and leads to more efficient production.

5. Some Empirical Estimates and Illustrative Calculations

Using cross-country data from a large number of countries over the period 1970–85, Backus, Kehoe, and Kehoe (1991) 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 (1990) 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.* 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.*

Consider a relationship of the form

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

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; $\Sigma_{i=1}^{I}(\bar{X}_i^j/\bar{Y}^j)^2$ is a specialization index based on exports at the three digit S.I.T.C. level; $\overline{GL}^j$ is the 1970 Grubel-Lloyd index of intra-industry 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 $\bar{X}_i^j = \epsilon\bar{Y}_i^j$ and $\Sigma_{i=1}^{I}(\bar{X}_i^j/\bar{Y}^j)^2 = \epsilon^2\,\Sigma_{i=1}^{I}(\bar{Y}_i^j/\bar{Y}^j)^2$ 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

$$g(y^j) = \underset{(5.761)}{3.151} + \underset{(0.255)}{0.729} \log \bar{Y}^j + \underset{(0.119)}{0.359} \log \sum_{i=1}^{I} (\bar{X}_i^j/\bar{Y}^j)^2$$

$$+ \underset{(0.416)}{1.018} \log \overline{GL}^j - \underset{(0.785)}{0.468} \log y^j + \underset{(2.187)}{2.064} \, PRIM^j$$

$$NOBS = 45 \qquad\qquad R^2 = 0.478.$$

(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.

	$\Sigma_{i=1}^{I}(\bar{X}_i^j/\bar{Y}^j)^2$	$\bar{GL}^j$
Canada	7.10×10^{-2}	0.642
Mexico	5.93×10^{-4}	0.323
U.S.	1.92×10^{-3}	0.597
Korea	5.43×10^{-2}	0.363

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.

Using the above regression results, we would estimate the increase in the growth rate of manufacturing output per worker of 1.645 percent per year

$$\begin{aligned} 1.645 &= 0.359 \log\left[\frac{1.00 \times 10^{-2}}{5.93 \times 10^{-4}}\right] + 1.018 \log\left[\frac{0.600}{0.323}\right] \\ &= 1.014 + 0.545. \end{aligned}$$

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 1.656 percent per year by taking advantage of both specialization and increased imports of specialized intermediate and capital goods. Then, after 25 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 Summer's and Heston's 1991 data). Our earlier calculations suggested that Mexico could increase its output per worker by about 66 percent by increasing its capital per worker until the rate of return on capital is equal to that in the U.S. 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 U.S. Both are already fairly open economies, and the U.S. 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 U.S., as the trade statistics in Figure 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 micro level. 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 mean open access to Mexican markets for the U.S. in the context of the NAFTA. It would be difficult, if not impossible, politically for Mexico to pursue selective protectionist policies like those of Korea.

6. 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 (1991), for example, finds that, while changes in total factor productivity in the OECD has been negligible in recent decades in agriculture, it has been significantly positive in services, although 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 U.S. differ substantially across industries. The growth effects of a NAFTA are, therefore, apt to vary across industries. The empirical results of Backus, Kehoe, and Kehoe (1991), 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 suggests that disaggregation is needed.

Obviously, much depends on the level of disaggregation of goods in the model. The costs of computing an intertemporal equilibrium, for example, go up very quickly with the number of sectors, at least if adding new sectors adds new state variables. The more sectors that we add, however, the more that we are able to capture gains from trade.

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

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

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

Backus, D. K., Kehoe, P. J.; and Kehoe, T. J. 1991. In search of scale effects in trade and growth. Research Department Working Paper 451, Federal Reserve Bank of Minneapolis.

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.

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

Brown, D. K.; Deardorff, A. V.; Stern, R. H. 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 Harris, R. G. 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. 1991. Changing sectorial composition and economic growth. Unpublished manuscript, University of Minnesota.

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

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

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

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

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

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

Hinojosa-Ojeda, R., and Robinson, S. 1991. Alternative scenarios of U.S.-Mexico integration: A computable general equilibrium approach. Discussion Paper 609, University of California-Berkeley.

Kehoe, T. J.; Polo, C.; and Sancho, F. 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.

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, DC: U.S. Council of the Mexico-U.S. Business Committee.

Levine, R., and Renelt, D. 1990. A sensitivity analysis of cross-country growth regressions. Unpublished manuscript, World Bank.

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

Lucas, R. E. 1989. Why doesn't capital flow from rich to poor countries? *American Economic Review*, Paper and Proceedings 80, 92–96.

Rivera-Batiz, L., and Romer, P. M. 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 Whalley, J. 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 Heston, A. 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.