Trade Specialization, Endogenous Innovation and Growth

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Abstract

In this paper, we develop a two-sector model of economic growth, in which both sectors can enjoy productivity growth by employing an ever-increasing variety of differentiated intermediate inputs. In contrast to many two-sector models of growth and trade, specialization in the "backward" sector is fully consistent with an output growth rate equal to the global output growth rate, even though such a country does no R&D and produces no intermediate goods. International trade improves the growth rate of all countries, but is especially beneficial for "backward" countries. These results support a more optimistic interpretation of the relationship between growth, technology and trade than other recent models also making a distinction between progressive and non-progressive sectors. (JEL Classification: F15, O41)

I. Introduction

This paper addresses an important dimension of the relationship between economic growth and international trade. While it is widely believed that lib-

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eral trade policies are growth-enhancing and the empirical evidence broadly supports this conception ⟨see Sachs and Warner [1995]⟩, the *mechanisms* by which trade promotes growth are as yet still not well understood. A central strand in the literature on trade and growth emphasizes the inter-relationship between trade and technological progress as a key channel by which trade promotes growth. According to this literature, trade can improve the growth prospects of a "backward" country by facilitating access to the common pool of know-how in the developed world, and hence improving the productivity of *R&D* in the backward country, or by enabling the backward country to produce imitations of the technologies invented in the developed world and hence reduce production costs. Grossman and Helpman [1991], for example, provide a number of models in which these mechanisms are emphasized.

However, in the recent literature on "trade, technology and growth", a number of authors have highlighted the possibility that free trade may have a negative effect on the rate of technological progress of a country and hence on its output growth rate ⟨see Grossman and Helpman [1991] (Chapters 6 and 8), Rodriguez-Clare [1993] and Ciccone and Matsuyama [1996]⟩. This can happen if trade induces a country to specialize in a "non-progressive" sector. Non-progressive sectors are those which are relatively less intensive in knowledge-based inputs and/or in which no *R&D* activity takes place. In such models, a country that specializes in a non-progressive sector in a trade equilibrium will fail to grow or will experience only consumption growth but not output growth.[1] In the former case, trade can actually be welfare-decreasing; in the latter case, welfare may improve but there remains the counterfactual prediction that backward countries experience a disparity between its consumption and output profiles.

One environment in which stagnation can occur is one in which there are two final sectors, one of which employs intermediate goods, the other using

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1. These papers focus on technological progress as embodied in differentiated intermediate goods. In other models, such as Matsuyama [1992], specialization in a non-progressive sector results in stagnation because technological progress is generated by "learning-by-doing" which is confined only to the "advanced" sector of the economy (in his analysis, destroying the productivity level in the backward sector may actually be welfare-increasing). See also Sah and Stiglitz [1984].

only "raw" labor ⟨see, for example, Grossman and Helpman [1991], Chapter 8⟩. If a country specializes in the latter "non-progressive" sector in a trade equilibrium, its level of production will stagnate. According to the endogenous growth literature, much new technology is embodied in intermediate goods and hence this sector is central to the growth process ⟨see Romer [1990]⟩. Accordingly, a country that specializes in a "non-progressive" sector fails to enjoy output growth because it does not experience the productivity benefits of using an ever-increasing variety (or ever-improving quality) of differentiated intermediate inputs. However, it may still enjoy *consumption* growth, because it also earns income from investing in foreign assets. According to this line of work, then, we would expect to see a set of less-advanced countries experiencing no productivity growth but enjoying rising consumption via a rising disparity between gross national product and gross domestic product.

A related framework that has been used by some authors is one in which trade takes place in final goods but intermediate inputs are nontraded (see especially Rodriguez-Clare 1993 and Ciccone and Matsuyama 1996).[2] Given this set-up and the existence of fixed costs in introducing new varieties of intermediates, the level of final demand for intermediate goods essentially determines the output growth rate. It follows that a key result of this line of work is that if free trade induces a less-advanced country to specialize in a final sector that does not use intermediate inputs intensively, that country will have permanently lower output due to the fact its (nontraded) intermediate sector will stagnate from a lack of final demand. Moreover, in these models, consumption growth as well as output growth stagnates for these countries.

