THE DYNAMIC EFFECTS OF TRADE LIBERALIZATION: A SURVEY

Report on Investigation No. 332–324
Under Section 332 of the
Tariff Act of 1930

USITC PUBLICATION 2608

FEBRUARY 1993

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The Dynamic Effects of Trade Liberalization: A Survey

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ABSTRACT

This report surveys the recent economic literature on the dynamic implications of international trade liberalization: that is, what determines economic growth and how do trade policy and trade liberalization affect the factors that determine economic growth.

Developments in the theory of economic growth during the 1980s have provided trade theorists with new models that may be used to analyze the effects of international trade on growth. These models explicitly show how market forces can, theoretically, give rise to technological innovation, and hence to economic growth. Recent economic studies of the interaction between trade and growth have shown that trade liberalization may have important effects over time (dynamic effects) that, in theory, could lead to changes in the long-run rate of economic growth. The effects of such changes would be compounded over time, much like simple interest, and thereby could have much more substantial effects on national income than the effects associated with static gains from trade.

While this literature highlights potentially important linkages between trade and growth, it is important to emphasize that the empirical application of the new growth theories in a trade context has barely started. The practical identification of active policy recommendations for specific sectors is highly problematic, and is well beyond the appropriate application of current empirical methods related to the dynamics of trade.

PREFACE

On May 7, 1992, at the request of the U.S. Trade Representative, (see Appendix A), and in accordance with section 332(g) of the Tariff Act of 1930 (19 U.S.C. 1332(g)), the United States International Trade Commission instituted Investigation No. 332-324, "The Dynamic Effects of Trade Liberalization: A Survey." This report on the Commission's study reviews the recent economic literature on economic growth and trade. It provides both a non-technical overview of the literature, and a more technical review and summary of the theoretical and empirical literature.

Public notice of this investigation was given in the *Federal Register* and by posting copies of the notice in the Office of the Secretary, U.S. International Trade Commission, Washington, DC. (See Appendix B).

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Overview and summary

Introduction

This report surveys the recent economic literature on the dynamic implications of international trade liberalization: that is, what determines economic growth and how trade policy and trade liberalization affect the factors that determine economic growth. The report consists of two parts. Part I presents a broad overview of the dynamic effects of trade liberalization. Part II presents both a more technical, theory-based treatment of these issues and a review of the recent empirical literature on the dynamic implications of trade policy changes.

Dynamic models emphasize changes over time and reflect the dynamic features of an economy, such as the interplay among savings rates, investment, innovation, and income. In empirical analyses of dynamic effects of trade liberalization, projected values for incomes, prices, and quantities for some period of time are compared with alternative values for the same period that reflect changes in the trade regime. Such dynamic comparisons include assessing changes in the rate of economic growth. In contrast, static models of international trade focus on changes that would be realized at a single point in time -- a specified base period. Thus, they do not consider changes in economic growth.

The Sources of Economic Growth

Classical Growth Models

The classical literature on economic growth has emphasized two sources of sustained economic growth: ongoing technical change and population growth.[1] Population growth can contribute to an increase in per capita income ("intensive growth"), or to a simple expansion of the base of economic activity, with no consequent increase in per capita income ("extensive growth").[2] At the extreme, population growth may actually depress long-run per capita income growth by taxing limited and nonrenewable resources.[3] Physical capital accumulation is also an important factor in classical growth models. A process of continuous capital accumulation is generally necessary to maintain income levels for a growing population. However, capital accumulation alone is not a source of sustained economic growth in the classical growth model.

In the classical growth literature, a distinction is drawn between two types of dynamic income effects: level effects and growth effects. Level effects refer to increases in long-term income levels but not to sustained increases in growth rates. Hence, although level effects may imply a temporary increase in growth rates as incomes increase, such growth levels off over time as incomes peak at new levels. In contrast, growth effects are permanent. They imply sustained, permanent changes in economic growth rates. This distinction is also relevant for discussion of the more recent literature on economic growth.

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[1] The standard reference in this literature is R.M.Solow, "A Contribution to the Theory of Economic Growth," Quarterly Journal of Economics, vol. 70 (Feb. 1956), pp. 65-94. Also see the discussion of this literature in A. Takayama, Mathematical Economics (Cambridge, England: Cambridge U. Press, 1985) and J.E. Stiglitz and H. Uzawa, eds., Readings in the Modern Theory of Economic Growth (Cambridge: MIT Press, 1969).

[2] L.G. Reynolds, "The Spread of Economic Growth to the Third World," Journal of Economic Literature, vol. 21, No. 3 (Sept. 1983), pp. 941-980.

[3] See the discussion in James Brander, "Innis Lecture: Comparative Economic Growth: Evidence and Interpretation," Canadian Journal of Economics, vol. 25, No. 4 (Nov. 1992), pp. 792-818.

The New Growth Theories

The more recent research on economic growth has emphasized technical change as a source of economic growth. In particular, economists have focused on how market forces can give rise to technical change and in turn to economic growth. Such economic theories are said to model technical change "endogenously"--as a result of the explainable, rational actions of individuals, rather than as the result of unexplained, "exogenous" developments that are beyond the influence of the economic decisions made by individuals. Such models show how the actions of individuals responding to market forces can lead to endogenous technical change and hence to growth. Because trade liberalization can change the market conditions under which firms operate, including available technologies and the incentives for funding education and research, it may in turn lead to changes in the rate of economic growth.

Models of endogenous technical change closely resemble, in terms of mathematical structure, static models of external scale effects (the decline in production costs associated with increased industry-level output). In dynamic models these declines are realized over time. Such scale effects are called "external" because the benefits they provide to firms are not within the firms' control. In contrast to "internal" scale economies realized within firms, external scale effects depend on the activities of all of the firms in an industry.

There are four main types of endogenous technical change emphasized in the growth literature: (i) growth from returns due to specialization; (ii) growth through human capital accumulation; (iii) growth through learning-by-doing; and (iv) growth through research and development. The dynamic processes underlying these types of growth can be traced, in large part, to returns due to increased specialization in production and the benefits that accrue from the introduction of new or improved product varieties.

Specialized Inputs

The first of these -- the idea that increased specialization can lead to increased efficiency, lower costs, and higher income levels -- is as old as the economics profession itself. Adam Smith, for example, observed in the late 18th century that increased specialization reduces the costs associated with task switching, encourages the development of activity-specific skills, and provides incentives for the development of specialized capital equipment. It also improves the preconditions for innovation.[4] More recently, economists have also emphasized increased innovation and product variety in consumer goods as another important aspect of specialization. The new growth theories highlight returns from specialization both at the intermediate and the final product level.

At the intermediate product level, greater efficiency can result from the development of increasingly specialized parts and machinery, such as electronic subcomponents or numerically controlled machine tools. Alternatively, efficiency can be improved by breaking down the production process into more highly specialized stages. For example, the production of a particular type of automobile could be separated into tasks associated with the engine, upholstery, body design and manufacture, and electronic components. Scale economies may then be realized as production becomes more focused on specialized activities, with an improved opportunity to specialize equipment and personnel, and a consequent reduction in the costs associated with task switching of personnel and equipment. As production is broken into stages, highly specialized auto parts suppliers may emerge. We refer to the process of specializing parts and machinery in production as "product specialization" and to the process of specializing stages of production as "process specialization."

Both process and product specialization have been highlighted in recent public discussion of trade

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[4] A. Smith, The Wealth of Nations, 1776, Modern Library Edition, 1937, 1965, pp. 7-11, 260-265, 416-417.

policy. Much of current auto-related production in U.S.-owned maquiladora plants in Mexico and in Japanese-owned plants in the United States involves process specialization and geographic separation of different aspects of auto production. At the same time, innovations in the production of specialized semiconductors highlight the advantages of product specialization. So too do advances in machine-tool technology. Notwithstanding the similarities, these specialization processes are also different in potentially important ways. However, at this point the models employed in the endogenous growth literature do not draw a substantive distinction between product and process specialization. The same basic model structure is applied to analyze a stylized process of specialization that represents, in various specific papers, final product innovation and intermediate product and process specialization.[5]

Given returns to specialization, growth occurs if the range or quality of specialized inputs, or the degree of specialization of production, increases over time. In his 1986 paper, for example, Romer modeled a process in which specialized capital goods (intermediate inputs) are combined with labor to produce a final good.[6] In this framework, increasing returns due to specialization imply that a given amount of labor and physical capital will yield a greater quantity of final output if the extent to which capital goods are specialized is increased. Such returns imply that an almost infinite degree of specialization is desirable, with an extremely small amount of each input being produced. However, in these models, the gains from specialization must be balanced against the costs -- particularly the fixed costs -- of producing an additional intermediate product.[7] In this context, larger markets imply a larger base over which to spread these costs, making higher degrees of specialization economically feasible.

With increasingly specialized capital equipment, specialized inputs are produced using known technology, subject to economywide resource constraints. Ultimately, the mechanism that drives growth is national savings and investment. Savings lead to growth because the economywide resource constraint is relaxed over time through savings and capital accumulation. As the size of the capital stock increases, an increased degree of specialization follows. In effect, the increased degree of specialization represents a spill-over effect associated with the size of the capital stock.

Human Capital Accumulation

The accumulation of human capital can also lead to sustained economic growth. In this context human capital refers to the stock of education or labor market experience that increases a worker's productivity. A worker's education, for instance, can yield productivity improvements for a wide range of products. However, the schooling required to build up human capital also takes time away from current production. The contribution of human capital formation to economic welfare therefore depends on the tradeoff between current and future production. A society will underinvest in education if the benefits of human capital generate social benefits, such as broad-based increases in productivity and technical innovation, that are not reflected in the income that individuals expect from their investment in education. Financial capital market imperfections can also lead to underinvestment in human capital. Again, the mechanism for growth is savings, embodied in the resources devoted to education. Growth is driven by the spill-overs effects associated with an increase in the stock of human capital.

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[5] For an analytic treatment of product specialization, see P.M. Romer, "Increasing Returns and Long-Run Growth," Journal of Political Economy vol. 94, (1986), pp. 1002-1037. For process specialization, see B.K. Edwards and R.M. Starr, "A Note on Indivisibilities, Specialization, and Economies of Scale," American Economic Review (Mar. 1987), pp. 77, 192-194, and J.F. Francois, "Increasing Returns Due to Specialization, Monopolistic Competition, and Trade in Producer Services," Canadian Journal of Economics, vol. 23 (Feb. 1990), pp. 109-124.

[6] Romer, "Increasing Returns and Long-Run Growth."

[7] Edwards and Starr, "A Note on Indivisibilities. . . ."

Learning-by-Doing

In contrast to human capital formation through education, learning-by-doing generates increased productivity as a result of experience in production. Learning-by-doing can lead to endogenous growth if the knowledge and experience developed in one industry is also useful in other industries. With knowledge and experience spillovers of this type, technical innovations in one industry lead to cost reductions for other industries as well. Returning to the theme of specialization, when the benefits of learning spill over onto neighboring inputs that have similar levels of technical sophistication, learning-by-doing will lead to an increased range of specialized intermediate products over time. Essentially, if knowledge obtained in accumulated production of old goods is partially applicable to newly developed goods, then learning-by-doing can lead to growth.

Research and Development

Finally, the fourth source of growth is the development and introduction of new or more sophisticated products through research and development activities. If originators of new ideas yield information that is useful to other inventors, a greater stock of general-knowledge capital will increase the productivity of resources devoted to research and development. Investment in research and development then leads to dynamic increasing returns in the stock of general knowledge rather than to dynamic increasing returns in general-purpose capital. Combined, again, with returns related to increased specialization, the accumulation of knowledge through research and development can also lead to continual expansion in the range of goods produced in equilibrium and hence to sustained growth.

There is evidence to suggest that the spillover effects of research are, indeed, important. For example, Bernstein has estimated that, for Canada, over one-half of the social returns generated by research and development activities are due to externalities, or to effects on other firms in the same or other industries.[8] Bernstein's estimates imply that when firms make decisions regarding research and development funding, they generally do not consider the true social benefits of such activities. Further evidence has been offered by Jaffe, who finds that over one-half of the patents that result from increased research expenditures are due to spillover effects.[9]

Similarities

The four different sources of endogenous technical innovation delineated above have much in common. Apart from the formation of human capital, increased specialization in production or the benefits that accrue from the introduction of more specialized or improved product varieties is usually at the root of these various sources of endogenous growth. Even for human-capital formation, increased specialization provides increased opportunity to develop job-specific skills and to apply expertise (human capital) to the improvement of efficiency in production. There is also considerable overlap among these processes. For example, growth due to specialization in production occurs as a result of learning-by-doing or as a result of investment in new product development (or quality improvement) through research and development. Also, human-capital accumulation is achieved either through schooling or through on-the-job training (learning-by-doing). Perhaps the sharpest distinction is whether technical change results from development of new blueprints through research and development or whether it results from more

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[8] J.I. Bernstein, "Cost of Production, Intra- and Inter-Industry R&D Spillovers: Canadian Evidence," Canadian Journal of Economics, vol. 21, No. 2 (May 1988), pp. 324-347.

[9] A.B. Jaffe, "Technological Opportunity and Spillovers of R&D: Evidence From Firms' Patents, Profits, and Market Value," American Economic Review, vol. 76, No. 5 (Dec. 1986), pp. 984-1001.

efficient use of existing blueprints through learning-by-doing. In one method, specialization results from changes in the application of the existing stock of knowledge; in the other it relates to expansion of the stock of knowledge.

There is another common element to each of the more recent models of economic growth. In each of the growth processes discussed, positive spillover or external effects from innovative activities are necessary to obtain sustained economic growth. Learning-by-doing in the production of existing goods, for example, must be at least partially applicable to the production of new products. That is, there must be a spillover from learning-by-doing in one set of goods in order to generate sustained economic growth. In processes based on research and development investment, skilled labor is used to create blueprints for new products. To generate continual new product introduction and growth, external benefits must result from research and development activity. That is, the amount of skilled labor needed to develop a new product must fall as the level of general knowledge increases. This is true if the knowledge accumulated in the development of one product is applicable to other products as well. Because firms are not forced to re-invent existing technology (they do not have to re-invent the wheel), the costs of new product development fall.

Linking Trade and Growth

There is a close relationship between the dynamic processes of specialization emphasized in the recent growth literature and the static scale effects of trade emphasized in models that include static returns to specialization. However, static theories with external scale economies and specialization generally highlight the mechanisms by which trade and economic integration lead to an increased or decreased value of output. These theories do not explicitly address economic growth. In contrast, the more recent dynamic theories emphasize how trade and economic integration can lead to sustained changes in the rate of innovation and changes in growth rates.

Although the application of recent growth theories to trade represents an emerging literature, the larger body of economic literature linking trade policy to static and dynamic external scale effects is much older and can be traced as far back as Frank Graham's argument for the protection of "infant" industries.[10] When these issues have been visited in the past, economists have emphasized, albeit less formally, the potential benefits to emerging national industries of scale economies resulting from such processes as learning-by-doing, returns to increased specialization, and knowledge spillovers. An important contribution of the more recent literature therefore has been the explicit modeling of these processes. The recent literature has also provided more explicit analyses of the linkages of trade to economic growth and innovation.

In static analyses of trade liberalization, emphasis is often placed on relative resource endowments (i.e., resource-based comparative advantage) as a source of benefits from trade. Even in a dynamic context, with endogenous savings and capital formation, the pattern of trade and the welfare implications of trade liberalization are driven by the underlying base of factor endowments in the absence of scale

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[10] Graham's arguments met with a great deal of initial criticism. F.D. Graham, "Some Aspects of Protection Further Considered," Quarterly Journal of Economics, vol. 37 (Feb. 1923), pp. 199-227, F.H. Knight, "Some Fallacies in the Interpretation of Social Cost," Quarterly Journal of Economics, vol. 38 (Aug. 1924), pp. 592-606, and J. Tinbergen, International Economic Cooperation (Amsterdam, 1945). In less formal terms, such arguments can actually be traced back much farther. The United States became a high tariff country early in the 19th century in part because of the acceptance of the infant industry argument. R.E. Caves and R.W. Jones, World Trade and Payments, 4th ed., (Boston: Little, Brown, 1985), ch. 13. In this same period Government encouraged the establishment of "high-technology" industries by subsidizing the transfer of embargoed British textile mill technology. D.J. Boorstin, The Americans: The National Experience (New York: Vintage/Random House, 1965), ch. 5.

effects.[11] However, the existence of dynamic external effects introduces important complications. Such effects can far outweigh the welfare effects of trade liberalization that are derived from differences in the resource base alone.

Dynamic models of trade with human-capital formation yield results that are similar to those that follow from classical models of growth through capital accumulation and from dynamic versions of more traditional trade models. In a recent paper Lucas presents a model of trade with human-capital formation in which countries that start out with more human capital remain forever wealthier than poorer countries, even with trade.[12] The primary effect of trade in such a world is faster growth. At the same time, the simple model of growth resulting from human capital accumulation implies a fixed world distribution of income.

Lucas argues that human-capital accumulation is not a satisfying explanation of the post-1945 growth experience. He contends that models of learning-by-doing, such as those developed by Stokey and Young, can better explain differences in rates of economic development.[13] By channeling resources into product lines with more potential for learning-by-doing, a country may increase its rate of growth.

With learning-by-doing, trade liberalization and free trade between developed and developing countries can yield a number of possible outcomes. Many of these outcomes have been examined by Young.[14] The picture of trade that emerges in his paper is one of comparative advantage that is determined at the level of individual inputs and products rather than in broad industry groups. Trade is also accompanied by a continually shifting pattern of comparative advantage.[15] Learning spillovers give rise to constant turnover in the set of goods for which production involves rapid learning-by-doing as new products come into production and production of old goods ceases. Learning is faster in the production of goods that are nearer to a country's technological frontier.

Given learning-by-doing, trade liberalization can lead to a widening of the technological gap between developed countries and less developed countries, an acceleration of growth in the developed countries, and a slowdown of growth in the less-developed countries. However, although such results are suggestive, they depend crucially on the assumptions underlying the analysis. In particular, these results presume that learning-by-doing effects are national in scope, meaning that they yield spillover benefits for neighboring products within each country but not for neighboring countries. The international transmission of such effects could easily reverse the effects of liberalization. Nonetheless, Young's paper does demonstrate how international trade can lead to changes in the rate of growth for an economy. The paper provides a rich framework for analyzing the growth effects of learning-by-doing.

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[11] Z. Chen, "Long-Run Equilibria in a Dynamic Heckscher-Ohlin Model," Canadian Journal of Economics, vol. 25, No. 4 (Nov. 1992), pp. 923-943.

[12] R.E. Lucas, Jr., "Making a Miracle," prepared for the Fisher-Schultz Lecture, given in September at the European meetings of the Econometric Society, Apr. 1992.

[13] N.L. Stokey, "Learning by Doing and the Introduction of New Goods," Journal of Political Economy vol. 96, No. 4 (Aug. 1988), pp. 701-717, and A. Young, "Learning by Doing and the Dynamic Effects of International Trade," Quarterly Journal of Economics, vol. 106, No. 2 (May 1991), pp. 369-406.

[14] Young, "Learning by Doing and the Dynamic Effects of International Trade."

[15] Such dynamics are typical of models of "North-South" trade. The basic pattern of shifting comparative advantage, driven by the rate of innovation and the vintage of existing product types, was emphasized in a 1966 paper by Vernon. R. Vernon, "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics, vol. 80 (1966), pp. 190-207, and D. Dollar, "Technological Innovation, Capital Mobility, and the Product Cycle in North-South Trade," American Economic Review (Mar. 1986), pp. 177-190.

