INTERNATIONAL TRADE AND GROWTH: An Overview From The Perspective of the New Growth Theory

by

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Presented at AAEA Annual Meeting Post-conference Workshop: Learning Workshop:
New Growth Theory and Applications in Agricultural and Rural Economics -
Nashville, Tennessee, Renaissance Hotel, August 11, 1999.

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Abstract

The role of international trade in the new growth theory is investigated from several perspectives. Following a historical outline and a brief analytical sketch of the R&D based models, the results from fitting three structural models to data are presented. Results show the relative impacts on growth from trade and R&D based policies including technological spillovers from trade. The mechnaism of inter-sectoral adjustments to the long-run growth path are also discussed. Results from selected econometric studies are reviewed. With emphasis on agriculture, this includes evidence of technological spillovers from trade, the effect of R&D expenditures on growth in total factor productivity, and the extent to which the stock of technological knowledge is accessible by others.

Key Words: Endogenous Growth, Trade, Technological Spillovers

JEL Classification: O3, 04, 05

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1 Introduction

It is generally agreed that the world's economy is in its second wave of globalization, the first which ended in the early 1900s, the second which began in the late 1950s and early 1960s. Based on UN data, world GDP grew at an average annual real rate of about 3.0 percent per annum over the period 1971-95 while the growth in world trade averaged about 5.9 percent per annum. This implies that the world's economies are moving in the direction of increased specialization. In terms of the volume of world trade, developing nations are vastly less important in the second wave than they were in the first wave, and the commodity composition of exports across developed nations is much more symmetric in the second than in the first wave (Baldwin and Martin, 1999). In 1997, more than half the volume of merchandise trade flowed between developed nations with similar factor endowments, and less than 15 percent between developing nations with the rest representing North-South trade. Moreover, most of this trade (about three-fourths) is two-way trade in manufactures, as is most of the North-South trade (about 79 percent in 1989). Relative to the first wave, trade in manufactures is associated with a re-industrialization of labor intensive manufacturing in the South, and de-industrialization of such industries in the North[2]. Many of the re-industrializing countries of the South, particularly the newly industrialized economies (NICs), have also experience, by world standards, historically unprecedented rates of growth in GDP.

The relationship of agriculture to this transformation of the trade pattern is quite interesting and worthy of investigation. This is because advances in bio-technology (discussed later) have meant that in the second wave, U.S.

[2] See for example Baldwin and Martin's Table 3: Industry's Employment Share, OECD Nations, 1950-1990.

agriculture has begun to evolve from its classic role as an exporter of primary commodities with a relatively small and internationally common set of attributes, supported mostly by public R&D expenditures, to a commodity base with an increasing array of attributes linked to private R&D efforts. Evidence of increasing value added in agricultural trade also points to this (Gopinath and Roe, 1996). This factor may also be in part responsible for the declining world export share of agricultural from developing countries.

While there is informed debate as to whether the current level of world financial integration has attained the level reached in 1914 (Sachs and Warner, 1995), it is clear that longer-term foreign direct investments (FDI) dominated total capital flows in the first wave. FDI flows in the second wave largely originated in and flow to developed countries. The composition of FDI has also changed. In the second wave, FDI is directed mostly to services and manufacturing instead of to the primary product sector. Baldwin and Martin cite evidence from several studies showing that, relative to the first wave, capital mobility is today very high for short-term instruments. This mobility is associated with the dramatic decline in costs of transmitting information (and knowledge) in contrast to the first wave which was associated, in relative terms, with a dramatic decline in spatial costs. They conclude that both globalization waves were driven by radical reductions in technical and policy barriers to international transactions, but "trade in ideas is more important in the second wave" (Baldwin and Martin, p 29)

In light of the above sketch, the general task of this paper is to provide a relatively non-technical discussion of the insights the new growth theory provides into the linkage between growth and trade. In particular, we focus on the role and importance of (a) intermediate capital variety, denoted in our sketch of the basic analytical model as $k(s)$ where (s) indicates a particular variety, (b) the decline in the cost of transmitting technical knowledge internationally and hence making available the world's stock of technical knowledge, denoted later as M, to a growing proportion of world's economies, and (c) the importance of international trade in this process.

The paper contains five major sections. Section 2 focuses briefly on the analytical antecedents. This helps to place into sharper focus the major thrust of the paper which is presented in Sections 3 and 4. Section 3 provides a non-technical overview of the Romer, (1990) (R) and the Grossman and Helpman, (1991*c*) (GH) research and development (R&D) driven model of growth. We thus omit discussion of the class of so called AK models and the learning by doing models. In this section we also discuss the key analytical implications these models provide as they pertain to trade and growth.

However, qualitative predictions are of limited usefulness. Thus, in section 4 we report on the empirical results from calibrating three R&D based models to data, one for the US, another for Japan and the third a North-South model of growth and trade. The results suggest the magnitude of the difference between observed growth rates and those that are possible using policy instruments to affect trade and resources allocated to R&D activities. Since calibration models tend to have a normative or "make believe" feature, we review briefly the econometric literature in Section 5, first from a broader non-agricultural point of view, and then more narrowly on agriculture. This literature tends not to identify structure per se, but insights are provided into the linkages between trade and growth, into technological spillovers, and into other facets of trade and growth that are consistent with R&D driven growth framework.

We conclude that the R&D based models of endogenous growth make a strong contribution to organizing our thinking of the growth - trade process, and to complement the contributions of Hayami and Ruttan and others studying technological change, trade and growth in agriculture. They also provide insights into the economic forces underlying the second wave of globalization, why import substitution industrialization policies were not only bad for agriculture, but why they tend to retard growth more broadly. Nevertheless, potential determinants of long-run growth are numerous and focusing on one main engine of growth surely only captures a part of a complex process. In his review of the growth experience of East Asian economies, Stiglitz (1996) suggest that the determinants of growth are generally caused by a host of market failures that vary by country, and by the level of development. We also question whether models of the nature discussed in Section 4 are up to the demands of economy-wide policy analysis. Thus, much remains to be done.

2 Analytical Background

Contributions to the theory of trade and growth in 1970s was based largely on the neoclassical growth theory in the context of the Heckscher-Ohlin trade model. Excellent reviews of these contributions are provided by Smith (1984) and Findlay (1984). Many of these models drew upon the Solow-Swan framework in which saving is a constant proportion of total output. This assumption results in inefficient over-saving, and is inconsistent with the assumption that agents otherwise optimize in choosing consumption bundles and factors of production. Cass (1965) and Koopmans (1965) drew upon the contribution of Ramsey (1928) to remedy this shortcoming. In models of Ramsey genre, optimizing households choose consumption and savings to maximize their dynastic utility, subject to an interemporal budge constraint in a decentralized - market economy[3]. This approach, with exogenous growth in total factor productivity (TFP), and extended to account for non-homethetic preferences and fixed factors of production receives broad application, examples of which are papers by Echevarria (1995), and Diao and Somwaru (1999).

The new growth theory expands on this tradition, a branch of which considers the mechanism by which new technical knowledge is generated. The paper by Romer (1990) and the book by Grossman and Helpman (1991c) are among the leading contributions. The key feature is that knowledge or new ideas are treated as an accumulable resource which is non-rival and only partially excludable. Grossman and Helpman develop two strands of the basic R&D model, one of which focuses on differentiated quality, the other on differentiated intermediate factor variety. The main features of the differentiated intermediate factor variety model, adapted to accommodate later discussion, are briefly sketched in the next section.

An essential component of the R and GH models is the presence of an imperfectly competitive sector. This component has its roots in the so called new trade theory, examples of which can be found in the papers by Krugman (1980) and Helpman (1981)[4]. The latter contributions incorporated increasing returns to scale and imperfectly competitive markets into static trade theory to help explain the presence of intra-regional trade. These contributions too have been cast into the Ramsey exogenous growth framework. An empirical application of this extension is Mercenier's (1995) analysis of European trade integration effects.

The new growth theory offers an avenue where the long-run rate of growth is a market determined outcome based on the economic choices of agents. These choices may not lead to the socially optimal rate of growth. The theory opens up the possibility that trade can also influence the long-run growth

[3]Barro and Sala-i-Martin (1995) provide an excellent treatment of this approach in Chapters 2 and 3.