However, the predictions of these approaches seem at odds with the empirical evidence. For instance, Dowrick and Gemmell [1991] study sectoral productivity growth for a sample of rich and middle-income countries and find agricultural productivity growth growing in line with industrial productivity growth, in contravention of the hypothesis that some sectors will

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2. These models typically assume a Ricardian framework with a small open economy facing exogenous world relative prices. Grossman and Helpman 1991 (Chapter 6), Fung and Ishikawa 1991 and Ishikawa 1992 also write models in which two final goods are traded but intermediate goods are nontraded.

exhibit stagnant productivity growth. Similarly, Blomstrom and Wolff [1993], using Mexican data, find little evidence of differential productivity growth between modern and traditional sectors. Lee [1995] establishes that output growth in developing countries is positively correlated with imports of sophisticated inputs from industrial countries, which is ruled out in the papers cited above. The potential for productivity growth in agriculture is also acknowledged in the recent development literature, with agriculture even being seen as a possible engine of growth. Empirically, moreover, there is no evidence of the trend consumption growth in excess of trend output growth for developing countries that is a feature of the equilibrium of the Grossman-Helpman "hysteresis" model outlined above, as is clear from the literature on savings-investment correlations that was initiated by Feldstein and Horioka [1980].[3]

The goal of this paper, then, is to provide a model in which technological progress in producing intermediate goods are at the heart of the growth process but in which trade is growth-enhancing for all countries, both in terms of output growth as well as consumption growth. This is true in the model that we develop even for countries that produce no intermediate goods themselves, conduct no *R&D* and specialize in a "backward" sector. Moreover, the model does not have counterfactual predictions in terms of productivity stagnation or consumption growth in excess of output growth for countries that specialize in a "non-progressive" sector.

As such, the model is consistent with the empirical results of Dowrick and Gemmell [1991], Blomstrom and Wolff [1993] and Lee [1995]. Indeed, Dowrick and Gemmell identify increased use of intermediate inputs as the mechanism by which technological progress takes place in the agricultural sector. In this way, the model can be interpreted as providing an environment in which endogenous global technological progress is the engine of growth, even for countries that specialize in "low-tech" sectors. Of course, the notion that trade is beneficial for all countries is hardly novel:

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3. Another way for consumption growth to exceed output growth would be via secular improvement in a country's terms of trade. There is no evidence of such a trend for the developing countries. See Grilli and Cheng [1988].

the contribution of this paper is to show that this can still hold in a model of "trade, technology and growth" even for a country that specializes in a "backward sector", in contrast to the models outlined above. In addition, this paper highlights the importation of intermediate goods as an important *mechanism* by which technological progress is transmitted to such countries, a channel that has been inadequately recognized in the literature.[4]

The model we develop is a two-sector model of growth and trade, in which both sectors employ a non-accumulable factor and differentiated capital inputs but invention of new varieties of the differentiated input can take place only in one sector, the 'progressive' sector. In contrast to the models of Grossman and Helpman ([1991], Chapter 6), Fung and Ishikawa [1991], Ishikawa [1992], Rodriguez-Clare [1993] and Ciccone and Matsuyama [1996], intermediate goods as well as final goods are tradable in our set-up. In the equilibrium of the model, even a country that specializes in a non-progressive sector enjoys the world *output* growth rate, which is also the world *consumption* growth rate in the model. The key feature of the model is that even the backward sector uses intermediate goods as inputs, even if *R&D* does not take place and no intermediate goods are produced in that country. Long-run output, and consumption, growth can occur in such a country by importing an ever-increasing variety of intermediate goods from a trading partner that specializes in the more advanced sector that employs intermediate goods more intensively and in which *R&D* takes place, leading to the continual introduction of new varieties of the intermediate good and hence generating endogenous growth. It should be noted that the mechanism that we specify in this paper is similar to that proposed by Canning [1988] for a closed economy, which allows the non-progressive sector to enjoy *output* growth via purchases of intermediate goods from a progressive sector characterized by increasing returns to scale.

