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GROWTH AND WELFARE IN A SMALL OPEN ECONOMY

ABSTRACT

We construct a model of growth based on endogenous technological change in a small, open economy. Entrepreneurs develop new intermediate products whenever the present value of potential profits exceeds the cost of R&D. Diversity of intermediates contributes to total factor productivity in the production of final goods. The economy produces two such final goods, and trades these at exogenously given world prices.

We study the welfare implications of R&D subsidies and commercial policy. There exists an optimal subsidy to R&D that speeds growth relative to the market-determined rate. The optimal subsidy achieves the first-best rate of growth, but not the first-best level of welfare. Small tariffs and export subsidies also affect both growth and welfare. Growth may increase or decrease, depending upon which sector is promoted by the trade policy. But an increase in the growth rate is neither necessary nor sufficient for a trade policy to improve welfare. Finally, we compare tariffs and quotas, when the latter give rise to rent-seeking behavior. The diversion of resources from innovative activities to rent seeking can have dire implications for growth and welfare.

Keywords: long-run growth, technological change, innovation, commercial policy

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I. Introduction

The resurgence of interest in theories of economic growth stems from a simple but powerful insight. When aggregate production possibilities are characterized by increasing returns to scale, the long-run rate of growth can be determined by factors that are endogenous to the economic environment (Romer, 1989). This observation stands in contrast to a central tenet from the Solowian, neoclassical growth tradition, namely that per capita income grows in the long run at the rate of exogenous technological progress.

Increasing returns arise naturally in the context of the creation and implementation of knowledge and ideas, as many forms of information display the characteristics of a public good. Recent research has focused therefore on the processes associated with the generation and dissemination of knowledge. Knowledge can be embodied in the individual worker, as in the studies of the formation of human capital (e.g., Lucas (1988)) or it may be disembodied, as when new technologies are created via research and development (e.g., Romer (1988)). The new models that have been developed along either of these lines enable an examination of the long-run growth effects of various government policies, an investigation that could not easily be carried out within the older paradigm emphasizing the accumulation of physical capital.

In our own earlier work (Grossman and Helpman (1989a,b)), we have drawn on the emerging literature on endogenous technological progress to study the determinants of long-run growth in an open world economy. We have examined the ramifications of both structural features of the international environment and policy interventions that individual trading countries might choose to undertake. We found, among other results, that trade policy can influence growth in the steady state, by altering the incentives that agents have to undertake research and development. R&D subsidies are a more direct policy

instrument that can be used in many circumstances to speed growth. Suggestive as these findings may be, they fail to provide a normative basis for policy intervention, because our analysis has been limited to an investigation of the positive effects of policy on long-run rates of growth.

In this paper, we study the welfare implications of growth-enhancing trade and industrial policies for a small, open economy. As in our earlier work, we focus on growth due to endogenous improvements in technology. Entrepreneurs devote resources to research and development whenever the present discounted value of the stream of operating profits that derive from a particular innovation justify the up-front costs of achieving that innovation. Innovation entails the development of new varieties of an intermediate input, and horizontal product differentiation of intermediates contributes, as in Ethier (1982), to total factor productivity in the final-goods sectors. We focus on a small economy that trades two final goods at exogenously given world prices, thereby abstracting from the complex intra-temporal and inter-temporal terms-of-trade considerations that hinder analysis of the more general, large-country case.

We find that trade policy does affect growth in our model. Protection (or promotion) of the human-capital intensive final-goods industry draws resources out of the R&D sector and so slows growth. Protection of the labor-intensive final good has just the opposite effect on growth. Moreover, "growth" is underprovided by the market equilibrium, because investment in the creation of knowledge generates benefits that are not fully appropriated by the entrepreneur who bears the cost of R&D. In consequence, a "small" dose of a growth-enhancing commercial policy may (but, as we shall see, need not) improve aggregate welfare.

We conduct a complete analysis of R&D subsidies. There always exists an optimal subsidy to R&D that speeds growth relative to the market-determined rate. Increasing the rate of subsidization beyond this optimum causes the growth rate to increase still further, but does so at the expense of welfare. R&D subsidies alone cannot be used to achieve the first best, due to the presence of a distortion in the pricing of intermediate goods when this market is characterized by an oligopolistic structure. But we establish that the growth rate under the optimal R&D subsidy equals that in the first-best equilibrium. The optimal R&D subsidy cannot in general be welfare ranked vis-a-vis the optimal trade policy.

Our analysis of commercial policy includes a comparison of tariffs and quotas. We follow Krueger (1974) in assuming that the presence of quota rents gives rise to rent-seeking behavior. In an historical review of numerous episodes of growth or stagnation through the centuries, Baumol (1988) has emphasized the adverse consequences of the diversion of entrepreneurial efforts from innovative endeavors to rent-seeking activities. We are able to formalize this intuitive claim, and find that trade policies that create opportunities for rent-seeking may be especially onerous in a growth context. Commercial policies that would enhance growth in the absence of rent seeking (due to the relative price effects and the associated intersectoral reallocation of resources) can have just opposite effect on growth (and also welfare) when rent seeking does take place.

The remainder of our paper is organized as follows. We develop our growth model in Section II, and solve for the dynamic equilibrium path. In Section III we study the effects of changes in the resource stocks on the composition of output and on growth. This exercise sheds light on the

structure of our model, and also facilitates discussion in the succeeding sections. In Section IV, we derive the first-best growth path and a constrained, second-best growth path, compare these to the market equilibrium, and show that a positive but finite R&D subsidy can be used to attain the second best. Sections V and VI focus on commercial policies. In Section V, we study import tariffs and export subsidies under the assumption that revenues are raised or redistributed by lump-sum means. In Section VI we examine quota restrictions that generate rent-seeking behavior. The final section contains a summary of the major findings.

II. The Model

A small economy trades two final goods at exogenously given prices. The world prices of the two goods, x and y , are p_x and p_y , respectively. Home consumers maximize a time-separable intertemporal utility function of the form

$$(1) \quad U_t = \int_t^{\infty} e^{-\rho(\tau-t)} \log u[c_x(\tau), c_y(\tau)] d\tau,$$

where ρ is the subjective discount rate and $c_i(\tau)$ is consumption of final good i at time τ . The instantaneous sub-utility function $u(\cdot)$ is non-decreasing, strictly quasi-concave, and homogenous of degree one in its arguments.