Potential linkages between trade and growth in models of knowledge accumulation through research and development have been cataloged in a monograph by Grossman and Helpman.[16] Drawing upon and extending earlier work by themselves and others, they link endogenous growth models with static international trade theory.[17] Focusing on specialization driven by research and development, Grossman and Helpman emphasize four channels through which integration of the world economy may lead to changes in incomes and growth. First, economic integration may enhance international dissemination of knowledge, even in the absence of trade flows. This dissemination leads to an effective expansion of the base of knowledge on which growth is driven: that is, from a national to a worldwide base of knowledge. Second, trade can eliminate redundancy of product designs. Third, the possibility of trade expands the effective market size for firms in each country. Fourth, trade can lead to changes in resource allocations resulting from changes in relative factor prices. Depending on whether such resource shifts expand or contract the resource base that drives growth, growth effects may be positive or negative. In particular, if dynamic sectors contract, growth may fall.[18]

The various mechanisms by which the world economy moves from one path to another over time are strikingly similar to the results in Young's paper. A country that has a technical lead initially will usually increase it over time and grow faster in the long run. Factor prices are not necessarily equalized through trade. If factor prices are not equal, then the country with an initial technical disadvantage may actually be made worse off after trade, as wages in the more advanced country rise over time.

As in the case of learning-by-doing, cross-border spillovers of external scale effects, through the international transmission of knowledge, can be important. If international knowledge spillovers depend on the volume of trade (exports plus imports), there will be a tendency for trade-promoting policies to improve economic welfare. The application of export subsidies is also more likely to improve welfare for all countries with international externalities (international scale effects) than under strictly national dynamic scale effects. At the same time, import tariffs may reduce welfare even if they stimulate domestic research and development and domestic production.

For models in which trade is driven in part by the accumulated stock of skills or knowledge, history matters when returns to specialization rest on learning-by-doing or on research and development. In particular, countries with an initial advantage may, under a broad set of circumstances, build on that advantage over time. However, even if trade slows growth for less advanced economies, welfare may still improve for those countries, because trade broadens access to specialized products and inputs even if growth rates slow. A consequent increase in the level of income may outweigh a slowdown in its future growth rate. Put another way, level effects can outweigh growth effects. There may be other static gains as well. It is also important to note that a country may suffer a reduction in its national welfare even if a trade intervention enhances the long-run rate of growth in production in the country. This is because trade intervention may cause an immediate reduction in national income that is not outweighed by increases in long-run growth.

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[16] G.M. Grossman and E. Helpman, Innovation and Growth in the Global Economy Cambridge: MIT Press, 1991).

[17] The literature they draw on includes P.M. Romer, "Endogenous Technological Change," Journal of Political Economy, vol. 98 (1990), pp. S71-S102, and L.A. Rivera-Batiz, and P.M. Romer, "Economic Integration and Endogenous Growth," Quarterly Journal of Economics, vol. 106, No. 2 (May 1991), pp. 531-556.

[18] G.M. Grossman and E. Helpman, "Comparative Advantage and Long-Run Growth," American Economic Review vol. 80, No. 4 (Sept. 1990), pp. 796-815.

Empirical Evidence

The gains from trade in static, perfectly competitive models stem from the increased efficiency of resource allocation and improved consumption possibilities. In static models with imperfect competition, additional gains from trade may result from increasing returns to scale, as firms realize internal scale economies, and from increased product and input variety for consumers and producers respectively.[19] Static gains imply a change in the amount of aggregate output (a level effect) but not its growth rate. For this reason the static gains from trade are relatively small as a percent of gross domestic product (GDP) in empirical studies of trade liberalization.

In contrast, dynamic gains from trade increase the rate of economic growth. Even a small change in the growth rate can lead to a substantial cumulative effect on GDP. As a result empirical assessment of the dynamic effects of trade policy changes can yield substantially larger estimates than those based on static models. The growth effects of trade liberalization can flow through a variety of channels, such as improved access to specialized capital goods, human-capital accumulation, learning-by-doing and the transfer of skills, and new product introduction. These activities can give rise to sustained economic growth.

Recent empirical studies on the dynamic effects of trade liberalization and trade intervention can be placed in two groups. The first group of studies is concerned with current economic integration efforts, including the proposed North American Free-Trade Arrangement (NAFTA) and the European Community's economic integration (EC 92) program. These studies estimate the likely effects of changes in current trade regimes. The second set of studies are historical in nature. Some assess how growth rates have been affected by past trade liberalization efforts, such as multilateral efforts in the post-World War II period. Others assess recent Government intervention in specific dynamic, innovation-intensive industries, such as semiconductors and aircraft.

The empirical literature on the likely effects of trade liberalization under NAFTA is primarily static, although it does include a few studies that focus on potential dynamic effects. Under a NAFTA one dynamic effect of trade liberalization may be related to increased incentives for investment in Mexico. Such investment could accumulate over time into higher capital stocks in Mexican industry and could lead to a one-time increase in long-run Mexican output per worker. Under such an outcome there would be short- to medium-term growth effects as incomes increased to new levels. However, these transitional growth effects would then be expected to taper off at a new, higher level of income.

In a recent study Young and Romero modeled the liberalization of Mexican tariffs on capital and intermediate inputs, as well as an exogenous reduction in the Mexican real interest rate.[20] Their assessment of tariff reductions highlights static efficiency gains. However, a reduction in interest rates for Mexico also can also have significant dynamic implications. In this context, Young and Romero also relate capital flows and reductions in real interest rates to dynamic level effects. Capital flows are important because an increase in Mexico's capital-to-labor ratio would lead to higher per capita output. In Young and Romero's assessment, current differences in capital-labor ratios between Mexico and the United States cannot fully account for differences in per capita output levels. Based on purchasing power parity comparisons, 1988 real GDP per capita was $14,581 in Mexico and $37,608 in the United States. In the same period the real return on bank equity in Mexico averaged 28.2 percent per year, compared with 5 percent in the United States. Although capital flows into Mexico are unlikely to equalize Mexican

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[19] Recall that scale effects refer to declines in production costs associated with increased output.

[20] L. Young and J. Romero, "Steady State and Transition in a Dynamic Dual Model of the North American Free Trade Agreement," in U.S. International Trade Commission, Economy-Wide Models of a U.S.-Mexico Free Trade Agreement and of a North American Free Trade Agreement, USITC publication 2508, 1992.

and U.S. per capita output, they are clearly very important. Simple calculations in the paper show that capital flows sufficient to bring Mexico's net interest rate down from 28 percent to 5 percent (roughly the U.S. level) would increase Mexican per capita GDP to about $24,300.

Trade liberalization under NAFTA may also increase the availability of specialized capital goods that embody advanced technology. In a broader sense trade liberalization may also widen the basis for specialization in production. Economic theory suggests that increased availability of specialized inputs can lead to a permanent increase in the rate of economic growth. If the conditions needed for increased growth are realized in the Mexican case, the dynamic gains from a NAFTA may far exceed static gains. In a recent paper Kehoe emphasized dynamic gains from NAFTA related to specialization.[21] By his assessment the dynamic benefits of specialization would yield an estimated increase in the growth rate of Mexican manufacturing output per worker of 1.645 percent per year. After 25 years output per worker would be more than 50 percent higher than it would otherwise have been. Although these calculations are very crude, they do illustrate that the dynamic gains for Mexico may dwarf the static gains.

Similar assessment of the dynamic effects of a NAFTA for the United States are not found in the literature. Some insight can be drawn, however, from the literature on the static scale effects of NAFTA. In general the literature on static scale effects reports that even though NAFTA implies relatively large-scale effects for Mexico, the effects on the United States are also positive, although much smaller, because the relative size of the Mexican economy precludes a large dynamic impact.[22] Hence, because of the relative size of the U.S. and Mexican economies, any positive dynamic scale effects, like the static scale effects, are likely to be much smaller for the United States.

The dynamic effects of Europe's EC 92 program may also magnify expected static gains. In two recent reports Baldwin estimated the dynamic gains from the EC 92 program to eliminate barriers to trade and factor movements within the EC.[23] Baldwin distinguishes between a "medium-term growth bonus" resulting from induced capital formation and a "long-term growth bonus" resulting from induced technical change. The medium-term growth bonus is a level effect, whereas the long-term growth bonus is a growth effect. Baldwin also emphasized that such dynamic effects may be an important source of gains to the European Free Trade Association countries if they join the EC.[24]

The medium-term growth bonus from the EC 92 program is really a temporary increase in the growth rate during a transition to higher income levels. This effect is due to increased productivity of existing resources. Higher incomes imply increased savings and investment. The increased investment in turn yields more output, leading to further increases in saving and investment. Baldwin shows that the medium-term growth bonus can be quite substantial, especially when compared with the static gains

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[21] T.J. Kehoe, "Modeling the Dynamic Impact of North American Free Trade," Working Paper 491, Federal Reserve Bank of Minneapolis, Research Department, Minneapolis, MN, Mar. 1992. Kehoe's assessments are based on regressions using a cross-country data set for a large number of countries over 1970-85. These results are reported in D.K. Backus, P.J. Kehoe, and T.J. Kehoe, "In Search of Scale Effects in Trade and Growth," Working Paper 451, Federal Reserve Bank of Minneapolis, Feb. 1991.

[22] USITC, Economy-Wide Models of a U.S.-Mexico Free Trade Agreement and of a North American Free Trade Agreement, USITC publication 2508, 1992.

[23] R.E. Baldwin, "The Growth Effects of 1992," Economic Policy, vol. 4, No. 2 (Oct. 1989), pp. 247-281, and R.E. Baldwin, "Measurable Dynamic Gains From Trade," Journal of Political Economy, vol. 100, No. 11 (Feb. 1992), pp. 162-174.

[24] R.E. Baldwin, "The Economic Logic of EFTA Countries Joining the EEA and the EC," EFTA Economic Affairs Department, Occasional Paper No. 41, Nov. 1992.

from economic integration. The static gains of EC 92 may range from 2.5 to 6.5 percent of GDP.[25] Baldwin concludes that these estimates of the economic benefits of 1992 are at least 30 percent too low. He also estimates that induced capital accumulation will lead to GDP increases in the range of 0.6 percent for the United Kingdom and of 8.0 percent for Belgium, Germany, and the Netherlands. These effects are in addition to the EC-wide static gains of 2.5 to 6.5 percent. Baldwin has also estimated that the liberalization will fuel a permanent growth-rate increase of 0.25 to 0.80 of a percentage point.

Among historical studies Reynolds asserts that economic growth in the industrial countries was the single most important factor generating growth in the Third World in the post-1945 period.[26] In this context, one role for trade has been to provide developing countries with access to innovation in the industrial countries. Barro offers evidence that market distortions, particularly with respect to investment goods, are negatively correlated with growth rates.[27] Barro also finds a positive relationship between human capital levels and growth rates. High levels of human capital investment are positively related to low fertility rates and high rates of physical investment. Finally, de Melo and Panagariya have concluded that, for developed countries that engaged in both regional integration arrangements and multilateral arrangements (i.e., the General Agreement on Tariffs and Trade), it was multilateral arrangements, not regional ones, that provided liberalization-related contributions to the acceleration of growth rates in the post-1945 period.[28] Like Barro, de Melo and Panagariya also find that education is significant for explaining growth in developing countries.

Recent empirical studies of trade intervention in specific, imperfectly competitive industries have tended to focus on the net effects of government intervention. These studies represent a nascent empirical literature that applies new theories of trade under imperfect competition. Although these studies focus on inherently dynamic issues, such as product development and learning processes, the actual empirical estimates are generally based on multiperiod models of static scale effects. In a paper on the market for wide-bodied commercial aircraft, Baldwin and Krugman assess the welfare effects of European subsidization of the Airbus A300.[29] Their results are somewhat mixed. There is a welfare gain for Europe, due primarily to reduced prices, and for consumers in the rest of the world. However, these gains are largely re-distributive, as they come at the expense of the United States. The net welfare effect for the United States is negative, with the losses to Boeing outweighing consumer benefits from lowered prices.

In a second paper Baldwin and Krugman also examine the semiconductor market.[30] They conclude that even though Japanese success in the industry depended on Japanese Government involvement, the actual welfare effect on Japan of Government intervention was negative. In another

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[25] Commission on the European Community, "The Economics of 1992," European Economy, No. 35 (also called the Cecchini Report.)

[26] Reynolds, "The Spread of Economic Growth to the Third World."

[27] R.J. Barro, "Economic Growth in a Cross Section of Countries," Quarterly Journal of Economics, vol. 106, No. 2 (May 1991), pp. 407-444.

[28] J.M. de Melo and A. Panagariya, "Regional Integration: An Analytical and Empirical Overview," presented at the World Bank and CEPR Conference on New Dimensions in Regional Integration, Washington, DC, Apr. 1992.

[29] R.E. Baldwin and P. Krugman, "Industrial Policy and International Competition in Wide-Bodied Jet Aircraft," in Trade Policy Issues and Empirical Analysis, Robert E. Baldwin, ed. (Chicago: U. of Chicago Press, 1988).

[30] R.E. Baldwin and P. Krugman, "Market Access and International Competition: A Simulation Study of 16K Random Access Memories," in R.C. Feenstra, ed., Empirical Methods for International Trade (Cambridge: MIT Press, 1988).

study of the semiconductor industry, Dohlman concludes that more recent U.S. Government action, in the form of the 1986 U.S.-Japan Semiconductor Trade Arrangement, led to a net reduction in welfare for the United States, Europe, and the rest of the world. The Japanese, however, were able to gain from this agreement through manipulation of increased market power.[31]

The presence of substantial capital, research, and product development costs plays a potentially important role in determining the effects of trade policy. However, the recent industry-specific empirical literature on government intervention in industries subject to rapid technical change and dynamic scale effects is still based on analysis of static scale effects. In addition, it is important to note that this literature is focused on specific industries and does not explicitly consider broader, economywide resource constraints. Dixit and Grossman have emphasized that in a general equilibrium setting, the cases for export promotion and active trade-related intervention with imperfect competition are much weaker than they appear in partial equilibrium.[32] While a large subset of such sectors may be able to make arguments for special trade treatment or assistance based on the "unique" characteristics of their industry, sufficient information usually is not available for weighing such conflicting claims. Their analysis demonstrates that, unless a particular industry stands out strongly as a unique case, free trade is likely to be the best policy option. Even though their analysis is concerned with static issues of scale and market structure, the basic point carries over to the dynamic benefits of trade liberalization and intervention as well. In general whole industrial sectors are likely to be competing for investment funds, available human capital, and other resources. Industry-specific intervention will shift resources among these competing sectors, and, as Dixit and Grossman have emphasized, may harm downstream sectors and yield muddied overall effects.

Summary and Insights

The recent literature on endogenous growth and trade has identified a number of issues that are important to the dynamic interplay between trade policy and dynamic changes in incomes, production, and overall economic activity. The issues raised in this literature include research and development incentives, incentives for investment in physical and human capital, and the benefits that follow the expansion and integration of markets. However, formal empirical application of the new growth theories in a trade context has barely started. The practical identification of active policy recommendations for specific sectors is problematic at best and is certainly beyond the appropriate application of current methods related to the dynamics of trade.

Even so, the empirical literature does provide some important insights regarding the dynamic effects of trade policy changes. Early estimates of the net welfare effect of broad-based trade liberalization efforts strongly suggest that dynamic effects can far outweigh static effects. It appears that through such dynamic processes trade liberalization efforts in the post-1945 period have contributed significantly to economic growth and likely will continue to do so. At the same time, given economywide resource constraints, it appears difficult at best to identify such dynamic processes in individual sectors, let alone to target them through selective trade measures.

In general terms specialization and consequent dynamic benefits are limited in part by the extent of the market because increased specialization in production is usually associated with fixed overhead,

[31] P.A. Dohlman, "The 1986 U.S.-Japan Semiconductor Arrangement: Political Economy, Game Theory, and Welfare Analyses," doctoral dissertation, Duke University, Durham, NC, 1993.

[32] A.K. Dixit and G.M. Grossman, "Targeted Export Promotion With Several Oligopolistic Industries," Journal of International Economics, vol. 21 (1986), pp. 233-249.

research, and product development costs. Larger markets allow for a greater base over which to spread such costs. In a dynamic context trade liberalization therefore implies potentially positive dynamic effects related to the expansion of markets. However, the actual welfare implications of such effects depend on the interaction of changes in scale and relative prices over time, along with the effects of resource reallocation. The actual result of particular trade actions is an empirical question.

Another potentially important factor in determining the dynamic implications of trade liberalization is the cross-border spillover of the externalities that drive endogenous growth. For example, an expansion of the general stock of knowledge can imply increased research productivity on a global scale rather than on a strictly national scale. Similarly the global and regional integration of production implies that the benefit of increased process specialization may yield scale and growth effects that spill across national borders. With the complete cross-country spillover of scale and growth effects, trade liberalization unambiguously improves economic welfare for small countries. For large countries the effect of trade liberalization is again an empirical question. At a minimum, though, the cross-border spillover of such dynamic effects is likely to be important. When spillover effects are present, multilateral approaches to trade policy will internalize more of these benefits than will unilateral or bilateral efforts, thereby making it easier to capture a greater share of potential dynamic gains through cooperative efforts.

Part II
A technical review of the literature

THE THEORETICAL LITERATURE

This section of the report provides a technical review of the recent theoretical literature on endogenous growth. Two sources of economic growth emphasized in the traditional growth theory literature are ongoing technical change and population growth. Population growth tends to yield higher gross output, but does not necessarily lead to higher per capita incomes. More recent economic theory has focused on technical change as a source of growth. In particular, theory has been developed to explain how market forces give rise to technical change and in turn to economic growth. Such theories are said to model technical change endogenously because the models show how maximization of the present value of profits by firms facing market prices leads to endogenous technical change and growth. Trade liberalization changes the incentives to invest in technical change and may in turn lead to changes in the rate of economic growth.

There are four main types of theoretical models used to explain growth due to endogenous technical change. The first relies on the existence of specialized intermediate inputs. Growth occurs if the range or quality of such inputs increases over time. A second theory is based on learning-by-doing in production. If knowledge obtained in accumulated production of old goods is partially applicable to newly developed goods, then learning-by-doing can lead to growth. Human capital accumulation is the basis for a third theory of economic growth. This refers to the accumulation of increased productive capacity by workers by virtue of their education or labor market experience. A worker's education, for instance, can yield productivity improvements for a wide range of products. The fourth and final theory models the development and introduction of new or more sophisticated products through research and development (R&D) activity.

Although these four theories have been advanced in the literature, there is considerable overlap. For example, growth due to specialization in production may be due to learning-by-doing or due to investment in new product development (or quality improvement) via R&D. Also, human capital accumulation is achieved either through schooling or through on-the-job training, the latter being another term for learning-by-doing. Perhaps the sharpest distinction is whether technical change results from development of new blueprints through R&D (expansion of the knowledge base) or whether it results from more efficient use of existing blueprints through learning-by-doing (accumulation of skills). This distinction can be important, especially when comparing trade liberalization in developed versus developing countries.

In each theory, there is a spillover or externality of some type from the innovative activity to obtain sustained economic growth. Learning-by-doing in the production of existing goods, for example, must be at least partially applicable to the production of other products.[33] That is, there must be a spillover from learning-by-doing to generate sustained economic growth. In theories based on R&D investment, skilled labor is used to create blueprints for new products. To generate continual new product introduction and growth, external benefits must result from R&D activity. That is, the amount of skilled labor needed to develop a new blueprint must fall as the level of general knowledge increases. Without spillover benefits, improved incentives for research yield an increase in the level of output per worker, but not its rate of growth.