[4]A review of this literature is provide by Krugman (1995)

path of a country. Trade in final goods can influences factor prices which in turn can raise or lower the R&D sector's ability to compete for knowledge intensive factors of production (e.g., Grossman and Helpman 1991c, Ch. 6). Trade can also alter the global availability of knowledge directly (e.g., Rivera-Batis, 1991; Grossman and Helpman 1991c, Ch 7), or the availability of knowledge can be altered indirectly by trade in intermediate goods which embody the R&D and thus allow for reverse engineering (imitation) in the South (e.g., Helpman, 1993, Datta and Mohtadi, 1999).

To illustrate these points, and to build a base for later discussion, the following section provides a non-technical sketch of a trade-growth model within the framework of the new growth tradition[5].

3 The R and GH Model of R&D Driven Growth

3.1 An Overview of Model Structure

Beginning with the basic model, the economy is small in the sense that it faces perfectly elastic demand for final goods in world markets at exogenously given prices. The economy contains four distinct components, a final good producing sector (the only sector which trades internationally), a household sector, a sector that produces intermediate capital variety and a R&D sector. These components are denoted in Figure I, where numbers in $(\cdot)$ refer to key linkages between sectors. The separation of the R&D sector from the sector producing intermediate capital variety is for ease of presentation; the two sectors can be modeled as one without loss of generality.

There are two primary factors, L and B. Their levels are constant over time, mobile among sectors but immobile internationally. Producers undertake three distinct activities. Producers in the R&D sector choose the services of two primary inputs, L_m, and B_m given the stock of existing knowledge M to produce new designs $\dot{M}$. The accumulation of new designs are proportional to accumulated knowledge M which is available to all. New designs should be broadly interpreted to include the production of technical

[5]Detailed derivations and proof of saddle-path stability for the model sketched in the next section can be found in the working paper by Diao et al (1996). R&D models specified to easily illustrate their basic properties can be found in Jones (1998) and Aghion and Howitt (1998).

knowledge that is embodied in patents and blue prints, and not to include trade secrets or those process innovations for which some type of property right is not possible. The R&D production function exhibits constant returns to scale over the contemporary inputs L_m, and B_m, but increasing returns over all inputs. Since the cumulative output of each individual firm's R&D activities expands the common pool of technological knowledge, R&D output is a technological spillover, a positive externality which increases the productivity of the two primary factors employed in R&D production. Spillovers are a source of technological progress preventing, over time, the onset of diminishing returns to primary factors, and of course, increasing the efficiency of producing additional new designs.

The market linking the R&D sector output to producers of intermediate capital variety, linkage (4), is competitive. However, there are two unique features at this point. First, each design is associated with only one firm in the differentiated capital goods sector. That is, one design is associated with one type of differentiated capital variety. Second, the design must be purchased before the production of a particular capital variety can take place. The uniqueness of a design associated with a capital variety means that the capital variety produced is differentiated from other varieties, thus allowing for producers of capital variety to behave monopolistically in the their output market, linkage (6). In order to purchase a new design, households must save. Households must forego consumption by providing "venture capital" that results in the creation of a new firm. Once obtained, a property right to knowledge embodied therein is presumed to lie with the producer of the capital variety pertaining to this particular patent forever. Through this mechanism, monopolistic power is also held by the firm forever.

Given the rights to a new design, firms in the differentiated capital sector use, for purposes of tractability, an identical constant returns to scale (CRS) technology and employ final goods as factors of production to produce intermediate capital. Capital accumulation is the increase in the number of differentiated capital. Since there is one new firm per capital variety, one capital variety per new design, and since the number of designs are proportional to accumulated knowledge, the number of new firms increase over time, and at any point in time t, are proportional to M_t. When the number of designs increase, the number of capital varieties (indexed by s) also increase and, hence, capital accumulation occurs. Firms in this sector are presumed to have forward looking behavior; they make an investment decision to buy a new blueprint and produce capital variety so as to maximize the long-run expected returns from an infinite stream of monopoly revenues. A capital market non-arbitrage condition, linkage (3), requires in equilibrium that the value of a firm is equal to its aggregate investment expenditures, which include the cost of a new blueprint plus the cost of final goods employed in the production of a capital variety. The monopoly rents are the incentives necessary for households to forego consumption by providing "venture capital."

The final goods sector uses CRS technologies and rents the services of the primary factors L, and B, and the services of intermediate capital variety $k(s)$, where s denotes a particular variety. Two features of the technology should be noted. The first and most important of which is the employment of capital variety, the term:

$$\left(\int_0^M k_y(s)^\delta ds\right)^{1/\delta}, \quad 0 < \delta < 1 \tag{1}$$

Notice that this function is akin to a CES function in capital variety arguments $k(s)$, $s \in [0, M_t]$. Thus, the various varieties of capital are imperfect substitutes. The parameter of substitution δ effectively limits the power of the monopolist suppliers (linkage 6) to announce prices above marginal costs. This margin tends to fall as M rises, and reaches a constant value in long-run equilibrium, i.e., the steady state. Final good suppliers face competitive output markets, linkages (1, 2, 7). Note that the final goods sector and the R&D sector compete for the services of the primary resources.

Households own the primary factors and the equity of monopoly firms, make consumption expenditures E and save $\dot{a}$ to maximize an inter-temporal utility function subject to an inter-temporal budget constraint. Wealth accumulation occurs as the stock of differentiated capital grows, and as real rental rates W_L, W_B of primary factors rise[6].

[6]It is tempting at this point to constrast this model with the partial equilibrium framework of the induced innovation developed by Ahmed (1966) and applied and extended by Hayami and Ruttan (1971). In the Ahmed model, the Innovation Possibilities Frontier (IPC) is the culmination of the stock of knowlege at a point in time from which an invention (or technique) is produced. Bias in the direction of technological change occurs so as to save the relatively most scarse factor of production. The R&D model can, loosely speaking, be seen as endogenizing the IPC. However, the direction of technological change is Harrod neutral.

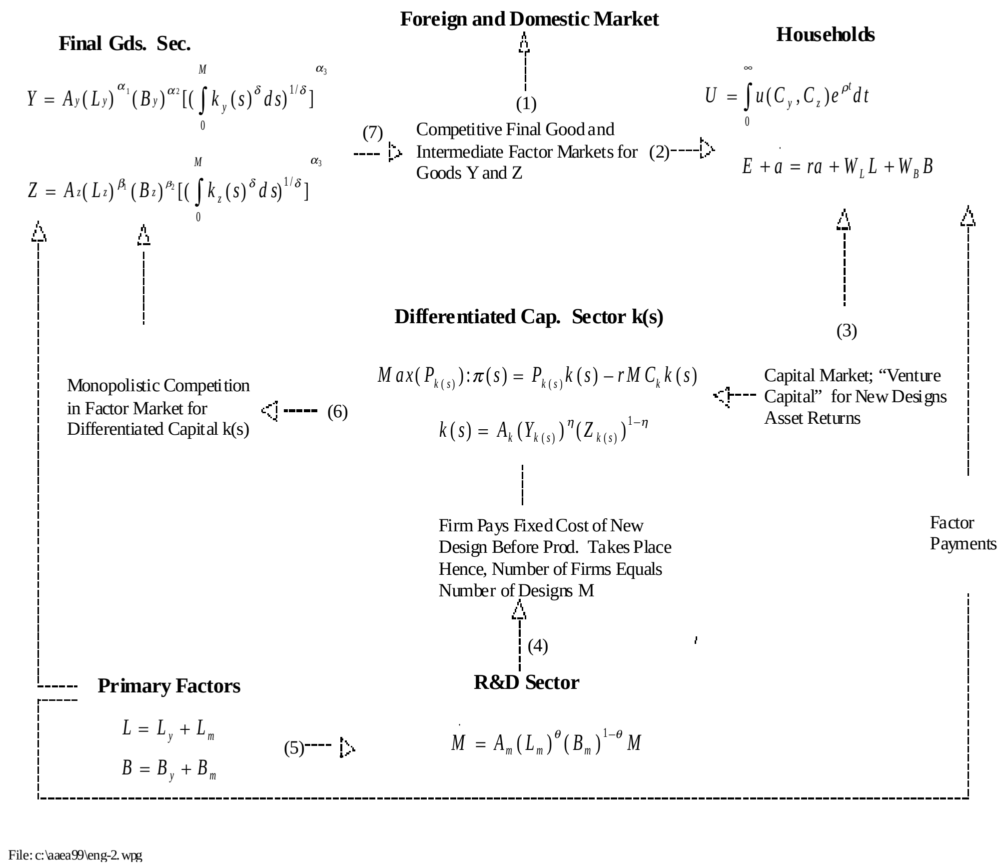


Figure 1: Basic Structure of the R&D Model of Growth

3.2 Key Overall Implications

It is useful to first consider the sources of growth, and then to focus on trade. First, economic growth in this model will not occur if, (a) households are unable to save, either because of preference structure or due to the non-existence of a capital market (linkage 3); (b), markets doe not exist for design or patent rights (linkage 4); or (c) firms producing differentiated capital are not permitted to earn monopoly profits (linkage 6). Whether or not these linkages do exist has a lot to do with the specificity of the institutions. Thus, implicitly, growth may be viewed as being “institution sensitive.”