A typical consumer maximizes (1) subject to an intertemporal budget constraint requiring that the present value of all expenditures after t not exceed the present value of factor income after t plus the value of asset holdings at t . In Grossman and Helpman (1989a) we have shown that the solution to this problems requires an instantaneous allocation of expenditure $E(t)$ that equates the marginal rate of substitution between x and y to the

instantaneous relative price, and a time path for expenditures that satisfies

$$(2) \quad \frac{\dot{E}}{E} = \dot{R} - \rho,$$

where $R(t)$ is the cumulative interest factor up to time t and thus $\dot{R}(t)$ is the instantaneous interest rate. Savings are used to accumulate corporate bonds or ownership claims in domestic firms. There is no possibility for international borrowing or lending.

The economy is endowed with fixed stocks of two primary factors, labor and human capital. Each final good is produced locally with one of the primary factors plus an assortment of intermediate inputs. Both final-good sectors exhibit Cobb-Douglas technologies, as follows:

$$(3) \quad \begin{aligned} X &= A_x I_x^\beta H_x^{1-\beta}; \\ Y &= A_y I_y^\beta L_y^{1-\beta}, \end{aligned}$$

where I_i is an index of aggregate intermediate usage in sector i , H_x is employment of human capital in the production of x , and L_y is employment of labor in the production of y .

The intermediate goods form a continuum of horizontally differentiated products. Following Ethier (1982), we assume that, for a given aggregate quantity of intermediates used in final production, output is higher the greater is the diversity in the set of inputs used. This specification captures the productivity gains from increasing degrees of specialization in the production of final goods. More specifically, we assume that the index of aggregate intermediate use for sector i , $i=x,y$, is given by

$$(4) \quad I_i = \left(\int_0^{n(t)} z_i(\omega)^\alpha d\omega \right)^{1/\alpha},$$

where $z_i(\omega)$ is the amount of intermediate good ω used in the production of final good i , and $n(t)$ is the measure of the number of varieties available at time t .

Intermediate goods are not traded. There exists an unbounded set of potential varieties of these goods, but only a subset of varieties with finite measure is produced at any point in time. This is because a particular variety of the intermediate must be developed in the research lab before it can be marketed. An infinitesimal addition to the measure of the number of varieties requires the allocation of a finite amount of human capital to R&D, so the activity of product development is spread over time.

At any point in time, the entrepreneurs who have developed varieties of the intermediates in the past compete as oligopolists. Each one takes as given the prices set by competing producers of intermediates, and also the aggregate outputs of the two final goods. Then each perceives a derived demand with constant elasticity $1/(1-\alpha)$, and each maximizes profits by pricing at a fixed mark-up over marginal production cost. Let $c_z(w_H, w_L)$ represent the marginal and average cost of producing any variety of intermediate good using a common, constant-returns-to-scale, production technology, where w_j is the wage paid to factor j , $j=H,L$. Then profit maximization implies

$$(5) \quad \alpha p_z = c_z(w_H, w_L),$$

where p_z is the price of any intermediate. Operating profits for the representative intermediate producer are $\pi = (1-\alpha)p_z(z_x+z_y)$.

Since all intermediates are priced similarly, final good producers will use equal quantities of each one. If $Z_i = nz_i$ is the aggregate quantity of intermediates employed in the production of good i , then by (4), $I_i = n^{(1-\alpha)/\alpha} Z_i$. Now unit cost equal to (the exogenous) world price implies

$$(6a) \quad p_x = n^{-\gamma} c_x(w_H, p_z) ;$$

$$(6b) \quad p_y = n^{-\gamma} c_y(w_L, p_z) ,$$

where $\gamma = \beta(1-\alpha)/\alpha$ and $c_i(\cdot)$ is the cost function dual (up to a constant) to the Cobb-Douglas production function in (3). We see from (6) that the introduction of new intermediate products acts like Hicks-neutral technological progress in both final-goods industries.

Equations (5) and (6) allow us to solve for the prices of the primary and produced inputs, as functions of the number of intermediate products and the prices of the traded goods. If n grows at rate $g(t)$, and p_x and p_y are taken to be constant over time, then w_L , w_H and p_z will all grow at rate $\gamma g(t)$. A constant relative price of the two traded goods thus implies constancy of all relative input prices.

We shall assume that new varieties are developed with two inputs, human capital and general knowledge. The greater is the stock of general knowledge among the scientific and engineering community, the smaller is the input of human capital that is needed to invent a new product. In particular, we assume that the set of available brands grows according to

$$(7) \quad \dot{n} = KH_n/a_{Hn} ,$$

where H_n is employment of human capital in the R&D sector, K represents the (momentary) state of general knowledge, and a_{Hn} is a productivity parameter.

General knowledge is created as a byproduct of research and development. That is, each R&D project generates an appropriable output, namely the blueprint for a new variety, but also a non-appropriable output in the form of a contribution to K . This specification, which we borrowed from Romer (1988) and used in our earlier work (Grossman and Helpman (1989a,b)), captures the idea that in the process of developing a particular product the research lab may discover certain scientific properties with more widespread applicability. These discoveries may find their way into the public domain, whence future generations of researchers will draw upon them freely. For simplicity we assume that dissemination takes place immediately and that each R&D project contributes similarly to the stock of knowledge. Then $K(t)$ is proportional to cumulative R&D activity up to time t , and we choose units so that $K=n$.

There is free entry by entrepreneurs into R&D. Since the set of potential intermediate products is unbounded, and all such products are symmetric, an entrepreneur will never choose to develop an already-existing variety. Free entry implies that, whenever innovation is taking place, the present discounted value of the infinite stream of oligopoly profits that accrues to an intermediate producer just equals the cost of introducing a new variety, or

$$\int_t^{\infty} e^{-[R(r)-R(t)]} (1-\alpha) p_z(z_x+z_y) dr = w_H a_{Hn} / n ,$$

Differentiating this zero-profit condition with respect to t , we find

$$(8) \quad \dot{R} = \frac{(1-\alpha) p_z (Z_x + Z_y)}{w_H a_{Hn}} + \left(\frac{\dot{w}_H}{w_H} - \frac{\dot{n}}{n} \right) .$$

Equation (8) expresses a no-arbitrage condition equating the rate of interest to the sum of the instantaneous profit rate for the representative firm (first term on the right-hand side) and the capital gain on the value of the firm (second term on the right-hand side). The instantaneous value of any firm is the current cost of developing a new product, so the capital-gain term reflects the rate of change in development costs.