The new growth theory was developed to show how forward-looking investment by firms (and workers in the case of schooling) in response to market incentives could give rise to economic growth without the need to assume that technical change occurs exogenously. However, a significant additional step is needed to link trade and trade liberalization to models of endogenous innovation and growth. In

[33] After a point, productivity improvements due to learning-by-doing in an individual product will cease. For growth in an economy's aggregate output to continue, knowledge gained in production of old goods must be partly applicable to new goods.

particular, to affect growth, trade liberalization must change the conditions underlying growth. These linkages have been developed to a greater degree in some models than in others.

With these considerations in mind, we begin by discussing traditional growth theory. Then, we present each of the four endogenous growth theories enumerated above. The link between trade and growth is examined in each model where it is applicable. Finally, an overall assessment is made of the implications of endogenous growth models for trade policy.

Traditional growth theory

This section presents a standard traditional growth model as a point of reference for the subsequent discussion of more recent endogenous growth theories.[34] The key elements of the model are as follows. Production is modeled in the most aggregate sense. Physical capital and labor are combined to produce a single final output. The aggregate supply of labor is assumed to be fixed. Labor-augmenting technical change is assumed to occur at an exogenously specified rate. Final output can either be consumed directly, or used as an investment good. Consumers face a tradeoff between current consumption and investment to increase future consumption. This economy tends toward a steady state in which output, the capital stock, and the effective labor supply grow at a constant rate equal to the rate of technical progress.

The production function specifies output as a function of physical capital and the effective labor stock:

$$Y_t = F(K_t,(A_t L)) \tag{1}$$

where
- Y_t = aggregate output (in year t)
- K_t = aggregate capital stock
- L = aggregate stock of labor (assumed fixed)
- A_tL = stock of labor measured in efficiency units
- A_t = e^{gt}
- g = rate of labor productivity change

In subsequent discussion, the time subscript is dropped for notational simplicity. The stock of labor is fixed. However, each worker is assumed to become more productive over time (as measured by the term A_t) so that the supply of labor services, measured in efficiency units, becomes effectively bigger at rate g.[35] It is assumed that doubling the size of the capital stock and the effective stock of labor will yield double the output. Given these conditions, we can write the production function in "intensive form" as represented by equation (2). In equation (2), y is output per effective labor unit and $k=(K/AL)$ is capital per effective labor unit. The term f(k) represents output for a single unit of labor services, which depends on the amount of capital available per unit of labor services.

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[34] The basic model is presented in Solow, "A Contribution to the Theory of Economic Growth." Also, see Stiglitz and Uzawa, Readings in the Modern Theory of Economic Growth.

[35] Note that this is identical with Solow's original model, except that the labor growth coefficient is interpreted as a technical change coefficient.

$$y = \left[\frac{Y}{AL}\right] = \left[\frac{F(K,AL)}{AL}\right] = f(k) \tag{2}$$

Fixed Savings Rates

To simplify, we consider first the case where households save a constant fraction s of current income Y_t. Savings are used to augment the existing capital stock:

$$I = \frac{dK}{dt} = sY \tag{3}$$

where investment, I, is equal to the change in the capital stock, dK/dt, absent depreciation. This equation says that each year consumers save a fraction of their income s and turn it over to firms in exchange for claims on future output. Firms use the savings to augment their capital stock which, accumulated over several years, yields additional output in the future.

With the aggregate production function (1) and the capital accumulation equation (3), it is possible to derive the following equation that describes the evolution of the capital-to-effective-labor ratio for this type of economy:

$$\frac{dk}{dt} = sf(k) - gk \tag{4}$$

where dk/dt is the rate of change in k per unit of time.

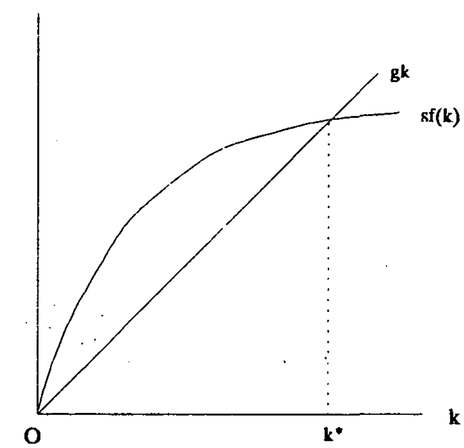
The two terms on the right hand side of equation (4) are shown in Figure 1. The curve sf(k) gives the level of savings at each level of the capital-labor ratio k.[36] The curve gk gives the level of investment needed to support growth of the effective labor supply at rate g. These curves intersect at k*. For levels of k less than k*, savings exceed investment needed to support growth of the effective labor supply so that the capital-labor ratio k grows. This is reflected in a movement to the right along the horizontal axis. Beyond k*, savings are less than the investment needed to support growth rate g in the effective labor stock so the capital-labor ratio k falls over time. This is reflected in a leftward movement

[36] Figure 1 is drawn based on some special assumptions regarding the shape of the production function. Specifically, f'(k) tends to infinity in the limit as k tends to zero from the right and f'(k) tends to zero as k tends to infinity. These are sometimes referred to as the "Inada conditions"; they are sufficient for existence of a steady state in this model but are not necessary. See Takayama, Mathematical Economics.

along the k axis. The economy reaches a steady state at k*, where savings are just sufficient to support exogenous growth in the effective labor supply. If the economy starts at a level of k different from the steady state level, k*, it will eventually move to k*.

In the steady state k*, the capital-labor ratio is constant over time (dk/dt=0 from equation (4)) so that the capital stock K grows at the same rate g as the effective labor stock. Based on the assumption of constant returns to scale, we know that if capital and effective labor grow at the same rate, then output will also grow at rate g. This is referred to as a "balanced growth path" because output, the capital stock, and labor productivity all grow at a common rate in the steady state.

Figure 1



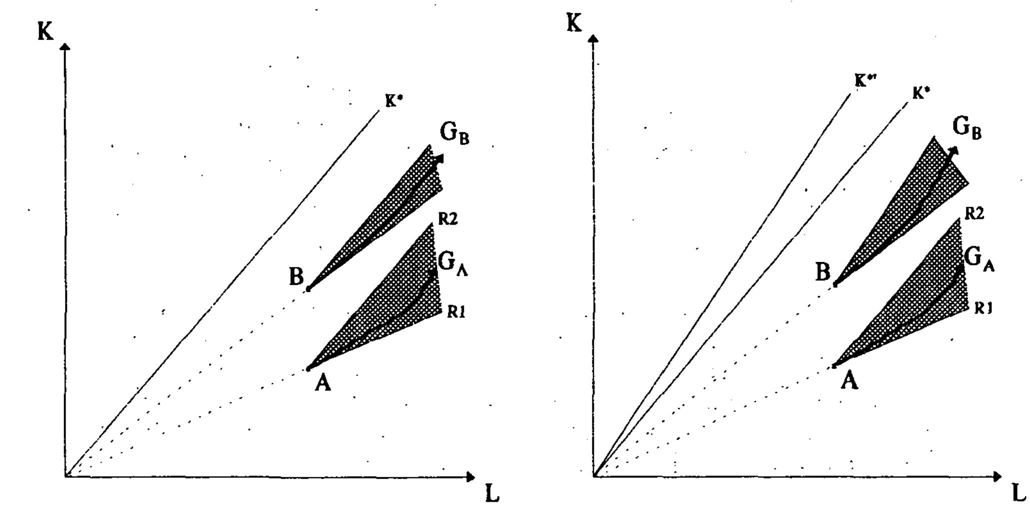
Given the dynamic characteristics of this model, the economy only converges to steady-state values in the limit, as time tends to infinity.[37] As a result, while the steady-state is a useful frame of reference, the transition path leading to the steady-state may be of more immediate importance. Figure 2 illustrates possible transition paths leading to the steady-state. In Panel a of Figure 2, the line *K** denotes the steady-state capital-labor ratio. Over time, an economy will follow a path like that drawn from point *A* (which defines endowments at a point in time) that remains within the shaded region defined by Ray R_1, through point *A* and the origin, and Ray R_2, which is parallel to the equilibrium capital-labor ratio.[38] Liberalization of trade and foreign investment restrictions can carry a number of possible dynamic implications in these models. Often, the dynamic effects are classified as either "level" effects, or as "growth" effects. These effects are defined with reference to steady-state values. Level effects imply an increase in the steady-state level of income, without consequent permanent changes in steady-state growth rates. In contrast, growth effects refer to permanent changes in the rate of growth in income. However, an economy may experience higher growth during the transition even when the steady-state growth rate and income levels are unaffected.

To illustrate these points, consider first a one-time inflow of capital, without a change in the long-run capital-labor ratio. In terms of Panel a, this would move the economy to some point like B rather than A. Since point B is above A, the set of growth paths in the shaded region around B is everywhere above the set around A. Since the shaded set of possible growth paths is redefined as the new endowment points evolve through time, the relevant set of resources along growth path G_B will be above those associated with the growth path G_A during the transition period. If the capital-labor ratio follows path G_B instead of path G_A, this implies a temporary increase in growth rates (as we move from A to B), along with higher income and consumption during the transition to the steady-state. Thus, even in the absence of level or growth effects, as defined with reference to the steady-state, we may still observe changes in growth paths and the path of income during the transition.

[37] In some models of endogenous technical change with "rational expectations," the economy moves to the steady state immediately.

[38] See A.V. Deardorff, "Growth Paths in the Solow Neoclassical Growth Model," Quarterly Journal of Economics, vol. 84 (1971), pp. 134-139.

Figure 2



Panel a

Panel b

While Panel a represents a case without level or growth effects, Panel b illustrates an increase in the capital stock that is accompanied by an increase in the steady-state capital-labor ratio. Such an outcome may result, for example, if trade liberalization yields static efficiency gains, and the gains then translate, in part, into higher savings and investment levels. In the figure, the shift from K* to K*' represents the increase in the steady-state capital-labor ratio, while the shift from point A to point B represents an initial increase in the capital stock. As in the case illustrated in Panel a, growth paths are higher. In contrast to the case represented in Panel a, however, there is also a level effect, because the stead-state capital-labor ratio has increased. In addition to higher income, growth rates will also, at least temporarily, be higher for path G_B than for path G_B. Even in the absence of per-capita growth effects, as defined with reference to the steady-state, we may still observe short-term increases in growth rates associated with level effects during the transition.

In the absence of technical progress, growth cannot be sustained in the steady-state in this type of economy if the marginal product of capital tends to zero as the capital stock is expanded. Eventually, additional investment drives the marginal product of capital to zero, so that investment and output growth cease. However, sustained growth is possible in this economy, even without technical progress, if the marginal product of capital instead tends to a positive constant (say b) for large values of the capital stock.

Growth in this model is due entirely to exogenous labor-augmenting technical change, which makes a given stock of labor more productive over time. The labor supply is assumed to be fixed. This assumption could easily be relaxed by assuming that the population grows at a constant rate. Without technical progress, however, growth in per capita income will cease in this economy as well, unless the marginal product of capital again is bounded from below by the ratio of the rate of population growth and the savings rate. To focus on technical change, we shall follow the endogenous growth literature and assume throughout the discussion below that the labor supply is fixed.

Endogenous Savings Rate

While the assumption of a fixed savings rate is a useful one, additional insight may be gained by making the household's allocation of income between consumption and savings endogenous. At a minimum, this involves specifying preferences over current and future consumption levels, the expected life-time of economic agents, and their intertemporal budget constraints.[39]

In the absence of technical progress, a Solow economy, expanded so that savings are chosen by households to maximize utility over an infinite time horizon, cannot sustain growth in the long run. With a fixed stock of labor, additional investment causes the marginal product of capital to fall. In an economy with endogenous savings behavior, the marginal product of capital eventually falls to the discount rate (unless it reaches a lower bound prior to this). For larger levels of the capital stock, consumers are no longer willing to provide additional savings to firms because the value of future output derived by postponing current consumption is less than that of current consumption.

However, as in the case of fixed savings, sustained growth is possible in Solow's economy, expanded to include endogenous savings behavior, even in the absence of technical change. In particular, suppose the marginal product of capital is bounded from below by a constant (say b), such that b exceeds the discount rate ρ. In this case, output and the capital stock grow at rate $b-\rho$. This result parallels that obtained in the Solow economy with no technical change and a fixed saving rate, for which sustained growth was not possible unless the marginal product of capital was bounded from below by a positive constant.

Specialized Producer Inputs

As Romer points out, the idea that specialization in production could lead to increasing returns is as old as the economics discipline itself.[40] In Romer's model of specialization, general purpose capital is used to produce specialized inputs. These intermediate inputs are then combined with labor to produce a final good. Increasing returns due to specialization are obtained from the assumption that fixed stocks of labor and general purpose capital (also referred to as the "primary resource") will yield a greater quantity of final output if the number of specialized inputs is increased. Increasing returns due to specialization imply that a large number of intermediate inputs, each produced at an infinitesimal level, would be optimal. This must be balanced against traditional economies of scale in the production of each specialized input, which imply declining costs at the level of each intermediate input producer.

There is a close relationship between dynamic increasing returns to scale in the endogenous growth literature and static models with economies of scale due to specialization in production. Romer makes this point explicitly by taking a static model similar to Ethier's model[41] as a departure point, transforming it into a dynamic model, and then showing that this is another form of the traditional growth model with exogenous labor-augmenting technical progress and endogenous savings behavior.

This subsection develops the notion that specialization in production of intermediates can lead to dynamic returns to scale and sustained economic growth. We first introduce a simple representation of a technology involving differentiated intermediate goods and discuss the implications for resource

[39] The specification of savings behavior is a contentious issue. Fixed savings rates are often justified by Simon Kuznets' observation for U.S. data. See L.J. Kotlikoff, What Determines Savings? (Cambridge: MIT Press, 1989). Dynamic models with endogenous savings include P.A. Diamond, "National Debt in a Neoclassical Growth Model," American Economic Review, vol 55, No 5, pp. 1126-1150. R.E. Lucas, Jr., "On the Mechanics of Economic Development," Journal of Monetary Economics, vol. 22, No. 1 (July 1988), pp. 831-844. G.M. Grossman and E. Helpman, Innovation and Growth in the Global Economy. The discussion in the text is based on Grossman and Helpman's treatment of the Solow model.

[40] P.M. Romer, "Growth Based on Increasing Returns due to Specialization," American Economic Review, vol.77, No. 2 (May 1987), pp. 56-62.

[41] See Ethier, "National and International Returns to Scale in the Modern Theory of International Trade."

allocation in a static setting. This static model is subsequently embedded in a dynamic one by allowing accumulation of primary resources over time. Implications for growth, trade, and government policy are then discussed.

Static Version

Assume there is a continuum of specialized inputs potentially available to final goods producers. Let x(i) denote the amount of intermediate input i used and assume it is given by the following equation:

$$x(i) = (N/M) \tag{5}$$

for inputs i in the range [0,M]. The total quantity of intermediate inputs is N, while M measures the range or number of such inputs. Total output of the final good is assumed to be given by the following production function:

$$Y = M^{1-a} L^{1-a} N^{a} \tag{6}$$

where L is the amount of labor used to produce the final good and 1-a is labor's share of production cost (a number between zero and one). This specification features constant returns to scale holding M fixed (doubling L and N causes Y to double) but increasing returns due to specialization (if M increases so does Y).

Scale economies limit the degree of specialization. Production of x units of any intermediate input is assumed to require $(1 + x^2)/2$ units of the primary resource. This implies a U-shaped average cost curve. Total production of intermediate inputs is limited by the economy-wide supply of primary resources Z.

We now describe equilibrium for this economy. Consumers are assumed to be price takers and there are constant returns in final goods production, given M, so perfect competition prevails there. The market for intermediate inputs reaches a monopolistically competitive equilibrium. This means each intermediate input is produced by a single firm (which is small compared to the total market for all intermediates) but free entry and exit drives profits to zero. Given the derived demand for intermediate input i and the price of primary resources, producer i behaves like a monopolist and charges a markup over marginal cost to maximize profits. By symmetry, all intermediates are produced in equal quantities, for those inputs that are produced.

It is useful to compare the market equilibrium with the solution of a social planner who maximizes output of the final good subject to the available technology. The social planning solution is identical to the market equilibrium in this case. This result relies crucially on the assumed functional form for the production function and upon the fact that the stock of primary resources, Z, is held constant.

Even with Z fixed, a different choice of functional form in equation (6) would cause the equilibrium levels of x(i) and M to diverge from optimal levels. There are two reasons for this. First, intermediate producers exercise market power and supply too low a level of x(i), thereby causing the range of products M to be too large. Second, new intermediates are supplied up to the point where total cost exceeds total revenue because there is free entry and exit. However, final goods producers' total willingness to pay for intermediate inputs (the area under the derived demand curve) exceeds total revenue so the number of intermediate products M is too small in equilibrium (and x(i) is too large). With this particular functional form, these two distortions exactly offset one another.

If the stock of primary resources were not held constant, it would be socially desirable to increase Z. Romer shows that the value of an additional unit of the resource in this model is R/a, which exceeds its market price R.

Dynamic Version

We now generalize the static model with increasing returns due to specialization by allowing primary input Z to grow over time. Z is defined as a durable general purpose capital good which is needed to produce a range of specialized intermediate goods. It is assumed that there are a large number of consumers and final goods producers, which is consistent with perfect competition in the market for final goods. Consumers are allowed to allocate a portion of their income toward investment in the general purpose capital good. Households effectively own capital and rent it to intermediate input producers. In return, they receive a stream of rental payments from firms. Consumers also receive labor income from final goods producers.

In equilibrium, consumption and the stock of capital, Z(t), grow at a constant rate. The economy grows more slowly in dynamic equilibrium than is optimal, even though the static allocation of resources is optimal for the given capital stock Z(t).[42]

The dynamic model of endogenous growth due to specialization can be expressed in the form of a traditional growth model with exogenous labor-augmenting technical change and endogenous savings. A key step here is that N(t) and M(t) are proportional to Z(t) in equilibrium, which Romer shows by explicit calculation. Given this, production function (6) can be expressed as follows:

$$\begin{aligned} Y_t &= M_t^{\,1-a}(L^{\,1-a} N_t^{\,a}) \\ &= A\, Z_t L^{\,1-a} \end{aligned} \tag{7}$$

where A is a constant. A one percent increase in the stock of capital Z causes a one percent increase in total income, of which 100a% is returned to capital. The remaining 100(1-a)% is returned to labor, which receives the additional income due to dynamic increasing returns in M(t).

The reason for suboptimal growth is as follows. Each consumer is assumed to take capital and labor income as given. In the aggregate, however, capital accumulation leads to an expansion in the number of specialized inputs that are produced in equilibrium, thereby increasing output of the final good. A portion (1-a) of the additional output is received by households as labor income and the remaining portion, a, is received as capital income.

Households do not anticipate the effect that additional savings will have on capital and labor income so they save too little. In this respect, M(t) behaves just like a positive externality, even though there is no true externality in the model. Each household has no incentive to increase M(t) via capital accumulation because it accounts for a small fraction of aggregate savings; however, all households benefit from an increase in M(t). A subsidy to savings is needed to achieve the optimal solution in this economy.

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[42] Optimality of the static resource allocation in market equilibrium is dependent on the choice of functional form in equation (6).

Trade Liberalization

We illustrate some of the basic implications of trade liberalization in the presence of increasing returns due to specialization based on the static model described above. The basic results described here depend on the existence of social returns from production that are not reflected in private prices and hence in the decisions made by individual firms.

