INCREMENTAL TRADE POLICY AND ENDOGENOUS GROWTH: A q-THEORY APPROACH

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ABSTRACT

Most trade-and-growth studies focus on the growth effects of autarky-to-free-trade changes, rather than those of incremental liberalizations. This paper characterizes how the strength and sign of openness-and-growth links depend upon the nature and level of trade barriers. For most types of trade barriers, we find that liberalization raises or lowers growth depending upon the initial level of the barrier. This suggests empirical studies that pool data from high and low protection nations are mis-specified, and that policy lessons based on autarky-to-free-trade results are of limited use to policymakers.

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1. Introduction

How are openness and growth related? Much of the seminal theoretical literature (e.g., Rivera-Batiz and Romer 1991a, Grossman and Helpman 1991, Segerstrom, Anant and Dinopoulos 1990, and Krugman 1988) studies this question in the context of extreme policy reform, in particular, switches from autarky to free trade or small deviations from free trade. These seminal works identify several pro-growth and anti-growth forces, but their results are of only limited use for theoretical, policy and empirical analysis.* The point here is that real-world trade liberalisations are incremental, not jumps from autarky to free trade. There are two theoretical reasons for thinking that this distinction matters and one reason for thinking that the distinction is important for the design of empirical studies.

First, the literature already contains one prominent example illustrating the difference between incremental and full trade liberalisation. With their famous U-shaped link between tariffs and growth, Rivera-Batiz and Romer (1991b) show that there is an important difference between autarky-to-free-trade liberalisations and incremental liberalisations. For symmetric nations and *ad valorem* tariffs, they show that autarky-to-free-trade liberalisation has no impact on the endogenous growth rate, while incremental liberalisations do have impact. In particular, an incremental cut from a very high tariff level is anti-growth, while an incremental cut from a low tariff level is pro-growth. This example alone shows that the autarky-to-free-trade lessons of Grossman and Helpman (1991) and others are not directly applicable to real-world liberalisations, which never involve autarky-to-free-trade shifts. Second, there are good reasons for questioning the robustness of the Rivera-Batiz-Romer U-shaped link. The literature on static trade policy analysis under imperfect competition (e.g., Helpman and Krugman, 1989) shows that incremental liberalisation affects prices and

*See Grossman and Helpman (1995) and Long and Wong (1996) for a survey of trade and growth models, and of pro- and anti-growth forces. Grossman and Helpman also summarize existing growth results for incremental trade liberalisations (this takes only 3 of the survey's 59 pages).

output in a very nonlinear manner. The Riveria-Batiz-Romer result was not, therefore, unexpected. However, this literature also demonstrates that the precise nature and even the sign of the effects depend crucially upon a long list of assumptions: the type of import barrier considered (e.g., quantitative barriers versus tariff protection), the type of liberalisation considered (reciprocal or unilateral), the type of countries considered (e.g., equal versus unequal sized nations), and the type of competition assumed (e.g., Bertrand versus Cournot). By analogy, it seems likely that the U-shape also depends crucially on the specific assumptions made in the seminal Rivera-Batiz-Romer work.

These theoretical reasons suggest that lessons from the study of autarky-to-free-trade liberalisations may not be directly applicable to real-world liberalisations that are, after all, always incremental. However, the motive for studying the growth effects of incremental trade liberalisation goes far beyond the usual importance of exploring the theoretical robustness of well-known results. The non-monotonicity of growth effects has important ramifications for the design of empirical investigations.

Most empirical studies of trade and growth - e.g., Barro (1991) and followers (see Harrison 1996 for a survey) -- pool data on highly protected economies with data on very open economies. Other studies (e.g., Coe and Moghadam 1993 and Coe and Helpman 1995) estimate an openness and growth link using panel data or single-nation, time-series data drawn from a period that involves substantial liberalisation. Both the cross-section and time-series studies implicitly -- and incorrectly -- assume that they are estimating stable parameters. As the Rivera-Batiz-Romer U-shape shows, it may be important to specify functional forms that allow for non-monotonicity in the openness and growth relationship. More specifically, by assuming that the impact of openness on growth is linear (or log linear), empirical studies disregard important information about trade and growth links.

The purpose of this paper is to contribute to our understanding of how incremental trade liberalisations affect long-run growth.*

*Some of these results were initially posited in our unpublished NBER working paper, Baldwin and Forslid (1996). That paper, however, tried to do too much. It introduced Tobin's q approach to endogenous growth models and discussed six trade and growth links. In order to more fully explore the novel trade and growth links, we have divided the working paper into two papers. The current paper focuses on the growth effects of incremental liberalisation and the dynamic home market effect – issues that were just touched upon in our NBER working paper. The other paper, Baldwin and Forslid (1997a), presents the q-theory approach in more detail and extends the basic product innovation model to allow for imperfect competition in the innovation and the financial intermediation sectors.

Our main results fall into two categories. First, we show that the nature of trade barriers as well as their level has an important effect on the growth-and-openness link. Specifically, we show that the Rivera-Batiz-Romer U-shape works only for *ad valorem* tariffs. For specific tariffs and quantitative restrictions, there is a bell-shaped relationship between the growth rate and the level of protection. In contrast, frictional (i.e., iceberg) barriers have no impact on growth unless the innovation sector uses traded intermediates.

Second, we show that the symmetry of nations assumed in most of the early trade-and-endogenous-growth literature matters a great deal when learning externalities are at least partially localised. For instance, when nations are symmetric in size, but trade liberalisation is not perfectly symmetric, we find a 'dynamic home-market effect'. That is, growth is stimulated when a nation unilaterally raises or lowers its import barriers. The mechanism is straightforward. Asymmetric liberalisation fosters agglomeration of innovation in the more protected nation. Given partly localized learning externalities, this agglomeration improves the productivity of the world's innovation workers and this stimulates world-wide growth.

Plan of the Paper. Following this introduction, Section 2 presents a simple trade-and-endogenous-growth model in which growth is driven by ceaseless product innovation. This section also shows that the growth path can be analysed through its 'static-economy representation'. That is, the steady-state equilibrium can be studied by determining the static allocation of labour among sectors. This approach – based on Tobin's q-theory – allows us to see that analysis of trade-and-endogenous-growth models is not much more difficult than analysis of static new-trade models. In both cases, the essence is to pin down the allocation of labour among various activities and to determine how policy affects the allocation. This insight allows us to draw quite directly upon the lessons of the static Helpman-Krugman trade-policy literature.

Section 3 examines the growth effects of incrementally liberalising specific tariffs, *ad valorem* tariffs, frictional (i.e. technical or 'iceberg' barriers) and quantitative restrictions. While we confirm the general Rivera-Batiz-Romer notion that growth effects are non-monotonic, their U-shape holds only for *ad valorem* tariffs. This section also studies the growth effects of trade liberalisation when the innovating sector employs traded intermediates.

Section 4 studies the growth effects of asymmetric market openings (i.e., unilateral liberalisation). Again we find very non-monotonic relationships between openness and growth. Section 5 of the paper contains our concluding remarks.

2. The Basic Symmetric Model

This section presents and analyses the model used in Section 3 to study the effects that the nature of import protection has on the openness-and-growth relationship. In particular, this section derives a proposition that opens the door to a very easy and intuitive approach to signing the growth impact of incremental liberalisation.

To focus clearly on the nature of trade barriers, the model assumes that nations are symmetric in all aspects. The basic model is similar to Baldwin and Forslid (1996), however it allows for expanding varieties to be used as intermediate inputs rather than being consumed directly. This extension is necessary to obtain the Riveria-Batiz-Romer U-shaped link between *ad valorem* tariffs and growth.

2.1 Assumptions

Consider a world with two nations, each with two factors (labour L and knowledge capital K) and three sectors (X, Z and I). Nations are symmetric in terms of tastes, technology, endowments, and trade barriers. Following the standard practice, goods are traded but factors are not.

The X-sector consists of differentiated goods produced under increasing returns and Dixit-Stiglitz monopolistic competition. Technology for a typical X-sector variety is simple. Production of each unique X-variety involves a one-time fixed cost that consists of one unit of K and a variable cost that consists of a_X units of labour per unit of output. The corresponding cost function for a typical variety is $\pi+wX_j$, where π is K's rental rate, w is the wage, X_j is the firm's total production, and $a_X=1$ by choice of units. Assuming free entry, the rental rate for capital, π, is a typical variety's operating profit due to K's variety-specificity.* X-varieties are not consumed directly; they are intermediate inputs into the production of the sole final good Z.

The Z-sector produces a homogeneous, freely traded, final good under perfect

*Units of K are variety specific, so rental rates are not set in competitive markets. Rather, K's reward is operating profit, i.e. what is left over from total revenue when the variable costs have been paid.

competition and constant private returns.* Specifically, Z firms combine labour and intermediates, according to the production function $Q_Z = a_Z L_Z^{1-\alpha} Q_X^{\alpha}$, where Q_Z is output, L_Z is Z-sector employment, and Q_X is a CES composite of all X-varieties ($\sigma>1$ is the constant elasticity of substitution). The Z-sector cost function is therefore:

$$w^{1-\alpha}\left(\int_{i=0}^{N} p_i^{1-\sigma} di\right)^{\alpha/(1-\sigma)} Q_Z \tag{1}$$

where N is the mass of varieties available, and $a_Z = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}$ by choice of Z units.

The I-sector (I is a mnemonic for innovation) uses a_I units of L to produce a unit of knowledge capital under perfect competition and constant private returns. Returns, however, are not constant at the sector level since – following Romer (1990) – we assume a sector-wide learning curve. That is to say, atomistic I-firms take a_I as a parameter but a_I falls as cumulative output of the I-sector (and therefore innovation experience) rises. Knowledge capital does not depreciate, so K and K* are the number (mass) of existing home and foreign varieties (i.e., N) as well as cumulative output of the I-sector. The specific production and marginal cost functions are:

$$Q_K = L_I / a_I\,, \quad F = w a_I\,; \qquad a_I \equiv 1/(K+K^*) \tag{2}$$

where Q_K and L_I are I-sector output and employment, and F is I-sector marginal cost (in equilibrium F is the X-sector fixed cost). Without depreciation $\dot{K} = Q_K$, so the I-sector production function in growth-rate form is:

$$g \equiv \dot{K}/K = 2L_I \tag{3}$$

Jones' Critique. This learning curve assumption is standard in most of the trade-and-endogenous-growth literature. It has, however, come under criticism on empirical grounds from Jones (1995a), so some comment here is in order. The knowledge-production function (3) implies that an increase in the resources employed in R&D should result in faster innovation. To test the plausibility of such specifications, Jones takes the number of scientists and engineers engaged in R&D as a proxy for the level of resources devoted to innovation. He then takes total factor productivity (TFP) as a proxy for the output of

*The Z sector is subject to scale economies on an aggregate level (an expanding range of varieties raises Z-sector labour productivity), but these effects are external to Z-firms.

innovations. He asserts that he can reject the assumption of a unitary learning elasticity (i.e., that K+K* enters the production function for Q_K in a linear fashion) since "TFP growth exhibits little or no persistent increase, and even has a negative trend for some countries, while the measures of L_A [Jones' notation for L_I] exhibit strong exponential growth."