Second, the two major market imperfections, the non-rival and only partially excludable nature of the stock of knowledge M, and the imperfectly competitive market for capital variety suggest that the market driven rate of economic growth is likely to be less than the rate of growth obtained by specifying the model as a central planner's problem. Thus, policy interventions can be Pareto superior to the functions of the market alone.

For the special case where $\alpha_3 = \delta$, it can be shown that the long-run *market driven* rate of economic growth is equal to

$$g = \frac{\alpha_3 \left(W_L L + W_B B\right) / P_m M - \rho}{\alpha_s + \sigma}$$

This equation shows that the market driven growth rate g increases with: the elasticity of inter temporal substitution in consumption $(1/\sigma)$, the value of endowment $\left(W_L L + W_B B\right) / P_m M$, and the share of differentiated capital in total output α_3, but decreases with the discount rate ρ. Several types of policy interventions can increase the market rate of economic growth g. First are those that correct the imperfections caused by the non-rival and partial excludability of common knowledge; second are those that correct for the market distorting effects of monopolistic competition; third are those that intervene in trade to alter the relative prices faced by producers of the final goods Y and Z. Thus, one possible instrument is an ad valorem cost subsidy to producers of R&D patents, linkage (5), another is an ad valorem rental price subsidy to the employers of differentiated capital, linkage (6), while another is trade policy, linkage (1).

An ad valorem cost subsidy to producers of R&D encourages them to bid primary resources away from the final goods sector. A subsidy to employers of differentiated capital increases the derived demand for $k(s)$, thereby providing incentives to bid up the price of new designs $\dot{M}$ which in turn stimulates their production. Since primary factor rental rates W_L and W_B, and the price of designs P_m are functions of world prices (which are exogenous due to the small country assumption), trade policy alone can affect the rate of growth of the economy through Stopler-Samuelson *like* effects.

Suppose, for example, that Y is an import competing good which uses labor L_y intensively, and that the R&D sector also uses labor L_m intensively. An increase in the international price of the Y good causes the labor rental rate W_L to rise relative the rental rate of the other primary factor B. Labor is attracted toward the production of Y and away from the producers of Z. While the derived demand for factor variety $k_y(s)$ in sector Y rises, the derived demand for capital variety employed in the production of Z falls, leaving the net change in factor demand indeterminate, but likely small. The rise in the rental rate of labor to the R&D sector increases its labor cost so that, in the new equilibrium, the production of new designs $\dot{M}$ falls even though the price of designs P_m may rise. The rate of economic growth g, savings $\dot{a}$, and welfare fall. Suppose instead, that an advalorum negative tariff is put in place to subsidize imports of the Y good. Then, the story unfolds in reverse "order," as g rises. Thus, by distorting the relative price faced by final good producers, welfare can rise.

3.3 Key Trade Implications

The general implications of the R&D model to trade and growth are particularly sensitive to the institutional structure the framework takes as given, a strength which we feel others often neglect to mention[7]. These institutional parameters relate to points (a) to (c) of the previous section. Institutional structures and technological developments (such as the emergence of practical biotechnology protocols for creating genetically modified plant varieties) that serve to strengthen incentives to forego consumption, linkage (3), including access to foreign savings will tend to stimulate growth. Another institutional parameter is the provision of property rights to new designs (whether mechanical, biological, or chemical), linkage (4), and policy to control monopolistic behavior, linkage (6), which is necessary to provide incentives to produce differentiated capital that maximizes the discount income stream of future designs[8]. Another "institutional" factor relates to the R&D technology, and the human capital and institutional capital implicitly required to make R&D output $\dot{M}$ contribute to the stock of technical knowledge M, and to make this stock of knowledge common. All of these factors appear to be playing a major role in the second wave of world globalization.

While these are some of the institutional implications of the framework,

[7] This appears to be one of the main points of departure seen by Ruttan (1998) between the new growth theory and development economics.

[8] The bio-technology area is an interesting case in this regard. Is the gap between the prices and marginal production costs of the new genetically modified plants in excess of that necessary to maximize social welfare from a production stream of future genetially modified varieties? Is the partial excludability to new designs that patent law provides of the approximate the time limit to maximizes benefits from future streams of new designs? Should this dimension of patent law vary by type of invention? Should these laws be harmonized across countries where, due to income differences, households are at different points on the surface of their non-homothetic preference functions?

how institutional changes come about are obviously outside of the framework. As Ruttan (1998, p22) notes in citing Nelson and Pack (1997), "Answers to more fundamental questions, such as why some countries save and invest more than others, why some countries invest a larger share of GNP on education or on R&D, why some countries were able to put the package of high pay-off inputs together more effectively than others, or why some countries have responded to shocks more effectively than other countries remain beyond the reach of models employed by both the neoclassical and the new growth economists."

The R&D framework makes clear that factor endowments, at least as defined in static neo-classical trade theory, are not necessarily the source of a country's comparative advantage. From the structure of the model, trade in

1. final goods (Y, Z)
2. differentiated capital $k(s)$
3. new designs $\dot{M}$, and
4. international access to the pool of technical knowledge M

now has important implications to trade patterns and growth. Taylor (1996) lists four separate effects through which "openness" to international markets in goods (Y, Z), knowledge M, and factors $k(s)$ can affect a nations trade pattern and growth rate. These effects are (a) scale (b) allocation, (c) spillovers, and (d) reduncency effects. Scale effects come about from integrating the flows of knowledge, goods and factors. Allocation effects are induced by trade which alters relative commodity prices and, through the Stopler-Samuelson like effects mentioned above, R&D activity.

Embodied in the importation of the final goods (Y, Z) is the capital variety, equation (1), embodied in the capital variety are the designs and technological knowledge M. This information can, in principle, be deciphered without incurring the cost of obtaining a patent by the importing country. The result is a positive externality, or technological spillover, from the exporting to the importing country. In either of these cases, policies that encourage openness in trade can have strong effects on growth and specialization.

GH (1991) show that when countries share a common pool of technical knowledge M, a national advantage in the research lab can derive only form differences in factor costs. Then, all else constant (including institutional structures) long-run patterns of specialization and trade are determined solely by countries' relative factor endowments, much as in the static theory of comparative advantage. If instead accumulated knowledge bears some of the characteristics of a local public good, then, initial conditions (e.g. prior experience, stock of technical knowledge, institutions) can influence the allocation of resources to research activities, and ultimately a country's trade pattern and growth rate relative to other countries.

In this case, all else the same, which ever country begins with a greater stock of knowledge capital enjoys an initial advantage in the research activities. GH show that the steady state equilibrium is characterized by concentration of research activity in one country. Since the market determined rate of growth is not likely to be socially optimal, it is possible for the "lagging country" to catch up by interventions to increase its stock of technical knowledge, such as the previously mentioned ad valorem cost subsidy to producers of R&D patents, linkage (5), and/or an ad valorem rental price subsidy to the employers of differentiated capital, linkage (6). Interestingly, to catch up, these interventions do not have to be carried out in perpetuity. As GH mention, this is a case of policy *hysteresis*, i.e., a temporary policy can have permanent effects.

Intermediate to a country producing its own stock of technical knowledge and having access to a world stock of knowledge is to infer or otherwise obtain access to the stock of technical knowledge of another country through foreign trade in final or intermediate factors of production $k(s)$ that embody this knowledge. To accomplish this, a country may need to distort its trade regime to encourage imports from the leading country, i.e., a country whose exports of differentiated capital embody a relatively high proportion of R&D expenditures. The gains from acquiring the technological spillover will need to exceed the dead-weight losses from distorted trade. The process of cumulative own technical knowledge depends on the growth in technological knowledge of the leading country, and own country technical sophistication and capacity in transmitting foreign R&D knowledge into the domestic economy. In this case, policies which stimulate own R&D activities and policies to stimulate knowledge spillovers from foreign R&D may be complementary in the sense that one makes the other more effective. This aspect has been referred to as learning to learn as distinguished from learning by doing.