The remaining equilibrium conditions reflect the clearing of factor markets. Let us define $a_{Hx}(\cdot) = \partial c_x(\cdot) / \partial w_H$, $a_{Ly}(\cdot) = \partial c_y(\cdot) / \partial w_L$, $a_{jz}(\cdot) = \partial c_z(\cdot) / \partial w_j$ for $j=H,L$ and $a_{zi}(\cdot) = \partial c_i(\cdot) / \partial p_z$ for $i=x,y$. Since relative factor prices are constant over time, so too are these input coefficients. We define as well the direct-plus-indirect coefficients $b_{Hx} = a_{Hx} + a_{Hz}a_{zx}$, $b_{Lx} = a_{Lx} + a_{Lz}a_{zx}$, $b_{Hy} = a_{Hy} + a_{Hz}a_{zy}$, and $b_{Ly} = a_{Ly} + a_{Lz}a_{zy}$. Now, using (6) and Shephard's lemma, we can write the conditions for equilibrium in the markets for labor and human capital as

$$(9a) \quad b_{Hx}\tilde{X} + b_{Hy}\tilde{Y} + a_{Hn}g = H ;$$

$$(9b) \quad b_{Lx}\tilde{X} + b_{Ly}\tilde{Y} = L ,$$

where $\tilde{X} = Xn^{-1}$ and $\tilde{Y} = Yn^{-1}$. The left-hand side of (9a), for example, gives the direct-plus-indirect demand for human capital by the two final goods sectors, plus the demand for human capital in innovation. This must equal the exogenous supply of human capital, H . The interpretation of (9b) is similar, except that no labor is used in R&D.

Let us assume provisionally that g is constant through time (i.e., that the economy jumps immediately to a steady state), and then check later that this supposition can be consistent with all of the conditions for a dynamic

equilibrium. From (9a) and (9b) the constancy of g implies that \bar{X} and \bar{Y} are constant as well. Then X and Y grow at constant rate γg . Since the current account must balance at every point in time in the absence of international trade in financial assets, nominal spending $E = p_x X + p_y Y$ also grows at rate γg . Finally, we combine (2) and (8) to derive

$$(10) \quad \frac{(1-\alpha)p_z(a_{zx}\bar{X} + a_{zy}\bar{Y})}{w_H a_{Hh}} = g + \rho$$

Equations (9a), (9b) and (10) determine \bar{X} , \bar{Y} and g , once (5) and (6) have been used to solve for factor prices. Provided that these equations have a solution with positive values for all three variables, our assumption of constant g is justified. We proceed to use these three equations in the succeeding sections to study the welfare properties of our growth model.

III. Resources and Growth

We study in this section the effects of changes in the stocks of the two primary factors on the rate of growth and the composition of output. These comparative dynamics exercises shed light on the structure of our model and also prove useful for understanding the policy analysis that follows.

As we noted in Section II, equations (9a), (9b) and (10) determine \bar{X} , \bar{Y} , and g , once (5), (6a) and (6b) have been used to solve for input prices. We show the equilibrium in (\bar{X}, \bar{Y}) space in Figure 1. We represent (9a) by the curve HH with slope $-b_{Hx}/b_{Hy}$, and (9b) by the curve LL with slope $-b_{Lx}/b_{Ly}$. The curve III depicts equation (10) and has slope $-a_{zx}/a_{zy}$. Since the locations of the HH and III curves depend on g , variations in the growth rate ensure that the three curves intersect at a single point (labelled E) as

shown. Our assumptions imply that production of X is the most human-capital-intensive activity in the sense of direct-plus-indirect inputs (since human capital is used directly in this activity together with intermediates, and since the share of intermediates in total cost is the same as for industry Y), while the production of Y is the most labor-intensive activity. Hence, the HH curve is the steepest of the three and the LL curve is the least steep.

Now consider an increase in the stock of human capital. So long as the new equilibrium involves positive production of both final goods, this endowment change does not alter the equilibrium input prices. So techniques of production do not change. Holding g constant for the moment, the HH curve shifts out in a parallel fashion, as illustrated by the broken curve whose intersection with LL is at point B. But point B lies above the III curve, so the initial level of activity in R&D is no longer consistent with equilibrium. At point B, the profit rate in the intermediates sector exceeds the interest rate. Human capital is drawn into R&D, implying a higher rate of innovation and a reduction in resources available for production of final goods. The III curve shifts out and the HH curve shifts in, until a new equilibrium is established at a point such as C. We conclude that accumulation of human capital speeds growth, and that at given n , output of the human-capital intensive activity expands, while output of the labor-intensive activity contracts. These changes in the composition of final production reflect of course the Rybczynski forces that are present in our model.

An increase in the labor force can be analyzed similarly. The LL curve shifts out, as depicted by the broken line that intersects the HH curve at B'. Since point B' lies above the III curve, the rate of innovation must increase. The reallocation of resources to R&D causes the HH curve to shift back and the

III curve to shift out, until they both intersect the new LL curve at a point such as C' . Thus, an increase in L augments output in the labor-intensive industry (for every n), and shrinks output in the capital-intensive industry. The economy experiences faster growth, just as it does when the stock of human capital expands.