We adopt a specification of the innovation process, derived from Barro

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4. In the "trade and growth" literature, the emphasis has been on imitation or global knowledge spillovers as mechanisms for technology transfer (see Krugman [1979] and Grossman and Helpman [1991]). Unlike those channels, which can take place even without trade in goods, the mechanism outlined here is more directly linked to the actual trading of goods.

and Sala-i-Martin ⟨[1995], Chapter 6⟩, which gives rise to a Ricardian basis for trade.[5]

The Ricardian (Classical) model of trade, being a single-factor model, emphasizes changes in relative prices as the mechanism by which international trade alters the pattern of specialization. This sharpens the role of the composition of final output in determining incentives to innovate. The Ricardian model is quite general: Baxter [1992] shows that the Heckscher-Ohlin model converges in the long-run to the single-factor Ricardian model, once we allow for endogenous capital accumulation. The model outlined here shares the characteristics of her model, in the sense that trade leads to sharp patterns of specialization and policies that change relative prices have important growth effects.

We study social planning solutions to the model. This route is taken in order to clarify the relationship between this model and the one-sector models of innovation and growth. Decentralization is conceptually straightforward – one method would be to allow monopolist producers of differentiated goods to price discriminate across different sectors – and would have the well-understood effect of introducing a distortion relative to the socially optimal outcome by virtue of monopoly pricing by the holders of patents. Given that the nature of this distortion is well known, and is in theory correctable by the appropriate public finance policy, we focus on the more transparent issue, which is the characterization of the allocations that would be chosen by a social planner.

Previewing the results of the analysis, the solution for the autarkic economy delivers an irrelevance result: the equilibrium growth rate is driven by the productivity of the sector that conducts R&D and by scale, and is independent of the characteristics of the 'backward' sector of the economy. When international trade is allowed in a two-country world, the equilibrium

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5. Young [1991] also writes a model in which the basis for trade is Ricardian. In this model, however, technological progress is driven by learning which is not the case here and a country grows by progressing to the production of ever more sophisticated products. Fung and Ishikawa [1991], Ishikawa [1992], Rodriguez-Clare [1993] and Ciccone and Matsuyama [1996] write Ricardian models with two final goods but all assume that invented inputs are nontraded and deal only with a small open economy facing exogenously determined goods prices.

may be characterized by complete or incomplete specialization depending on the technological "distance" between the countries. Both countries enjoy an increase in the consumption and output growth rate (and grow at the same rate), even if one country ends up doing no *R&D* in equilibrium; the country with the inferior *R&D* technology benefits proportionately more from the opportunity to trade.

The rest of the paper has the following structure. In section 2, we study growth and the structure of production in an autarkic country. In section 3, we introduce international trade and study specialization and incomplete-specialization equilibria. The results are discussed in section 4. Section 5 concludes.

II. Autarky

The economy that we analyze has the following characteristics. The representative consumer maximizes the present discounted value of her consumption flows

$$V_0 = \int_0^\infty e^{-\sigma t} (\log(C_{1t}) + \log(C_{2t})) dt \qquad \sigma > 0 \tag{1}$$

where C_1 and C_2 are consumption of the two final goods, labeled good 1 and good 2. There is a single non-accumulable factor which is labeled L and which can be taken to be either raw labor or human capital. There are Cobb-Douglas production technologies in both sectors but sectors differ in the relative intensities in which they use the non-accumulable factor and differentiated inputs

$$Y_1 = AL_1^\beta \sum_{i=1}^N X_{1i}^{1-\beta} \tag{2}$$

$$Y_2 = BL_2^\alpha \sum_{i=1}^N X_{2i}^{1-\alpha} \qquad \alpha, \beta \in [0, 1] \qquad \alpha > \beta \tag{3}$$

where A and B are sectoral productivity parameters that are unrelated to endogenous innovative activity. The condition $\alpha > \beta$ implies that the production of good 2 is relatively more intensive in its use of intermediate inputs. The number of varieties of differentiated inputs N is fixed at a point in time

but can be increased via *R&D* activity. The structure of the *R&D* activity is that the invention of a new variety of input requires a fixed investment of η units of sector 2 output.