Since knowledge is a non-rival good, redundancy wastes resources. Trade policy can lower the originality of research and thus save resources. Trade policies that eliminate competition in intermediate goods can create redundancy in R&D activities and hence lower growth. Trade in goods provides an economic incentive to eliminate duplication and competitive forces push resources out of redundant R&D activities.

The over-riding implication of this discussion is the point emphasized by Romer (1992, p.86) "..we must recognize that ideas are economic goods which are unlike conventional private goods and that markets are inherently less successful at producing and transmitting ideas than they are with private goods." The two safe policy implications, particularly for developing countries, is that integration with world markets offers large potential gains, and policies to increase savings and schooling are likely to complement the gains from openness.

Without actually specifying a model with some sectoral detail, and fitting it to a country(s) data, the above qualitative predictions are of limited use. It is not clear for example, which of the three mentioned interventions will provide the greatest net social benefit. For this, we turn to the next section.

4 Empirical Applications of the R&D Model

The empirical results of three R and GH based structural models are discussed in this section. The first two are models calibrated to country level data by Diao and Roe (1997) for the case of the US and Diao et al (forthcoming) for the case of Japan[9]. The third is a North - South model developed by Datta and Mohtadi (1999). The empirical models have the essentially the same structure as depicted in Figure I, except for modifications stipulated by data, such as two way trade, and considerably more sectoral detail. The model of Japan differs from the US model by taking into account technological spillovers from international trade. These studies provide quantitative insights into the affects of policy on growth rates and trade.

4.1 The R&D Growth Model of the US Economy

The US model contains four final good sectors, agriculture and food processing, mineral and materials, manufacturing, and services. Each sector

[9] For model details, calibration and other issues, the reader is referred to the mentioned references.

produces a single output using inputs of two non-augmented factors (L, B) a set of differentiated capital $k(s)$ which accumulates, and a set of other intermediate goods. Since bi-directional sectoral trade is observed in the data, exports of each domestically produced good are derived from a constant elasticity of transformation function, while the demand for domestic goods are treated as imperfect substitutes for foreign goods through an Armington system. The model is specified in discrete time and solved using GAMS software. The transitional dynamics are obtained over an interval of 200 years, with equilibria spaced one year apart.

As the discussion in Section 3 indicates, the results obtained will be sensitive to relative factor intensities in production, and the extent to which domestic prices are affected by trade policy. The data for the US suggest that the R&D sector, in terms of the quantity of quality adjusted labor, is relatively labor intensive. Agriculture is relatively capital intensive, while manufacturing, in contrast to agriculture, is labor intensive. Data on US foreign trade reveal a tariff rate of 19 percent for agriculture, and zero for services. The experiments performed entailed the imposition of tariffs, (Figure 1, linkage 1), an input subsidy to producers of new designs (linkage 5), and an input subsidy on the purchase of intermediate capital variety (linkage 6).

Key results are reported in Table 1. They are reported relative to a benchmark, or base run path. Hence, transition results for year 1 are compared to transition results for year 1 of the base run, and steady state results are compared to the corresponding year of the steady state results of the base run.

The first important result is that trade policy yields predictions of the simpler analytical model, but the effect on growth is very small. Protecting US agriculture, a relatively capital intensive sector, results in Stopler-Samuelson like effects, i.e., the cost of labor falls which lowers the cost of R&D activity, resulting in an increase in R&D output, an increase in the production of differentiated capital, and an increase in the rate of GDP growth in the steady state. Notice however, that the rate of GDP growth is only 0.05 percent higher in the steady state than in the base run's steady state. Since this result might obtain because agriculture employs a small share of US labor, an experiment in which the manufacturing sector is protected is performed.

Protecting the manufacturing sector, which is labor intensive relative to agriculture, we again obtain the result predicted by the simpler analytical model, i.e, the rate of steady state growth falls. However, the decline is small, only 0.08 percent. Nevertheless, a significant result is that protecting agriculture causes agricultural output to increase by over 4 percent, and in the long-run, the level of real US GDP is higher than GDP of the base run's long-run equilibrium by about 0.11 percent.

Table 1: Selected Results From An R&D Based Growth Model Of The U.S.

	Percent Change Relative to the Base Run					
	GDP Level	Agr. Output	Mat. Output	Mnfc. Output	Serv. Output	GDP Grth
30% Ag. Tariff						
Year 1	-0.1103	4.2063	-0.4812	-1.5872	-0.0232	
St. State	0.1071	4.4080	-0.2761	-1.3655	0.1803	0.05
30% Mnfc. Tariff						
Year 1	-0.7582	-2.8648	-3.1700	1.114	0.0149	
St. State	-3.0506	-5.7302	-4.8606	3.3403	-2.4179	-0.08
10% R&D Sub.						
Year 1	0.1134	-1.8474	-1.3545	0.7241	-1.785	
St. State	68.100	65.2400	65.2200	65.8800	65.0111	11.82
10% $k(s)$ Sub.						
Yeare 1	0.1503	-2.1175	-1.3074	1.7510	-1.9390	
St. State	75.3300	71.5200	72.5900	76.9600	71.6900	11.79

Source: Diao and Roe, 1997

The remaining two experiments entail a 10 percent advalorem subsidy to the costs of R&D production, and an advalorem subsidy to the purchasers of differentiated capital. A lump-sum household income tax is imposed simultaneously to assure that the budget for these transactions are balanced. In the case of the R&D subsidy, the lump-sum tax is equivalent to 1.3 percent of total household income. The subsidy to buyers of differentiated capital equals 2.7 percent of household income. The basic results from these two experiments are that relatively large welfare and gains in the rate of growth are obtained. In the steady state, US GDP grows at a rate that is almost 12 percent higher than that of the Base Run.

The mechanics of adjustment to the R&D subsidy are as follows. A reduction in R&D costs induces a decline in the market price of new designs as production of new designs rise. This decline provides incentives for households to advance venture capital so that new monopolistically compeititive firms can enter the capital production sector. Initially, the output of all sectors except manufacturing fall because households, seeing a new opportunity to invest, forego consumption of final goods, while at the same time the subsidy allows the R&D sector to bid some primary resources away from final good production. The output of manufacturing rises because the technology for producing differentiated capital uses manufactures intensively. Monopoly profits per firm fall along the entire transition path as the result of a decline in the demand for each variety and the increase in the number of varieties of capital. The increase in the number of capital varieties exceeds the fall in profits per firm however, so that the sum of monopoly profits of all firms in the capital variety sector increase. An increase in the accumulation of differentiated capital along the transition path is required to "compensate" the final goods sectors' "loss" of the primary resources that are initially reallocated to R&D production.

From the perspective of households, changes in their consumption and savings reflects the outcome of inter temporal decision over the entire path. Household savings rise throughout the time path, while household consumption falls in the first year and then rises along the transition path. Consumption does not exceed consumption levels of the base run until period 21. In the long run, the pool of common knowledge M grows. Concomitant with the increase in the production of new designs and capital variety, is the employment of a larger share of the economy's primary resources in the production of R&D. The production of a larger number differentiated capital substitutes for primary resources in final production. Since trade in this model must be balanced, both exports and imports grow.

While the results of an advalorem subsidy to purchasers of capital variety, linkage (6), are similar to the R&D subsidy, the mechanics of adjustment are quite different. The initial direct beneficiaries of the subsidy in this case are producers of final goods. The subsidy induces them to increase capital demand. The monopoly price for capital is a mark-up price chosen by the monopoly firms based on the marginal cost of capital production, and the interest rate. The increase in capital demand causes the interest rate to rise, which in turn induces producers of differentiated capital to respond by raising the price of capital they lease to final good producers. Given the subsidy to final good producers, the market for differentiated capital clears at a higher price to producers of differentiated capital and a lower price to employers of differentiated capital (because of the subsidy - price wedge). The rise in monopoly profits to holders of new designs induces an increase in forgone consumption and investment in new designs rise. The increased investment demand bids up the price of new designs and the allocation of more resources to R&D production. As in the case of the R&D subsidy, the initial increase in foregone consumption and the increase in primary resource demand by the R&D sector causes the output of agriculture, minerals and materials and the service sector to decline. Manufacturing output tends to rise since the production of differentiated capital uses manufacturing output intensively. As new designs are produced and differentiated capital rises, the output of all sectors rise. In the steady-state, GDP is 75 percent higher than the corresponding benchmark and the long-run growth of the economy is increased by almost 12 percent.