IV. Optimal Growth and R&D Subsidies

The market equilibrium described above differs from the social optimum due to the presence of two market distortions. First, the existence of a non-appropriable benefit from research in the form of a contribution to general knowledge means that the private incentive to conduct R&D may deviate from the social incentive. Second, the monopoly power exercised by each producer of intermediates causes the consumer price of these inputs to exceed the social opportunity cost. These distortions interact, of course, inasmuch as the monopoly rents provide the private incentive for R&D in our economy. In general, two policy instruments will be needed to achieve the first-best equilibrium. We begin, however, with an examination of a second-best problem as follows. What is the optimal growth path when the government is constrained to allow market forces to govern the determination of input prices and the allocation of inputs to intermediate and final goods producers? And what is the nature of the government intervention that attains this growth path in a decentralized equilibrium?¹

We take as the objective of the government the maximization of utility

¹ A command economy interpretation of our second-best problem is as follows. Suppose the government performs all R&D, but then must grant exclusive rights to each blueprint to a single, private producer. What path of R&D expenditures by the government maximizes social welfare?

for the representative consumer. Given the linear homogeneity of $u(\cdot)$, the associated indirect utility function has the form $v(p_x, p_y, E) = \phi(p_x, p_y)E$. Then, using (1), the government's maximand can be written as

$$(11) \quad \rho U = \log \phi(p_x, p_y) + \rho \int_0^{\infty} e^{-\rho t} [\log \bar{E}(t) + \gamma \log n(t)] dt ,$$

where, by the definition of $g = \dot{n}/n$, we have

$$(12) \quad \log n(t) = \log n_0 + \int_0^t g(r) dr .$$

The constraints imposed by technology and by the assumed use of the market mechanism for allocating inputs to all activities other than R&D can be expressed as follows. Input prices are determined by (5), (6a) and (6b). These fix the production techniques. Then (9a) and (9b) will determine $\bar{X}(t)$ and $\bar{Y}(t)$ as linear functions of the government's choice of $g(t)$. We can multiply (9a) by $\bar{w}_L = w_L n^{-\gamma}$, multiply (9b) by $\bar{w}_H = w_H n^{-\gamma}$, and add these two together, to express the resource constraint as

$$(13) \quad [1 - (1-\alpha)\beta]\bar{E} + \bar{w}_H a_{Hn} g = \bar{V} ,$$

where $\bar{E} = E n^{-\gamma}$ and $\bar{V} = \bar{w}_H H + \bar{w}_L L$. In writing (13), we have made use of the fact that β is the share of middle products in the total cost of manufacturing final goods, and that the current account must balance in a country lacking access to international capital markets; i.e., $E = p_x X + p_y Y$. We can interpret (13) as requiring savings to be equal to investment, since $[\bar{V} + (1-\alpha)\beta\bar{E}]n^\gamma$ represents total income (i.e., factor income plus profits), $\bar{E}n^\gamma$ represents

expenditure, and $\bar{w}_H a_{Hn} g n^7$ represents outlays on R&D.

The second-best growth path maximizes (11) subject to the constraints expressed in (12) and (13). The solution to this maximization problem implies a time-invariant second-best growth rate g^* , where

$$(14) \quad g^* = \bar{V} / \bar{w}_H a_{Hn} - \rho / \gamma .$$

We illustrate the solution for the second-best growth rate in Figure 2. Given the constancy of the second-best growth rate, we can substitute (12) into (11), and thereby express the objective function as

$$(15) \quad \rho U = \log \phi(p_x, p_y) + \rho \log n_0 + \log \bar{E} + (\gamma / \rho) g .$$

Equation (15) defines an implicit trade-off between the initial level of spending and its rate of growth. We plot two representative "indifference" curves in (\bar{E}, g) space in the figure. The government maximizes (15) subject to the linear "budget" constraint given by (13). The optimum is found at the point of tangency (point A) as usual.

Figure 2 can also be used to locate the market equilibrium rate of growth. Notice that the "budget" constraint (13) applies equally to the market outcome. But now, the no-arbitrage condition (10) also obtains. Recognizing that middle products comprise a share β of the cost of final goods, we can rewrite this condition as

$$(16) \quad (1 - \alpha) \beta \bar{E} / \bar{w}_H a_{Hn} = g + \rho .$$

The line III in the figure represents equation (16). The equilibrium growth rate is found at the intersection of this line and the budget line. A simple calculation reveals

$$(17) \quad g = \alpha\gamma\bar{v}/\bar{w}_g a_{Hn} - \rho(1-\alpha\gamma) .$$

Comparing (17) with (14), we find

$$\alpha\gamma g^* - g = \rho(1-\alpha)(1-\beta) > 0 .$$

Hence, $g^* > g/\alpha\gamma = g/\beta(1-\alpha) > g$; that is, the second-best rate of growth exceeds the market-determined growth rate. Intuitively, the market underprovides research and development, because the entrepreneur does not capture all the social benefits from her efforts.²

We show now that a simple subsidy to R&D (financed by lump-sum taxes) can be used to achieve the second-best equilibrium. Let $(S-1)/S$, $S \geq 1$, be the fraction of R&D expenditures borne by the government. This policy alters only the no-arbitrage condition among all the equilibrium relationships. With the policy in effect, we replace a_{Hn} in (10) and thus (16) by a_{Hn}/S . Input prices (determined by (5) and (6)), input-output coefficients, and the requirement of current account balance are not affected. Hence, the budget constraint (13) continues to apply.

² The entrepreneur fails to appropriate the social gain from her contribution to general knowledge, as well as part of the contribution she makes to consumer surplus. Against this, the entrepreneur sees as a private benefit the profit that she realizes at the expense of other producers, whereas the social benefit from this profit capture is nil. With our constant elasticity specification, the last two effects just offset, and the R&D spillovers turn out to be decisive.

From this discussion we see that the effect of the subsidy is shift the III line in Figure 2 down and to rotate it in a clockwise direction. Welfare increases monotonically as the equilibrium moves from B to A. The optimal subsidy achieves the second-best allocation. Note, however, that once the subsidy brings the economy to A, further increases in the rate of subsidy reduce welfare. This is true despite the fact that such subsidies continue to speed growth. Faster growth comes at a cost in our economy, and thus growth is not desirable beyond some optimal rate.

It is easy to see that the larger is the country the larger will be the optimal subsidy to R&D. Increasing the size of the economy shifts the budget line out. The equilibrium for the larger economy falls farther out along the original III line. But the new second best obtains on a horizontal line through point A.³ Thus, the subsidy that rotates the III line to pass through point A no longer suffices to attain the second-best growth rate.