Jones' evidence, however, is no better than his proxy for the rate of innovation, and TFP is a notoriously bad measure of innovation (Nelson 1996). In particular, TFP figures depend critically on aggregate price indices and these systematically underestimate the impact of quality and variety. This is important since in the Grossman-Helpman product innovation model, growth is driven entirely by the ceaseless fall in an ideal price index, which is itself driven by an ever-expanding range of varieties. Quite simply, a price index that is not revised every year to reflect expanding variety will systematically understate innovation. To take an extreme example, suppose that TFP is measured with a price index that aggregates all varieties together (i.e., it divides expenditure by the average price of varieties). Since the physical output of the manufacturing sector (X) is constant through time in the Grossman-Helpman model, such a price index would indicate, as Jones found, that there was no relationship between L_I and TFP growth even if (3) were an accurate description of the innovation process. The same sort of problem holds *a fortiori* for quality-ladder models. Thus while Jones (1995a) is an important contribution, one cannot reject (3) out of hand until more detailed empirical work is undertaken.

Trade Barriers. Intermediates (i.e., X-varieties) are traded. However, this trade is subject to three types of barriers: an *ad valorem* tariff (denoted as $\tau=1+t$, where t is the tariff rate), a specific tariff of T units of numeraire per unit of X imported, and an 'iceberg-cost' barrier such that $\Lambda \geq 1$ units must be shipped to sell one unit abroad. Here Λ (a mnemonic for iceberg) represents technical barriers to trade that raise the cost of imports without generating tariff revenues or quota rents. τ, Λ and T are equal for all X-varieties. Tariff revenue is either returned lump-sum to consumers or destroyed, depending upon the scenario studied. Operating profit for a typical variety j is:

$$\pi \equiv (p_j - w)x_j + (p_j^*/\tau - w\Lambda - T)x_j^* \tag{4}$$

where p_j, p_j^*, x_j and x_j^* are prices and sales in the local and export markets, respectively. Notice that $x_j+x_j^* \equiv X_j$.

Preferences of the infinitely-lived representative consumer are ${}_0\int^{\infty} e^{-\rho t} \ln[C(t)]dt$ where C is consumption of Z, and ρ is the time-preference parameter. The flow budget constraint is Y+R=E+I where Y is factor income $wL+\pi K$, R is tariff revenue, E is consumption expenditure, and I is spending on new K.

2.2 Key Intermediate Results

On the demand side, the key intermediate results are the Euler equation, $\dot{E}/E=r-\rho$ (r is the return on savings), a transversality condition, and Z's demand function, E/p_Z.

Given Z-sector technology and market structure, total spending on intermediates (X-varieties) equals $\alpha p_Z Q_Z$. Because $E=p_Z Q_Z$, the demand in a particular market for a typical X-variety is[1] (numbered notes refer to attached "Supplemental Guide to Calculations"):

$$x_j = s_j \alpha E / p_j \, ; \qquad s_j \equiv p_j^{1-\sigma} / \left(\int_i p_i^{1-\sigma} di \right) \tag{5}$$

where s_j is variety j's market share.

X-firms choose local- and export-market prices (p and p*) taking other firms' prices as given. The first-order conditions thus imply[2]:

$$p(1-1/\sigma) = w \, , \qquad p^*(1-1/\sigma) = (w\Lambda + T)\tau \tag{6}$$

Rearranging these (using the definition of operating profit), we have[3]:

$$\pi = M\frac{\alpha E}{K} \, ; \qquad M \equiv \frac{1}{\sigma}(1-S^*+\frac{S^*}{\tau}), \quad S^* \equiv \frac{\phi}{1+\phi} \, , \quad \phi \equiv (\frac{p^*}{p})^{1-\sigma} \tag{7}$$

Here M (a mnemonic for margin) is the average operating profit margin, $\alpha E/K$ is per-variety sales, S* (a mnemonic for foreign share) is the import penetration ratio, and ϕ (a mnemonic for trade 'free-ness') measures openness, since ϕ rises from zero (with prohibitive trade barriers) to unity (with free trade). (7) permits a decomposition of π-changes into changes in $\alpha E/K$ (the sales effect) and changes in M (the procompetitive effect).

Using the demand function for a typical X-variety, total tariff revenue, R, is[4]:

$$R = \alpha \eta E \, , \qquad \eta \equiv \frac{(\tau-1) + T(1-1/\sigma)/(w\Lambda+T)}{\tau(1+\phi^{-1})} \tag{8}$$

In scenarios where the tariff revenue is assumed to be wasted, we set $\eta=0$.

I-sector competition implies $P_K=F$, where P_K is the price of K. Finally, using symmetry, Z's cost function, and (6), we see that p_Z falls as K rises, that is[5]:

$$p_Z = w\,[K(1+\phi)]^{\alpha/(1-\sigma)}\,(1-1/\sigma)^{-\alpha} \tag{9}$$

2.3 Dynamic Analysis

We take L_I as the state variable and L as numeraire. These choices are not standard, but they make the analysis much easier, so they deserve some comment. First, consider why L is the natural numeraire. The model has only one primary factor L, as in Grossman and Helpman (1991 Chapter 3), and labour is the only variable input in our model. Moreover, given the structure of the model -- (3) in particular -- any time-invariant allocation of L among the three sectors (X, Z, and I) will result in a constant long-run growth rate. The converse is also true, for any given long-run growth rate, there is a unique allocation of labour among the three activities X, Z and I. It seem clear, therefore, that L allocation is the basis of both the representative consumer's decisions and the production decision of Z firms. This makes L the natural numeraire.

Consider next why L_I is the natural state variable. The principle task at hand is to determine the steady-state growth rate. Growth in our model is driven by the ceaseless expansion of product varieties, so the task boils down to finding the rate of expansion, namely g. This suggests g as a good state variable and indeed it is possible to solve the model in this way. However, g is not the fundamental determinant of growth -- L_I is. The point is that in all growth models, the accumulation of human, physical, or knowledge capital is what drives growth. Investment is what drives this accumulation, so investment is the fundamental determinant of growth. This makes L_I is the natural state variable, since L_I is the level of investment measured in units of the numeraire.[*]

Given that L_I is real investment, so solving for the steady state requires characterisation of investment in a general equilibrium framework. An intuitive approach to this is Tobin (1969), who posits that equilibrium investment is characterised by equality of a unit of capital's present value – call this V – and its replacement cost P_K. Tobin's famous steady-state condition q=1 is, therefore, equivalent to an X-sector free entry condition, $V=P_K$.[**]

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[*]To see that L_I is real investment, note that competition in the I sector implies that the value of output (measured in L units) equals the value of inputs (measured in units of L).

[**]Turnovsky (1996), which was independently developed, seems to be the first published use of the Tobin-q approach in an open economy endogenous growth model.

Calculations proceed by finding the present value V. To this end, we first need the steady-state discount rate. Given our choices of numeraire and state variable, we see immediately that $\dot{E}$ must be zero in steady state. After all, labour not devoted to producing investment goods (viz. L_I) must be devoted to producing consumption goods. The value of consumption goods produced (measured in units of L) must, therefore, be time-invariant in steady-state. Of course the value of production must equal the value of consumption, so we know that $\dot{E}=0$ in steady state. More formally, we manipulate E=Y+R-I, using (7) and (8), to get[6]:

$$E = w(L-L_I) \,/\, [1-\alpha(\eta+M)] \tag{10}$$

By choice of state variable and numeraire, w=1 and $\dot{L}_I=0$ in steady state. Thus, from (10), $\dot{E}=0$ in steady state. From the Euler equation, this means that r equals ρ in steady state. (The appendix shows that the symmetric-country system is always in steady state)

From (7), π 's evolution depends on E and K. Of course, $\dot{E}=0$ and K's time-invariant growth rate is $g=2L_I$. Thus, π falls at the rate g and is discounted at the rate ρ, so:

$$\bar{V}_t = \int_{s=t}^{\infty} e^{-r(s-t)}\, \pi_s \, ds = \frac{\pi_t}{\rho+\bar{g}} \tag{11}$$

where 'bars' indicate steady-state values here and in the rest of the paper. Since q's denominator is $P_K=F$, (2) and (3) permit us to write q as a function of L_I, or alternatively as a function of g[7]:

$$q[\bar{L}_I] = \frac{2\alpha M(L-\bar{L}_I)}{(\rho+2\bar{L}_I)(1-\alpha(\eta+M))}, \qquad q[\bar{g}] = \frac{\alpha M(2L-\bar{g})}{(\rho+\bar{g})(1-\alpha(\eta+M))} \tag{12}$$

By inspection, steady-state q is monotonically declining in the steady-state L_I (first expression), or alternatively in the steady-state g (second expression).

Solving Tobin's famous $\bar{q}=1$ condition, using (12), the steady state is given by:

$$\bar{L}_I = \frac{2\alpha ML - \rho(1-\alpha(\eta+M))}{2(1-\alpha\eta)}, \quad \bar{g} = 2\bar{L}_I \tag{13}$$

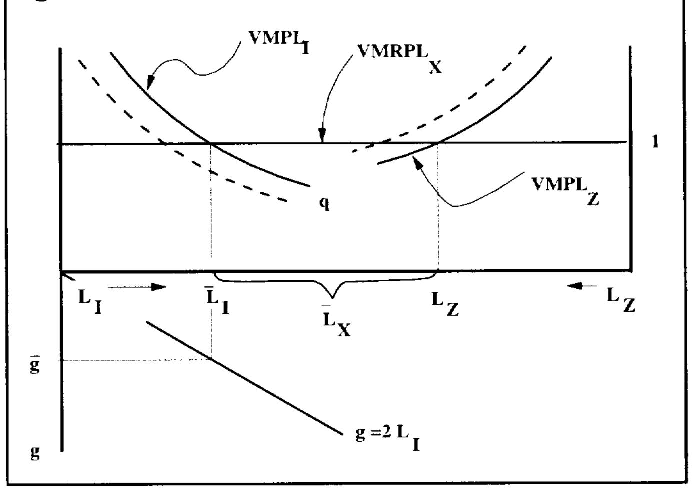
Recall that 'bars' denote steady-state values.