We focus on two alternative sources of divergence between social and private returns from production: national returns and international returns. Under national returns to scale, the rate of social transformation in production depends not only on resource allocations, but also on the national scale of production of variable returns sectors. A major point of the national returns literature has therefore been that manipulation of the scale of increasing returns sectors through tax-cum-subsidy schemes may increase welfare. With international returns to scale, externalities spill over borders. Hence, under international returns to scale, the efficiency of an increasing returns sector only depends on the domestic scale of production to the extent that domestic producers contribute significantly to the global scale of production. Efficient domestic operating scale is thus more important for large countries than for small ones if there are internationally increasing returns. The relative efficiency of a national consumer electronics industry, for example, may depend on the global scale of production. As a result, the benefits of national intervention schemes intended to aid a particular domestic industry may spill-over national boundaries, meaning that such programs may also benefit producers in other countries through changes in the global scale of production that in turn affect the cost of production in those countries as well.

Consider a country with two sectors, denoted by X and Y. The Y sector is subject to scale economies, and its output is priced at average cost. The X sector can be interpreted as the rest of the economy. National returns to scale imply that the benefits of specialization are contained within national boundaries. In this case, production in the Y sector can be denoted as

$$Y = M^{1-a} L^{1-a} N^{a} \tag{8}$$

Alternatively, with international scale economies, we have

$$Y = (M + M*)^{1-a} L^{1-a} N^{a} \tag{9}$$

where M + M* represents the total extent of home country and rest-of-world specialization.

The effect of trade liberalization under national returns depends on the trade-off between the distortions introduced by protection related to consumption, and the social returns generated by an expanded national Y sector. If a country protects its increasing returns sector Y from imports, the tariff drives a wedge between domestic and world prices. At the same time, domestic prices do not reflect the social trade-off between allocating resources to the X and Y sectors.[43] If trade liberalization leads to

[43] Recall from Romer's model of increasing returns, due to the existence of specialized intermediate inputs, that labor and specialized intermediates are needed to produce good Y. In turn, primary resource Z is needed to produce specialized intermediates. Increasing returns due to specialization imply that production of Y is an increasing function of the range of available specialized intermediates (M for national scale economies and M + M* for international scale economies). Individual firms and households do not incorporate the full value of additional units of Z into their decision-making, due to increasing returns, so the market equilibrium level of the primary resource

a contraction of the increasing returns sector, national income (measured at world export prices) may be reduced. In contrast, if trade liberalization leads to an expansion of the increasing returns sector, then the effects of increased scale economies compound the basic benefits that follow elimination of distortions so that trade liberalization leads to an unambiguous increase in national income, again measured at world export prices.

Some of the basic implications of trade liberalization under national scale economies can be summarized as follows. A small country may face reductions in national welfare as a result of trade liberalization. In a static context, the level of income may be reduced. This possibility may arise if trade shifts resources away from increasing returns sectors. The actual outcome is ambiguous and must therefore be assessed empirically. For economies with relatively large nationally increasing returns sectors that are relatively far down the average cost curve, the basic gains from trade are magnified by the presence of scale economies, when we control for changes in the country's terms of trade.[44] However, terms-of-trade effects will also be important because large countries, implicitly, have market power. Hence, large countries may be able to increase national income by forcing up the price of exports. Taking advantage of increased scale implies the opposite effect, because increased output tends to depress prices. There is, thus, a potential tension between taking advantage of scale effects, and taking advantage of national market power. Abstracting from terms-of-trade effects, the socially optimal policy with national scale economies is a subsidy scheme that targets the increasing returns sector, combined with free trade.

The basic results of trade liberalization under international returns to scale also depend on the existence of social returns from production that are not reflected in market prices and hence in the decisions of individual firms. The primary difference is that such social returns benefit other countries as well. For a small country, the primary effects of trade liberalization are related to: (1) the elimination of price distortions; and (2) increased productivity for the increasing returns sector. As trade barriers protecting a domestic increasing returns sector are reduced, the national industry becomes more closely integrated with the global industry and is able to exploit scale economies across large, integrated national markets. Hence, trade liberalization leads to an unambiguous increase in national income for a small country if there are international returns to scale.

Similar effects occur in large countries as well. Again, trade liberalization in the increasing returns sector leads to an increased degree of specialization as internationally increasing returns sectors are integrated globally, given pre-liberalization resource allocation patterns. However, the resource shifts that accompany multi-sector trade liberalization may lead to a contraction of such sectors, and to adverse scale effects. The net effect of trade liberalization on national income for a large country subject to international returns to scale is theoretically ambiguous and must be assessed empirically. The primary differences between the effects of trade liberalization for large and small countries are that, for large countries: (1) liberalization leads to changes in productivity in trading partners as well; and (2) liberalization leads to (possibly adverse) terms-of-trade effects.

The basic implications of trade with international scale economies can be summarized as follows. A small country gains unambiguously from trade liberalization. In a static context, the level of income increases. This increase is associated with increased productivity for the increasing returns sector. For large economies, the basic gains from trade are magnified by the presence of scale economies when the increasing returns sector expands, once we control for terms-of-trade effects. With international returns to scale, the global socially optimal policy is a subsidy scheme that targets the increasing returns sector,

is lower than the socially optimal level. With average cost pricing, which does not reflect the true social value of activity in the Z sector, the private rate of transformation between Z and X will be less than the true social rate of transformation.

[44] See J.F. Francois, "Optimal Commercial Policy with International Returns to Scale," Canadian Journal of Economics, vol. 20, No. 1 (February 1992), pp. 184-195.

combined with free trade.[45] For individual countries, the trade-off between scale economies and terms-of-trade effects determines the optimal policy mix.

The static implications of trade emphasized in the literature on national and international scale economies lend insight into the dynamic implications emphasized in the more recent literature. With dynamic scale effects that are strictly national in scope, trade may imply reduced growth rates for smaller, less advanced economies. Even when growth rates fall, however, welfare may still be improved. For relatively large, more advanced economies, trade implies an acceleration of growth rates and a more rapid expansion of dynamic sectors. With dynamic scale effects that are international in scope, the growth rate for a small country is determined by global economic conditions and global growth rates. Small countries will gain unambiguously with dynamic international spillovers. For relatively large economies, trade may again imply an acceleration of growth rates. However, the resource allocation effects of trade policy changes will determine whether growth increases as a result. Whether dynamic scale effects are national or international, the actual welfare implications of trade liberalization for a large economy will also depend on the time-path of prices. This is because, by definition, the structure of a large economy will influence its terms-of-trade over time as it evolves. As a result, positive growth effects may be accompanied by adverse welfare effects.

Human Capital Accumulation

Accumulation of human capital can also lead to sustained growth. We shall work with the following definition. Human capital refers to an accumulation of education or labor market experience that increases a worker's productivity. Schooling takes time away from current production whereas learning-by-doing generates increased productivity as a result of production experience. This subsection presents a simple model of growth due to schooling contained in a paper by Lucas.[46] We present a model of endogenous growth due to learning-by-doing in the next subsection.

Lucas' model of schooling is a reinterpretation of the traditional growth model discussed above. We replace production function (1) with the following equation:

$$Y_t = F(K_t, uH_t) \tag{10}$$

where K_t is the stock of physical capital, H_t is the stock of human capital, 1-u is the fraction of time that people spend in school, and u is the fraction spent on the job. Investment is equal to the savings rate times income. For convenience, we reproduce equation (3) below:

$$I_t = \frac{dK_t}{dt} = sY_t \tag{11}$$

The savings rate is assumed to be exogenous.

People accumulate human capital by allocating a fraction of their time to schooling. An individual goes to school to earn a higher wage. Education makes the worker more productive, so firms can afford to pay this worker a higher wage. However, schooling takes time away from work. Consequently, there is an earnings loss associated with time spent in school. An individual increases the

[45] In a multi-sector context where numerous sectors are subject to international scale economies, subsidization is only justified for the subset of sectors subject to relatively strong scale effects.

[46] See R.E. Lucas, "Making a Miracle."

fraction of time devoted to schooling, u, to the point where the increase in lifetime earnings from additional education equals the earnings loss during the extra time spent in school.

Once an individual has an education, earnings are higher throughout the remainder of the person's career. Therefore, a person maximizes lifetime earnings by investing in education at the beginning of life and by working thereafter. In a steady state, labor force entrants are equal to retirements in number and in their level of education.

The rate at which human capital grows in the aggregate will depend on its existing level and the effort devoted to developing more. We assume for simplicity that human capital accumulation is linearly related to time spent in school, 1-u, and take this fraction to be exogenous. If there are diminishing returns to the accumulation of human capital, then growth will not be sustainable in this model. Human capital accumulation, dH(t)/dt, is described by the following equation:

$$\left[\frac{dH_t}{dt}\right] = c(1-u)H_t^d \tag{12}$$

where c and d are positive constants. If d is less than one, increases in the stock of human capital lead to successively smaller increments to H_t. In other words, there are diminishing returns to the accumulation of human capital. In this event, $(dH_t/dt)/H_t$ tends to zero as H_t becomes very large, so that growth asymptotically comes to a halt. If d is equal to one, then the proportional rate of human capital growth, $(dH_t/dt)/H_t$, is equal to c(1-u). Lucas adopts this choice based on prior empirical studies of individual earnings behavior.

This model is equivalent to a traditional one with labor-augmenting technical change, as described above. Comparing production function (10) with the production function in Solow's model, equation (1), we let $A_tL = uH_t$ and note that H_t grows at rate g = c(1-u). Output, the stock of physical capital, and the stock of human capital all grow at rate c(1-u) in the steady state. Further, the ratio of physical capital to human capital converges to a constant. Finally, the level of a country's income at any point along the balanced growth path is proportional to the economy's initial stock of human capital. Therefore, countries which start out with more human capital will remain wealthier forever but grow no faster than poorer countries.

Consider a world made up of several such countries. Following Lucas, assume that (physical) capital is perfectly mobile internationally while (skilled) labor is internationally immobile. Then international capital flows will equate the marginal product of capital in each country to the common world rate of return. Output in each country will be proportional to the size of its labor force, weighted by its labor productivity. If savings rates are equal across countries, then the world economy will behave exactly like a traditional Solow model with labor-augmenting technical change for a single economy. Growth rates will be equal across countries but incomes will be proportional to each country's initial level of human capital. Thus, the simple model of growth due to human capital accumulation implies a fixed world distribution of income.

In this paper, Lucas rejects the schooling model as an explanation of cross-country differences in economic development. Without some modification, we have just seen that such a schooling model implies a static distribution of world income. In addition, observed rates of investment in physical capital and accumulation of human capital via schooling are not sufficient to explain growth rates for countries like Korea.[47] Lucas argues that models of learning-by-doing, such as those developed by Stokey and

[47] However, both de Melo and Panagariya, "Regional Integration: An Analytical and Empirical Overview," and Barro, "Economic Growth in a Cross Section of Countries," find that growth rates, at least for developing countries, are positively correlated with human capital levels.

Young, have more potential for explaining differences in rates of economic development.[48] By channeling resources into product lines with more potential for learning-by-doing, a country may increase its rate of growth. Trade may be an important force affecting the allocation of resources to sectors affected by learning-by-doing.

Learning-by-doing

We have seen that specialization in production gives rise to dynamic increasing returns and sustained long run economic growth. If output of final goods utilizes a range of specialized intermediate inputs, an increase in the range or number of such inputs leads to an increase in output. In models based on specialized capital equipment, the range of available intermediates depends on the stock of general purpose capital, so that an increase in capital leads to growth.

In this setup, a dynamic model with endogenous growth can be generated by adding any mechanism whereby the range or number of specialized intermediates increases over time in response to decisions by market participants. Romer adds endogenous savings by households to generate endogenous capital accumulation.[49] It is assumed that the technology for producing general purpose capital is the same as that of final goods so that output can be either consumed or invested. Since the range of specialized inputs produced in equilibrium is proportional to the stock of general purpose capital, endogenous capital accumulation by households leads to sustained growth.

Other ways of generating endogenous growth are possible based on specialization in production. One way is to assume that the unit cost of producing each intermediate falls with cumulative production volume (due to learning-by-doing) and that the benefits of learning spill over onto neighboring inputs that have similar levels of technical sophistication. Given the economy-wide resource constraint, learning-by-doing will shift the range of specialized intermediates produced in equilibrium toward increasingly sophisticated products, and widen it. It should come as no surprise that this specification of learning-by-doing generates endogenous growth given our discussion of dynamic increasing returns to specialization.

It remains, then, to establish a set of conditions under which learning-by-doing will lead to an expansion in the range of differentiated goods that are produced in equilibrium. This is precisely what Young has done, albeit in the context of differentiated consumer goods. We shall discuss Young's model, which builds upon Stokey's 1988 paper,[50] in this subsection.

Young takes the additional step of considering international trade between two economies that exhibit learning-by-doing. He describes equilibrium dynamics in addition to balanced growth paths and attempts to evaluate the welfare consequences of trade. The picture of trade that emerges in this model is one of comparative advantage being determined at the level of individual inputs and products, rather than in broad industry groups, and of a continually shifting pattern of comparative advantage.

The remainder of this subsection presents consumer preferences and the assumptions regarding technology that give rise to an expanding range of goods via learning-by-doing. We then discuss general

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[48] N.L. Stokey, "Learning by Doing and the Introduction of New Goods." A. Young, "Learning by Doing and the Dynamic Effects of International Trade."

[49] See Romer, "Growth Based on Increasing Returns due to Specialization."

[50] Young, "Learning by Doing and the Dynamic Effects of International Trade," and Stokey, "Learning by Doing and the Introduction of New Goods." In Stokey's model, consumers derive utility from product characteristics. Goods are ranked according to the number of characteristics they contain. The important advantage of this specification, compared to the "love of variety" specification, is that it allows older goods to become obsolete. Over time, learning-by-doing increases the upper and lower bounds on the range of goods produced. In a world composed of several such economies, Stokey's formulation implies that the pattern of comparative advantage will shift continually as existing goods become standardized with production experience and new goods, with a higher number of desirable product characteristics, enter the market.

equilibrium with two countries, one developed (DC) and the other less developed (LDC), when international trade is prohibited (autarky). Finally, the world economy is opened up to trade. Implications for the pattern of trade, technical progress, growth, and welfare are discussed for several different cases.

Preferences and Technology

Previous models, such as Krugman's 1987 paper and Lucas' 1988 paper, have assumed two sets of goods, one of which experiences more rapid learning-by-doing.[51] International trade tends to reinforce existing patterns of comparative advantage in this type of model because the country that is initially specialized in goods with rapid learning enhances its comparative advantage as additional production experience is accumulated.

As Lucas has pointed out in his 1992 paper, long run growth is possible in a model of learning-by-doing even if knowledge obtained as a result of producing a good does not have positive benefits or spillovers for producers of other goods. Sustained growth can be obtained by assuming that new, higher quality products are introduced at an exogenously specified rate, so that learning is not exhausted on a fixed set of goods. He shows that the long-run rate of growth is independent of: (1) the rate at which cumulative production experience leads to increased output; and (2) the allocation of workers to goods of different vintages. In other words, the long run growth rate is independent of learning behavior in a model of learning-by-doing that does not assume spillovers.

In Young's model, learning spillovers give rise to continual turnover in the set of goods that experiences rapid learning-by-doing, as new products come into production and production of old goods ceases. There are a continuum of goods, indexed by s, which are produced using only labor. Higher numbered goods s are produced using more sophisticated techniques.

Learning occurs more rapidly in goods that are nearer to a country's technological frontier. A country can grow more rapidly by shifting resources into products where learning rates are higher. Initially, workers suffer a drop in productivity because they are better at performing familiar tasks. This must be balanced against the higher learning rates in more technologically sophisticated activities.

Young's technology reflects these two conflicting influences on productivity. It is assumed that unit cost for each good s at time t, a(s,t), falls with production experience, ultimately reaching a lower bound, $a_{LB}(s)$. Potential unit costs $a_{LB}(s)$, which can only be achieved through considerable production experience, are lower for more sophisticated goods. The functional form chosen for potential costs reflects this property:

$$a_{LB}(s) = a_{LB}\, e^{-s} \tag{13}$$

At any point in time, however, actual unit costs a(s,t) are higher for more sophisticated goods (unless learning potential has been exhausted) because workers have had less experience producing them.

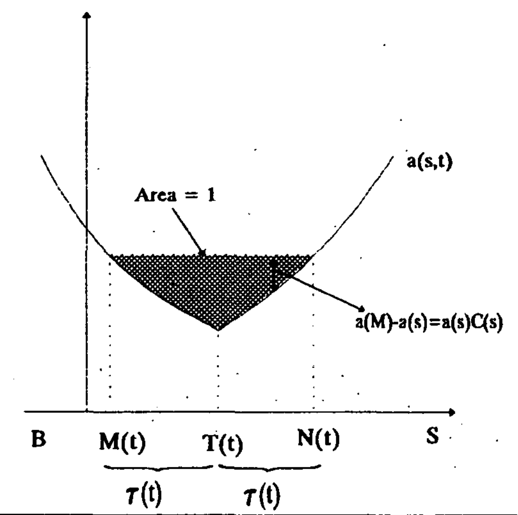
Goods in which learning has yet to be exhausted are assumed to contribute symmetrically to productivity increases in all other such goods. This ensures that learning is exhausted sequentially in all goods. At any point in time t, there is an index T(t) such that learning is exhausted in all goods to the left of T(t) and learning is taking place in all goods to the right of T(t). For a single economy with no international trade (autarky), the good T(t) that divides these two sets of goods moves continually to the right over time. To reflect these properties, a functional form is chosen for a(s,t) that is decreasing and equal to $a_{LB}(s)$ to the left of T(t), increasing to the right of T(t), and symmetric about T(t):

[51] See R.E. Lucas, Jr., "On the Mechanics of Economic Development," and P.R. Krugman, "The Narrow Moving Band, the Dutch Disease, and the Competitive Consequences of Mrs. Thatcher," Journal of Development Economics, vol. 27, No. 1-2 (October 1987), pp. 41-55.

$$a(s,t) = a_{LB}\, e^{-s} \quad for\ s < T(t)$$
$$= a_{LB}\, e^{s} \quad for\ s > T(t) \tag{14}$$

A graph of a(s,t) as a function of s is shown in Figure 3.

Figure 3



A large number of identical consumers are assumed, each of which has preferences over the continuum of different products which reflect a "love of variety," but not an unbounded one.[52] The representative consumer maximizes the following utility function at each point in time:

$$U(t) = \int_B^{\infty} \ln[C(s,t)+1]\,ds \tag{15}$$

where the range of goods s is [B,Infinity] and B is a large negative number. Each consumer is endowed with one unit of labor, which it supplies to firms in exchange for wage W. Expenditure on all goods cannot exceed income:

$$\int_B^{\infty} P(s,t)\,C(s,t)\,ds \le W \tag{16}$$

where P(s,t) is the price and C(s,t) is the quantity consumed of good s at time t. The consumer is assumed to take prices and wages as given and maximize utility subject to the budget constraint. Under perfect competition, price equals unit labor cost for each good: P(s,t) = W a(s,t). Therefore, the budget constraint may also be expressed as follows:

$$\int_B^{\infty} a(s,t)\,C(s,t)\,ds \le 1 \tag{17}$$

Consumers maximize utility by choosing consumption levels of each good so that the marginal rate of substitution equals the price ratio for all pairs of goods (s,s') that are consumed in positive quantities:

$$\left[\frac{C(s',t)+1}{C(s,t)+1}\right] = \left[\frac{P(s,t)}{P(s',t)}\right] = \left[\frac{a(s,t)}{a(s',t)}\right] \tag{18}$$

[52] Marginal utility is positive but finite at zero for each good.

or, omitting time indexes for simplicity and rearranging,

$$a(s')C(s') + a(s') = a(s)C(s) + a(s) \tag{19}$$

For the representative consumer, there exists a limiting good, M, such that all goods with prices lower than good M will be consumed in positive quantities and all goods with higher prices than good M will not be consumed. The location of good M is determined from the budget constraint. From equation (18) and the fact that C(M) = 0, it follows that

$$a(s)\,C(s) = a(M) - a(s) \tag{20}$$

for every good s. According to this equation, expenditure on good s can be read off the graph of a(s,t) as the vertical height between a(s) and a(M). The area above the graph of a(s,t) and below the horizontal line a(M) is equal to total expenditure, which is equal to one because of the budget constraint.