How does the subsidy to R&D affect the composition of final output in the economy? We answer this question with the aid of Figure 3. There, as in Figure 1, point E represents the equilibrium with no intervention. The subsidy to R&D shifts III inward, as represented by the broken line. Since the intersection of HH with LL now falls above the III curve, resources shift to R&D, which speeds growth. The increase in g causes the III curve to shift back out, and the HH curve to shift in, until they intersect along LL . Hence, the equilibrium with the subsidy in place occurs at a point such as S, where output of the labor-intensive sector is greater and output of the human-capital intensive is smaller (for given n) than before the subsidy.

³ From (13) and (14) we see that the level of \bar{E} at the second-best outcome is independent of \bar{V} .

We conclude this section by establishing that the second-best rate of growth actually coincides with the first best in our model. In the first best, intermediate inputs are priced at marginal cost. Thus, the α in (5) vanishes in the first best, and so input prices and input-output coefficients differ from those in the second-best equilibrium. The unconstrained optimum obtains when (11) is maximized subject to (12) and (13), but with the first-best input prices and techniques of production inserted in (13). The solution to this problem takes the same form as (14), except that different values for \bar{V} and \bar{w}_H from those used in the calculation of the second best now apply. But note that these variables enter (14) in ratio form, and also that $\bar{V}/\bar{w}_H = H + (w_L/w_H)L$. Direct manipulation of (5) and (6) reveals that removal of the distortion caused by the mark-up pricing of intermediates raises the payments to labor and human capital in exactly the same proportion, and so has no effect on \bar{V}/\bar{w}_H . It follows that the first-best and second-best growth rates are equal. The first best can be achieved by means of subsidies to both research and development and the production of intermediates.

V. Tariffs and Export Subsidies

We turn now to an investigation of commercial policies. We first ask how tariffs and export subsidies affect the growth rate in our economy. We then consider the welfare consequences of "small" policy interventions starting from an initial equilibrium with free trade. Finally, we study "small" policies introduced from the point of the second-best equilibrium described in Section IV.

Let T_i , $i=x,y$, represent one plus the rate of trade protection provided to sector i , where protection takes the form of an import tariff if good i is

imported or an export subsidy if that good is exported. Then domestic prices for the final goods become $q_i = T_i p_i$, and these replace the international prices on the left-hand side of equations (6a) and (6b). Differentiating (5), (6a) and (6b) with respect to the T_i , and letting $\hat{}$ denote proportional rates of change, we find

$$(18a) \quad \hat{w}_H = (1 - \beta \theta_{Hx}) \hat{T}_x / (1 - \beta) - \beta \theta_{Lx} \hat{T}_y / (1 - \beta) ,$$

$$(18b) \quad \hat{w}_L = -\beta \theta_{Hx} \hat{T}_x / (1 - \beta) + (1 - \beta \theta_{Lx}) \hat{T}_y / (1 - \beta) ,$$

where θ_{jz} , $j=H,L$, is the share of factor j in the cost of producing intermediates. Equations (18a) and (18b) imply that protection of the human-capital-intensive final good raises the reward to human capital and reduces the reward to labor, while protection of the labor-intensive final good has the opposite effects on these wages.

Let us define $\bar{Q} = q_x \bar{X} + q_y \bar{Y}$, which represents the value of final goods (normalized to account for the number of intermediates) at domestic prices. Then we can find the equilibrium values of \bar{Q} and the growth rate by proceeding in a manner analogous to that pursued in Section IV. The resource constraint corresponding to (13) now becomes

$$(19) \quad [1 - (1 - \alpha)\beta] \bar{Q} + \bar{w}_H a_{Hn} g = \bar{V} ,$$

while the arbitrage condition (16) becomes

$$(20) \quad (1 - \alpha)\beta \bar{Q} / \bar{w}_H a_{Hn} = g + \rho .$$

Of course, (19) and (20) correspond exactly to (13) and (16) when $T_i=1$ for $i=x,y$, in which case $\bar{Q}=\bar{E}$. We solve (19) and (20) for g and \bar{Q} , which gives an equation for the growth rate that is exactly the same as in (17), and

$$(21) \quad \bar{Q} = \bar{V} + \bar{w}_H a_{Hn} \rho .$$

Differentiating (17) with respect to the T_i , and making use of (18), we find the following effects of trade policies on the growth rate:

$$(22) \quad dg = \frac{\alpha\gamma}{1-\beta} \frac{w_L L}{w_H a_{Hn}} (\hat{T}_y - \hat{T}_x)$$

Protection of the human-capital-intensive final good, by raising the reward to human capital, makes R&D more costly and thus slows growth. But protection of the labor-intensive good reduces the cost of R&D and so speeds growth. In effect, the X-sector and the R&D sector are substitutes in production, since both draw on the fixed stock of human capital, whereas the Y-sector and R&D are complements in production. We note that these results are global, in the sense that the larger is the rate of protection the greater is the effect on the growth rate, provided that the economy remains incompletely specialized.

We turn now to welfare, restricting attention to small departures from free trade. Our welfare measure again is given by (15), except that the arguments of $\phi(\cdot)$ now are the domestic consumer prices, q_x and q_y . Balance in the current account now requires

$$(23) \quad \bar{E} = \bar{Q} + \sum_i (T_i - 1) p_i \bar{m}_i ,$$

where \bar{m}_i denotes imports of good i (negative for exports) multiplied by n^{-1} . Equation (23) constrains the value of spending at domestic prices to be equal to the sum of the value of final output at domestic prices and tariff revenue (or subsidy outlay). We assume that the latter is redistributed to (or collected from) consumers in a lump-sum fashion.

We differentiate (15), (21) and (23) about the point where $T_i=1$ and $\bar{Q}=\bar{E}$, and make use of Roy's identity, to obtain⁴

$$(24) \quad \rho dU/dT_x = \alpha\gamma\theta_{Lz}/(1-\beta) + (\gamma/\rho)dg/dT_x .$$

Then, substituting from (22), and using (20) and the formula for $\bar{w}_L L/\bar{Q}$ in footnote 4, we find

$$(25) \quad \frac{(1-\beta)\rho}{\alpha\gamma} \frac{dU}{dT_x} = \theta_{Lz} - \frac{g+\rho}{\alpha\rho} [\alpha\beta\theta_{Lz} + (1-\beta)\theta_y]$$

The expression for dU/dT_y is the same, except that the sign is reversed.