2.3.1 Static-Economy Representation

The model's steady-state growth path has a 'static-economy representation' (Baldwin and

Forslid 1996). That is, since $g=2L_I$, long-run growth can be time-invariant if and only if L_I is time-invariant. The demand for L_I's output, however, depends upon X- and Z-sector employment, namely, L_X and L_Z. Finding the long-run growth path is therefore equivalent to determining L's equilibrium allocation among sectors, hence the term static-economy representation. In fact, our model's static-economy representation (Figure 1) is similar to the Ricardo-Viner model. The length of the horizontal axis is the national L endowment, with L_I and L_Z measured from the left and right, respectively. L not employed in I or Z is employed in X.

Figure 1



In this model, the value of the marginal product of labour in the I-sector (call this $VMPL_I$) is Tobin's q. To understand this somewhat unexpected fact, note that it takes F units of labour to produce V's worth of output, so q=V/F is the value of the average product of L_I. Because I-firms face constant private returns (learning effects are external), the average and marginal products of L_I are identical; thus, $q=VMPL_I$. In the imperfectly competitive X-sector, the proper concept is the value of the marginal <u>revenue</u> product of L_X ($VMRPL_X$), and, due to mark-up pricing, $VMRPL_X=1$ for all equilibrium divisions of L.[8] Z-firms choose L_Z such that the value of the marginal product of labour ($VMPL_Z$) equals w=1. From (1), (5), (6) and (10)[9]:

$$VMPL_Z = \left(\frac{(1-\alpha)(L-L_I)/L_Z}{1-\alpha(\eta+M)} \right)^{\alpha} \tag{14}$$

By inspection, $VMPL_Z$ is decreasing in L_Z for any given L_I. As in a static economy, the intersections identify the equilibrium division of labour. The steady-state growth rate, $\bar{g}$, is read off (3), which is graphed in the lower quadrant.

Dynamic/Static Block Recursion. The remaining dynamic features of the steady-state growth path all follow from $\bar{g}$. For instance, real income grows at $\bar{g}\alpha/(\sigma-1)$ because nominal income, i.e. $L+\alpha(\eta+M)(L-\bar{L}_I)/[1-\alpha(\eta+M)]$ is time-invariant, yet from (9), the consumption-good price, p_Z, falls at $g\alpha/(\sigma-1)$.[10]

Policy Analysis. As Baldwin and Forslid (1997a) pointed out in a simpler model, the static-economy representation and the recursiveness of the static/dynamic features suggest a simple approach to gauging the growth effects of policy changes. Figure 1 illustrates this. In steady-state q=1, but policy and/or parameter changes can lead to incipient changes in q.* For instance, consider a change that lowered the q schedule (as shown by the dashed line). If L_I were unchanged, pure profits losses would appear in the I-sector (since q<1 implies V<F). These incipient losses would direct I-firms to fire labour, so $\bar{L}_I$ decreases instead of V and $\bar{V}$=F is restored. The drop in $\bar{L}_I$, however, lowers the long-run growth rate. Since L_I can jump, the growth effect is instantaneous. Notice also that a drop in $\bar{L}_I$ raises $VMPL_Z$, so $\bar{L}_Z$ also rises, but this has no dynamic implications.

Because the incipient change in q is a sufficient statistic for the growth effects of trade policy changes, we have:

Proposition 1: The sign of a policy reform's growth effect depends only upon the sign of $(\partial\pi/\partial\Theta_i)-(\partial P_K/\partial\Theta_i)(\rho+g)$, where Θ_i is an element of the policy vector $\Theta\equiv(\tau,\Lambda,T,\eta)$.

To see this, note that π can be written as a function of g and Θ. In the basic model, P_K is independent of Θ, but in one extension developed below, P_K is a function of Θ. Allowing P_K to (possibly) depend upon Θ, total differentiation of q=1 yields[11]:

$$\frac{d\bar{g}}{d\Theta_i} = \frac{\partial\pi/\partial\Theta_i - (\rho+\bar{g})\ \partial P_K/\partial\Theta_i}{P_K - \partial\pi/\partial g} \tag{15}$$

From (2), (7) and (10), the denominator is everywhere positive.[12] The sign of the growth effect of any policy change therefore depends only upon the sign of the numerator. Proposition 1, which is derived in Baldwin and Forslid (1997a) but not applied to the analysis of import protection, shows that analysing the growth effects of protection is not more difficult than analysing the impact of protection on π and/or P_K in a static model.

3. Liberalisation and Growth with Symmetric Countries

This section uses the basic model presented in Section 2, and Proposition 1, to study how the <u>nature</u> and <u>level</u> of the four types of barriers (frictional barriers, *ad valorem* tariffs, specific tariffs, and quantitative restrictions) affect long-run equilibrium growth. In

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*Introducing transitional dynamics via quadratic I-sector hiring costs would permit q to deviate from unity in transition as in Blanchard and Fisher (1989).

particular, given that P_K is independent of Θ in the Section 2 model, Proposition 1 tells us that signing the growth effects of incremental trade liberalisation requires only investigation of the static impact of liberalisation on π.

This section begins by considering three protection types (*ad valorem* tariffs, specific tariffs, and iceberg barriers) in the context of the Section 2 model. Since we are working with monopolistic competition, a quantitative restriction (QR) is equivalent to a specific tariff with the tariff set at the market value of import licenses (see Helpman and Krugman 1989 on this point). An empirically important trade-and-growth channel operating via on the cost of capital. To study this channel, the last part of this section extends the Section 2 model in a way that allows traded intermediates to be employed by the I sector.

3.1 Frictional Barriers

Considering only frictional barriers, $\tau=1$ and $T=0$, but $\Lambda>1$. In this case, the average profit margin M is $1/\sigma$ and there is no tariff revenue ($\eta=0$), so from (7) and (10):

$$\pi = \alpha(L-L_I) \;/\; (\sigma-\alpha)K \qquad \textbf{(16)}$$

Plainly, Λ does not affect π. Thus by Proposition 1, liberalising Λ has no growth effects.

Intuition and Welfare Analysis. Since Λ affects neither the marginal benefit of innovation, nor its marginal cost, the lack of a growth effect is obvious from one perspective. However, from another perspective, it is surprising. Wastage due to Λ reduces the amount of labour available for consumption and investment. In most endogenous growth models, including ours, g increases with L, so one might expect that this wastage would lower g. Λ has no growth effect because the general equilibrium incidence of this tax falls entirely on L. This unusual incidence can be understood as follows: Λ raises the marginal cost of exporting, but under Dixit-Stiglitz monopolistic competition, X-firms fully pass this on to customers. Since their customers are perfectly competitive Z-firms, the tax gets fully passed on to final consumers, (i.e., labourers). Capital escapes the tax entirely (Victor Norman pointed this out to us).

While $d\Lambda<0$ has no growth effect, it is welfare enhancing. The discounted utility of the representative consumer is (ignoring constants)[13]:

$$U_0 = \frac{\alpha \bar{g}}{\rho^2(\sigma-1)} + \frac{1}{\rho}\left(\ln[L-\frac{g}{2}] - \ln[1-\alpha(\eta+M)] + \frac{\alpha\ln[1+\phi]}{\sigma-1}\right) \qquad \textbf{(17)}$$

With only frictional barriers, $M=1/\sigma$, $\eta=0$, and $\phi=\Lambda^{1-\sigma}$, so U_0 is increasing in $\phi=\Lambda^{1-\sigma}$. Since

$\sigma>1$, we see that $dU_0/d\Lambda<0$. The welfare improvement here stems from standard static gains from trade.

3.2 Specific Tariffs: The Tariff-Revenue Effect

To isolate the impact of a specific tariff, we assume that $\tau=1$ (thus $M=1/\sigma$), $\Lambda=1$, and $T>0$. Also, to fix ideas concerning tariff revenue, assume for a moment that R is wasted, i.e., $\eta=0$. In this case, π is given by (16), so as with Λ, liberalising T enhances welfare, but has no impact on growth. By contrast, if tariff revenue is returned to consumers[14]:

$$\pi = \frac{\alpha(L - g/2)}{K[\sigma-\alpha(\eta\sigma+1)]}\ ; \qquad \eta \equiv \frac{T(1-1/\sigma)}{(1+T)+(1+T)^{\sigma}} \tag{18}$$

Noting that the tariff-revenue multiplier, η, is bell-shaped (due to Laffer-curve considerations), inspection of this expression shows that π is increasing in T for low levels of T and decreasing in T for high levels of T.[15] Proposition 1 therefore implies a bell-shaped relationship between T and growth.[16] We call this the 'tariff-revenue effect' since (as the wasted-revenue case shows) the growth effect depends entirely upon the tariff revenue being returned lump-sum to consumers/savers.

As is usual with monopolistic competition, reciprocal quantitative restrictions have a specific-tariff representation; the level of the equivalent specific tariff is the equilibrium shadow price of a one-unit import license. Thus, analysis of the growth effect of specific tariffs (with returned revenue) applies directly to the case of quantitative restrictions.

Intuition and Welfare Analysis. The tariff-revenue effect is straightforward given the intuition provided above for $dg/d\Lambda=0$. Here, as with frictional barriers, the general equilibrium incidence of T falls entirely on L. Since we are free to think of the tariff as paid in units of L, what is really going on when R is returned to consumers is that some of their consumption expenditure is returned. Since this 'transfer' is lump-sum, consumers quite naturally allocate some transfer income to investment and some of it to consumption. To the extent that they allocate it to investment, faster growth is the result.

Due to second-best issues, the welfare implications of incremental T liberalisation are somewhat involved in the returned-revenue case. At free trade, the laissez-faire growth rate is suboptimal due to I-sector learning externalities (see Grossman and Helpman, 1991). Thus $dT>0$ tends to raise welfare via its dynamic effect, but tends to lower welfare via its static effect. There may, therefore, be a bell-shaped relationship between protection and welfare. That is, at very low levels of T, the static losses from marginal protection are modest, but the dynamic gains from trade are positive. Thus when parameters are such that growth effects are important (eg, when α is large), the dynamic gains more than offset the static losses. However, at high levels of T, dT>0 both lowers growth and raises the static cost of protection, so the extra protection unambiguously lowers welfare. More precisely, the bell-shape appears for parameter values that satisfy $\alpha^2(2L+\rho)>\rho\sigma$.[17] The first-best policy (ignoring the usual information problems) is to subsidise innovation directly and set T=0.