This specification of the innovation process is similar to the "lab equipment" model of Rivera-Batiz and Romer [1991] and the model of Barro and Sala-i-Martin ([1995] Chapter 6). That is to say, the production function for *R&D* is the production function for good 2: *R&D* uses invented goods as inputs (*i.e.* "lab equipment"). This set-up generates positive endogenous long-run growth without relying on the knowledge spillover in the *R&D* sector that is at the heart of the Grossman and Helpman [1991] approach ⟨see Lucas [1993] for a call for models in which technological progress is the result of internalized decisions⟩.

From this assumption on *R&D* activity, it follows that the 'variety accumulation' equation has the form

$$\dot{N} = \frac{1}{\eta}[Y_2 - LC_2 - NX_1 - NX_2] \tag{4}$$

where the equilibrium symmetry conditions that $X_{1i} = X_1 \; \forall_i$ and $X_{2i} = X_2 \; \forall_i$ have been imposed. We assume that production of one unit of a differentiated input requires one unit of sector 2 output.

A solution to the social planning problem consists of sequences of allocations $\{X_1\}$, $\{X_2\}$, $\{L_1\}$, $\{L_2\}$ and growth rates $\{g_t\}$ maximizing V_0. We can set up the social planner's problem as a Hamiltonian problem. The Hamiltonian to be solved, subject to the appropriate terminal condition and non-negativity constraints, is

$$H = e^{-\sigma t}U(C_1, C_2) + \lambda[AL_1^\beta NX_1^{1-\beta} - LC_1]$$
$$+ \frac{\gamma}{\eta}[BL_2^\alpha NX_2^{1-\alpha} - LC_2 - NX_1 - NX_2]$$
$$+ \phi[L - L_1 - L_2] \tag{5}$$

The first order conditions on consumption in an interior equilibrium are given by

$$\frac{\partial H}{\partial C_1} = e^{-\sigma t}\frac{1}{C_1} - \lambda L = 0 \tag{6}$$

$$\frac{\partial H}{\partial C_2} = e^{-\sigma t} \frac{1}{C_2} - \frac{\gamma}{\eta} L = 0 \tag{7}$$

which jointly imply that

$$\frac{C_2}{C_1} = \left(\frac{\lambda}{\gamma}\right) \eta \tag{8}$$

We can think of $(\frac{\lambda}{\gamma})\eta$ as the relative price of good 1 in terms of good 2, which we label p. The growth rate of consumption of both goods, if p is fixed (which is true in equilibrium), is given by

$$g = \frac{\dot{C_2}}{C_2} = \frac{\dot{C_1}}{C_1} = -\frac{\dot{\gamma}}{\gamma} - \sigma \tag{9}$$

X_1 and X_2 are also control variables in this problem and the first order conditions on these variables in an interior equilibrium are

$$\frac{\partial H}{\partial X_1} = \lambda(1-\beta)AL_1^\beta X_1^{-\beta} - \frac{\gamma}{\eta} = 0 \tag{10}$$

$$\frac{\partial H}{\partial X_2} = \frac{\gamma}{\eta}[(1-\alpha)BL_2^\alpha X_2^{-\alpha} - 1] = 0 \tag{11}$$

These conditions imply the demand functions for differentiated inputs

$$X_1 = p^{\frac{1}{\beta}}(1-\beta)^{\frac{1}{\beta}} A^{\frac{1}{\beta}} L_1 \tag{12}$$

$$X_2 = (1-\alpha)^{\frac{1}{\alpha}} B^{\frac{1}{\alpha}} L_2 \tag{13}$$

Sectors must compete for allocations of the non-accumulable factor. The first order conditions are

$$\frac{\partial H}{\partial L_1} = \lambda\beta AL_1^{\beta-1}NX_1^{1-\beta} - \phi = 0 \tag{14}$$

$$\frac{\partial H}{\partial L_2} = \frac{\gamma}{\eta}\alpha BL_2^{\alpha-1}NX_2^{1-\alpha} - \phi = 0 \tag{15}$$

By substituting the equations for X_1 and X_2 into these expressions, it turns

out that this equalization of value marginal products of labor across sectors fixes p the relative price of good 1 in terms of good 2

$$p = \left(\frac{\alpha}{\beta}\right)^{\beta} A^{-1} B^{\frac{\beta}{\alpha}} (1-\beta)^{\beta-1} (1-\alpha)^{\frac{\beta(1-\alpha)}{\alpha}} \tag{16}$$

This technological determination of prices is of course a typical feature of single factor models when the factor is fully mobile across sectors. The relative price is increasing in B/A, the ratio of productivity parameters in the two sectors.