From (25), protection of the human-capital-intensive final good, although it always slows growth, may raise or lower aggregate welfare. To see the former possibility, recall from Figure 1 that variations in H will alter the

⁴ Our calculations use the following relationships derived from (8):

$$\bar{w}_H H/\bar{Q} = (1-\beta)\theta_x + \alpha\beta\theta_{Hz} + \bar{w}_H a_{Hn} E/\bar{Q} ;$$

$$\bar{w}_L L/\bar{Q} = \alpha\beta\theta_{Lz} + (1-\beta)\theta_y ,$$

where θ_i , $i=x,y$, is the share of the value of output in sector i in \bar{Q} . These relations and (21) imply

$$\hat{Q} = \theta_x \hat{T}_x + \theta_y \hat{T}_y + \alpha\gamma\theta_{Lz}(\hat{T}_x - \hat{T}_y)/(1-\beta) .$$

composition of final output, causing θ_y to vary from zero to one. At the same time, changes in a_{Hn} will alter the growth rate. Both of these changes will not affect θ_{Lz} , as factor prices are determined from (5) and (6). So there exist values for H and a_{Hn} such that θ_y and g are both near zero.⁵ In this case the right-hand side of (25) must be positive. Alternatively, the right-hand side of (25) will certainly be negative if $\theta_{Lz}=0$; i.e., if intermediates are produced with human capital alone. By similar reasoning, a tariff on imports of Y may raise or lower welfare even though the growth rate always responds positively.

The ambiguous welfare implications of growth-enhancing (or growth-retarding) trade policies reflect the presence of two different distortions in our economy. On the one hand, the private incentives for R&D are insufficient, so any policy that stimulates growth ceteris paribus will boost welfare. On the other hand, the monopoly pricing of intermediates means that these inputs are under-produced in the market equilibrium. Protection of the labor-intensive good, by drawing resources into that sector and into the R&D sector, may reduce the output of intermediates. If so, this effect counteracts the beneficial effect of faster growth.

We may calculate the impact of trade policy on the output of intermediates using $p_z \hat{Z} = \beta \hat{Q}$, the formula for \hat{Q} from footnote 4, and the expression for \hat{p}_z that comes from differentiating (5), (6a) and (6b). We find

$$(26) \quad \hat{Z} = \left[\frac{(1-\alpha\gamma)}{(1-\beta)} \theta_{Lz} - \theta_y \right] (\hat{T}_x - \hat{T}_y) .$$

⁵ When θ_y is near zero, good Y must be imported. Then the trade policy under discussion (i.e., protection of the human-capital-intensive industry) involves a subsidy to exports of good X .

Intermediate production is more likely to rise in response to protection of the human-capital-intensive good and fall in response to protection of the labor-intensive good the larger is the share of labor in the cost of producing the inputs. This follows from the fact that an increase in the domestic price of X causes w_H to rise and w_L to fall, whereas an increase in q_y has the opposite effect on factor prices. For given θ_{Lz} , the output of intermediates is more likely to rise the greater is the share of the protected sector in the value of final production. We recognize this as a demand-side effect, recalling the fact that intermediates are non-traded goods. Since protection causes one final good sector to expand and the other to contract, it has offsetting effects at given prices on the derived demand for intermediates. The more important is the expanding sector in total derived demand, the more likely it will be that the demand curve for intermediates shifts out.

Comparing (26) and (25), it is easy to show that a decrease (increase) in output of intermediates is necessary but not sufficient for protection of the labor-intensive (human-capital-intensive) industry to lower (raise) welfare. A growth-enhancing policy is more likely to increase welfare despite a fall in the output of intermediates when $g/(g+\rho)$ is large, since the beneficial effect of the tariff through its indirect inducement to R&D is largest in this case. Similarly, a growth-retarding trade policy can give rise to a welfare improvement only when the initial growth rate is relatively low. Finally, (25) reveals that, in general, a trade policy is more likely to improve welfare the larger is the share of the protected sector in the value of final output.

In general, we cannot rank the optimal R&D subsidy of Section IV and the optimal tariff or export subsidy. This reflects the second-best nature of either form of policy intervention. The R&D subsidy most efficiently offsets

the externality present in the process of knowledge generation, but does nothing to correct for the under-supply of intermediate goods. Trade policy, on the other hand, has only an indirect effect on growth. But since trade policies alter domestic factor prices, they can be useful as a means to promote the production of intermediate goods.

Finally, we note that if both trade policy and R&D subsidies are available to the government as tools of intervention, then in general both will be used to augment welfare. Starting from the second-best equilibrium identified in Section IV, we can again calculate the welfare effect of a small dose of trade policy. We find

$$\text{sgn } dU = \text{sgn} [(\theta_{Lz} - \theta_y)(\hat{T}_x - \hat{T}_y)] .$$

When an R&D subsidy is available to spur growth, trade policy should be used to promote production of intermediates. This goal is achieved by protecting the sector that is large (a demand-side influence) or the one that competes least for primary inputs with producers of intermediates.

VI. Tariffs versus Quotas

We turn now to a comparison of tariffs and quotas. We assume that the presence of quota rents gives rise to rent-seeking behavior that diverts resources from the productive sectors. We establish that the occurrence of such behavior necessarily slows growth. This finding is in keeping with the description of various historical epochs provided by Baumol (1988). We also show that the diversion of resources to rent seeking has an adverse effect on welfare, and so small tariffs are preferable to small quotas on efficiency

grounds.

We specify a quantitative import restriction that fixes \bar{m}_x , so that the volume of imports grows at rate γg .⁶ In so doing, we are assuming that the trade authorities continuously adjust the permissible level of imports to keep pace with growth in the economy. We consider a quota that slightly reduces the level of imports below the free-trade level at every moment in time.