3.3 Ad Valorem Tariffs: The Profit-Margin Effect

Rivera-Batiz and Romer (1991b) find a U-shaped relationship between *ad valorem* tariffs and growth. Here we confirm that their U-shaped link holds in our basic model both when tariff revenue is returned and when it is wasted. More importantly, we also show that the Rivera-Batiz-Romer finding is driven by the procompetitive effect of *ad valorem* tariffs.

The *ad-valorem*-tariffs-only case involves $\Lambda=1$, T=0, and $\tau>1$. To keep effects separate, we first consider the case of wasted tariff revenue, where (7) and (10) imply:

$$\pi = \frac{\alpha(L-L_I)/K}{1/M - \alpha}; \quad M = \frac{S}{\sigma}+\frac{S^*}{\tau\sigma}, \quad S = \frac{1}{1+\tau^{1-\sigma}} \qquad (19)$$

and S+S*=1. Clearly, τ enters π only via M, so τ only affects π via its procompetitive effect. Thus, from Proposition 1 all growth effects are due to τ's procompetitive effect.

To study the specific nature of the link between π and τ, we differentiate M to get:

$$\frac{dM}{d\tau} = \frac{dS}{d\tau}\frac{1}{\sigma} + \frac{dS^*}{d\tau}\frac{1}{\sigma\tau} - \frac{S^*}{\sigma\tau^2} \qquad (20)$$

The first right-hand term is positive, since $d\tau>0$ raises local-market sales and thereby operating profits earned by local firms on local sales. The second term is negative, since additional foreign protection (τ's change is reciprocal) lowers export sales and operating profit, holding the profit margin, $1/\tau\sigma$, constant. We refer to these two terms as the 'sales effect' and note that the sum of the two, $(1-1/\tau)dS/d\tau$, is never negative.

While the sales effect is obvious, the pure procompetitive effect (the third term) is not. Intuition for it – from Helpman and Krugman (1989, p.65) – is as follows. If an X-firm lowers its export producer-price by one dollar, foreign consumers see the consumer price fall by $1+t\equiv\tau>1$ dollars (the border tax collected falls with the producer price). Thus the optimal profit margin in terms of consumer prices is $1/\sigma\tau$ rather than $1/\sigma$. Consequently, τ

has a procompetitive effect in that it lowers the consumer-price profit margin on exports.

Now we turn to the U-shaped relationship. When τ is low, the export market is important to a typical X-firm, so the negative second and third terms outweigh the first term. To see why, note that when $\tau=0$, $d\tau>0$ has no effect on sales evaluated at consumer prices ($d\tau>0$ lowers S^* as much as it raises S and $S+S^*=1$), but $d\tau$ does lower revenue-per-export sale (via its procompetitive effect). The net result is that $d\pi/d\tau$ is negative for low τ. However when τ is high enough, S^* becomes small enough to allow the positive sales effect to dominate (recall that $(1-1/\tau)dS/d\tau\geq 0$). Finally, note that π is identical under free trade and autarky.

Next, when tariff revenue is returned lump-sum, π is given by:

$$\pi = \frac{\alpha(L-L_I)/K}{1/M-\alpha-\alpha\eta/M}; \quad \eta = \frac{(\tau-1)\tau^{-\sigma}}{1+\tau^{1-\sigma}}, \quad M = \frac{1+\tau^{-\sigma}}{\sigma(1+\tau^{1-\sigma})} \qquad \textbf{(21)}$$

This expression for π contains only one extra term compared to (19), namely $-\alpha\eta/M$. With only τ-barriers, $\eta/M=\sigma(\tau-1)/(1+\tau^{\sigma})$. This term, which is everywhere nonnegative, becomes zero at $\tau=1$ and $\tau=\infty$, and it is bell-shaped (i.e., its derivative changes sign only once, being positive for small τ's and negative for large τ's).[18] Given these facts, the extra term merely dampens the U-shaped relationship between M and τ established above. That is, there is still a U-shaped link between π and τ, but the revenue-returned π lies everywhere above the revenue-wasted π except at the autarky and free trade levels of τ (where they coincide).[19] Using Proposition 1, this tells us that switching from $\eta=0$ to $\eta>0$ is always pro-growth (apart from the extremes of $\tau=0$ and $\tau=\infty$). In both tariff-revenue cases, moreover, protection is anti-growth, since $\bar{g}$ in free trade (call this $\bar{g}^{FT}$) is always higher than $\bar{g}$ with a positive, finite level of τ (the autarky and free trade $\bar{g}$'s are identical).

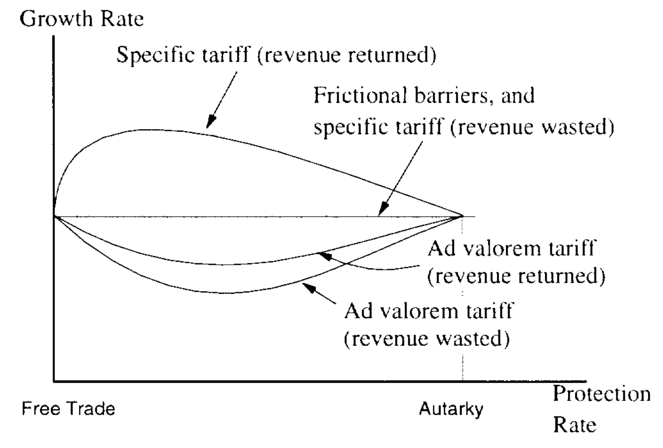
Welfare. Starting at free trade ($\tau=1$), marginal protection is welfare reducing since it lowers growth and distorts static resource allocation. Outside the neighbourhood of free trade, it is more difficult to sign $dU/d\tau$ since, although the static distortion rises smoothly with τ, the growth effect is U-shaped. Thus is it conceivable that a marginal increase in τ could raise welfare for some levels of τ (this occurs, for example, for very high levels of τ when σ is very low). Nevertheless, we know that the level of discounted utility is always lower with $\tau>1$ (since $\bar{g}\leq\bar{g}^{FT}$ and the static distortion rises with τ), so a sufficiently large liberalisation of τ always improves welfare.

Figure 2 summarises the various relationships between protection and growth in the

Section 2 model.

3.4 Protection, the Price of Capital and Growth

Figure 2



One set of trade-and-growth links found important in the real world concerns the impact of protection on the price of capital (see Lee, 1993, 1994 for example). The simple I-sector marginal cost function assumed in Section 2 does not have such a link, so we here enrich the model by allowing the I-sector to use traded intermediate inputs.

Specifically, we modify (2) by supposing that K is produced using labour and traded intermediate inputs in the form of a CES composite (elasticity of substitution equal to σ) of all X varieties. This extension of the basic model is related to the Rivera-Batiz and Romer (1991a) 'lab equipment' model. With this generalisation of the I-sector cost function, the new marginal cost function is:

$$F = P_X^{\alpha} w^{1-\alpha} / K^{\Omega} \qquad (22)$$

where P_X is the standard CES price index and Ω is the learning elasticity.

As Lucas (1988) shows, endogenous growth models produce constant steady-state growth only under knife-edge parameter assumptions. In particular, K must enter (22) exactly as it enters V, namely with an elasticity of minus one. If it does not, K does not drop out of Tobin's q, so q=1 defines a steady-state level of K and a steady-state K is, of course, inconsistent with ceaseless growth. In this extended model, raising K affects F for two reasons: external economy effects (stemming from the CES function's well-known 'variety' effect) and learning effects. The knife-edge parameter assumption necessary here is that the two effects combine to yield an elasticity of F with respect to K that is equal to minus one, i.e., that $\Omega=1-\alpha/(\sigma-1)$.[20] Of course, the assumption of unitary elasticity in the basic model has a certain elegance that $\Omega=1-\alpha/(\sigma-1)$ lacks, and elegance matters in theory. At any rate, both assumptions are equally arbitrary and equally necessary to ensure a time-invariant steady-state growth rate.

When the I-sector uses traded intermediate inputs, trade policy affects Tobin's q via its direct impact on P_K=F. Using very different methodologies, this link was pointed out by Rivera-Batiz and Romer (1991a) in the context of an autarky-to-free trade liberalisation and in the context of incremental liberalisation by Lee (1994). Lee assumes that the country under study imports all capital goods, so it is best thought of as a North-South model. The model in this section differs from Lee's in that it allows for two-way trade in intermediates. Our model is, therefore, best thought of as a North-North model.

As shown above, tariff revenue introduces interesting, but complex, interactions. To focus on the novel elements here, we assume that all trade barriers are frictional (i.e., iceberg). Using the CES-price-index definition, (6), and $\Omega=1-\alpha/(\sigma-1)$[21]:

$$P_K = (1+\phi)^{\alpha/(1-\sigma)} \,/\, [K(1-1/\sigma)^{\alpha}] \tag{23}$$

By inspection, P_K is monotonically decreasing in openness, so from Proposition 1, growth is monotonically increasing in openness. While this openness-and-growth link is monotonic, it is not linear. Using (13), $M=1/\sigma$ and $\eta=0$, the derivative is:

$$\frac{dg}{d\phi} = \frac{\alpha^2(1-1/\sigma)^{\alpha}(\sigma-\alpha)(2L+\rho)/(\sigma-1)}{[\alpha(1-1/\sigma)^{\alpha}(1+\phi)^{\alpha/(\sigma-1)}+2(\sigma-\alpha)]^2}(1+\phi)^{\frac{\alpha}{\sigma-1}-1} \tag{24}$$

As long as $\alpha/(\sigma-1)<1$ (a sufficient condition being $\sigma>2$), the nonlinearity goes in the expected direction. Namely, incremental liberalisation has a bigger growth effect in highly protected economies than it does in very open economies.[22]

4. Asymmetric Liberalisation

Real-world countries are never symmetric, so one might ask whether the assumed symmetry in Sections 2 and 3 (and in most of the trade and growth literature) is innocuous. The answer is most definitely no, as the static analyses of, for example, Helpman and Krugman (1989) and Krugman (1991) show. The asymmetric-countries case, however, is analytically much harder. To concentrate on essentials, we therefore streamline the Section 2 model before considering asymmetries in the level of protection.