The rate of invention of new varieties of differentiated inputs remains to be determined. The first order conditions on the number of varieties, the state variable in the system, can be written as

$$\frac{\partial H}{\partial N} = -\dot{\gamma} = \lambda A L_1^{\beta} X_1^{1-\beta} + \frac{\gamma}{\eta} [BL_2^{\alpha} X_2^{1-\alpha} - X_1 - X_2] \tag{17}$$

Substituting in the expressions for X_1, X_2 and $\frac{\lambda}{\gamma}$, we can write the growth rate (of Y_1, Y_2, C_1, C_2 and N) as

$$g = -\frac{\dot{\gamma}}{\gamma} - \sigma = \frac{1}{\eta} B^{\frac{1}{\alpha}} (1-\alpha)^{\frac{1-\alpha}{\alpha}} \alpha L - \sigma \tag{18}$$

That is, in equilibrium, growth is increasing in the scale of the economy (as indexed by L), is decreasing in the fixed cost of invention, η, and is positively related to the productivity of the R&D sector, B. Note that the growth rate is constant over time. The irrelevance for growth of the characteristics of the backward sector may be said to provide some intellectual justification for single-good models of economic growth. We now open up the possibility of international trade.

III. International Trade

Consider a two-country world. Assume that the home country and the foreign country (identified by * superscripts) are identical in size. If, in addition, countries share identical technologies [i.e. $A = A^*$ and $B = B^*$] and agents in both countries have identical tastes, then trade in final and inter-

mediate goods has the same effect as full integration of the two economies: the rate of return doubles (being linear in scale) and there is also a positive level effect to the extent that the inputs invented prior to trade in both countries do not overlap. The relative price of goods 1 and 2 is unchanged by the opportunity to trade. This is the straightforward two-sector extension to the analysis of integration among identical economies in the 'lab equipment' model of Rivera-Batiz and Romer [1991].

Now let countries differ in productivity levels in the high-tech sector [$i.e.$ $B \neq B^*$]. Countries may differ in the productivity of their $R\&D$ sectors for reasons that are unrelated to scale or the number of varieties that are available. $B \neq B^*$ may reflect differences in public finance policies, natural endowments and local amenities that favor the high-tech sector differently across countries. For example, Baxter [1992] emphasizes tax policies as an important determinant of relative prices: a subsidy to the high-tech sector is equivalent to increasing B.

The effect of $B \neq B^*$ is to create a Ricardian basis for trade: technological differences generate gains to trade and international trade potentially alters relative prices and hence the composition of output. The logical possibilities in a Ricardian model are: (a) both countries completely specialize and the price ratio is strictly intermediate to autarkic price ratios; (b) one country produces only good 1 and the other country produces both goods; or (c) one country produces only good 2 and the other country produces both goods. In cases (b) and (c), the price ratio under trade is equal to the autarkic price ratio of the country that is incompletely specialized. We concentrate on cases (a) and (c).

To identify under what conditions case (a) will prevail, we adopt the strategy of assuming both countries are completely specialized and checking to see if the resulting price ratio is intermediate to the autarkic price ratios. That is, the global social planner solves the Hamiltonian, subject to the appropriate terminal condition and non-negativity constraints[6]

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6. We assume the social planner maximizes the welfare of the representative global citizen. The analysis of growth would be the same if the social planner maximizes a linear combination of the utility functions of the representative citizens of the two economies.

$$H = e^{-\sigma t}U(C_1, C_2) + \lambda[AL^\beta NX_1^{1-\beta} - 2LC_1]$$

$$+ \frac{\gamma}{\eta}[B^* L^\alpha NX_2^{1-\alpha} - 2LC_2 - NX_1 - NX_2] \tag{19}$$

where we assume $B^* > B$.