We suppose that import licenses are distributed in proportion to the resources that an entrepreneur devotes to "seeking", and that all licences are "up for grabs". We allow a general, constant-returns-to-scale technology for seeking, with unit cost function $c_R(\bar{w}_H, \bar{w}_L)$. Let R be a measure of the intensity of seeking activity. Then, in a competitive equilibrium, total rents, $(q_x - p_x)\bar{m}_x$ must equal the total industry cost of seeking, $c_R(\bar{w}_H, \bar{w}_L)R$, or multiplying both sides by n^{-1} ,

$$(27) \quad (q_x - p_x)\bar{m}_x = c_R(\bar{w}_H, \bar{w}_L)R .$$

The use of resources in seeking import licences must now be incorporated into the factor-market-clearing conditions. We use modified versions of (9a) and (9b), multiply the former by \bar{w}_H and the latter by \bar{w}_L , and add, to derive

$$(28) \quad [1 - (1-\alpha)\beta]\bar{Q} + \bar{w}_H a_{Hn}g = \bar{V}(\bar{w}_H, \bar{w}_L) - c_R(\bar{w}_H, \bar{w}_L)R .$$

This is our "resource constraint" that takes the place of (19), which we used in the tariff case. The no-arbitrage condition (20), derived for the tariff

⁶ The analysis of a quota on imports of good y , if that happens to be the import good, is analogous. The conclusions regarding the comparison of the tariff and quota are identical.

case using domestic prices in the calculation of profits, continues to apply.

Now consider the introduction of a small restriction to imports from an initial position of free trade. From (27) and the fact that initially $R=0$, we have

$$\bar{m}_x dq_x = c_R(\bar{w}_H, \bar{w}_L) dR .$$

The quota generates an increase in the domestic price of the importable good, and draws some resources into rent seeking. These two effects of the quota can be distinguished for purposes of analyzing the implications for resource allocation and growth.

The implications of the rise in the domestic price of the importable are identical to those for a tariff. From (6a) and (6b), \bar{w}_H rises and \bar{w}_L falls. Then, ignoring the last term in (28) for the moment, this change in factor prices alters the allocation of resources given by (20) and (28) in the same way that the tariff affected the allocation given by (19) and (20).

The diversion of resources to rent seeking acts like a shrinkage of the resource endowment of the economy. The partial effect of this (for given \bar{w}_H and \bar{w}_L) can be seen in Figure 4. There we have plotted (20) and (28) in (g, \bar{Q}) space. From (28), an increase in R , holding \bar{w}_H and \bar{w}_L constant, causes the resource constraint to shift in, while leaving the no-arbitrage condition unaffected. The resource contraction reduces both the growth rate and the value of the output of final goods, as the equilibrium shifts from E to E' .

We conclude that, whatever is the effect of a small tariff on the growth rate, a quota cum rent seeking which similarly protects the domestic importables industry will be more deleterious. The same can be said with

regard to welfare. The welfare consequences of a small departure from free trade continue to be a function of the effects of policy on the rate of growth and the (normalized) level of spending, as they were for the tariff. Under the quota, trade balance again requires $\bar{E} = \bar{Q} + (q_x - p_x)\bar{m}_x$. So a quota must be inferior to a price-equivalent tariff, since the former has both smaller g and smaller \bar{E} .

VII. Conclusions

In this paper, we have examined the welfare properties of a dynamic model of trade and growth in a small, open economy. Growth stems from endogenous technological progress, as far-sighted entrepreneurs introduce innovative (intermediate) products whenever the present value of the stream of operating profits covers the cost of product development. Diversity of intermediate inputs contributes to total factor productivity in two consumer-good sectors, and a balanced growth path generally exists. In the dynamic equilibrium, the small country trades the two final goods at exogenously given terms of trade.

Two market distortions featured prominently in our analysis. First, we posited an externality in the process of knowledge generation. We assumed that when entrepreneurs invest in research and development they fail to appropriate all of the social benefits from the scientific and engineering discoveries they make. This captures, we feel, an important aspect of knowledge creation, which relates to the public good nature of most information. Second, the producers of innovative products must capture some private rewards in the form of monopoly profits if they are to have incentive to bear the cost of R&D. But the exercise of monopoly power means that the supply of innovative products generally will not be statically efficient.

We identified the first-best growth path and a constrained, second-best path. The first best can be attained with subsidies to both R&D and the production of intermediates, with each policy instrument set so as to correct one of the two distortions noted above. The second-best problem involves maximization of welfare of the representative consumer when the government is constrained to allow market forces to determine factor prices and the allocation of resources to all manufacturers of tangible products. We showed that the first and second-best rates of growth are the same, and that the second best can be achieved with a subsidy to R&D alone. Subsidies to R&D beyond the rate that we have shown to be optimal accelerate growth even further, but do so at the expense of welfare.

We have examined the growth and welfare implications of commercial policy. We have shown that promotion of the human-capital-intensive final-goods sectors by means of an import tariff or an export subsidy speeds growth, while promotion of the labor-intensive final-goods sector slows growth. But acceleration of growth is neither necessary nor sufficient for trade policy to improve welfare. A trade policy that spurs growth may nonetheless reduce welfare if it causes a fall in the output of (under-supplied) intermediates. And similarly, a trade policy that encourages production of intermediates by means of the induced reallocation of resources can raise welfare even if expansion of the intermediates sector comes partly at the expense of R&D and hence growth. We have derived an exact expression for the welfare effects of small import tariffs and export subsidies in either sector.

Finally, we have compared tariffs and quotas as tools of trade protection under the assumption that the distribution of quota licences can be influenced by rent-seeking behavior. As in the static models of Krueger (1974) and

others, the diversion of resources to rent seeking reduces the production possibilities for the economy. In our growth model, some of the resources that engage in rent seeking come at the expense of the R&D sector, and so the occurrence of rent seeking reduces the rate of growth. We have shown that a small restriction of trade achieved via a quota-cum-rent-seeking leads to a lower level of welfare than a similar restriction achieved by means of a tariff.