4.2 The R&D Growth Model of the Japanese Economy

The model of Japan is specified so as to capture more of the features of the mentioned second wave of world globalization. The country's trade partners are aggregated into three separate countries/regions: the US, the EU, and the rest of the world (ROW). Final production is aggregated into seven sectors: agriculture and minerals, intermediate materials, textiles, transportation equipment, other machinery, other manufacturing, and services. Each sector produces a single output using three primary factors, labor (L), scientists/engineers (G), a non-human resource (B) , a set of differentiated capital, and other intermediates. Trade occurs in final products while factors of production are only traded internally. To conduct R&D, monopoly firms need to employ the three primary factors, while the production of new varieties of capital require all seven final outputs as intermediate factors. Thus, relative to the US study, the R&D sector is "integrated" into the monopoly sector producing differentiated capital, and the model contains more sector detailed. To this point its basic structure remains the same as that of Figure 1.

However, at this point a departure is made. Based on the econometric findings of, Coe et al, (1997), and Wang and Xu, (1997), which we discuss briefly later, cross-border spillovers from trade with the US, the EU and the ROW are assumed to be generated through the imports of investment goods. These spillovers are modeled to further augment the productivity of the domestic R&D activity. This specification allows us to link specific countries' technological knowledge with domestic R&D activities. While international trade is considered as a "carrier" for transmitting the spillovers, the existence of a well established system of domestic R&D activities determines the "absorptive capacity" of the country to realize such technological spillovers.

More formally, the scale parameter A_m of the R&D production function

$$\dot{M} = A_m L_m^{\theta_1} G_m^{\theta_2} B_m^{\theta_3} M, \quad \sum_i \theta_i = 1$$

is expressed as a function of cross border spillovers as follows

$$A_m = \left(1 + \xi \sum_r \omega_r M_r\right) \bar{A}_m$$

The technology is factor intensive in scientists and engineers (G). The weight ω_r is the share of Japan's investment good imports from country $r = US$, *EU*, *ROW*, and M_r is the stock of R&D in country/region r. ξ is a coefficient chosen such that the benchmark value of $(1 + \xi \sum_r \omega_r M_r)$ is comparable with the ratio of estimated total factor productivity elasticities with respect to foreign R&D stock and own R&D stock for the seven largest OECD countries in Coe et al, 1997. Since the efficiency of producing new designs is now affected by Stopler-Samuelson like effects as well as the technological knowledge embodied in imports intermediate capital, trade policy will have a greater impact than it did in the case of the US study. Note also that this is a "learning to learn" structure. As A_m increases, more $\dot{M}$ is produced and the country's stock of technical knowledge rises which, in turn, lowers the cost of producing future contributions to knowledge.

The model is fit to GTAP 1992 data which is further augmented by data from other sources (e.g., R&D expenditures, occupational shares of professional personnel, growth rate of GDP). The analysis entailed testing the sensitivity of the results to various parameters including ξ in the above equation. Tariff rates protecting the three manufacturing sectors are very low (ranging from 1 - 3 percent). The tariff plus non-tariff equivalent for the case of agriculture varies depending on the source of imports. Protection from US agricultural imports averages 106 percent and 82 percent for the case of EU agricultural imports. Thus, reform is largely agricultural trade liberalization.

The major findings are that trade policy affects long-run growth mainly through its effects on cross-border technological spillovers. The Stopler-Samuelson (SS) effects are strongest when the trade policy increases the demand for scientists and engineers in other sectors thus pulling them from the R&D sector. Still, the SS effects on growth through change in domestic R&D activity are quite small in the absence of spillovers. In the presence of spillovers, a strategic trade policy that biases trade toward the import of investment goods allows the country to take greater advantage of foreign R&D, and hence, leads to higher welfare gains in the longer-run.

Consider first the full trade liberalization experiment without international spillovers, i.e. $\xi = 0$. Liberalization means increasing the relative prices of transportation equipment and other machinery, both of which are relatively intensive users of scientists and engineers (G). While one effect is to increase the derived demand for differentiated capital, the net result is to pull these resources, namely G, away from R&D activities. Since this primary resource is inelastically supplied, R&D costs rise and monopoly profits of capital producers fall. Nevertheless, the net effect on growth is relatively small because, as in the case of the US model, the SS effects are small (Table 2).

Next, consider the case where spillover effects from trade are positive $\xi > 0$. With the high elasticity specification, the rate of growth falls throughout the transitional path, and falls to 2.72 percent in the new steady state in contrast to the 2.85 percent long-run benchmark (Table 2). The cause for this decline is the decline in the share of investment good imports (since the country is now supplies a greater proportion of its own needs), or effectiviely, a decline in the importation of knowledge capital embodied in these imports. Under the full liberalization scenario, investment goods import shares from the US and the EU fall by about 10 percent. Thus, the acceleration of domestic R&D productivity slows down, and so does the rate of long-run growth.

To further illustrate this adjustment, an experiment is performed in which a 30 percent ad valorem tariff is placed on the three manufacturing sectors, while agriculture is liberalized. The result is a sharp decline in growth which comes about due to the decrease in the production of new designs and a slowing of the growth in the stock of technical knowledge. That is, a decrease in the rate of "learning to learn" and from an increase in the sectoral competition for scientists and engineers in manufacturing sectors of the economy.

The effect of ad valorem cost subsidies to producers of new designs, and differentiated capital subsidies to final goods producers are also analyzed. As in the US case, R&D subsidies induce a relatiely large reallocation of primary resources. Initially, the three primary resources employed by the

R&D sector increase by 8 to 10 percent. Thereafter, the rate of growth of inputs demand by the R&D sector falls along the transition path. When the R&D production cost is reduced by the subsidy, the stream of monopoly rents from the property rights to new designs rise, which in turn induces households to forego consumption and invest in new monopoly firms. While R&D output rises quickly, time is required for differentiated capital to accumulate to "compensate" for the final goods sectors' initial loss of primary resources. Consequently, the outputs of all final goods fall in the first few years following the subsidy. In the long-run, increases in the R&D output enlarges the pool of domestic technical knowledge, and the outputs of new designs rises steadily along the transition path to the steady state.

Concomitant with this rise is the increase in the numbers of capital variety. Employment of larger capital variety in final good production in turn increases the productivity of primary resources in the final goods sector in a Hick's neutral manner. Thus, in contrast to the benchmark, outputs of all sectors increase after several years, and continue to do so through the steady state. Subsidizing R&D activity also stimulates cross-border R&D spillovers by increasing the share of investment good imports along the transition path. However, in the long-run, the effects are quite modest. The reason is that, when more resources are absorbed by the domestic R&D activity, the production of final outputs falls initially, and the increase in investment demand is met by an increase in imports, making technological spill overs fairly significant in the initial periods of transition. However, as the number of capital varieties increase, domestic production of investment goods rise and import demand falls. This fall in import demand lowers technological spill overs. Consequently, the evolution of the cross-border spill overs are not uniform over time, and, interestingly, their effects on the long-run growth rate are marginal. The discounted present value of welfare gains of course are higher with spillovers than without.

The final experiment entails the subsidizing of differentiated capital employed by final good producers. The mechanism of adjustment is similar to that discussed for the US model. In this case however, the increase in final good output occurs more quickly than with the R&D subsidy, which in turn, lowers the rate of international spillovers. However, the long-run rate of growth is virtually the same as the R&D subsidy.

Table 2. Long-Term Growth Rate Under Various Policy
Policy Experiments, Japan

	Growth Rate of GDP (%)		
	Without	Spillover With	
	Spillovers	High Elast.	Low Elast.
Benchmark	2.850	2.850	2.850
Full Trade Lib.	2.830	2.723	2.800
30% Tariff on Mnfc.	2.830	1.884	2.549
5% R&D Subsidy	3.033	3.034	3.033
5% $k(s)$ Sub.	3.033	3.034	3.033

Source: Diao et al, table 2

To summarize, the major findings are that disprotecing the machinery and other manufacturing sector encourages the spillover of knowledge embodied in intermediate capital imports and it tends to release scientists and engineers to R&D activities. Interestingly, Japan's protection of agriculture amounts to an implicit tax on other sectors of her economy so that, implicitly, Japan has pursued such a policy[10]. However, other domestic interventions which encourage growth in the production of domestic technical knowledge remains a major policy to raise the rate of economic growth. At a benchmark growth rate of 2.85 percent per annum, Japan will double its income in about 24.3 years. The R&D subsidy will allow it to double its income in about 22.85 years. The 30% tariff to protect manufacturing yields a growth rate requiring 36.79 years to double income. This range suggests that Japanese policy, at least up to the current financial crisis, has been fairly effective at encouraging growth and that "good performance" can be undone by "bad" policy.