4.1 Assumptions

Specifically, we assume that freely traded Z is produced with L only; its cost function is $a_Z wQ_Z$, where $a_Z=1$ by choice of units. The CES composite of X-varieties, denoted as C_X, is consumed directly. Thus, intertemporal preferences are as before, ${}_0\!\int^{\infty} e^{-\rho t}\ln[C(t)]dt$, but now $C \equiv C_Z^{1-\alpha} C_X^{\alpha}$, where C_Z is consumption of Z. To highlight the importance of asymmetries, only frictional (iceberg) barriers are considered, so $M=1/\sigma$, $\eta=0$, and $\phi=\Lambda^{1-\sigma}$. Recall from Section 3.1 that $d\bar{g}/d\Lambda=0$ with symmetric nations, so any growth effects found here depend critically on asymmetries.

We enrich the model in two directions. First, learning effects are assumed to spill over imperfectly, as indicated by many empirical studies – e.g., Eaton and Kortum (1996), Caballero and Jaffe (1993), and Keller (1997). To this end, a spillover parameter $0 \leq \lambda < 1$ is added, so the new home I-sector cost function, which replaces (2), is:

$$F = wa_I \ ; \qquad a_I \equiv 1/(K+\lambda K^*) \ , \qquad 0 \leq \lambda < 1 \tag{25}$$

With $\lambda<1$, home learning from foreign innovators is dampened. Thus foreign experience is 'discounted' by λ, and $K+\lambda K^*$ is the discounted cumulative experience available to home I-sector workers. The foreign equivalent is $a_I^*=(K^*+\lambda K)^{-1}$. The corresponding I-sector production function in growth rate terms is:

$$g = L_I A \ ; \qquad A \equiv 1+\lambda(1-\theta_K)/\theta_K \ , \qquad \theta_K \equiv K/K^w \tag{26}$$

where $K^w \equiv K+K^*$. Foreign expressions are isomorphic, i.e. $g^*=L_I^* A^*$, where $A^* \equiv 1+\lambda[\theta_K/(1-\theta_K)]$. Note that with $\lambda<1$, the international distribution of K^w, denoted with the Jonesian share notation $\theta_K \equiv K/(K+K^*)$, influences nations' I-sector labour productivity. Specifically, $dA/d\theta_K<0$, $dA^*/d\theta_K>0$.

Second, nations are allowed to differ in size ($L \neq L^*$) and in protection levels ($\phi \neq \phi^*$). With asymmetries and only iceberg barriers, it is convenient to write π as:

$$\pi = B\left(\frac{\alpha E^w}{\sigma K^w}\right) ; \quad B \equiv \frac{\theta_E}{\theta_K+\phi(1-\theta_K)} + \frac{\phi^*(1-\theta_E)}{1-\theta_K+\phi^*\theta_K}, \quad \theta_E \equiv \frac{E}{E^w} \tag{27}$$

where E^w is world expenditure and ϕ^* reflects foreign trade free-ness. Analogous expressions apply to the foreign nation.[23] B (a mnemonic for 'bias') is the ratio of a home X-firm's world-wide sales to the average world-wide sales per variety (this latter quantity is $\alpha E^w/K^w$). Thus, (27) permits us to decompose protection's impact on π into its global effect (changes in $\alpha E^w/\sigma K^w$) and its national effect (changes in B).

4.1 The Steady-State Equilibrium

The asymmetric model has three state variables (L_I, L_I*, and θ_K) and transitional dynamics because θ_K cannot jump. From its definition, θ_K's law of motion is:

$$\dot{\theta}_K = \theta_K(1-\theta_K)(g - g*) \tag{28}$$

By inspection, only two types of steady states are possible: an interior steady state marked by equal rates of K accumulation (g=g*), and corner solutions (called 'core-periphery' outcomes in the economic geography literature) where θ_K=0 or 1.

The possibility that policy changes will result in a core-periphery solution is of considerable interest in its own right, as several papers have recently shown – see Martin and Ottaviano (1996), Baldwin and Forslid (1997b), and Baldwin, Martin and Ottaviano (1997). Here, however, we limit ourselves to policy and parameter constellations that result in interior steady states.

As before, we characterise the steady state by working with the static-economy representation. That is, sectoral allocations of L are time invariant in steady state, so $\dot{E}=\dot{E}^*=0$ and $\bar{r}=\bar{r}^*=\rho$. Moreover, in any interior steady state, g=g*. Thus $\bar{V}$ and $\bar{V}^*$ are given by (11). Using (25), (26) and (27), the q=1 conditions become:

$$\bar{q} = \frac{\alpha\bar{B}\bar{E}^w\bar{\theta}_K\bar{A}}{\sigma(\bar{g}+\rho)} = 1 \,, \qquad \bar{q}^* = \frac{\alpha\bar{B}^*\bar{E}^w(1-\bar{\theta}_K)\bar{A}^*}{\sigma(\bar{g}+\rho)} = 1 \tag{29}$$

These involve $\bar{\theta}_E$, $\bar{\theta}_K$, $\bar{L}_I$ and $\bar{L}_I$*. To eliminate $\bar{\theta}_E$, note that optimal $\bar{E}$ is given by the 'permanent income hypothesis'. That is, expenditure (in units of L) is wage income L plus ρ times steady-state wealth. From (29), V=F and V*=F*, home and foreign steady-state wealth levels (VK and V*K*) equal 1/A and 1/A*, respectively. Thus[24]:

$$\bar{\theta}_E = \frac{L+\rho/\bar{A}}{L+L^* + \rho[1/\bar{A} + 1/\bar{A}^*]} \tag{30}$$

Substituting (30) into (29) implicitly defines the steady-state θ_K. Using the resulting $\bar{\theta}_K$, the $\bar{L}_I$'s follow from $\bar{q}$=1 and $\bar{q}$*=1, using (27), (26), and $\bar{E}^w=L+L^*+\rho(1/\bar{A}+1/\bar{A}^*)$.[25]

Expressions (29) and (30) are easily solved with symmetric nations, the solution being $\bar{\theta}_E=\bar{\theta}_K=1/2$. However, when nations are not perfectly symmetric, the model is analytically intractable. In particular, the steady-state θ_K is defined by an un-solvable polynomial.[26]

We rely on numerical simulations to get around this difficulty.

4.2 Stability of the Symmetric Steady State

To have confidence in numerical simulations of marginal policy changes, the initial equilibrium must be stable. To investigate stability, we linearise the differential equations – (28) and the Euler equations – and find the eigenvalues of the corresponding linear system evaluated at the symmetric equilibrium. The eigenvalues are[27]:

$$
\begin{aligned}
&e_1 = L(1+\lambda)+\rho \ , \quad e_2 = \frac{-b + \sqrt{b^2-4ac}}{2\sigma(1+\phi)^2(1+\lambda)} \ , \quad e_3 = \frac{-b - \sqrt{b^2-4ac}}{2\sigma(1+\phi)^2(1+\lambda)} \ ; \\
&-b \equiv (L(1+\lambda)+\rho)\ \{\sigma(1-\lambda)(1+\phi)^2 + 4\alpha\phi(1-\lambda\phi)\} + 2\lambda\rho\sigma(1+\phi^2), \\
&c \equiv \{\ -2\alpha(L(1+\lambda)+\rho)\ [(\lambda\phi^2-2\phi+\lambda)(L(1+\lambda)+\rho) - \rho\lambda(1-\phi^2)]\ \}
\end{aligned}
\tag{31}
$$

where $a \equiv \sigma(1+\phi)^2(1+\lambda)$. Inspection reveals that e_1 is real and positive, 'a' and '-b' are positive, and b^2-4ac is positive when the X-sector's expenditure share, α, is sufficiently low.[28] Thus, for α's below the critical level, the second and third eigenvalues are everywhere real, and $e_2>0$.[29] The sign of the last eigenvalue depends upon the level of trade free-ness, ϕ. To see this, note that $e_3<0$ when $\phi=0$, and $e_3>0$ when $\phi\approx1$. Moreover, e_3 switches sign at the ϕ where c=0.[30]

Two of the state variables can jump, so saddle path stability requires only one negative eigenvalue.[31] Consequently, the system is stable for $\phi=0$, unstable for $\phi\approx1$, and switches from stable to unstable at the level of ϕ, call this ϕ^{crit}, where e_3 changes sign. In particular, the solution to the quadratic expression c=0 defines the critical level of trade free-ness above which the model is unstable.[32] The relevant root is[33]:

$$
\phi^{crit} = \frac{\gamma - \sqrt{(1-\lambda^2)\gamma^2+\rho^2\lambda^2}}{\lambda(\gamma+\rho)} \ ; \quad \gamma \equiv L(1+\lambda)+\rho \tag{32}
$$

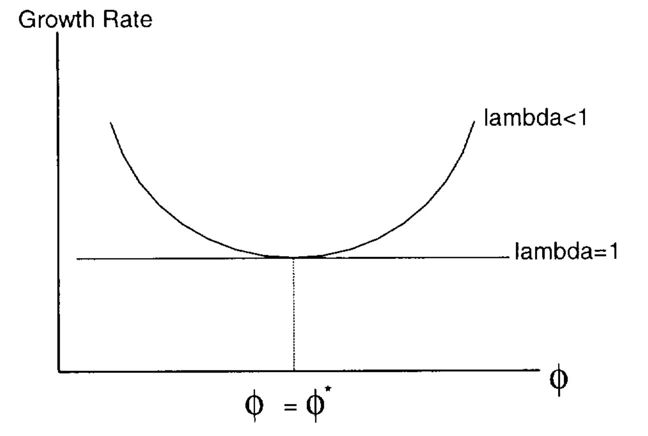
This analysis implies that we must restrict our numerical investigation to $\phi<\phi^{crit}$.

4.3 Dynamic Home Market Effect: Asymmetric Protection and Growth

When international learning effects are positive but imperfect ($0<\lambda<1$), non-reciprocal trade liberalisation can have growth effects. We turn now to numerical simulations that demonstrate this. We study a unilateral home policy reform, and for simplicity countries are taken to be of equal size and, initially, to have symmetric import barriers. Figure 3 illustrates the numerical results for small changes in home's import barriers, $\phi=\Lambda^{1-\sigma}$. Interestingly, raising or lowering ϕ raises long-run growth in both countries. This unexpected result stems from the interaction between trade policy's location effects and I-sector externalities.