Autarky

The market for each good is assumed to be perfectly competitive, with a large number of producers for each good. Benefits of learning-by-doing are instantly shared by all firms in each industry, and partially shared by firms in other industries, so there is no incentive for a firm to alter its production level to accumulate knowledge. There is no physical capital and goods cannot be stored so identical consumers have no reason to save. In contrast to models based on increasing returns to specialization, the equilibrium in this model is perfectly competitive.

Equilibrium in a closed economy (autarky) is shown in Figure 3. The graph depicts the continuum of goods indexed by *s* on the horizontal axis and the (actual) unit cost for each good at time t, a(s,t), on the vertical axis. It follows from the assumptions made regarding learning-by-doing that learning has been exhausted on all goods to the left of T and that learning continues on goods to the right of T. Over time, T shifts to the right at a rate equal to the labor allocated to goods where learning is still taking place:

$$dT(t)/dt = \int_T^{\infty} L(s)\,ds = L/2 \tag{21}$$

where L(s) is the amount of labor allocated to the production of good s and L is the size of the population.[53] Consumers allocated expenditure to maximize utility by purchasing goods in the range [M,N] in positive quantities. The area shown denotes total expenditure, which is constrained to equal one by the value of labor income. Another property of Young's model is that the range of goods consumed, [M,N], widens over time. As knowledge improves, consumers are made better off, both because of an increase in the range of goods consumed, and because of an increase in the quantity of each good consumed. Finally, it can be shown that the long-run rate of output growth in autarky is positive and equal to the rate of technical progress:

[53] Given the assumed symmetry of demand about T(t), half of the labor force is allocated to goods to the right of T(t) where learning is not yet exhausted.

$$g(t) = L/2 \tag{22}$$

Free Trade

We now consider two economies, a DC and an LDC, of the sort described above that are linked together through international trade. Variables for the DC will be denoted by a star. The two countries differ only in their population and initial levels of technological sophistication. Let L* and L be the populations for the DC and LDC, respectively. Both populations are assumed to be constant over time. Let W* and W be the wage rates in the DC and LDC, respectively, and w = W*/W be the DC/LDC wage ratio. We measure all values in units of LDC labor and therefore set the LDC wage W = 1. The defining characteristic of a DC in this model is that it is initially more advanced technologically. Levels of technological sophistication are measured by the indexes T* and T, with T* assumed greater than T.

Five different types of equilibria are possible depending on how the DC's population L* compares to the LDC's population L and on the size of the DC's initial technical advantage, X = T* - T.

Equilibrium A, for instance, assumes that wage rates are equal in the two countries so that wage ratio w = 1. This is the lowest relative wage consistent with world equilibrium. Otherwise, the cost of production would be lower in the DC for all goods, DC exports would exceed its imports, and trade would not be balanced. Unit costs in the DC, wa*(s), are less than unit costs in the LDC, a(s), for every product where learning has not been exhausted in the LDC (s > T) and unit costs are equal for products where learning has been exhausted in both countries. Expenditure is equal to one in each country because the wage ratio w is one in Equilibrium A and each consumer is endowed with one unit of labor. Consumers have identical tastes and income in each country and face identical prices, so they purchase the same range of products [M*,N*] = [M,N]. Producers in the DC make all products to the right of T because they have lower unit costs. Goods below T may be made in either the DC or the LDC. Technical progress occurs in the DC at the following positive rate:[54]

$$dT^*/dt = (L^* + L)/2 \tag{23}$$

but there is no technical progress in the LDC:

$$dT/dt = 0 \tag{24}$$

Moving to free trade from autarky increases the rate of growth in the DC:

$$g^* = \left[\frac{L^* + L}{2}\right] \left[\frac{L^* + L}{L^*}\right] \tag{25}$$

but growth comes to a halt in the LDC: g = 0.

Equilibrium B assumes that the relative wage w is at its maximum level, w = $e^{(2X)}$. If the wage ratio w exceeds this level, the cost of production is lower in the LDC for every good so trade cannot be balanced. The LDC makes all goods to the left of T* because it has a cost advantage and some products

[54] The LDC does not produce any goods where learning is still possible (s > T). World demand is symmetrical about T* so an amount of DC labor equal to half the world's labor force is allocated to production of goods where learning is still taking place.

to the right of T*. Consumers in the DC have a higher income than consumers in the LDC so they consume a wider range of products and a greater quantity of each product.

Equilibria C through E are based on wage ratios w between the extreme values in Equilibrium A and B [$1 < w < e^{(2X)}$]. As the DC's initial technical lead increases for a given level of the LDC's technical knowledge (an increase in $X = T^* - T$ for a given T), equilibrium moves from C to D to E. As this occurs, the ranges of goods produced in the two countries becomes disjoint, as do the ranges of goods consumed.

A multiplicity of dynamic paths are possible for the world trading equilibrium, which moves the world economy from Equilibrium A or B (depending on whether the DC population L* is greater than or less than the LDC population L) onward into Equilibria C through E as the DC's technical lead over the LDC, $X = T^* - T$, increases over time.[55] If the DC's labor force is greater than or equal to the LDC's labor force, the technical gap between the two will increase without bound. Relative to autarky, free trade increases the growth rate of the DC and lowers that of the LDC.

This model shows that free trade between developed and developing countries can widen the technological gap between DCs and LDCs, increase growth in the DCs, and cause the LDCs to grow more slowly than they would in autarky. While these results are suggestive, they depend crucially on the assumption that learning-by-doing has spillover benefits for neighboring products within each country but not internationally. A model that incorporated international spillovers could easily reverse this conclusion. Nonetheless, Young's model shows how international trade can lead to changes in the rate of growth for an economy and provides a useful framework for analyzing the growth effects of learning-by-doing.

R&D and New Product Introduction

We have seen that expansion of the range of differentiated goods available can lead to endogenous growth. Growth is possible based on learning-by-doing, by which production experience initially yields rapid productivity advances for goods close to a country's technological frontier. These models take the set of production techniques and products as given. An alternate and potentially complementary approach is to examine development of new or higher quality products through R&D and assume that the new technology is utilized instantly so there is no learning-by-doing. We discuss models of R&D, innovation, and growth in this subsection.

Accumulation of knowledge through R&D adds another layer to the theory of dynamic increasing returns due to specialization. In Romer's 1987 model discussed above, general purpose capital is used to produce specialized inputs using technology summarized by a cost function and subject to an economy-wide resource constraint. Savings by households leads to accumulation of general purpose capital under the assumption that the technology for producing capital is identical to that of final goods. Additional specialized inputs are produced over time in equilibrium because the economy-wide resource constraint is relaxed via capital accumulation.

A more explicit way to model the production of additional goods over time is to assume that the rate of new product introduction depends on the stock of general knowledge capital, and on the level of resources devoted to R&D. If originators of new ideas yield information that is useful to other inventors, a greater stock of general knowledge capital will make resources devoted to R&D more productive. This leads to dynamic increasing returns in the stock of general knowledge rather than the dynamic increasing returns in general purpose capital found in Romer's 1987 paper. Combined with a preference for variety by consumers or, equivalently, gains from specialization for producers, accumulation of knowledge

[55] If the LDC's population is very large compared to the DC's population (several orders of magnitude) and the DC's technical lead is initially small, it is possible for the LDC to overtake the DC. This is what Lucas ("Making a Miracle") calls a "nuisance implication of the theory that we want to dispose of," since it "... carries the unwelcome implication that a country like India should have enormous growth advantages over a small country like Singapore."

through R&D leads to continual expansion in the range of goods produced in equilibrium and to sustained growth.

The various linkages between trade and growth in models of knowledge accumulation via R&D have been thoroughly catalogued in the Grossman and Helpman monograph.[56] Drawing upon and extending earlier work by themselves and others, such as Romer and Rivera-Batiz and Romer,[57] they link endogenous growth models to static international trade theory in the tradition of Helpman and Krugman[58] and Ethier.[59]

Closed economy endogenous growth models are discussed below in which R&D leads, in two alternative specifications, to new product introduction or to quality upgrading in existing brands. Equilibrium dynamics and steady state equilibrium are discussed for these models. Extending the above two "canonical models" to include a traditional sector that is not subject to innovation, implications of opening up to international trade are considered, first for a small open economy and then for two large economies.

Extreme assumptions are made in two successive models regarding international knowledge spillovers to illustrate the range of possible outcomes. In the first model, there is assumed to be a free flow of knowledge internationally so that the base of general knowledge is the same at home and abroad. Given this, steady state equilibrium for the world economy satisfies the theorems of static trade theory, and resource allocation and trade flows are determined by comparative advantage. If factor endowments are within the range that is consistent with factor price equalization, then both countries have equal consumption possibilities and income paths. However, R&D and high-technology production may concentrate in one country so that output growth is higher there.

In the second model, knowledge spillovers are assumed to be limited to the national market so that a country with an initial advantage in the production of new products may sustain and even increase its lead over time. In contrast to the model with international knowledge spillovers, equilibrium dynamics are explicitly analyzed. This is important because the steady state equilibrium depends on initial conditions if knowledge spillovers are strictly national, unlike the case of international spillovers. In the present case, the long-run growth rate for a country depends on how its initial state of general knowledge compares with its trading partners because productivity in R&D is an increasing function of the stock of general knowledge.

Given the discussion of international equilibrium in Young's paper, in which strictly national knowledge spillovers were assumed, it is not surprising to find that a number of different types of equilibria are possible and that the steady state equilibrium depends on initial technological levels in each country. These various types and dynamics by which the world economy moves from one type to another over time are similar to the results in Young's paper. A country that has a technological lead initially will usually increase this lead over time and grow faster in the long run. While there are transition paths for which factor prices are equalized across countries for some combinations of behavioral parameters, this is not always the case. If factor prices are unequal, then the country with an initial technological disadvantage may actually be made worse off due to trade as wages in the more advanced country rise over time.

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[56] Grossman and Helpman, Innovation and Growth in the Global Economy.

[57] P.M. Romer, "Endogenous Technological Change," and L.A. Rivera-Batiz and P.M. Romer, "Economic Integration and Endogenous Growth."

[58] E. Helpman and P.R. Krugman, Market Structure and Foreign Trade (Cambridge: MIT Press, 1985).

[59] W.J. Ethier, "National and International Returns to Scale in the Modern Theory of International Trade," American Economic Review, vol. 73, No. 3 (June 1982), pp. 389-405.

It is possible for a country with a very large labor force to overtake a more advanced country if the initial technological disadvantage is not very large. This corresponds to the case where India overtakes Singapore due to its large population which Lucas dismisses as a "nuisance" scale effect. Grossman and Helpman show that an R&D subsidy may enable the large but initially less advanced country to overtake the small country and that such a subsidy can be a temporary one that just carries the economy past the half-way point and allows it to capture the entire market for high-technology goods in the long run. However, a country that succeeds in using an R&D subsidy may not succeed in raising its welfare.[60]

In the remainder of this subsection, we present the two canonical models of endogenous innovation due to R&D (expanding product variety and quality upgrading). Subsequently, a traditional manufacturing sector is added and unskilled labor is distinguished from human capital. This model is then opened up to trade by invoking the small country assumption. Finally, world equilibrium with two large countries is analyzed first under international and then under national knowledge spillovers.

Canonical Closed Economy Models

Innovation may either reduce the cost of producing given products (process innovation) or generate new product designs (product innovation). We have discussed how an economy learns to exploit existing product designs as it gains production experience (learning-by-doing). This subsection discusses the generation of new product designs through R&D.

Two alternative forms of product innovation are considered. First, R&D is assumed to generate designs for new products, leaving the quality of existing products unchanged. Products can be interpreted either as differentiated varieties of a final good or as specialized intermediate inputs. Second, R&D is assumed to generate designs for higher-quality versions of existing products, leaving the range of different products unchanged. Although these models are carried through independently, reality is presumably a combination of the two. Most results concerning trade and growth are valid for both models. In view of this, we focus primarily on the first of these two models, in order to pursue our analogy with models of increasing returns due to specialization, and only briefly discuss the quality-upgrading model.

We begin with the model of increased product variety. It is assumed that there is only one primary factor of production, labor (L), which is in fixed supply. There are two sectors in the closed economy: R&D and manufacturing. There are a continuum of varieties of the manufactured good, which are indexed by j on the interval [0,n].

Infinitely-lived families of consumers are assumed to have identical preferences over manufactured goods x(j) in each time period t, which are summarized in the following (intertemporal) utility function:

$$U_t = \int_t^{\infty} e^{-\rho(s-t)} \log[D(s)]ds \tag{26}$$

where D(s) is an index of goods consumed at time s and ρ is the rate at which consumers discount future consumption back to the present (subjective rate of time discount). The representative household's lifetime expenditure cannot exceed lifetime earnings plus initial net wealth (intertemporal budget

[60] There are two reasons why the large country may reduce its welfare by imposing an R&D subsidy. First, it is initially a less productive location for R&D so a subsidy further distorts its allocation of resources in favor of R&D and away from traditional manufacturing. Second, the aggregate rate of innovation in the world economy may fall, reducing welfare in both countries. Even if the rate of innovation in the world economy increases as a result of the subsidy, the large country may lose because it bears the cost of the subsidy but consumers in the small country share in the fruits of additional product development.

constraint). Maximization of utility subject to the budget constraint implies that total spending in each time period (E) grows at a rate equal to the market rate of interest (r) minus the discount rate (ρ). Normalizing prices in each time period so that $E = 1$, this implies that the market rate of interest in each time period, r(t), is equal to the discount rate, ρ.

At each moment, consumers are assumed to have preferences over the continuum of product varieties j that are summarized by the following (instantaneous) utility function:

$$D = \left[\int_0^n x(j)^\alpha \, dj \right]^{1/\alpha} \tag{27}$$

where x(j) is the level of consumption of variety j and α is a constant ($0 < \alpha < 1$) that is related to elasticity of substitution $\epsilon = 1/(1-\alpha) > 1$.

To highlight the role of knowledge spillovers in generating sustained growth, it is useful to distinguish between a situation where returns to innovation are purely private and a situation where innovation has spillover benefits. If returns to R&D are private, then growth must eventually come to a halt. If innovation contributes to the general stock of knowledge and thereby facilitates future innovation by others, it turns out that growth can be sustained in the long run.

An entrepreneur can expand the set of products available by employing labor to conduct R&D. Productivity of labor in the research lab is assumed to depend on the stock of general knowledge, as measured by the number of past inventions, n. In particular, the number of product varieties in existence at any given time, t, is assumed to evolve according to the following equation:

$$dn/dt = L_n n \tag{28}$$

where L_n is the amount of labor devoted to R&D by all research labs.[61] The crucial feature of this specification is that the flow of new inventions, dn/dt, is linear in the existing stock of inventions, n. This implies that the potential for obtaining new product designs through investment in R&D is unbounded. As a result of this assumption, the economy achieves positive rates of long-run innovation and growth.

To illustrate this point, suppose there are no knowledge spillovers from R&D. In this event, inventions do not contribute to the stock of general knowledge and labor does not become more productive in the research lab as the number of inventions increases. The number inventions evolves according to the following equation:

$$dn/dt = L_n \tag{29}$$

so that the rate of technical progress is as follows:

$$(dn/dt)/n = L_n/n \tag{30}$$

[61] One unit of labor yields an increase of n in the flow of new inventions, dn/dt.

Assuming that new inventions are produced by R&D, the rate of technical progress will tend toward zero as the number of inventions becomes large and growth will eventually come to a halt.

We now return to the case where there are knowledge spillovers and describe market equilibrium at each moment in time (momentary equilibrium). It is assumed that there is only one producer for each variety.[62] The firm accordingly sets price in accordance with standard monopoly theory. Given that product varieties enter demand symmetrically and are produced using the same technology, firms all charge the same price ($p = w/\alpha$) and earn the same profits [$\pi = (1-\alpha)/n$], where w is the cost per unit of labor.

The R&D sector is assumed to be perfectly competitive. Doubling the resources devoted to R&D is assumed to double the flow of inventions (constant returns to scale) and there is free entry and exit. There is no uncertainty associated with investment in R&D in this model and perfect foresight is assumed for all market participants.[63] Acquisition of a blueprint allows a manufacturer to generate a stream of monopoly profits. Therefore, the market value of an invention is equal to the present value of the stream of monopoly profits generated by manufacturing the new product. Free entry ensures that the market value of an invention, v, is equal to the cost of developing it, w, if the equilibrium rate of innovation is positive: $v = w$.

Firms finance the cost of developing a new product design by issuing equity. In equilibrium, the stock market value of a firm is equal to the market value of an invention, v. A necessary condition for capital market equilibrium is that there are no profitable, unexploited opportunities for arbitrage (no-arbitrage condition):

$$\pi + (dv/dt) = rv \tag{31}$$

Profits (π) plus capital gains (dv/dt) must be equal to the market rate of return (r) on a riskless loan of equivalent size (v) in equilibrium. Rearranging the no-arbitrage condition, using the expression for profits developed above [$\pi = (1 - \alpha)/n$] and the fact that $r = \rho$, we have the following equation:

$$(dV/dt)/V = (1-\alpha)V - g - \rho \tag{32}$$

where $V = 1/nv$ is the inverse of the economy's aggregate equity value and $g = (dn/dt)/n$ is the rate at which new products are introduced.

Labor market equilibrium requires that demand for labor in the R&D and manufacturing sectors are equal to the aggregate supply of labor, L. L_n units of labor yields a flow $dn/dt = L_n n$ of new inventions so the demand for labor in the R&D sector is $(dn/dt)/n$. Demand for labor in the manufacturing sector is $X = nx = 1/p$:[64]

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[62] This assumption can be justified by assuming that infinitely-lived patents are awarded to original inventors or by assuming that imitation is costly so copiers cannot earn profits in price competition with the original inventor.

[63] In contrast, potential innovators conduct research to increase the probability of obtaining a new invention in the second canonical model of R&D (quality upgrading). Rational expectations are assumed there.

[64] Maximization of instantaneous utility D subject to the constraint that spending on all varieties cannot exceed E yields the following demand function for variety j:

$$x(j) = E\, p(j)^{-\epsilon}/[\textstyle\int_0^n p(j')^{1-\epsilon}\, dj']$$

Profit maximization by firms implies that $p(j) = w/\alpha$. Therefore, equilibrium prices of all varieties are identical $p(j) = p$. Prices in each period are normalized by setting $E = 1$. Substituting these facts into the demand function yields the equilibrium quantity of each variety, $x = 1/np$.

$$(dn/dt)/n + (1/p) = L \tag{33}$$

Combining the labor market equilibrium condition (33) with the monopolist's pricing rule ($p = w/\alpha$) and free entry into R&D ($w/n = v$ if $dn/dt > 0$) yields the following necessary condition for equilibrium:

$$g = L - \alpha V \quad for\ V < L/\alpha$$
$$= 0 \quad for\ V \geq L/\alpha \tag{34}$$

This equation gives the maximum rate of innovation, g, that is feasible for each value of inverse aggregate equity value, V, given labor market equilibrium, profit maximization by producers of differentiated goods, and free entry into the R&D sector. Equilibrium in the economy occurs at a point in time if equations (32) and (34) are satisfied.