4.3 North and South Trade and Growth

Keeping in mind the characteristics of the second wave of globalization mentioned in the introduction, we report on the empirical results of North-South trade and growth obtained by Datta and Mohtadi (1999) using an R&D

[10] This policy is the reverse of the policies pursued by countries included in the Kruger, Schiff and Valdez synthesis. There, major emphasis was placed on the effects of import substitution - industrialization on agriculture. The effects of these policies on growth may have been equally devistating.

based model of North - South trade and growth. The model is similar to the structure depicted in Figure I.

When countries are symmetric in their technical know-how and human capital endowments, it is relatively easy to extend R and GH to a symmetric world and thus generalize from innovation in one country to innovation in many, as in Rivera-Batiz and Romer's (1991 a, b) North-North models. But when knowledge is transferred from the North to the South, the symmetry breaks down because the North innovates but the South imitates (Grossman and Helpman 1991a, b; Helpman 1993). In the absence of this apparent symmetry between the North and the South, it is necessary to capture the microeconomic specificity of the "mechanism" of technology transfer.

The overall empirical result is that the process of innovation and imitation can lead to gains from trade on *both* sides. While innovation drives growth in the North, trade helps to facilitate the innovation process further. This happens because, as the North buys manufactured goods from the South it releases some human capital from final good production, which is then employed in research, thereby leading to higher innovation. On the other hand imitation cuts down on the time and cost of product development in the South thereby leading to higher growth. Thus, trade is found to affect productivity in the following ways: (a) new 'technologically superior' imported intermediate goods complement and enhance the productivity of domestic resources, (b) trade facilitates imitation of foreign technology and its adaptation for domestic use, and (c) trade raises productivity of 'innovation' and 'imitation'.

4.4 Framework and Results

The broad outline of this mechanism is one of " reverse engineering" through which the South imitates Northern technology using an R&D type mechanism as in Figure 1, with exceptions to be noted later. "New knowledge" is embodied in the technology intensive capital goods $k(s)$ produced by the advanced North. The Southern country imports these products and later uses "reverse engineering" to create clones. The learning that takes place under this process leads to the accumulation of a new kind of knowledge i.e. "imitation knowledge", which raises the productivity of the southern country.

The North has a comparative advantage in research and development (R&D) and therefore is the region that innovates. We assume that the South does not innovate, as it is cheaper for the South to imitate, given its low productivity in innovation activity[11].

Both regions are characterized by sectors appearing in Figure 1. The research sector in the North produces designs for new intermediate goods with the help of human capital and the existing stock of knowledge M. Innovation is captured through expanding intermediate product variety $k(s)$ in the North which is then used to produce domestic final goods and exported to the South.. Imitation represents the stylized facts of a southern country that lacks the resources to invest in the minimum efficient scale to conduct basic R&D, but has a small pool of human capital with a capacity to emulate Northern technologies.

Due to its relative disadvantage in conducting basic research, the Southern country imports technology intensive intermediate goods $k(s)$ from the North, e.g., a 'new' generation of computers. The imitation sector then employs the stock of human capital in the South to undertake 'reverse engineering' to unravel the technology embodied in the Northern good, and thus create new 'imitated designs' $\dot{I}$. These designs are then used by the intermediate goods producers to produce clones $k^{South}(s)$. Finally, the manufacturing sector, which unlike the North is assumed to be labor-intensive, buys the southern intermediate goods and combines it with unskilled labor to produce final goods in the South. This assumption is consistent with the structure of trade mentioned by Helpman (1999) and Bladwin and Martin (1999). and follows from the fact that the South is human capital scarce. The manufacturing sector in the South sells a part of its output domestically and exports the rest to the North, thus closing the model. As in the North, imitation must take place before intermediate capital variety can be produced. The equivalent of the North's R&D production function is the imitation function

$$\dot{I} = \delta H_s^{\mu} k_n^{1-\mu}(s) I$$

where H_s is labor allocated to reveres engineer intermediate capital imports $k_n(s)$ from the North given the stock of imitation knowledge I. Thus, given $\dot{I}$, producers of $k^{South}(s)$ are also presumed to be monopolistically competitive, thereby generating a rent stream to remunerate the consumption foregone

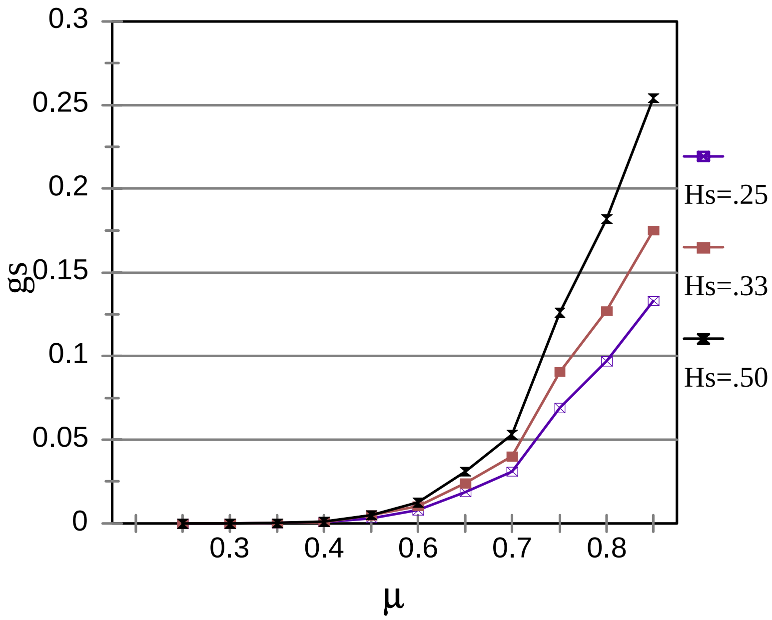
[11] Connolly models the case where the South also innovates. He likens this case to Advanced Micro Devices, Inc. and Samsung which first reversed engineered and cloned Intel's 386 and 486 chips in the 80's and early 90's, but have since begun producing their own microprocessor chips, first the K5 and now the K6.

to cover the cost of obtaining patent rights to the imitated new design. As Grossman and Helpman (1991c) point out, imitation by the southern country is profitable under certain conditions: First, the enforcement of patent rights should be not too strict to make imitation prohibitively expensive; Second, manufacturing costs in the imitating country must be sufficiently low to allow the imitator to capture market share by underpricing the original inventor.

An additional assumption is that $k^{South}(s)$ is not re-exported to the North. This is true of many developing countries with large domestic markets like India and Brazil. What explains this behavior? Imitation generally occurs with a lag. As the 'quality ladders' model of Grossman and Helpman (1991b) suggests, by the time southern producers successfully imitate and start producing the clones, northern consumers could have moved to newer upgrades of the product. This is especially true in the market for computers, where a newer generation of computers often makes the older varieties obsolete. Moreover copying, in developing countries, of many products such as pharmaceuticals, represents infringement of intellectual property rights, which makes sale in other markets illegal. Finally, the cost of entry into the northern market, such as the cost of advertising, often poses a significant barrier to southern firms.

Given the implicit nature of the solution to our system, simulations were performed to provide insights into the model's sensitivity to important relationships. Figure 2 shows the relationship between the coefficient, μ, of human capital in the South, and growth rate, g_s, in the South, for different levels of human capital employed in imitation H_s. The graph shows a positive relationship between μ and g_s. However this effect is scale sensitive as it becomes significant for values of $\mu > 0.5$.