Consider first the location effects of asymmetric liberalisation. If home liberalises unilaterally, home X-firms' sales fall relative to those of foreign firms – a fact that can be seen from inspection of B and B*. This lowers π compared with π^* and thus leads to an incipient fall in q relative to q*. As a result, foreign begins to accumulate K* faster than home accumulates K, so θ_K falls. This downward shift in home's q comes through a decrease in the marginal benefit of investment, namely V. The impact on q, however, is amplified by a shift in the marginal cost of investment. By inspection of A and A*, a decrease in θ_K raises the productivity of foreign I-sector workers and lowers that of home I-sector workers. This amplification is potentially de-stabilising but, since we start with $\phi<\phi^{crit}$, the system eventually reaches a new interior steady state with $\bar{\theta}_K<1/2$ and $g=g^*$. Consider next the growth implications of agglomeration.

Figure 3



With $\lambda<1$, global I-sector efficiency is maximised when $\bar{\theta}_K=0$ or 1, (i.e., all K production is, and has always been, concentrated in one country). It is minimised when $\theta_K=1/2$, as in the symmetric equilibrium. Because $d\bar{\theta}_K/d\phi<0$, raising or lowering ϕ leads to agglomeration of I-sector activity. Specifically, unilaterally raising home protection ($d\phi<0$) yields agglomeration in home, while unilaterally lowering protection yields agglomeration in foreign. Yet wherever the agglomeration occurs, it boosts global I-sector efficiency and thus promotes capital formation and growth. This is the dynamic version of what Helpman and Krugman (1989) and Venables (1987) call the 'home market effect'.

The flat schedule in Figure 3 also depicts the perfect-international-spillovers case ($\lambda=1$), where the static home market effect occurs, but $d\bar{g}/d\phi=0$.

Moreover, given the logic presented above, reciprocal liberalisation of frictional barriers never affects growth, even with $\lambda<1$, since $d\phi=d\phi^*$ has no location effect.

Finally, note that the possibility of instability suggests that the Grossman and Helpman

(1991) analysis, which only compares autarky and free trade equilibria, can be misleading when applied to gradual trade liberalisation. For instance, in our model – as in Grossman and Helpman (1991) – a reciprocal jump from autarky (i.e., $\Lambda=\infty$) to free-trade ($\Lambda=1$) would maintain the symmetric equilibrium and therefore have no growth effect. However, gradual reciprocal liberalisation, which is the typical real-world policy experience, does have a growth effect. The point is that raising trade free-ness from $\phi=0$ to 1 eventually destabilises the system. The core-periphery outcome therefore occurs and, given that $\lambda<1$, the resulting agglomeration creates a positive growth effect.

5. Concluding Remarks

While trade and endogenous growth has been an important topic for theoretical and empirical research during the past decade, few studies have investigated the impact of incremental trade liberalisation on growth. Rather, studies such as Grossman and Helpman (1991) have focused on extreme autarky-to-free-trade liberalisations or on small variations in the neighbourhood of free trade. An important exception is the example in Riveria-Batiz and Romer (1991b), which shows that even in a model where autarky-to-free-trade liberalisations have no long-run growth effects, an incremental liberalisation may affect growth (gradual liberalisation from autarky first lowers and then raises the endogenous growth rate).

This hole in the theoretical literature is important. Due to the lack of theoretical results on the growth effects of incremental liberalisation, empirical researchers continue to specify growth and openness regressions in a manner that assumes a single, monotonic relationship between the level of openness and national growth rates. For instance, cross-country-regression studies pool data from nations that have very different levels of import barriers, and time-series studies pool data for individual nations over time periods when the level of protection has fallen significantly.

Building on the Riveria-Batiz-Romer example, this paper shows that the strength and even the sign of the openness-growth link depends upon the nature and level of trade barriers. We find that, in most cases, the growth effects of a liberalisation depend critically upon the initial level of protection and upon the type of protection. In some cases, marginal liberalisation is anti-growth for high level of barriers, but pro-growth for low levels of barriers. In other cases, the opposite result holds. Moreover, we find that unilateral and reciprocal liberalisations can have radically different growth effects.

Our finding of pervasive non-monotonicities in trade and growth links suggests that many empirical studies are mis-specified. It also suggests that the lessons from the early trade and endogenous growth literature – which focused mainly on autarky to free trade liberalisations – are of limited use for real-world policy analysis.

Extension to Non-Scale Growth Models. Following the important criticism of Jones (1995a), a new class of growth models, the so-called non-scale models, has emerged. Jones (1995b), Segerstrom (1995), Young (1995), and Eicher and Turnovsky (1996, 1997) are some examples. In these models, the long-run growth rate does not depend upon the size of the market. Nevertheless, the capital-labour ratio, which is time-invariant in steady state, is typically increased by market expansion of the autarky-to-free-trade type. In these models, reciprocal trade liberalisation between two symmetric nations has a transitional, or medium-run growth effect, rather than a long run growth effect (Young, 1995).

The impact of incremental trade liberalisation in these models has not been worked out, but we conjecture that the reasoning in our paper would carry through in these models as well. The point is that our analysis focuses on how trade policy affects the level of resources employed in the I sector. In the early trade-and-growth models, such resource shifts have permanent growth effects, while in the non-scale models they have transient growth effects. This conjecture, however, needs to be worked out carefully and as such constitutes an important direction for future work.

References

Baldwin R.E. and R. Forslid, 1996, Trade Liberalization and Endogenous Growth: A q-Theory Approach, NBER Working Paper No. 5549.

Baldwin R.E. and R. Forslid, 1997a, Trade Liberalization and Endogenous Growth: A q-Theory Approach, manuscript (substantially revised version of NBER Working Paper).

Baldwin R.E. and R. Forslid, 1997b, The core-periphery model and endogenous growth, CEPR Working Paper No.1749.

Baldwin, R.E., P. Martin, and G. Ottaviano, 1997, The Geography of Growth Takeoffs, forthcoming NBER Working Paper.

Barro, R. 1991, Economic Growth in a Cross-Section of Countries, Quarterly Journal of Economics 61, 407-443.

Blanchard, O. and S. Fischer, 1989, Lectures on Macroeconomics (MIT Press, Cambridge).

Caballero and Jaffe, 1993, How high are the 'giants' shoulders?, in O.Blanchard and S.Fischer, eds, NBER Macroeconomics Annual (NBER, Cambridge).

Coe, D. and E. Helpman, 1995, International R&D spillovers, European Economic Review, 859-887.

Coe, D. and R. Moghadam, 1993, Capital and Trade as Engines of Growth in France, IMF Staff Papers 40, 542-566.

Eaton, J. and S. Kortum, 1996, Trade in ideas: Productivity and patenting in the OECD, Journal of International Economics 40, 251-278.

Eicher,T. and S. Turnovsky, 1996, Toward a general theory of economic growth, manuscript (University of Washington).

Eicher,T. and S. Turnovsky, 1997, Convergence speeds and transitional dynamics in non-scale growth models, manuscript (University of Washington).

Grossman, G. and E. Helpman, 1991, Innovation and Growth in the World Economy, (MIT Press, Cambridge).

Grossman, G. and E. Helpman, 1995, Technology and Trade, in G. Grossman and K. Rogoff, eds., Handbook of International Economics, Vol. 3 (North-Holland, Amsterdam) 1279-1338.

Harrison, A., 1996, Openness and growth: A time-series, cross-country analysis for developing countries, Journal of Development Economics 48, 419-447.

Helpman, E. and P. Krugman, 1989, Market Structure and Trade Policy, (MIT Press, Cambridge).

Jones, C., 1995a, R&D based models of economic growth, Journal of Political Economy 103, 759-784.

Jones, C., 1995b, Time series tests of endogenous growth models, Quarterly Journal of Economics 110, 495-527.

Keller, W., 1997, Trade patterns, technology flows and productivity growth, manuscript (University of Wisconsin-Madison).

Krugman, P., 1988, Endogenous Innovation, International Trade and Growth, manuscript, reprinted in P.Krugman, 1990, Rethinking International Trade, (MIT Press, Cambridge).

Krugman, P., 1991, Geography and Trade (MIT Press, Cambridge).

Lee, J-W, 1993, International Trade, Distortions and Long-run Growth, IMF Staff Papers 40, 299-328.

Lee, J-W, 1994, Capital Goods Imports and Long-run Growth, NBER Working Paper No.4725.

Long, N.W. and K. Wong, 1996, Endogenous Growth and International Trade: A Survey, manuscript (University of Washington).

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

Martin, P. and G.Ottaviano, 1996, Growing locations: Industry location in a model of endogenous growth, forthcoming European Economic Review.

Nelson, R., 1996, The sources of economic growth (Harvard University Press, Cambridge).

Rivera-Batiz, L. and P. Romer, 1991a, Economic Integration and Endogenous Growth, Quarterly Journal of Economics 106, 531-555.

Rivera-Batiz, L. and P. Romer, 1991b, International Trade with Endogenous Technological Change, European Economic Review 35, 715-721.

Romer, P., 1990, Endogenous Technological Change, Journal of Political Economy 98, 71-102.

Segerstrom, P., 1995, Endogenous growth without scale effects, manuscript (Michigan State University).

Segerstrom, P., T.C.A. Anant and E. Dinopoulos, 1990, A Schumpeterian Model of the Product Life Cycle, American Economic Review 80, 1077-92.

Turnovsky, S., 1996, Fiscal policy, growth and macroeconomic performance in a small open economy, Journal of International Economics 40, 41-66.

Tobin, J., 1969, A General Equilibrium Approach to Monetary Theory, Journal of Money, Credit and Banking, 15-29.

Venables, A., 1987, Trade and trade policy with differentiated products: A Chamberlinian-Ricardian model, Economic Journal 97, 700-717.

Venables, A., 1996, Equilibrium location with vertically linked industries, International Economic Review 37, 341-359.

Young, A., Growth without scale effects, NBER Working Paper No.5211.

Appendix: Transitional Dynamics in the Symmetric Model

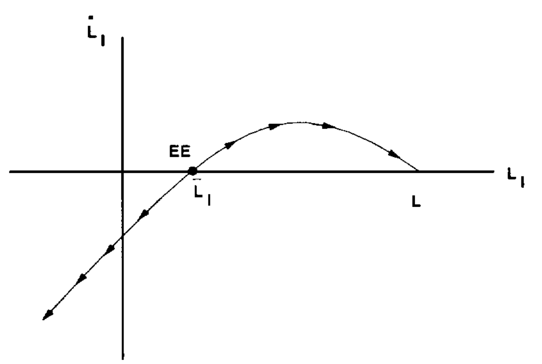
Here we demonstrate the lack of transitional dynamics. With L_I as the state variable, the system's dynamics are characterised by the transformed Euler equation[34]:

$$\dot{L}_I = (L-L_I)\ \left(\rho - \frac{2\alpha M(L-L_I)}{1-\alpha(\eta+M)} + 2L_I\right) \qquad \text{(A-1)}$$

The figure plots this differential equation, ignoring the non-negativity constraint on L_I.