We are now in a position to describe the equilibrium dynamics and long-run equilibrium for this economy. Given perfect foresight, the economy must jump to the steady state immediately. This occurs where equations (32) and (34) are satisfied and the aggregate value of equity in the economy (or its inverse, V) is constant. Otherwise, expectations of future profitability, as reflected in the equity value of a representative firm, are inconsistent with actual future profitability.[65] The steady state rate of innovation is obtained from equations (32) and (34) and the condition that $(dV/dt)/V = 0$ in the steady state:

$$g = (1-\alpha) L - \alpha \rho \tag{35}$$

The steady-state rate of innovation is higher for an economy with a larger resource base L, patient consumers (smaller discount rate, ρ), and more market power for firms (smaller α).

Rates of final output and real gross domestic product (GDP) growth are positive for this economy but differ from the rate of innovation. Final output grows at the following rate:[66]

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[65] There are two cases in which the economy is away from its steady-state. First, V can be too high for the given g in order to satisfy equation (32) with $dV/dt = 0$. Then V must rise over time and, by equation (34), g must eventually fall to zero because the entire labor force is eventually employed in manufacturing. The number of varieties n (or, to be precise, their measure) remains constant since $g = 0$. But this is inconsistent with expectations of a continually rising $V = 1/nv$, since this implies the value of each firm v tends to zero. With a fixed number of brands, profits per brand remain constant and strictly positive.

Second, V can be too low for the given g in order to satisfy $dV/dt = 0$. In this case, V tends to zero over time while g attains its maximal value L, which results when the entire labor force is employed in R&D. With a continually rising number of varieties n, it can be shown that the discounted stream of monopoly profits for each firm v is less than $(1 - \alpha)/\rho n$ so that $V = \rho/(1 - \alpha)$ is expected to remain strictly positive. Therefore, expectations are unfulfilled along this path as well.

[66] Output per firm is constant in equilibrium and therefore total resources devoted to manufacturing, $X = nx$, grows at the rate of new product introduction, g. However, the index of final goods consumption (D) is equal to $Xn^{(1-\alpha)/\alpha}$ in equilibrium. This follows by substituting $x(j) = x$ into the definition of D. Therefore, D grows at rate $g_D = g\ (1 - \alpha)/\alpha$.

$$g_D = g(1 - \alpha)/\alpha \tag{36}$$

Gross domestic product is equal to the value of final output plus the market value of the flow of inventions from the R&D sector:

$$G = p_D D + v(dn/dt) \tag{37}$$

Growth in real GDP is equal to the weighted sum of growth rates for the final goods and R&D sectors:

$$g_G = [\theta_D(1-\alpha)/\alpha + (1-\theta_D)]g \tag{38}$$

where $\theta_D = p_D D/[p_D D + v(dn/dt)]$ is the value share of final output in GDP. A shift of resources toward the R&D sector will therefore lead to an increase in the rate of real GDP growth, even if there is no concomitant increase in consumption possibilities and welfare.

We now consider briefly the effects of various industrial policies in this economy. If the government pays a fraction of all research expenses (R&D subsidy), this lowers the private cost of innovation. The rate of innovation increases in the steady state, while aggregate output in manufacturing falls due to the resource constraint. An ad valorem rate of subsidy to manufacturers of differentiated products (output subsidy) leads to an equiproportionate increase in the profitability of research and manufacturing. This bids up the equilibrium wage but leaves the allocation of labor between sectors unaffected. As a result, an output subsidy leaves the rate of innovation and aggregate manufacturing output unchanged. We shall reconsider the socially optimal rate of R&D subsidy after discussing the efficiency of market equilibrium below.

The market equilibrium may in general differ from the socially optimal allocation. This latter allocation is obtained by maximizing the representative household's utility function subject to the constraints imposed by resource availability and technology. If there are no knowledge spillovers, then the market and socially optimal allocations are identical. Imperfectly competitive pricing in manufacturing is a potential source of static distortion but lack of a second manufacturing sector and identity of markups across firms precludes such a distortion. There are two potential distortions in the allocation of resources across time. First, entrepreneurs fail to account for the addition to consumer surplus generated by a new product (consumer-surplus effect). Second, they fail to account for the loss of profits that a new product has on producers of existing varieties (profit-destruction effect). An idiosyncrasy of the specification of consumer preferences in this model, as summarized in equation (27), is that these two dynamic distortions offset one another exactly. As a result, the market equilibrium is socially optimal when there are no knowledge spillovers generated by R&D.

We now consider the efficiency of market equilibrium when there are knowledge spillovers. Static efficiency is unchanged from the situation where there are no spillovers. However, knowledge spillovers imply that the socially optimal rate of innovation exceeds the market equilibrium rate. Innovation efforts have dynamic spillovers because they unintentionally result in additions to the stock of general knowledge. This makes it easier for subsequent inventors to produce new designs.

Accordingly, a subsidy to R&D is needed to achieve the socially optimal allocation of resources between R&D and manufacturing in the event that there are knowledge spillovers from R&D efforts. The optimal subsidy is an increasing function of the resource base L and market power ($1/\alpha$); it is a decreasing function of the discount rate, ρ. The subsidy level should be set to balance the long-term benefits from more rapid innovation against the immediate costs of foregone consumption.

Having described the model of R&D and innovation with expanding product variety in detail, we now consider briefly the second canonical model that features quality upgrading. It is assumed that consumers have preferences over a continuum of products j in the range [0,1] but successive generations of each product exhibits incrementally higher quality. Specifically, each successive generation yields λ times as many services as the preceding one, where λ is a number greater than one.[67]

A firm that manufactures a state-of-the-art product maximizes profits by charging a price just low enough to deter all sales by producers of previous generations of the product. If production costs are identical for different generations, the firm that makes the latest generation charges a price equal to λ times the cost of the previous generation of the product.

The economy immediately jumps to the steady-state equilibrium. Otherwise, expectations regarding future firm profitability are not fulfilled. In a steady state, the economy satisfies the following two conditions. First, the expected profit rate in the R&D sector is equal to the risk-adjusted interest rate:

$$(1 - \delta)\, V = \rho + i \tag{39}$$

where $\delta = 1/\lambda$, V is the inverse of aggregate equity value in the economy, ρ is the discount rate, and i is the rate of innovation. Given the normalization E = 1, the market interest rate is equal to the discount rate. Here, i reflects the risk that a potential innovator will be successful in taking all of a firm's customers away by inventing the next generation of the firm's product. Therefore, $\rho + i$ is the risk-adjusted rate of interest. The economy also satisfies the following labor market equilibrium condition:

$$i + (\delta/w) = L \tag{40}$$

where w is the wage rate and L is the supply of labor.[68]

We now consider the social optimality of market equilibrium for the quality ladder model. If the quality increment, λ, is exogenous, then the static resource allocation is efficient. However, the market innovation rate may be either too high or too low due to distortions in the dynamic allocation of resources. There are consumer-surplus and profit-destruction effects here, which will not generally cancel one another in this model. In addition, there is an intertemporal spillover effect because innovation provides information to later innovators that makes their R&D efforts more productive. The net effect of these three distortions is ambiguous. The government may achieve an optimal allocation, however, by a suitable choice of R&D subsidy or tax.

If the quality increment is chosen endogenously, market forces give rise to a less-than-optimal quality step size. Unfortunately, neither an output subsidy nor an R&D subsidy affects the entrepreneur's optimal choice of λ. It is difficult to devise a policy to correct this distortion. If the government adopts the second-best solution of subsidizing or taxing R&D but with the market quality increment, innovation may be either higher or lower than the first-best rate.

A Small Open Economy

We can now take an enlarged version of the canonical expanding product variety model and open it up to international trade. This enables us to examine the variety of effects that trade policy can have on long-run growth. Trade policy can affect the return to R&D directly if differentiated products are traded internationally. Even if differentiated products are not traded internationally, trade policy will generally affect the allocation of resources between R&D and other sectors in the economy indirectly by

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[67] Initially, it is assumed that the size of quality increments, λ, are exogenous. Subsequently, λ is chosen endogenously.

[68] The careful reader may notice that this model is identical in reduced form to the model of expanding product variety described above.

changing the relative returns to factors of production. Finally, even if trade policy succeeds in promoting long-run growth by shifting resources from manufacturing to R&D, it may make the economy worse off if it reduces output of differentiated goods and thereby worsens the distortion caused by monopoly pricing.

To highlight some of the indirect effects of trade policy on welfare and long-run growth, we consider a model with two tradeable final goods sectors (Y and Z), a nontraded intermediates sector (D), and two primary factors of production (H and L). The primary factors are skilled labor or human capital, H, and unskilled labor, L (referred to simply as "labor"). Good Y uses human capital and intermediate inputs but no labor. Good Z uses labor and intermediate inputs but no human capital. The two final goods sectors are assumed to be perfectly competitive. Intermediates are differentiated in the manner described in the preceding subsection and we employ the model of expanding input variety. Designs for new varieties of intermediate inputs can be obtained using human capital in the research lab (labor is not used in R&D). Factor supplies are assumed to be fixed. By expanding the canonical model to include two final goods and two primary factors, we can examine the implications of trade for long-run growth via changes in factor rewards.

This economy is allowed to trade on international markets but is assumed to be too small to affect world prices of final goods, the world interest rate, or the world's stock of intermediate product designs. It shall be assumed that international trade in financial assets is not permitted, except where noted, so that the country's trade is balanced at each moment in time.

Under these assumptions, the economy jumps immediately to a steady state. If the economy produces both final goods in equilibrium, then the prices of intermediates and primary factors are determined by the state of technology and the prices of final goods. With final goods prices fixed on world markets, prices of intermediates and primary factors will grow at the rate of productivity change. Returns to primary factors, adjusted for productivity change, are thus linked to final goods prices in the usual manner (Stolper-Samuelson theorem): an increase in the relative price of the human-capital-intensive good (Y) will raise the relative return to human capital.

If a country moves from autarky to free trade and imports the human-capital-intensive good Y as a result, the return to skilled labor will fall relative to the return to unskilled labor. This lowers the cost of R&D and so more of it is conducted, thereby enhancing long-run innovation and growth. If a country exports Y as a result of moving from autarky to free trade, the return to human capital rises and this retards long-run innovation and growth.

It is important to note that a country may suffer a reduction in welfare even if a trade intervention enhances long-run economic growth. To see this, we consider the efficiency of market equilibrium and the effects of various government policies on welfare. The static efficiency of market equilibrium is similar to that of the canonical model described above. Here, however, monopoly pricing does distort resource allocation because there are two perfectly competitive final goods sectors. Accordingly, the (common) level of production of each intermediate input producer is too low in the market equilibrium compared to production levels for final goods Y and Z. Dynamic distortions include consumer-surplus, profit-destruction, and intertemporal-spillover effects, as before. For the expanding input variety model, the intertemporal spillovers dominate the other two dynamic distortions so that too little R&D is undertaken in the market equilibrium.

Two policy instruments are needed to achieve the socially optimal or first-best allocation of resources. A subsidy to final goods producers in proportion to the cost of their components is needed to offset the static distortion caused by monopoly pricing of components. This should be designed to equate the user cost of intermediates with the marginal cost of producing them. A subsidy to R&D is needed to correct for the dynamic distortion caused by knowledge spillovers. New inventions increase the productivity of later inventors in the research lab, which is not reflected in the market rate of return to R&D.[69]

Finally, we consider the effect of trade policy on welfare for a small open economy. As discussed above, trade policy (an import or export tariff or subsidy) can affect the allocation of resources between manufacturing and R&D through its effect on factor prices. In addition, trade policy drives a wedge between domestic prices faced by consumers and world prices, thereby distorting household purchasing decisions. Furthermore, trade policy can distort the allocation of resources between the two manufacturing sectors Y and Z.

The small open economy described above suffers from two different distortions. Innovation is too low due to a dynamic distortion (intertemporal knowledge spillovers) and production of components is too low due to a static distortion (monopoly pricing). Trade policy acts on both of these distortions. Therefore, it may succeed in raising the rate of innovation by lessening the dynamic distortion but reduce welfare by reducing the production of components. Alternatively, trade policy may retard the long-run growth rate but improve welfare.

We shall conclude this discussion of the small open economy by considering the role that international transmission of knowledge has on long-run growth. If international knowledge spillovers are assumed to be an increasing function of trade volume (exports plus imports), there will be a tendency for trade-promoting policies to improve economic welfare. Export subsidies will improve welfare in all cases where this was previously so and, if there are international knowledge spillovers, in some additional ones as well. Import tariffs may reduce welfare even if they stimulate R&D and production of intermediates. Finally, trade liberalization will unambiguously improve welfare if it has no impact on factor prices. This will be the case, for example, if a country is completely specialized in production of one of the manufactured goods.

Trade Between Two Large Economies

We have seen how trade liberalization affects long-run growth and welfare of a small open economy in the preceding subsection. If a country is large enough to affect the prices of traded goods, trade policy can influence the rest of the world and this can have feedback effects on the domestic economy. In a dynamic setting, a country may also be large in two other senses. First, it may be large enough to affect world interest rates via trade in financial assets. This does not play a large role in the present context. Second, domestic R&D activity may yield spillover benefits to foreign inventors and this too may produce feedback effects on the domestic economy. As noted above, the effects of trade between two large economies will depend crucially on the degree of international knowledge spillovers.

This subsection considers the applicability of the static trade theory based on differences in factor-endowments and on the existence of static scale economies for predicting trading patterns in dynamic, two-country models with R&D and endogenous technical change. This is done first for the case where there is perfect dissemination of knowledge internationally and then for the case where knowledge spillovers are confined to the domestic economy.

Subsequently, we examine the various channels through which international trade can affect economic growth, both in the transition and in the steady state. This subsection is key for our purposes because it analyzes how moving from autarky to free international trade can lead to an increase in the rate of growth, in contrast to the finding from static trade theory and traditional growth theory that trade leads to an increase in the level of output only.

To analyze the relationship between trade and growth, a taxonomy is developed wherein there are four distinct channels by which international trade or other external linkages can affect growth: (1) international knowledge transmission; (2) reduced overlap of domestic and foreign inventions; (3)

[69] While an R&D subsidy is always called for in the model of expanding input variety, an R&D tax is optimal in the model of quality upgrading if the market rate of innovation exceeds the socially optimal rate and may be called for even if the market rate falls short of the socially optimal rate.

enlargement of market size; and (4) changes in intersectoral resource allocation. This taxonomy of linkages between trade and long-run output growth is very similar to the taxonomy of linkages between trade and output level in static models of trade with economies of scale internal to the firm, differentiated product varieties or intermediate inputs, and external scale economies that are either national or international in scope.[70]

Finally, we reconsider the effects of trade and industrial policy, which were already addressed for the case of a small open economy. Here, the existing analysis is in somewhat more limited supply. The analysis of partial trade liberalization through, say, changes in tariffs, is more complex analytically than complete liberalization. For this reason, the existing literature on the effects of commercial policy (import and export taxes and quotas) has not yet been as fully developed.

Assuming fixed production coefficients and confining analysis to the steady state, it is possible to derive the effects of R&D subsidies, production subsidies, and trade policies on long-run economic growth in the home and foreign economies. While the limitations of this analysis are severe, the essential insight is that there are important international feedback effects of such policies that complicate this analysis, in comparison with analysis of industrial and trade policy for a small open economy.

Trade and comparative advantage

We now consider the relevance of static trade theory for a dynamic economy in which R&D by potential inventors leads to endogenous technical change and growth. Two cases are considered: perfect dissemination of knowledge internationally and strictly national dissemination of knowledge.

Dixit and Norman[71] consider the effect of moving from autarky to free international trade by employing a conceptual device which they refer to as the "integrated world equilibrium." This denotes the resource allocation and price system that would obtain if all goods and factors were free to move internationally so that the world economy was in fact perfectly integrated. Analysis of free trade between countries then consists of devising allocations of resources to different sectors in each country and of factor returns so that free international trade reproduces the integrated world economy. If this is possible, then factor prices in different countries are equal in the free trade equilibrium. Factor price equalization greatly simplifies the analysis of moving to free trade, although the cases for which factor prices are unequal are also of great importance.

The concept of an integrated world economy was subsequently employed by, for example, Helpman and Krugman[72], to analyze the effect of moving from autarky to free trade in the presence of a variety of forms of scale economies but in a static setting. Trade patterns and resource allocation continue to follow appropriately extended versions of the theorems based on differences in factor endowments. With firm-level or internal scale economies and differentiated products, there is two-way trade in differentiated products but net trading patterns reflect resource endowments. With external scale economies, the effects of free trade depend crucially on whether economies are international or strictly national in scope.

We now consider a model with two countries, each of which has three sectors (R&D and two manufacturing sectors) and two primary factors (labor and human capital). Good Y is the high technology manufacturing sector and good Z is the traditional manufacturing sector. We assume the following factor intensity ranking of sectors, running from most to least human capital intensive: R&D,

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[70] See Ethier, "National and International Returns to Scale in the Modern Theory of International Trade," and J.R. Markusen, "Trade in Producer Services and Other Specialized Intermediate Inputs," American Economic Review, vol. 79, No. 1 (March 1989), pp. 85-95.

[71] A.K. Dixit and V. Norman, Theory of International Trade: A Dual, General Equilibrium Approach (Cambridge, England: Cambridge U. Press, 1980).

[72] See Helpman and Krugman, Market Structure and Foreign Trade.

high technology manufacturing, and traditional manufacturing. The high technology manufacturing sector consists of n^i differentiated products, where i = A,B refers to the country. Thus, we employ the expanding product diversity model presented above, modified to include a traditional sector and an additional factor of production (human capital). Perfect international knowledge transmission is assumed.

The key insight here is that R&D and high technology can be viewed as a composite activity in free trade equilibrium with factor price equalization so that the dynamic two-country model with endogenous growth is equivalent in the steady state to a static two-sector, two-country model with increasing returns. This implies that the usual trade theorems apply to trade between two large economies even in the dynamic setting elucidated above.

Viewing R&D and high technology manufacturing as a composite activity, the steady state equilibrium with factor price equalization is equivalent to a static equilibrium under the factor proportions theory. In such a steady state equilibrium, rates of innovation are identical across countries; otherwise, the share of differentiated products in one country would tend to zero and so negligible resources would be devoted to R&D there. The human capital abundant country conducts more R&D than its partner, compared to output of the traditional manufactured good. It produces a wider range of differentiated products as well, so total output of differentiated products is greater in this country.

We can now describe the long-run pattern of international trade for these two economies. Each country is assumed to make unique brands so there is intra-industry trade. Households have a preference for increased product variety but firms must bear fixed costs to supply each additional variety. Static models have fixed costs as a component of total production costs; here, there are up-front costs associated with R&D.

If financial assets are not traded internationally, trade must balance at all times. Then, making some standard assumptions regarding consumer preferences (identical and homothetic preferences), the standard predictions from static trade theory hold here as well. The human capital abundant country will be a net exporter of high technology goods and an importer of traditional goods. The labor abundant country will be a net importer of high technology goods and an exporter of traditional goods.