The consumption optimality conditions are the same as before and the demand functions for the differentiated inputs are given by

$$X_1 = [p^w(1-\beta)A]^{\frac{1}{\beta}} L \tag{20}$$

$$X_2 = (1-\alpha)^{\frac{1}{\alpha}} B^{*\frac{1}{\alpha}} L \tag{21}$$

where p^w is the relative price prevailing in the integrated equilibrium. In the full specialization equilibrium, the equilibrium price ratio is determined by the consumption equilibrium condition and the adding-up conditions in each sector. The integrated equilibrium solution for the relative price p^w is

$$p^w = \left(\frac{\eta\sigma}{2\beta}\right)^\beta (1-\beta)^{\beta-1} A^{-1} L^{-\beta} \tag{22}$$

Notice that p^w is a constant (*i.e.* the terms of trade are constant). The equilibrium growth rate is given by

$$g = \frac{1}{\eta} B^{*\frac{1}{\alpha}} \alpha(1-\alpha)^{\frac{1-\alpha}{\alpha}} L + \frac{\sigma\beta}{2} - \sigma \tag{23}$$

That is, the full-specialization growth rate exceeds the autarkic growth rate for the economy which specializes in the *R&D* sector by a constant factor. This constant factor is increasing in the rate of impatience, σ, and in the share of the fixed factor in sector 1 output, β. The foreign country's growth rate is increased by this constant factor whereas the home country's growth rate enjoys an additional benefit from the improved productivity of the innovation technology relative to that available to it in autarky. While Grossman and Helpman [1991] also have the result that a country need not engage in *R&D* to enjoy consumption growth, the mechanism here is quite different in that the non-innovating country enjoys growth in output as well as in con-

sumption, which accords better with what is observed in the world.

In order for full specialization to be supported, it must be the case that the relative price in the integrated equilibrium is intermediate to the autarkic relative prices $i.e.$ $p^* > p^w > p$. This implies the following conditions on technologies

$$B^* > \left(\frac{\eta\sigma}{2}\right)^\alpha L^{-\alpha}\alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} > B \qquad (24)$$

That is, full specialization can be supported only if country-specific differences in sector 2 productivity are large enough.

We now turn to case (c). To solve for the incomplete-specialization equilibrium, consider the social planner's problem when the foreign country is constrained to specialize in sector 2. The Hamiltonian to be solved is

$$H = e^{-\sigma t}U(C_1, C_2) + \lambda[AL_1^\beta NX_1^{1-\beta} - 2LC_1]$$
$$+ \frac{\gamma}{\lambda}[B^* L^* NX_2^{*1-\alpha} + BL_2^\alpha NX_2^{1-\alpha} - 2LC_2 - NX_1 - NX_2 - NX_2^*]$$
$$+ \phi[L - L_1 - L_2] \qquad (25)$$

The derived demand functions for differentiated inputs are:

$$X_1 = [p(1-\beta)A]^{\frac{1}{\beta}} L_1 \qquad (26)$$

$$X_2 = (1-\alpha)^{\frac{1}{\alpha}} B^{\frac{1}{\alpha}} L_2 \qquad (27)$$

$$X_2^* = (1-\alpha)^{\frac{1}{\alpha}} B^{*\frac{1}{\alpha}} L \qquad (28)$$

The equilibrium price is $p^w = p$. We can solve for the equilibrium growth rate:

$$g = \frac{1}{\eta}\alpha(1-\alpha)^{\frac{1-\alpha}{\alpha}} B^{\frac{1}{\alpha}} L + \frac{1}{\eta}\alpha(1-\alpha)^{\frac{1-\alpha}{\alpha}} B^{*\frac{1}{\alpha}} L - \sigma \qquad (29)$$

That is, the incomplete-specialization rate of return is simply the sum of the two autarkic rates of return. In the special case when $B = B^*$ autarkic rates of return are identical so trade implies a doubling of the rate of return.

Related to this result, it can be shown that, using the consumption equilibrium condition and the sectoral resource constraints, the allocation of the fixed factor to sector 1 under incomplete specialization is the same as the autarkic allocation. This is hardly surprising: given that the home country does not experience a change in relative prices upon the liberalization of trade, its optimal allocations should not change either.