Clearly, there is a unique, interior steady-state value of L_I at EE. Also the equation is 'saddle path unstable', but the 'saddle path' is the point EE. As usual, the optimising representative consumer will always choose L_I=EE to avoid violating necessary conditions for utility maximisation.

Appendix Figure 1



To formally show that the system jumps to EE, consider what would happen if the initial value of L_I were above point EE. The Euler equation only holds when L_I increases continually, so starting out above EE would require L_I to rise without bound. Once all resources are devoted to investment, E=0. Given preferences, this implies an infinite marginal utility of consumption -- a situation that would clearly violate the transversality condition. If the initial L_I started out below point EE, L_I must decrease forever to respect the Euler equation. Of course, L_I cannot be negative, so when L_I=0, we would violate the Euler equation. Thus if L_I starts out below or above EE, the system eventually violates a necessary condition for utility maximisation.

Supplemental Guide to Calculations

1. Shepard's lemma is used to derive this from the Z-sector cost function using perfect competition to set p_Z equal to marginal cost.

2. Using the demand functions, the flow of operating profit is:

$$\left(\frac{p_j^{1-\sigma}\alpha E}{\Delta} - w\frac{p_j^{-\sigma}\alpha E}{\Delta}\right) + \left((\frac{1}{\tau})\frac{p_j^{*\,1-\sigma}\,\alpha E}{\Delta^*} - (w\Lambda+T)\frac{p_i^{*\,-\sigma}\alpha E}{\Delta^*}\right)$$

where

$$\Delta \equiv \int_0^{K+K^*} p_i^{1-\sigma}di\ , \quad \Delta^* \equiv \int_0^{K+K^*} p_i^{*1-\sigma}di$$

The Dixit-Stiglitz monopolistic competitors take other firms' prices as given, so the large-group first-order conditions are:

$$(1-\sigma)x - w(-\sigma)\frac{x}{p} = 0\ , \quad \frac{1}{\tau}(1-\sigma)x^* - (w\Lambda+T)(-\sigma)\frac{x^*}{p^*} = 0$$

Simplification of these yields the pricing rules in the text.

3. Rearranging the first order conditions, operating profit earned in the local and export markets are:

$$(p_j-w)x_j = \frac{p_jx_j}{\sigma} \iff (p_j-w)x_j = \frac{S\alpha E}{\sigma K}\ ;\ S \equiv \frac{Kp_jx_j}{\alpha E}$$

$$(\frac{p_j^*}{\tau}-w\Lambda-T)x_j^* = \frac{p_j^*x_j^*}{\tau\sigma} \iff (\frac{p_j^*}{\tau}-w\Lambda-T)x_j^* = \frac{S^*\alpha E}{K\tau\sigma}\ ;\ S^* \equiv \frac{Kp_j^*x_j^*}{\alpha E}$$

where E=E* by symmetry, and S and S* are the sum of market shares of local and nonlocal X-firms in a typical market (K is the number of X-firms per nation). Thus:

$$\pi = \left(S + \frac{S^*}{\tau}\right)\frac{\alpha E}{\sigma K}$$

Using the prices implied by the first order conditions, symmetry, and the demand function (2-5), the equilibrium S is related to protection according to:

$$S \equiv \frac{Kp_jx_j}{\alpha E} = \frac{K}{\alpha E}\ \frac{p_j^{1-\sigma}\alpha E}{K(p_j^{1-\sigma} + p_j^{*\,1-\sigma})} = \frac{1}{1+\phi}\ ;\quad \phi \equiv (\frac{p^*}{p})^{1-\sigma} = (\frac{\tau(w\Lambda+T)}{w})^{1-\sigma}$$

Note that S* is the import penetration ratio and S+S*=1.

It is possible to simplify M's expression further, but this does not serve intuition.

4. Revenues from *ad valorem* and specific tariffs are $K(\tau-1)p^*x^*/\tau$ and KTx^*, respectively. From the demand function (5), symmetry of varieties, and $\phi\equiv(p^*/p)^{1-\sigma}$, spending on imported varieties (evaluated at border prices) is:

$$K\frac{p^*}{\tau}x^* = \frac{1}{\tau}\frac{p^{*\,1-\sigma}\alpha E}{p^{1-\sigma}+p^{*\,1-\sigma}} = \frac{1}{\tau}\frac{\alpha E}{1+\phi^{-1}}$$

Multiplication by the tariff rate $(\tau-1)$ yields the result in the text for *ad valorem* tariff revenue.

Revenue for specific tariffs is TKx^*. Using the demand function and symmetry:

$$KTx* = T\frac{p^{*\,1-\sigma}\alpha E}{p^{1-\sigma}+p^{*\,1-\sigma}}\left(\frac{1}{p^*}\right) = \frac{T\alpha E}{1+\phi^{-1}}\frac{1-1/\sigma}{\tau(w\Lambda+T)}$$

Gathering terms yields the expression in the text.

5. The cost function that corresponds to the Cobb-Douglas production function is:

$$w^{1-\alpha}P_X^{\alpha}\,Q_Z\ ; \qquad P_X \equiv \left(\int_{i=0}^{2K} p_i^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

where P_X is the standard CES price index. From X-sector pricing rules and symmetry:

$$w^{1-\alpha}\left(K^{\frac{1}{1-\sigma}}\ p(1+\phi)^{\frac{1}{1-\sigma}}\right)^{\alpha} = w^{1-\alpha}\ (K(1+\phi))^{\frac{\alpha}{1-\sigma}}\ \left(\frac{w}{1-1/\sigma}\right)^{\alpha}$$

Recall that $\phi\equiv(p^*/p)^{1-\sigma}$. Gathering terms yields the expression in the text.

6. Using (7) and (8), $E=Y+R-I$ is:

$$E = wL + \pi K + R - I = wL + \alpha EM + \eta\alpha E - wL_I$$

since spending on investment is L_I. (This is due to the fact that I-sector competition eliminates pure profits, so the value of I-sector sales, I, equals the value of inputs wL_I.) Collecting terms yields the expression in the text.

7. The expression for q at time t is:

$$q[L_I] = \frac{V_t}{P_{Kt}}$$

Using the expressions derived in the text for V and π, and imposing $w=1$ and $F_t=P_{Kt}$, we have:

$$q[L_I] = \frac{\pi_t\,/(\rho+g)}{F_t} = \frac{\dfrac{M\alpha E}{K_t(\rho+g)}}{1/2K_t}$$

Using the expression for E in the text, we have:

$$q[L_I] = \frac{2\alpha M(L-L_I)}{(\rho+2L_I)(1-\alpha(\eta+M))}$$

Using (3) yields the expression in the text.

8. Since the marginal revenue product is $p^p(1-1/\sigma)/a_X$ – where p^p is the producer price of a typical X-variety (equal on sales to all markets with Dixit-Stiglitz monopolistic competition) – the optimal p^p equals $a_X/(1-1/\sigma)$ by choice of numeraire. Thus $VMRPL_X=1$ everywhere.

9. From the Z-sector production function:

$$VMPL_Z = p_Z a_Z(1-\alpha)L_Z^{-\alpha}X^{\alpha}$$

where symmetry and the standard CES function form imply that:

$$X = K^{\frac{1}{1-1/\sigma}}(x^{1-1/\sigma} + x^{*1-1/\sigma})^{\frac{1}{1-1/\sigma}}$$

Using the optimal pricing rules for x, we have:

$$X = K^{\frac{1}{1-1/\sigma}}x\left(1 + (\frac{x^*}{x})^{1-1/\sigma}\right)^{\frac{1}{1-1/\sigma}} = K^{\frac{1}{1-1/\sigma}}x\left(1 + (\frac{p^*}{p})^{-\sigma(1-1/\sigma)}\right)^{\frac{1}{1-1/\sigma}}$$

Using the demand function for a typical X-variety

$$X = K^{\frac{1}{1-1/\sigma}}\frac{\alpha E/p}{K(1+\phi)}(1+\phi)^{\frac{1}{1-1/\sigma}} = K^{\frac{1}{\sigma-1}}(1+\phi)^{\frac{1}{\sigma-1}}\alpha E/p$$

Using the expression for E calculated in the text, this becomes

$$X = K^{\frac{1}{\sigma-1}}(1+\phi)^{\frac{1}{\sigma-1}}\left(\frac{\alpha(L-L_I)}{1-\alpha(\eta+M)}\right)\frac{1-1/\sigma}{w}$$

so with w=1, $a_Z=\alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}$ and (9):

$$VMPL_Z = \left(\frac{1-\alpha}{\alpha}\right)^{\alpha}L_Z^{-\alpha}\left(\left(\frac{\alpha(L-L_I)}{1-\alpha(\eta+M)}\right)\right)^{\alpha}$$

Rearranging terms yields the expression in the text.

10. The expression of nominal income comes from $Y=L+\pi K+R$, using (7), (8) and (10). The expression for p_Z is:

$$p_Z = w\,(1-1/\sigma)^{-\alpha}(K(1+\phi))^{\frac{\alpha}{1-\sigma}}$$

Time differentiation of this (taking logs first) yields the result in the text, since w=1 and trade policy is time-invariant.

In using the consumption price p_Z, we are guided by microeconomic theory. That is, $\ln(E/p_Z)$ is the indirect utility function for a moment in time. In this way, real income is related to a welfare measure. Alternatively, nominal income may be deflated with an output price index (something akin to a GDP deflator), i.e., an index that reflects the output prices of the X, Z and I sectors. Unfortunately, we do not have solid microfoundations behind the production price index, so we are free to choose the exact specification.