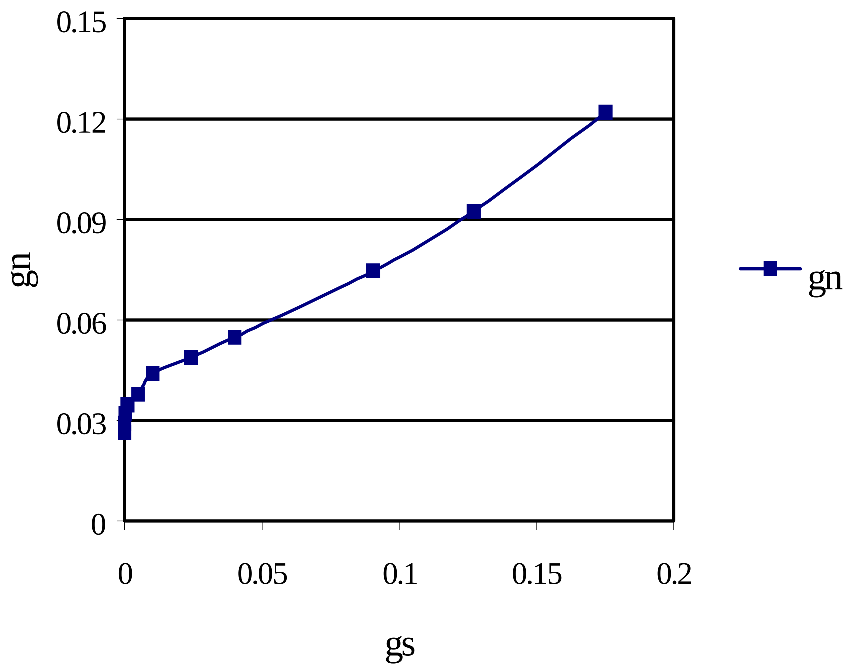
Figure 2



Relationship Between Growth and Labor Intensity

Finally and most significantly, the study shows a positive relationship between growth in the North and the South. Figure 3 indicates this relationship. From Figure 2, we have learned that an increasing share of human capital in the imitation sector leads to higher growth in the South. Figure 3, further suggests that higher southern growth also implies a higher growth in the North.. This confirms, perhaps surprisingly, that a positive feedback relationship exists between the processes of innovation and imitation, as is seen in the imitation model of Grossman and Helpman (Ch. 11, 1991c).

Figure 3



Relationship Between Growth in the North and Growth in the South

Effectively, trade allows for the specialization of division of labor in North innovation and South imitation. Consequently, the *North grows more rapidly than under autarchy.* For the North, trade with the South releases human capital from the manufacturing sector (i.e., Baldwin and Martin's de-industrialization of the North from labor intensive manufactures), which can be allocated to greater research activity, thereby leading to higher growth. A result that seems supported by casual observation that for example in the U.S. one of the largest contributing factors to economic growth over the past several years, until the recent slowdown, came from increasing exports of the innovation-intensive sectors of the U.S. economy (e.g., the computer industry) to those regions of the world with the greatest imitation potential, (i.e., Baldwin and Martin's re-industrialization of the South in labor intensive manufactures).

We also find that the process of imitation cuts down the time and cost of product development for the South, thereby leading to higher growth, as one would expect. Of course, import substitution policies in the South drastically reduce its rate of growth. An interesting result from the solution of balanced growth for the North is that growth in the North is sensitive to the returns to human capital in the imitation process. As long as the returns to human capital in the South, is less than one, which holds under the assumption of constant returns to scale, a higher δ is associated with higher growth in the North. An interesting question that may be asked then is, what happens if the South enjoys increasing returns to human capital in its imitation activity. Although the present work does not answer this question, it has been noted by Grossman and Helpman (1991c) that trade can lead to a fall in the innovation rate in the human-capital rich North as the efficiency of imitation in the South goes up.

5 Econometric and Sector Based Studies

The above three studies are structural models calibrated to data. As such, they have a normative or "make believe" feature. In this section, we briefly review results from econometric models which lack these structural features but nevertheless shed light on growth trade linkages.

The econometric studies of the new growth theory relate to the question of R&D and growth. Because most of these studies take a cross-country time series approach, the question of growth quickly entails international comparisons of growth rates and overlaps with both the convergence of growth rates and debate on the presence and source of technological spillovers[12]. At the heart of all this is of course is the role of international trade since it is through trade, or at least so argued, that much of new knowledge seems to be transmitted. Our overview of this literature first pertains to the broader economy. Then, since agriculture is rather unique, we provide a brief overview of the evidence on the sources of growth in agriculture's factor productivity and evidence for convergence. These studies all find evidence that is at least consistent with various aspects of the R&D model.

[12] An overview and critque of many of these studies is provide by Temple (1999).

5.1 Broader Based Econometric Studies

As has been shown, the engine of growth is R&D which produces an accumulable, non-rival and only partially excludable good (knowledge). Thus the first empirical question is whether such effects can be detected as technological spillovers. At the sector or industry level, evidence for large spillover effects was found by Griliches (1992) both within industry and agriculture. In manufactures, Bernstein and Nadiri (1988) also find that not only do own R&D expenditures lower own costs of production, they also spillover to lower the cost of production in other "related" industries. Gopinath and Roe (forthcoming) find strong evidence for technological spillovers between R&D investments in primary agriculture and cost reductions in food processing, and smaller technological spillovers between the category farm machinery and equipment, and agriculture.

At the economy-wide level, Fagerberg, 1988 finds for OECD that investment in R&D affects own country growth rates while Litchenberg, (1993) for 74 countries, finds that own R&D expenditures also affect the growth rates of other countries. On the latter point, support for international R&D spillovers among 21 OECD countries plus Israil is found by Coe and Helpman, (1995). They find that the rate of return on own R&D is not only high in the performing countries, but that significant benefits also accrue to their trade partners. They further argue that the cross-border spillover effects are stronger the more open an economy is in its trade with countries having high levels of R&D capital stock.

Along similar lines of query, a panel study of OECD by Park (1995) found that public sector expenditures do have stronger indirect effects on private R&D through generating cross-border spillovers into research. Wang and Xu (1997) continue this thrust but instead of using total imports as carriers of foreign technological knowledge, they focus on capital goods imports. They find strong spillover effects among trading patterns to be higher the higher is the proportion of exporting country R&D in capital good imports. Extending their earlier work Coe, Helpman and Hoffmaister (1997) investigate the extent of the international spillovers of R&D from the industrial North to the less developed South. Their data suggest that the North accounts for about 92 percent of total world R&D expenditures. Based on data for 77 developing countries, they found evidence that R&D spillovers from the North to the South are substantial and that "a developing country's total factor productivity is larger the lareger is its foreign R&D capital stock, the more open it is to machinery and equipment imports from the industrial countries, and the more educated is its labor force' (p. 135).

These studies lend strong support to the notion that a country's stock of knowledge M is not costlessly accessible by other countries and that trade is a major vehicle of obtaining access to it. As the cost of maintaining access to and trading in ideas falls, growth should accelerate. Is this the phenomena we are experiencing in the second wave of globalization? In fact trade or its absence should explain why some countries converge to a common level of per capita income while others do not. This debate largely began with the simple cross-sectional regressions of Baumol (1986) who argued for international convergence. But, the debate soon graduated into more complex econometric studies including those of De Long (1988), Quah (1993), Bernard and Durlauf (1995), Bernard and Jones (1996) and Barro (1997). Most of these studies reached the conclusion that taken as a whole the world economies are either diverging or they are converging into variously grouped diverging convergence clubs. Connolly (1997), using panel data for DCs and LDCs, finds a significant relationship between high technology imports from DCs as a share of GDP and domestic innovation and imitation. Furthermore, such imports are far more important to LDCs than to DCs, concluding that trade appears to play an important role in technological diffusion and, in turn, conditional convergence, especially for developing countries. In a similar vane, Mohtadi and Datta (1998) adopt a time-series approach and find, for OECD countries, positive own R&D effects for most countries where convergence to the US (as a base country) prevails.

While this line of query is not without its critics, e.g., Jones (1995a), Temple's (1999) "reading of the literature" leads him to the conclusion that ".. poor countries are not catching up with the rich, ... the Solow-Swan model is almost certainly correct in assuming that returns to physical capital are diminishing, and ... policy can have a major impact on a country's level of welfare, and .. the welfare effects of changes in R&D expenditure can be large" (pp. 151-152).