The social planning solutions to a two-sector model of endogenous innovation, both under autarky and with international trade, reveal some interesting properties of the model. The autarkic solution demonstrates an irrelevance result: the autarkic growth rate depends only on the characteristics of the sector that does R&D.

With international trade, the effect on the growth rate depends on the productivity gap between countries. If one country is sufficiently more productive in R&D than the other, a full-specialization equilibrium can be supported. Although one country does no R&D, both countries share a common output growth rate which is greater by a constant factor than the autarkic growth rate of the more productive country.

When the productivity gap between the two countries is more narrow, the international trade equilibrium involves incomplete specialization. The rate of return in this case exhibits an interesting property: it is simply the sum of the autarkic rates of return. The sectoral allocations of the fixed factor in the country that is incompletely specialized are the same as under autarky. It is noteworthy that in both types of trade equilibria, convergence in growth rates occurs. This is consistent, for instance, with the empirical evidence provided by Ben-David [1993] on the effects of trade integration on intra-European convergence.

IV. Discussion

These findings demonstrate that it is possible to specialize in a "backward" sector in a model of "trade, technology and growth" and still enjoy the world *output* growth rate, even without engaging in R&D or producing the intermediate goods that embody new technology. The characteristics of the model that are responsible for generating these results are that intermediate goods are traded and that even the "backward" sector uses intermediate

inputs, albeit less intensively than the "progressive" sector. The former feature distinguishes the model from those of Grossman and Helpman ⟨[1991], Chapter 6⟩, Rodriguez-Clare [1993] and Ciccone and Matsuyama [1996]; the latter feature distinguishes the model from Grossman and Helpman ⟨[1991], Chapter 8⟩, which assumes the "backward" sector employs only the raw factor (labor). The assumptions in those models essentially rule out *output* growth if a country specializes in a "backward" sector.

The specification adopted here permits a more benign view of the prospects for such countries, by allowing such countries to achieve productivity growth by importing an ever-increasing variety of intermediate goods from its trading partners. Given the lack of evidence of productivity growth differentials across sectors or disparities in the national paths for consumption and output (see the papers cited in the introduction), this set-up may perhaps match more closely what is observed in the world.

However, the simplified model in this paper should be interpreted as only an illustration of the kind of economic environment that can produce these results. In particular, the model assumes convenient functional forms for preferences, production functions and the "innovation" technology in order to derive the results as cleanly as possible. Investigating the effects of relaxing these assumptions is a task for future research.

V. Conclusion

In this chapter, we have analyzed a two-sector model of international trade, endogenous innovation and economic growth. The main results are as follows. In an autarkic economy, the growth rate depends only on scale and the characteristics of the sector that is used for *R&D*. Allocation of the fixed factor across sectors is constant over time, as are sectoral shares in output. The socially optimal growth rate exceeds the decentralized growth rate, due to the monopoly pricing distortion in the market solution.

The model is optimistic with regard to the effects of international trade integration even when technological progress, as embodied in intermediate goods, is the engine of growth. Its single-factor property gives its trade predictions a Ricardian bent. Trade liberalization has classical relative price effects which may induce production specialization on the part of one or

both countries. Comparative advantage here is determined by relative productivity levels in the high-tech sector, which are sensitive to differences in variables such as tax policies.

Importantly, in contrast to the models of "trade, technology and growth" discussed in the introduction, trade here is always growth-enhancing for both countries: there is no distinction between static and dynamic comparative advantage. This is the case even when one country does no *R&D* in equilibrium and imports all its intermediate goods. This result indicates that investment in *R&D* may not be a prerequisite for output growth for those countries which comparative advantage suggests ought to specialize in "non-strategic" sectors: productivity growth in these countries can be achieved by increased imports of differentiated inputs from more high-tech countries. That is to say, following Romer [1992], "using ideas" may be an alternative to "producing ideas" in achieving increasing prosperity. In addition, this paper highlights the importation of intermediate goods as an important *mechanism* by which technological progress is transmitted to such countries, a channel that has been inadequately recognized in the literature.

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