If financial assets are traded internationally, then trade need not balance at each moment though it must balance in a present value sense. Thus, a trade deficit may be balanced by a services surplus.[73] The human capital abundant country will still have a higher import share for traditional goods than for high technology goods even if it imports both on net. Alternatively, if the labor abundant country imports both goods in equilibrium, its net import share for high technology goods will exceed its import share for traditional goods.

In the steady state equilibrium with free trade, real output and GDP growth are higher for the human capital abundant country than for the labor abundant country. However, consumption possibilities are the same for the two countries so the labor abundant country is as well off as the human capital abundant country under a free trade regime. The human capital abundant country conducts more R&D and produces more high technology goods, relative to production of traditional manufactured goods, than the labor abundant country. This results from differences in factor endowments. The human capital abundant country has a higher innovation rate in the free trade equilibrium and so it also has a higher rate of real output growth, since the steady state rate of output growth is a scalar multiple of the steady state rate of innovation. In addition, GDP growth is higher in the human capital abundant country because the rate of output growth is higher there and, furthermore, R&D constitutes a larger share of its GDP.

We now move to the situation where there is free international trade but not factor price equalization, while maintaining the assumption that knowledge spillovers occur internationally. In this situation, there may be incentives for manufacturers of high technology goods to move production offshore if cost is lower there. Alternatively, there may be incentives for firms in the labor abundant

[73] For example, consumption in the home country may exceed production if the home country can borrow from abroad. In this situation, the home country runs a trade deficit and finances this deficit by net sales of equity in its high technology firms.

country to imitate products developed by firms in the human capital abundant country. A firm in the human capital abundant country may choose to license the technology in this case.

Turning now to the case where knowledge spillovers are strictly national, initial technological levels and country size are crucial determinants of the long run effect of moving from autarky to free trade. Only one country conducts R&D in the steady state equilibrium.[74] The country with the technological lead initially, as measured by the number of differentiated high technology products that it produces, usually conducts research and produces all high technology goods in the steady state. It is possible for a country that is initially behind technologically to surpass the more advanced country in two situations. First, a less advanced country may surpass a more advanced country if it has a very large labor force. This corresponds to Lucas' "nuisance" scale effect. Second, a country may surpass its more advanced trading partner through the use of a temporary R&D subsidy. However, this policy may not improve the country's welfare. These results are reminiscent of Young's findings discussed above regarding learning-by-doing, which also assume strictly national knowledge spillovers.

Consider an expanding product variety model with two countries (A and B), one factor (labor), and three sectors (R&D, high technology manufactures, and traditional manufactures). Input-output coefficients are all set equal to one by a suitable choice of units of measurement. Productivity of labor in R&D is assumed to depend on the number of previous varieties developed in the inventor's own country so that knowledge spillovers are strictly national in scope. In all other respects, the model is identical to the two-country model used above to analyze free trade for the case of international knowledge spillovers.

If wage rates are equalized between countries, then both countries will produce positive amounts of traditional goods in the steady state. This is possible if the countries are not too different in size, as measured by the ratio of their labor forces, or if the share of world spending on high technology goods is not too large.[75] Otherwise, the wage in the more advanced country (A) exceeds the wage in the less advanced country (B) and only Country B produces traditional manufactures.

To see how country size and the share of world spending on traditional goods affects steady state equilibrium with free trade, consider the case in which wages are equalized across countries in the steady state. As the size of the labor force of the less advanced country (B) is increased, holding the size of the advanced country's (A) labor force constant, a larger portion of traditional manufacturing will occur in Country B, since it specializes in this good, and the wage will fall. If Country B's labor force is sufficiently large, all traditional manufactures will be produced there and further increases in Country B's labor force will not influence Country A's wage.

If, on the other hand, world spending on high technology goods constitutes a large share of total world spending, then large amounts of labor must be devoted to their production in the advanced country (A) and no labor is left over to produce traditional goods in Country A. In this situation, Country A will specialize in research and high technology manufacturing, its wage rate will exceed Country B's, and all traditional goods will be produced in Country B.

Regarding transition to the steady state, the case where wages are equal at each moment is distinct from the case where wages are not necessarily equal at every point in time. With wage equalization, the country that has an initial technological lead (A) will come to occupy a larger and larger share of the market for high technology products, eventually supplying the entire world market. As Country A's share of the high technology market increases, so will its rates of innovation and growth. The interesting

[74] There exists a steady state equilibrium with positive levels of R&D in each country but it is unstable. It will only be obtained if initial conditions are identical to steady state values.

[75] The condition needed for both countries to have equal wage rates and produce positive amounts of traditional manufactures in the steady state equilibrium is as follows:

$$L^B/(L^A + \rho) \leq (1 - \sigma)/\sigma$$

where L^i is the labor force of Country i (i = A,B), ρ is the discount rate, and σ is the share of world spending on high technology manufactures.

feature of transition to the steady state with equal wages and strictly national knowledge spillovers is that the country with the initial technological lead (A) will experience accelerating rates of innovation and growth over time. Rates of innovation and growth in Country B will be zero at each point in time and Country B will import an increasing amount of high technology products on net. However, consumers in Country B will be just as well off as consumers in Country A because they have full access to consumption and investment opportunities through international trade.[76]

Even if wages are not equal at all moments during the transition to the steady state equilibrium, the country with an initial technological lead (A) will eventually perform all research while the other country (B) will manufacture traditional goods. In the long run, Country A will exchange high technology goods for traditional goods, while Country B will continue to export those high technology goods that it was initially able to produce. If Country A's initial share of the world high technology market is sufficiently small, there may be an initial period of time during which there is wage equalization. The wage rate in Country A will be greater than the wage rate in Country B for the remainder of the transition path and in the steady state. Alternatively, it is possible for there to be an initial period during which both countries conduct R&D, with Country A innovating more rapidly during this initial phase. Eventually, however, Country A will come to dominate the research sector and R&D activity in Country B will cease. Finally, it is possible for a very large country to overtake a small country if the initial technological disadvantage is small, since the larger country will have a cost advantage in R&D and yet also have sufficient resources to satisfy demand for traditional products.

By providing a sufficiently large R&D subsidy, it is possible to shift the location of the research sector away from the country that has an initial technological advantage (A) to the initially lagging country (B). Once Country B has obtained at least half of the world market for high technology products, the R&D subsidy can be discontinued. Eventually, Country B will come to dominate the market for high technology products and all research will be conducted there, even if the R&D subsidy is temporary.

It is unclear, however, whether such a policy will increase welfare, even for Country B. Assuming that wage rates are equalized and that Country B's residents can acquire shares in Country A's high technology firms, a subsidy will move R&D to a less efficient location, which will harm consumers in both countries by reducing the stock of resources available for manufacturing. The effect of an R&D subsidy on the rate of new product introduction is ambiguous. A subsidy increases production of new designs directly but reduces the efficiency of R&D activity. Consumers may suffer as a result of an R&D subsidy if the rate of new product introduction falls, since this worsens an existing distortion.

This subsection has discussed the changes in resource allocation that result from trade liberalization between two large countries. For the case where knowledge spillovers are international in scope, long-run trade patterns reflect differences in factor endowments irrespective of which country has a larger stock of general knowledge initially. If spillovers are strictly national, the pattern of production and trade depends on which country has a higher stock of knowledge capital initially and on country size.

Trade and growth

With the preceding discussion of trading patterns between two large economies as a foundation, we are now in a position to discuss how trade affects growth rates in each country and in the world as a whole. Static trade theory and open economy exogenous growth models show how moving from autarky to free trade may increase the level of aggregate output but not its rate of growth. A potentially important implication of endogenous growth theory in an international setting is that trade can lead to a permanent increase in the rate of output growth. It is also possible, however, for trade to lower a country's growth rate due to attendant changes in factor prices.

[76] If wage rates in the two countries are equalized at each moment in time, then consumers in the technologically less advanced country will be just as well off as consumers in the more advanced country if they are equally wealthy initially. Consumers in each country have access to the full range of high technology products through international trade in goods and have access to the full set of investment opportunities via international trade in financial assets.

Given this, we consider four channels through which integration of the world economy may lead to changes in growth. First, economic integration may enhance international dissemination of knowledge even in the absence of trade flows. Second, trade may eliminate redundancy of product designs. Third, the possibility of trade expands the effective market size for firms in each country. Fourth, trade may lead to changes in resource allocation due to changes in relative factor prices.

knowledge diffusion

We begin by considering the role that international knowledge flows can play in speeding up growth even if commodity trade is prohibited. Implications of moving from autarky to free commodity trade for the pattern of production and trade have already been discussed for the cases of strictly national knowledge spillovers and complete international knowledge spillovers. Here, the effect of international knowledge diffusion is identified by assuming that commodity trade is not permitted.

Assume there are two economies that are identical in structure to the canonical expanding differentiated product variety model described above, with one exception. The cost of developing a new product design is assumed to depend not on the country's own stock of general knowledge, as measured by the number of its existing differentiated products, but on both home and foreign knowledge stocks. This reflects the possibility that innovation in the foreign country has some spillover benefits for the home country as well. By comparing growth in the resulting equilibrium with growth for each country absent any international knowledge spillovers, the effect of international knowledge spillovers will be identified.

Specifically, assume there are n^i differentiated products in each country i, for i = A,B. Absent international knowledge spillovers, the cost of developing a new product is w^i/n^i, where w^i is the wage rate in country i. This specification of R&D cost reflects the fact that research productivity is an increasing function of the stock of general knowledge, which is measured here by the number of existing product designs n^i. From equation (35) and the discussion of a canonical expanding product variety model with knowledge spillovers, recall that the rates of long-run growth for the two countries are as follows:

$$g^A = (1 - \alpha)L^A - \alpha \rho \tag{41}$$

$$g^B = (1 - \alpha)L^B - \alpha \rho \tag{42}$$

The larger country will grow faster in autarky absent international knowledge diffusion.

International knowledge spillovers lower the cost of product development in each country. In general, there will be some overlap in product designs so that with international knowledge flows, the stock of general knowledge available to Country A is given by $n^A + \psi^A n^B$, where ψ^A is the fraction of Country B's products that are not also produced by Country A. Similarly, Country B's knowledge stock is $n^B + \psi^B n^A$. These knowledge stocks are identical since each gives the measure of unique product designs available worldwide. Given this, the cost of new product development in Country i is $w^i/(n^A + \psi^A n^B)$. In all other respects, the model is unchanged from a situation of autarky.

If we simplify by assuming that there is no overlap in the set of products manufactured by each country, then the long run growth rate in the world economy with open channels of communication (but no international trade) is as follows:

$$g = (1 - \alpha)(L^A + L^B) - \alpha \rho \tag{43}$$

Each country obtains the benefits from knowledge accumulated through research in either country. Therefore, the long run rate of growth depends upon the size of the world's labor force. Comparison of equations (41) and (42) with equation (43) shows that opening up international channels of communication increases long run growth in each country.

If the sets of goods produced in each country overlap in the absence of international knowledge flows and trade, then the long run growth rate is correspondingly reduced. The (common) rate of innovation in each country, with communication flows but not trade, is given by the following expression:

$$g = (1 - \alpha)(L^A + \psi^A L^B) - \alpha \rho \tag{44}$$

Here, the increase in growth obtained by opening international channels of communication depends on the degree of overlap in the set of goods produced in each country. If the degree of overlap is great, the increase in growth will be small because the two countries have little to learn from one another.

<u>duplication of research effort</u>

Suppose now that the world economy described above is opened up to international trade. If there is no overlap in the set of goods produced by the two countries, it is apparent that an integrated world economy satisfies all of the same equations as each closed economy except that the stock of labor is the sum of labor stocks for each country, $L^A + L^B$. Therefore, the long run growth rate for the integrated world economy is given by equation (43). Thus, there will be no increase in growth as a result of trade in commodities if the sets of products manufactured in each country (absent trade) are disjoint and if trade is introduced into a world economy in which international knowledge spillovers are already present.

If there is some overlap in the set of products prior to trade, the effect of international trade will be to eliminate this redundancy. It makes no sense for firms to incur up-front product development costs if a foreign firm has already incurred these costs. Therefore, the long run rate of economic growth will increase in each country, from the rate given in equation (44) to that given in equation (43).

Even if overlap is absent and thus trade has no effect on growth, the usual static gains from trade are still present. Consumers are now able to purchase the full range of differentiated products, rather than just domestically produced varieties, so their utility increases. In this case, international trade will have level effects but not growth effects.

<u>expansion of market size</u>

Trade opens up the effective size of the market for producers. This has two potentially offsetting effects on firm profits. First, producers can now sell to the entire world market so that there is a tendency for profits to rise for each firm. Second, home firms must now compete with foreign firms and this tends to reduce each firm's profits. The net effect of enlargement in market size is unclear.

Expansion of market size due to trade will not affect profits per firm if both countries innovate at the same rate, given the model we have just considered. In this model, the market share of brands unique to Country A is equal to Country A's share of total world expenditure. While firms in Country A must compete with additional total sales of $n^B p^B x^B$ by n^B additional producers due to trade, total spending on high technology products also increases by $E^B = n^B p^B x^B$. Since all firms in each country are of equal size (x^i) in equilibrium, profits per firm will not change as a result of trade. The increase in market size due to the opening of trade will not influence rates of innovation and growth in this model because incentives for investment in new product development are unchanged.

In general, however, expansion of market size due to trade may alter incentives to innovate. As we have seen, there is a tendency for the initially more advanced country to take over the entire market for high technology products if knowledge spillovers are strictly national in scope.

To distinguish the effects of market size from intersectoral factor reallocation, we briefly discuss the effects of market size in a model with only one manufacturing sector. This is accomplished by considering a two-country world, where each economy is identical in structure to the canonical expanding differentiated product variety model described above, and with strictly national knowledge spillovers. That is, the cost of developing a new product design depends only on the individual country's stock of general knowledge, the latter being measured by the existing number of differentiated products.

In autarky, the larger country will have a higher long run growth rate. Given national spillovers, the larger country will come to dominate the market for high technology products since it has an initial technological lead. During at least the final stages of the transition to the steady state, the larger country will have a higher rate of innovation than its rate of innovation in autarky. Once it captures the entire high technology market, the rate of innovation subsides to a level equal to the larger country's autarky rate and stays there. For the smaller country, its share of the high technology market tends to zero. The smaller country's long run rate of innovation is positive but lower than its rate of innovation in autarky. Therefore, expansion of market size can influence the pattern of production and trade even if intersectoral factor reallocation effects of trade are absent.

While trade slows innovation in the smaller country, welfare of this country may either rise or fall as a result of trade. Trade tends to reduce welfare for this country because it reallocates resources away from research and toward manufacturing, thereby worsening an existing distortion. Offsetting these welfare losses are static gains to consumers from access to increased product variety through trade and dynamic gains from an increase in the worldwide rate of innovation. The net effect of trade on welfare of the smaller country is unclear.

factor movements between sectors

In addition to the other effects of international integration of two large economies on growth, trade may lead to movements of factors between manufacturing sectors through induced changes in factor rewards. We have already seen how this can work in a small open economy. Resources will move into the sector whose price has increased as a result of trade. By the Stolper-Samuelson theorem, the factor used intensively in this sector will see its relative reward increase. If the factor whose relative price falls as a result of trade happens to be human capital, which is used intensively in R&D, then trade will spur innovation and growth.

To see how international trade between two large countries will affect growth rates, we consider a model with two countries (A and B), two manufacturing sectors (traditional goods, Z, and high technology goods, Y), two factors (labor, L and human capital, H), and international knowledge spillovers. Each sector uses each factor although the traditional manufacturing sector is the most labor-intensive and R&D is the most human capital-intensive. Country A is assumed to be more human capital abundant than Country B.

Given this model, we must examine how the rate of innovation and growth in the integrated world economy compares with autarky rates of innovation and growth for each country. As compared to Country B's situation in autarky, the integrated world equilibrium adds relatively more human capital than labor to the stock available for research and manufacturing. If input-output coefficients are assumed fixed, the Rybczynski theorem applies. Moving from Country B's autarky endowments to integrated world economy endowments, this will lead to an expansion of the research and high tech manufacturing sectors and a contraction of the traditional manufacturing sector. The reverse is true in Country A. Traditional manufactures expand while R&D and high technology sectors contract.

It is thus possible for trade to reduce growth in the human capital abundant country if opportunities for factor substitution are low. This possibility arises because the world economy has a greater abundance of (unskilled) labor than Country A so that the cost of human capital rises in the integrated world equilibrium as compared to autarky for Country A. This raises the cost of R&D, which uses human capital intensively, and retards growth.

If skilled and unskilled labor are sufficiently substitutable, then the increase in factor endowments which results from moving from Country A's autarky endowments to the integrated world economy's endowments will always lead to an expansion of the R&D and high technology manufacturing sectors in Country A, even if this expansion is biased toward unskilled labor. In particular, increased supply of unskilled labor will always increase the rate of innovation if the factor substitution elasticity exceeds one in both manufacturing sectors. To sum up, trade must stimulate innovation in each country if factor substitution possibilities are sufficiently great.

Industrial and trade policy

Having analyzed the polar cases of autarky and free trade for a world economy with two large countries, we now consider briefly the effects of intermediate levels of openness. A nonprohibitive tariff may have very different effects than is revealed by a comparison of autarky with free trade. Many additional forms of trade barriers are also possible and these will generally differ in their effects from a simple tariff. Relatively little theoretical work has been done to analyze the effects of commercial policy in models with endogenous growth; yet this is clearly a needed step if such models are to inform trade policy.

In view of the limited amount of theory in this area, we discuss the effects of tariffs on the long run rate of innovation in the situation where production coefficients are fixed. The assumption of fixed coefficients represents a severe limitation in the present context, as we have just seen.

A policy that taxes imports and subsidizes exports of traditional manufactured goods raises the internal cost of such goods. This is equivalent to a subsidy to domestic production of traditional manufactured goods. If the country's free-trade share of the world market for high-technology manufacturing exceeds its share in world spending, the world rate of innovation rises following the imposition of a small tariff on traditional manufactures. Otherwise, the rate of innovation falls.

By the Lerner symmetry theorem, a policy that taxes imports and subsidizes exports of traditional manufactures is equivalent to a policy that subsidizes imports and taxes exports of high technology manufactures. Thus, the above analysis also applies to a small subsidy to imports of high technology products.

THE EMPIRICAL LITERATURE

The European Community

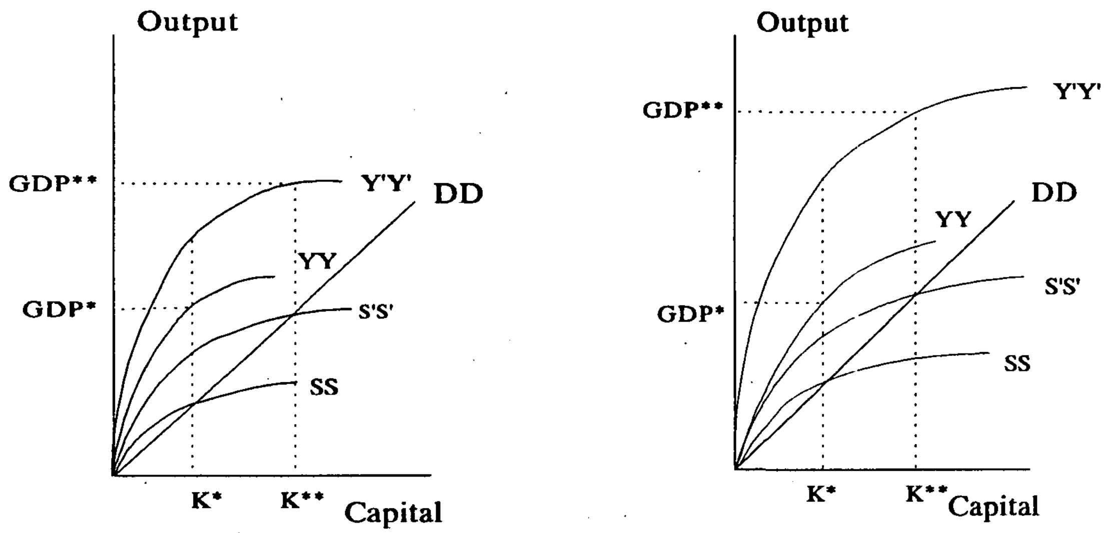
Baldwin[77] computes the dynamic gains from the 1992 program to eliminate all barriers to trade and factor movements within the European Community. He distinguishes between a "medium-term growth bonus" due to induced capital formation and a "long-term growth bonus" due to induced technical change. Using Solow's terminology, the medium-term growth bonus is a level effect whereas the long-term growth bonus is a growth effect.