5.2 Evidence From Agricultural Based Studies

As documented by Huffman and Evenson (1993), Alston, Norton and Pardey (1995), and Alston and Pardey (1996), much of the past research expenditures in agriculture have been of a public nature with most studies reporting annual rates of return well in excess of 30 percent per annum (Alston, et al 1999). While a number of studies have estimated the rate of growth in US agricultural total factor productivity (TFP) e.g., Ball et al, 1997, results from our own work are comparable and appear in Figure 4.

The height of the bars indicate the average annual rate of growth in primary agricultural TFP over the indicated period. The average over the entire 1948-91 period is about 2.3 percent per annum. Public and private R&D stock account for almost 70 percent of the growth in TFP on average over the period. Investment in public infrastructure was important during the earlier periods when rural electrification and the interstate highway system was being expanded. Improvements in the quality of material inputs (both quality and variety) contributed about 8 percent to TFP growth.

Insights into the extent to which the stock of technological knowledge pertaining to agriculture is accessible by others might be gleamed from evidence on technological spillovers, and convergence of agricultural TFP among nations. Applying a methodology similar to that of Bernstein and Nadiri, (1988), Gopinath and Roe (forthcoming) find strong evidence that the stock of technological knowledge pertaining to agriculture is accessible by others. Indirect evidence of possible cross-country spillover effects in agriculture, can also be gleamed from Park's (1995) panel study of OECD which found that public sector expenditures do have stronger indirect effects on private R&D through generating cross-border spillovers into research. Since much of agricultural R&D expenditure has been histrionically public, the possibility arises that agriculture may have been responsible for a large component of international R&D spillovers. Given the presence of the CGIAR system, and thus giving the world access to its stock of agricultural knowledge, it would be surprising if the growth in agricultural TFP among nations did not show evidence of convergence[13].

In fact, a recent paper by Martin and Mitra (1999) provides this result. They focus on growth in agricultural TFP and non-agricultural TFP based on data for fifty countries. They find growth in agricultural TFP to exceed that of the non-agricultural sector, as did Gopinath and Roe (1997) for the case of the US[14]. They then search for evidence of convergence by regressing the ratio of TFP of the i-th country to US TFP on country specific dummines and

[13]Of course, growth in the productivity of any factor employed in agriculture should vary across countries, as Craig et al (1997) find, and may not exhibit convergence since agriculture must compete for economy-wide resources with other sectors.

[14]In the R&D growth model discussed above, all sectors grow at the same rate.

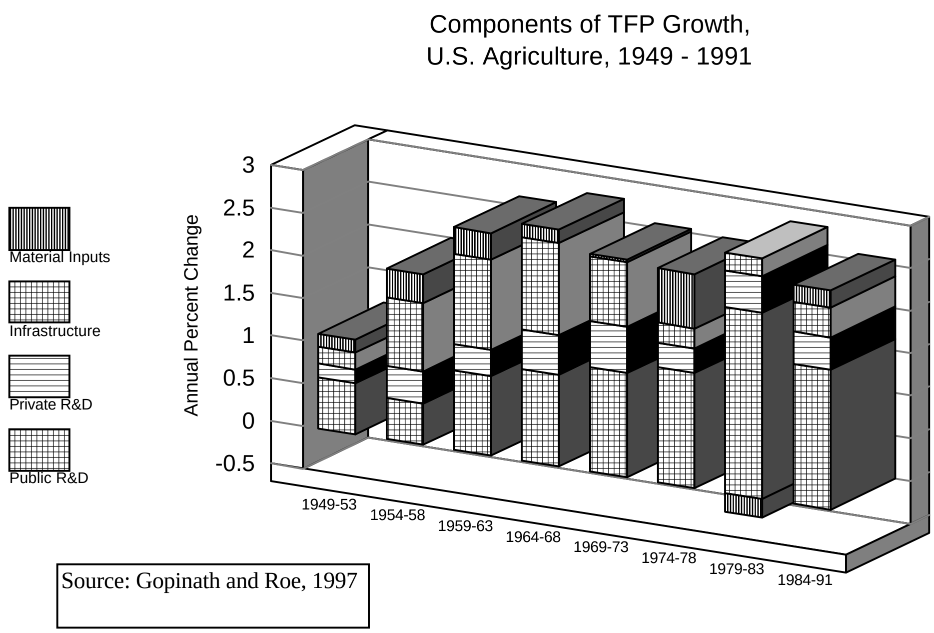
a common time trend. For the case of agriculture, they find a negative and highly significant time trend coefficient which suggests absolute convergence. The rate of convergence is about 10 percent per year. Thus, for the case of agriculture the stock of technical knowledge appears accessible to other countries, but the speed to which this knowledge causes a closing of the gap between advanced and less developed countries is relatively slow.

However, growth in real US public research expenditures in agriculture has declined from a five-year moving average of over 6 percent in the last half of the 1950s to virtually no growth in the mid 1990s, Alston and Pardey (1996), while the level of private US expenditures on agricultural R&D began to exceed the level of public expenditures in the mid 1970s (Moschini and Lapan, 1997). This trend towards increased privatizing is also occurring in other OECD countries, while the influence of nonfarm groups has tended to broaden the public research agenda to include conservation and environmental issues Alston and Pardey (1999).

Concomitant with the increase in private agricultural R&D expenditures in the US has been the emergence of practical biotechnology protocols for creating transgenic plants and the increased ability to protect intellectual property in plant innovations. Perhaps the most obvious area of rapid innovation as been the supplying improved plant varieties by the private sector. AgrEvo, Novartis, DuPont and Monsanto have been among the few leading firms to have introduced genetically modified (GM) seeds. Traxler et al (1999) report that a total of 51 GM articles[15], have been approved, or have approval pending as of May, 1999. They indicate that herbicide tolerance is the event that has received the most approvals with 20, followed by insect resistant varieties for cotton, soybeans and maize. The increased intellectual protection for sexually reproduced plants is provided by the Plant Variety Protection Act of 1970 in the form of "protection certificates." Although the certificates are not patents, the 1995 Supreme Court decision restricting the farmer's right to resell protected seeds grants certificates the status of utility patents (Fuglie et al). Other developments aimed at protecting biotechnology innovations started with the 1980 Supreme Court decision in Diamon v. Chakrabarty which was reinforced buy a 1985 Patent and Trademark Office ruling which essentially provide protection for genetically modified plans. The 1994 TRIPS agreement of the Uruguay Round of GATT helps to globalize protection.

[15] A unique gene-crop combination is referred to as an "article."

Empirical evidence on how patent protection is likely to affect the pattern of trade tends in patened goods tends to focus on whether strengthening intellectual property rights leads trade expansion because of the property rights provided by protection, or to trade contraction due to increased market power (Maskus and Penubarti, 1998). Smith (1999), using a gravity model framework, finds that weak patent rights in an importing country are a barrier to US exports, but only to countries that pose a strong threat of imitation. She finds that patent rights enhance market power of US exporters in countries where the threat of imitation is weak. Overall, she concludes that the magnitude of the US export response to stronger patent rights standards required under the WTO-TRIPs agreement is substantial.



6 Conclusions

The recurring theme of the new growth theories has lead to the focusing of attention on the role of new knowledge, how it is produced, how it accumulates, and how its impacts on growth. Globalization of capital markets, international trade, human capital and the decline in the costs of trade in ideas have been the primary vehicle for the diffusion of this knowledge. Both structural-empirical and econometric studies confirm the central role of R&D in the economy and the central role of trade in its diffusion. Trade also ties in the new growth theory with the convergence debate as it is the vehicle by which such convergence might materialize.

Trade in agriculture occupies a particularly fascinating role in all this. This is because advances in bio-technology have meant that in its second wave of globalization, agriculture has begun to evolve from its classic role as the primary commodity export that characterized it in the first wave, to an R&D based commodity Yet innovations in bio-technology are taking place in an increasingly privatized form, altering agriculture's historically publicly based of R&D pattern. What does this new and emerging picture imply for the pattern of trade in agriculture? Already trade in bio-technology-based agricultural products shows characteristics that are highly unusual for agriculture but more common in industry. For example, companies such as Monsanto disallow reseeding of bio-technology-based products upon exports, or else insert codes for non-regeneration into the product genes. At the dawn of the new millennia the rise of "knowledge-base agriculture" has meant that the institutions and regulations surrounding agricultural innovation and trade are in the process of dramatic changes. Many more changes will expected in the near future. Nevertheless, due to their non-rival and only partially excludability nature, trade in ideas and the specialization and division of labor in their production among countries in the world will unlikely resemble the pattern seen for other commodities.

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