REFERENCES

- Baumol, William J. (1988), "Entrepreneurship: Productive, Unproductive and Imitative; or the Rule of the Rules of the Game". Unpublished paper.
- Ethier, Wilfred J. (1982), "National and International Returns to Scale in the Modern Theory of International Trade," American Economic Review 72, pp.389-405.
- Grossman, Gene M. and Helpman, Elhanan. (1989a), "Comparative Advantage and Long-Run Growth." NBER Working Paper No. 2809. Cambridge, MA: National Bureau of Economic Research.
- _____. (1989b), "Endogenous Product Cycles." Discussion Paper in Economics No. 144. Princeton NJ: Woodrow Wilson School of Public and International Affairs.
- Krueger, Anne O. (1974), "The Political Economy of the Rent-Seeking Society," American Economic Review 64, pp.291-303.
- Lucas, Robert E. Jr. (1988), "On the Mechanics of Economic Development," Journal of Monetary Economics 22, pp.3-42.
- Romer, Paul M. (1988), "Endogenous Technological Change." Paper presented at the SUNY-Buffalo Conference on 'The Problem of Development'.
- _____. (1989), "Capital Accumulation in the Theory of Long Run Growth," in R. Barro (ed.), Modern Macroeconomics. Cambridge, Harvard University Press, forthcoming.

Figure 1

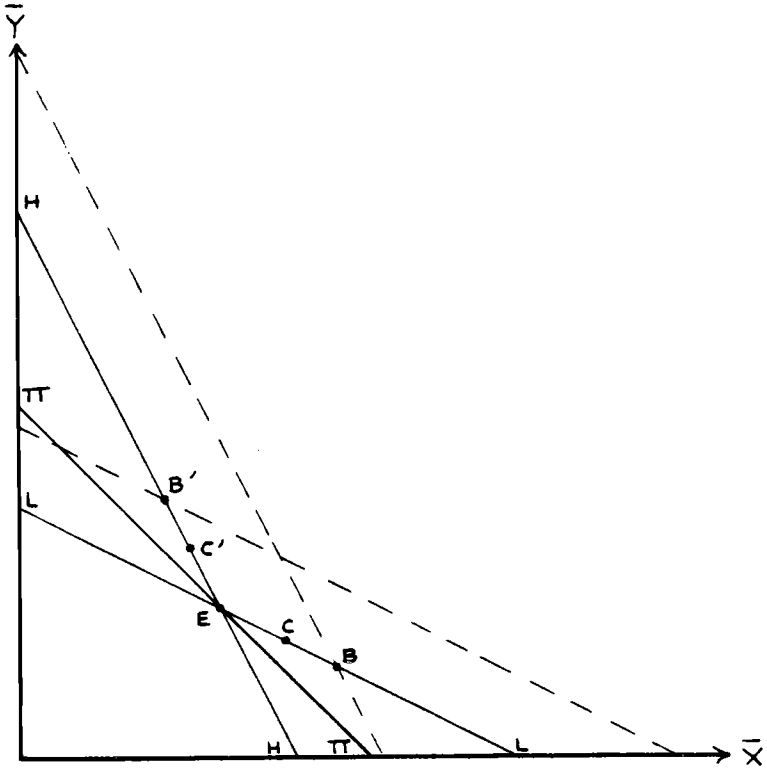


Figure 2

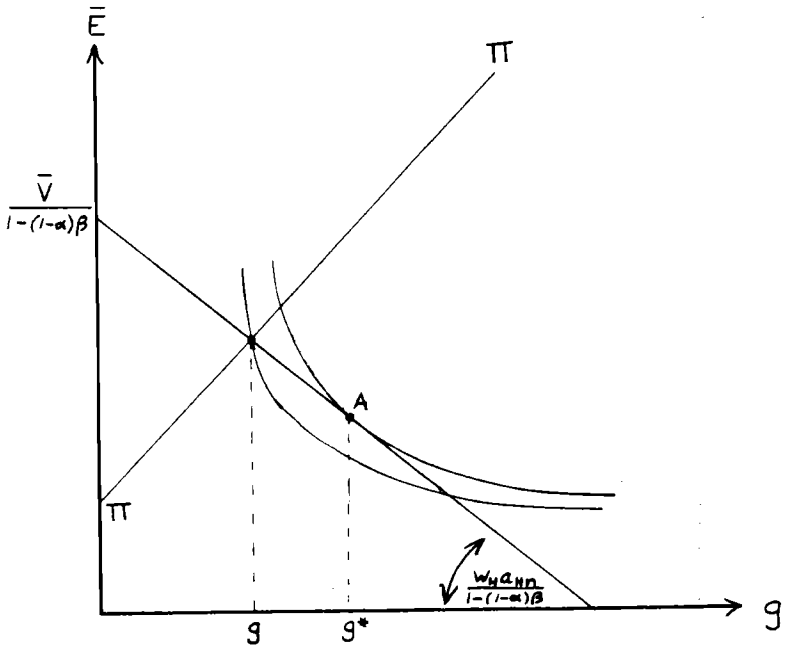


Figure 3

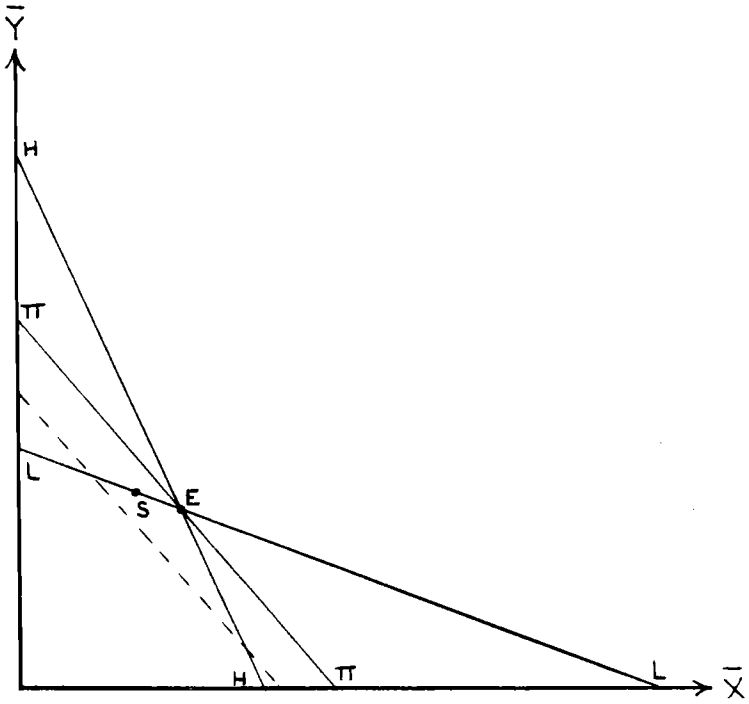


Figure 4