The medium-term growth bonus is really a temporary increase in the growth rate during the transition to the new steady state, at a higher level of income but with no increase in the permanent rate of economic growth. This comes about as EC 1992 increases the productivity of existing factor endowments, thereby leading to increased income, saving, and investment. The added investment yields more output, leading to further increases in saving and investment. This process converges at a higher level of output and the capital stock; growth then comes to a halt.

Figure 4 shows the medium-term growth effect of 1992. Static gains shift the production function YY up to Y'Y'. Assuming that savings are proportional to income, the savings function is given by SS and this shifts up to S'S' due to 1992. Depreciation is assumed to be proportional to the size of the capital stock and is given by DD. Prior to 1992, GDP is equal to GDP* and the capital stock is equal to K*. Static gains lead to an increase in GDP with the capital stock held fixed at K*. At this level of the capital stock, savings exceed depreciation so that the capital stock rises over time. During the transitional period when capital is still growing, there is a positive level of output growth. Eventually, the capital stock reaches its new steady-state level, K**, at a higher level of GDP, GDP**. Once the

[77] See Baldwin, "The Growth Effects of 1992," and Baldwin, "Measurable Dynamic Gains from Trade."

Figure 4



(a) no scale economies (b) scale economies

economy has adjusted to the new steady state, economic growth comes to a halt.

The medium-term growth bonus occurs whether returns to scale are constant or increasing. If there are increasing returns to scale, the marginal productivity of capital is higher at each level of the capital stock, holding labor's share of output constant.[78] Therefore, static efficiency gains lead to a larger medium-term growth bonus if there are increasing returns to scale. This is shown in Figures 4(a) and 4(b), which depict the medium-term growth bonus under constant and increasing returns to scale, respectively.

Baldwin shows that the medium-term growth bonus can be quite substantial as compared with the usual static gains from economic integration. He interprets the estimated gains from the Cecchini Report as static gains; these range from 2.5 to 6.5 percent of GDP. Under the assumption of constant returns to scale, he obtains a range of estimates of the elasticity of output with respect to changes in the capital stock from the econometric literature for Belgium, France, Germany, Netherlands, and the United Kingdom:

	Belgium	France	Germany	Neth.	UK
Low estimate:	0.276	0.23	0.263	0.26	0.195
High estimate:	0.576	0.444	0.564	0.446	0.483

[78] Let the aggregate production function be defined as follows:

$$Y = j\,K^{a+b}\,L^{1-a}$$

where Y is aggregate output, j is an efficiency parameter, K is the capital stock, L is labor, 1-a is labor's share of output, and b is a measure of aggregate scale economies.

Then the marginal product of capital is given by the following equation:

$$\delta Y/\delta K = (a+b)Y/K$$

and the derivative of the marginal product of capital, taken with respect to changes in capital, is as follows:

$$\delta^2 Y/\delta K^2 = (a+b-1)(a+b)Y/K^2$$

Under constant returns to scale, b=0; under increasing returns b > 0. Therefore, the marginal product of capital is higher under increasing returns than under constant returns. If 0 < 1-a < 1 then a+b < 1 under constant returns. If b is small enough under increasing returns so that a+b < 1, then the marginal product of capital is declining in K.

Based on this information, he computes a range for the medium-term bonus as a percent of the static efficiency gains:[79]

	Belgium	France	Germany	Neth.	UK
Low estimate:	38	30	36	35	24
High estimate:	136	80	129	81	93

Baldwin concludes that the Cecchini Report's estimates of the economic benefits of 1992 are at least 30 percent too low. He then calculates the indirect percentage increases in GDP due to induced capital accumulation:[80]

	Belgium	France	Germany	Neth.	UK
Low estimate:	1-2.5	0.8-2	0.9-2.3	0.9-2.3	0.6-1.6
High estimate:	3.4-8.8	2-5.2	3.2-8.4	2-5.2	2.3-6.1

His conclusion is that induced capital accumulation will at a minimum boost UK GDP by 0.6 percent and at a maximum will boost GDP in Belgium and Germany by over 8 percent. These induced output effects are added to static gains of 2.5-6.5 percent to obtain estimated total effects of 1992 on GDP:

	Belgium	France	Germany	Neth.	UK
Low estimate:	3.5-9	3.3-8.5	3.4-8.8	3.4-8.8	3.1-8.1
High estimate:	5.9-15.3	4.5-11.7	5.7-14.9	4.5-11.7	4.8-12.6

Baldwin employs two other models to compute growth effects of 1992 in his 1989 paper. First, he calibrates the 1987 model developed by Romer discussed above.[81] For this model, the steady-state rate of output growth is equal to the savings rate times the steady-state output-capital ratio, minus the rate of depreciation. Static gains increase the output-capital ratio by 2.5 to 6.5 percent and, based on a savings rate of 10 percent, this leads to an increase in the growth rate of one-quarter to three-quarters of a percentage point. This represents a growth effect rather than a level effect because there are dynamic increasing returns to capital accumulation, as discussed above in connection with the 1987 Romer model.

[79] The medium-term growth bonus as a percent of the static efficiency gains is given by the following equation:

$$100[(Y^{**}/Y) - 1]/[(Y^{*}/Y) - 1] - 100 = 100\,(a+b)/[1 - (a+b)]$$

For example, the low estimate for Belgium's output capital elasticity of 0.276. The above formula implies that the medium-term growth bonus as a percent of the static efficiency gains is as follows:

$$100\,[0.276/(1 - 0.276)] = 38 \text{ percent}$$

[80] The induced percentage increase in GDP due to capital accumulation is computed as follows:

$$100\,\{[1/(a+b)] - 1\}^{-1}\,[(j^{*} - j)/j]$$

where $100\,[(j^{*} - j)/j]$ is the percentage increase in efficiency due to static gains.

For example, the range of low estimates of the induced percentage increase in Belgian GDP is computed as follows:

$$100\,[(1/0.276) - 1]^{-1}\,(0.025) = 1 \text{ percent}$$

and

$$100\,[(1/0.276) - 1]^{-1}\,(0.065) = 2.5 \text{ percent}$$

This range is based upon the range of static gains from the Cecchini Report.

[81] The first model used by Baldwin and discussed above is modified by assuming that $a+b = 1$.

He also calibrates a simple endogenous growth model based on a paper by Krugman.[82] This model features investment in R&D to lower the cost of producing existing product designs (process innovation as opposed to product innovation). On this basis, 1992 would add between about 0.3 to 0.8 percentage points to the permanent growth rate. Neither of these latter two models are carried through into Baldwin's 1992 paper, which contains calculations of the medium-term growth bonus that are identical to those contained in the 1989 paper and those described above.

The North American Free Trade Agreement

Kehoe[83] emphasizes the dynamic gains from trade liberalization that are beyond the scope of the static applied general equilibrium models currently used to analyze the North American Free Trade Agreement (NAFTA). As we have shown, dynamic gains from trade may increase the rate of economic growth.

Capital flows

Mexico's motivation to implement a NAFTA stems in part from the desire to increase capital flows into Mexico. Some modelers have incorporated capital flows by assuming that Mexico's aggregate capital stock increases by a given percentage or, alternatively, to maintain the rate of return on capital that prevails in the absence of a NAFTA.[84] Young and Romero take the further step of modeling the liberalization of Mexican tariffs on capital and intermediate inputs, as well as an exogenous reduction in the Mexican real interest rate.[85] Capital flows are important because an increase in Mexico's capital-to-labor ratio would lead to higher per capita output.

Differences in capital-labor ratios between Mexico and the United States cannot fully account for differences in per capita output levels, however. Based on purchasing power parity comparisons, 1988 real GDP per capita was $14,581 in Mexico and $37,608 in the United States.[86] During the 1988-90 period, the real return on bank equity in Mexico averaged 28.2 percent per year, far less than the 86 percent that would be expected, based on the simple calculations performed by Kehoe, if differences in capital-labor ratios alone accounted for per capita output differences.

Although capital flows into Mexico are unlikely to equalize Mexican and U.S. per capita output, they are clearly very important. Simple calculations by Kehoe show that capital flows sufficient to bring

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[82] See P.R. Krugman, "Endogenous Innovations, International Trade and Growth," Working Paper presented at SUNY-Buffalo Conference on Development, 1988.

[83] See T.J. Kehoe, "Modeling the Dynamic Impact of North American Free Trade."

[84] For example, see C. Bachrach and L. Mizrahi, "The Economic Impact of a Free Trade Agreement between the United States and Mexico," in Economy-Wide Modeling of the Economic Implications of a FTA with Mexico and a NAFTA with Canada and Mexico, USITC Publication 2508, U.S. International Trade Commission, Washington, DC, May 1992, D.K. Brown, A.V. Deardorff, and R.M. Stern, "A North American Free Trade Agreement: Analytical Issues and a Computational Assessment," World Economy, vol. 15 (Jan. 1992), pp. 11-29, and H.E. Sobarzo, "A General Equilibrium Analysis of the Gains from Trade for the Mexican Economy of a North American Free Trade Agreement," in USITC Publication 2508.

[85] See L. Young and J. Romero, "Steady State and Transition in a Dynamic Dual Model of the North American Free Trade Agreement."

[86] Information on prices of comparable items in different countries is collected as part of the International Comparison Project (ICP), sponsored by the United Nations, World Bank, and the University of Pennsylvania. Relative prices from this survey are used to compare differences in the cost of purchasing a representative bundle of commodities across countries in the survey. International comparison of per-capital GDPs based on this survey are referred to as purchasing power parity comparisons, since the differences in per-capita real GDP across countries obtained from the ICP survey reflect differences in the buying power of a person's income in different countries.

Mexico's net interest rate down from 28 percent to five percent (roughly the U.S. level) would increase Mexican per capita GDP to about $24,300. This would close about 42 percent of the current gap between Mexico and the United States.

Interindustry specialization

As discussed above, learning-by-doing in production is one possible channel through which trade can lead to increased economic growth. A firm learns to produce a good more cheaply with experience. If other firms benefit from this experience, the average cost of production for each firm will depend on cumulative output of the entire industry. As industry output increases, learning-by-doing results in continual productivity improvements and thereby provides a source of sustained economic growth.

Growth for the economy as a whole is a weighted average of growth rates for individual industries, with weights given by industry output shares. Levels of experience in production, and hence productivity, differ among industries. To the extent that trade leads to specialization in industries with high rates of productivity, this can lead to increased economic growth for the economy as a whole. Kehoe develops a specialization index to capture the relationship between trade, interindustry specialization, and economic growth. This index is subsequently used in a regression to estimate the effects of free trade on Mexican economic growth, as discussed below.

Intra-Industry trade

Trade can also lead to growth by allowing a country to import specialized inputs. A country may produce specialized intermediates itself or import them. With no trade, there is a dynamic scale effect. Larger countries can produce a broader range of capital goods and thereby achieve higher rates of economic growth. By liberalizing trade, a country gains access to the accumulated experience of other countries in the production of specialized inputs. In this way, trade may lead to increased growth.

Based on these considerations, it is to be expected that countries with a greater volume of trade in intermediates would have higher rates of growth. The Grubel-Lloyd index is often used to measure the extent to which a country trades in specialized intermediate inputs. Kehoe uses this index, along with the aforementioned index of interindustry specialization, in a regression to estimate the growth effect of trade liberalization for Mexico, as discussed below.

Free Trade and Mexican Growth

To illustrate the importance of dynamic gains from trade liberalization for Mexico, Kehoe employs results from a regression of output growth per worker on the specialization and Grubel-Lloyd indexes and other variables using a cross-country data set.[87] He then makes rough assumptions regarding the effects of free trade on the specialization and Grubel-Lloyd indexes described above.[88]

[87] Regressions using a cross-country data set for a large number of countries over the 1970-85 period were reported in D.K. Backus, P.J. Kehoe, and T.J. Kehoe, "In Search of Scale Effects in Trade and Growth."

[88] Average specialization and Grubel-Lloyd indexes for 1970-85 are as follows:

	Specialization Index:	Grubel-Lloyd Index:
Canada	7.10×10^{-2}	0.642
Mexico	5.93×10^{-4}	0.323
United States	1.92×10^{-3}	0.597

It is assumed that free trade allows Mexico to increase its specialization index to 1.00×10^{-2} and its Grubel-Lloyd index to 0.600.

These assumed changes, when combined with coefficient estimates from the regression, yield an estimated increase in the growth rate of Mexican manufacturing output per worker of 1.645 percent per year.[89] After 25 years, output per worker would be more than 50 percent higher than it would otherwise have been. These calculations are crude but illustrate that the dynamic gains Mexico may expect from free trade would dwarf the static gains.

Conclusions

While Kehoe's calculations of dynamic gains from trade liberalization for Mexico are rough, it is clear that even a modest increase in the growth rate will accumulate into large changes in per capita output over extended periods. This insight does not depend greatly on how the growth rate increase is calculated.

There is nothing in these calculations to tie the dynamic gains specifically to the removal of Mexican trade barriers or to the enactment of the NAFTA. It is simply assumed that trade liberalization takes the form of increased specialization and intra-industry trade indexes. Thus, there is no model that links changes in tariffs or other barriers to dynamic gains from trade. This type of linkage would require a dynamic applied general equilibrium model of Mexico that incorporates endogenous growth, a task that lies in the future.[90]

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[89] Estimated regression coefficients on the specialization index and the Grubel-Lloyd index were 0.359 and 1.018, respectively. The increase in Mexican output growth per worker is estimated as follows:

$$0.359 \ln(1.00 \times 10^{-2} / 5.93 \times 10^{-4}) + 1.018 \ln(0.600/0.323) = 1.645$$

[90] For a first attempt to construct such a model, see R.K. McCleery, "An Intertemporal, Linked, Macroeconomic CGE Model of the United States and Mexico Focusing on Demographic Change and Factor Flows," in USITC Publication 2508.

The specification of dynamic gains is based on K.J. Arrow, "The Economic Implications of Learning by Doing," *Review of Economic Studies*, vol. 29 (June 1962), pp. 155-73. The rate of learning by doing is assumed to be a function of the level of aggregate investment. Unfortunately, this specification precludes a variety effects of trade on the growth rate that have been emphasized by Kehoe, Lucas, Stokey, Young, and others.

Appendix A

(Request letter)

THE UNITED STATES TRADE REPRESENTATIVE
Executive Office of the President
Washington, D.C. 20506

DOCKET NUMBER 1685

Office of the Secretary
Int'l Trade Commission

RECEIVED OFC OF THE SECRETARY U.S. INT'L TRADE COMMISSION '92 APR 15 A11:50

RECEIVED OFC OF THE SECRETARY U.S. INT'L TRADE COMMISSION '92 APR 15 A11:11

The Honorable Donald E. Newquist
Chairman
U.S. International Trade Commission
500 E Street, S.W.
Washington, D.C. 20436

Dear Mr. Chairman,

The Administration, Congress and the American public will be in a position of having to make judgements about the value to the United States of various trade liberalizing agreements -- in the near term with respect to the Uruguay Round and NAFTA and later with respect to other agreements. I believe such judgements should be made in as informed a manner as possible. In this regard, the NAFTA symposium recently held by the Commission and the Commission's forthcoming publication of the symposium proceedings are important contributions to our understanding of the economic effects of free trade in North America.

I believe, however, that the process of formal, quantitative economic assessment can and should be taken a step further. Most of the studies presented at the symposium employed a so-called "comparative static" framework of analysis. One common theme throughout the NAFTA symposium was recognition by the participants of the need to complement analysis done in the comparative static framework, with analyses attempting to capture better the "dynamic" effects of trade liberalization.

Recent innovations in economic theory and applied economic policy modeling place emphasis on such dynamic effects of economic policy changes. These relate to the effects of policy changes upon rates of technical change and innovation, ongoing specialization of production, and other dynamic effects. It was made apparent at the NAFTA symposium that such dynamic changes may be at least as important, and possibly much more important, than the initial effects measured in a comparative static framework. The issue of dynamic effects is, of course, not just limited to a NAFTA but is germane to any major trade agreement presented for Congressional and public consideration.

To assist in understanding the implications of these developments in economic theory, under authority delegated by the President and pursuant to Section 332(g) of the Tariff Act of 1930, I request that the Commission institute an investigation to survey this body of economic research and provide a summary of the existing literature, both theoretical work completed and in progress, as well as empirical applications completed or in progress. In addition to a summary of this literature, the

Commission should also provide a general assessment of the insights the body of literature provides regarding the dynamic gains from trade.

Please inform my office when the Commission will be able to complete this report, which we would appreciate receiving at the earliest practicable date.

In view of the outstanding instruction to the Commission on the security classification of reports prepared by the Commission at the request of the U.S. Trade Representative, I request that all reports on this investigation be made available to the public at the same time they are submitted to my office.

The Commission's assistance in this matter is greatly appreciated.

Sincerely,

Carla A. Hills

Carla A. Hills

Appendix B

(Notice of institution of investigation)

UNITED STATES INTERNATIONAL TRADE COMMISSION
Washington, D.C. 20436

Investigation No. 332-324

The Dynamic Effects of Trade Liberalization: A Survey

AGENCY: United States International Trade Commission

ACTION: Institution of investigation

SUMMARY: Following receipt on April 15, 1992 of a request from the U.S. Trade Representative (USTR), the Commission instituted investigation No. 332-324, The Dynamic Effects of Trade Liberalization: A Survey, under section 332(g) of the Tariff Act of 1930 (19 U.S.C. 1332(g)). As requested, the investigation will survey theoretical and empirical literature on these effects and in its report the Commission will provide a summary thereof and will seek to provide a general assessment of the insights the body of literature provides regarding the dynamic gains from trade.

EFFECTIVE DATE: May 7, 1992

Written Submissions: Interested persons are invited to submit, on or before August 21, 1992, written statements concerning the matters to be addressed in the report. Commercial or financial information that a party desires the Commission to treat as confidential must be submitted on separate sheets of paper, each clearly marked "Confidential Business Information" at the top. (Generally, submission of separate confidential and public versions of the submission would be appropriate.) All submissions requesting confidential treatment must conform with the requirements of § 201.6 of the Commission's Rules of Practice and Procedure (19 CFR 201.6). All written submissions, except for confidential business information, will be made available in the Office of the Secretary to the Commission for inspection by interested persons.

FOR FURTHER INFORMATION CONTACT: Joseph Francois or Clinton Shiells (202-205-3223), Office of Economics, U.S. International Trade Commission.

Hearing impaired persons are advised that information on this investigation can be obtained by contacting the Commission's TDD terminal on 202-205-1810.

By order of the Commission.

Kenneth R. Mason
Secretary

Issued: May 15, 1992

Appendix C

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