A natural (although arbitrary) specification is a Cobb-Douglas price index of p_Z, P_X and P_K, where the I, Z and X sector value-added shares are the Cobb-Douglas power-coefficients (the value added shares are time-invariant in steady state). Since nominal income is time-invariant, GDP deflated by the production price index rises at a rate that is the weighted average of $g/(\sigma-1)$ (X-sector production price growth), g (the rates at which P_K falls), and $g\alpha/(\sigma-1)$. Comparing the consumption-based and production-based aggregate growth rates we have:

$$g_{real\ income} = \frac{g\alpha}{\sigma-1}, \qquad g_{GDP} = \zeta_X \frac{g}{\sigma-1} + \zeta_I g + \zeta_Z \frac{g\alpha}{\sigma-1}$$

where the value-added weights (the ζ's) sum to unity. We cannot, *a priori*, say which growth rate is greater. While this point seems straightforward, it has caused confusion in the literature.

Grossman and Helpman (1991), for instance, contains a systematic mistake based on a confusion of this point (see pages 188 and 205, inter alia). For example, Chapter 7 on dynamic comparative advantage, they state that human-capital-rich country grows faster since it has a higher share of the world's R&D activity. Without stating it, those authors must be assuming that the spending share on manufactured goods (α in our terminology) is less than $(\sigma-1)$. This result would be exactly reversed if $\alpha>\sigma-1$.

11. The implicit function is:

$$q[g,\Theta] = \frac{\pi[g,\Theta]}{P_K[\Theta](\rho+g)} = 1$$

Total differentiation with respect to g and an element of Θ yields:

$$\left(\frac{\partial P_K}{\partial \Theta_i}(\rho+g)\right)d\Theta_i + P_K dg = \frac{\partial \pi}{\partial \Theta_i}d\Theta_i + \frac{\partial \pi}{\partial g}dg$$

Rearrangement gives the expression in the text.

12. Given the expressions for π and P_K=F:

$$\pi = \frac{\alpha M(L - g/2)}{(1-\alpha(\eta+M))K}; \qquad P_K = F = \frac{1}{2K}$$

The denominator equals:

$$-(\partial\pi/\partial g) + F = \frac{1}{2K}\left(\frac{\alpha M}{1-\alpha(\eta+M)} + 1\right)$$

which is everywhere positive by inspection.

13. The indirect utility function is $\int e^{-\rho t}\ln(E/p_Z)dt$. Using the fact that $K_t=K_0e^{gt}$, where g is the steady state g, we have from (3), (9) and (10):

$$\frac{E}{p_Z} = \frac{L-g/2}{1-\alpha(\eta+M)}\,(K_o e^{gt}(1+\phi))^{\frac{\alpha}{\sigma-1}}\,(1-1/\sigma)^{\alpha}$$

Thus:

$$\ln(\frac{E}{p_Z}) = \ln[L-g/2] - \ln[1-\alpha(\eta+M)] + (\frac{\alpha g t}{\sigma-1}) + (\frac{\alpha\ln[1+\phi]}{\sigma-1}) + constants$$

Taking the integral over time:

$$U_0 \equiv \int_0^{\infty} e^{-\rho t}\ln(\frac{E}{p_Z})dt = (\frac{\alpha g}{\sigma-1})\int_0^{\infty} e^{-\rho t}\, t\, dt$$

$$+ (\frac{1}{\rho})\left(\ln[L-g/2] - \ln[1-\alpha(\eta+M)] + (\frac{\alpha\ln[1+\phi]}{\sigma-1})\right) + constants$$

Noting that integration-by-parts tells us that the integral on the right-hand side solves to $1/\rho^2$ since:

$$\int_0^{\infty} e^{-\rho t}\, t\, dt = \frac{-t}{\rho}e^{-\rho t}\Big|_0^{\infty} + \frac{1}{\rho}\int_0^{\infty} e^{-\rho t}dt$$

Thus, the expression becomes (ignoring constants):

$$U_0 \equiv \int_0^{\infty} e^{-\rho t}\ln(\frac{E}{p_Z})dt = \frac{\alpha g}{\rho^2(\sigma-1)} + \frac{1}{\rho}\left(\ln[L-\frac{g}{2}] - \ln[1-\alpha(\eta+M)] + \frac{\alpha\ln[1+\phi]}{\sigma-1}\right)$$

14. The formula for π follows from plugging $M=1/\sigma$ into the general π formula:

$$\pi = \frac{\alpha M(L - g/2)}{(1-\alpha(\eta+M))K}$$

The general formula for η is:

$$\eta \equiv \frac{(\tau-1) + T(1-1/\sigma)\ /(w\Lambda+T)}{\tau(1+\phi^{-1})}$$

so with only specific tariffs:

$$\eta \equiv \frac{T(1-1/\sigma)\ /(1+T)}{(1+\phi^{-1})}\ ; \qquad \phi \equiv (1+T)^{1-\sigma}$$

Rearranging gives the result for η in the text.

15. The elasticity of η with respect to T is:

$$1 - \frac{T}{1+T}\left(\frac{\sigma+(1+T)^{1-\sigma}}{1+(1+T)^{1-\sigma}}\right)$$

so for T=0, it is positive (specifically, it is equal to unity), but the limit of the elasticity as T approaches ∞ is negative (specifically, it is equal to $1-\sigma$).

16. Specifically from (13) and (8) with $M=1/\sigma$:

$$\bar{g} = \frac{2\alpha L[1+T+(1+T)^{\sigma}] - \rho[(\sigma-\alpha)(1+T)^{\sigma}+\sigma(T(1-\alpha)+1)-\alpha]}{\sigma[1+T+(1+T)^{\sigma}] - \alpha T(\sigma-1)}$$

17. Differentiating U_o with respect to T and evaluating the result at T=0, we find:

$$\frac{dU_o}{dT}\Big|_{T=0} = \frac{\alpha}{2\rho^2\sigma^2}[\alpha^2(2L+\rho)-\rho\sigma]$$

When this is positive, U_0 is upward-sloped at T=0. Since we know that U_0 eventually falls as T gets big, this is sufficient to establish the non-monotonicity of the relationship.

18. The derivative of $\eta/M=\sigma(\tau-1)/(1+\tau^{\sigma})$ is:

$$\frac{\sigma}{1+\tau^{\sigma}}\left(1-\sigma\frac{(\tau-1)\tau^{\sigma-1}}{1+\tau^{\sigma}}\right)$$

By inspection this is positive for τ near unity (free trade), and negative for large τ (since $\sigma>1$). The sign depends only upon the terms in large parentheses. At $\tau=1$, the second term in large parentheses is zero, so the derivative is positive. The second term in large parentheses, however, is monotonically increasing and limits to sigma, so the derivative is negative for sufficiently high τ, and it changes sign only once.

19. The two expressions for π are:

$$\pi_{wasted} = \frac{\alpha M(L-L_I)/K}{1 - \alpha M}, \qquad \pi_{returned} = \frac{\alpha M(L-L_I)/K}{1 - \alpha(\eta+M)}$$

Gathering M terms in both expressions, we have:

$$\pi_{wasted} = \frac{\alpha(L-L_I)/K}{1/M - \alpha}, \qquad \pi_{returned} = \frac{\alpha(L-L_I)/K}{1/M - \alpha - \alpha\eta/M}$$

The denominator of the first expression is greater than the denominator of the second, so π_{wasted} is never greater than $\pi_{returned}$. For $\tau=0$ and $\tau=\infty$, $\eta=0$, so the two coincide.

20. Since K enters V with an elasticity of -1, K must enter F with an elasticity of -1. Given the definition of a CES price index, the markup pricing rules (2-6), symmetry of countries and w=1:

$$F = \frac{K^{\frac{\alpha}{1-\sigma}}(p^{1-\sigma}+p^{*1-\sigma})^{\frac{\alpha}{1-\sigma}}}{K^{\Omega}}$$

Thus the requirement is that $(\alpha/(1-\sigma))-\Omega=-1$. Notice that $\alpha/(1-\sigma)$ may be greater than or less than -1, so Ω may be positive or negative.

21. Plugging in the optimal pricing rules, the CES price index is:

$$P_X = K^{\frac{1}{1-\sigma}} \frac{a_X(1+\phi)^{\frac{1}{1-\sigma}}}{1-1/\sigma}$$

Using this in (22) with w=1, yields the expression in the text.

22. When $\alpha/(\sigma-1)<1$ this derivative is decreasing in ϕ since ϕ enters the expression in the denominator with a positive power $\alpha/(\sigma-1)$ and enters the denominator with a negative power. When $\alpha/(\sigma-1)>1$, however, $d\bar{g}/d\phi$ is always positive, but it may be largest for intermediate values of ϕ.

23. Specifically

$$\pi^* = B^*(\frac{\alpha E^w}{\sigma K^w}) \; ; \quad B^* \equiv \phi\frac{\theta_E}{\theta_K+\phi(1-\theta_K)} + \frac{(1-\theta_E)}{1-\theta_K+\phi^*\theta_K}$$

24. The representative consumer's incomes equals $L+\pi K$. Her expenditure is income less investment spending, i.e. L_I. Thus, showing that $E=L+\rho/A$ in steady state only requires demonstrate of the fact that $\pi K=L_I+\rho/A$ in steady state. From $\bar{q}=1$, $\bar{\pi}=F(\rho+\bar{g})$. Multiplying through by K, using the growth rate form of the I-sector production function and the definition of A yields the result after some manipulation.

25. The q=1 condition can be arranged to:

$$\bar{g} = \frac{\alpha\bar{B}\bar{E}^w\bar{\theta}_K\bar{A}}{\sigma} - \rho$$

but the steady-state B, A and E^w are all functions of the steady-state θ_K, so we easily get a closed-form solution for the steady state g. Using (26) we get the steady-state L_I from the steady state g. Similar manipulations yields the steady-state L^*_I .

26. The general solution calculated with Maple (the worksheet 'calc_ss.mws' is available from the authors) is:

$$\bar{\theta}_K = Z$$

Here Z is the solution to the polynomial:

$$0 = c4*Z^4 + c3*Z^3c + c2*Z^2 + c1*Z + c0$$

where:

```
c4=(-4*ρ*phi2*λ+L2*λ^3*phi1-L2*λ^3*phi2-3*L1*λ^2+3*L1*λ*phi1+3*L1*λ
-3*L2*λ-L1*phi1-2*ρ*phi1+4*ρ*λ*phi1+3*L2*λ^2-3*L1*λ^2*phi1+L1*λ^3+L1*λ^3*phi1
-2*ρ*λ^2*phi1-3*L2*λ^2*phi2*phi1+3*L2*λ^2*phi2+2*ρ*λ^2*phi2+3*L1*λ^2*phi2*phi1
-3*L2*λ^2*phi1+L1*phi2+L1*phi2*phi1+3*L2*λ*phi1-L2*phi1+L2*phi2-L2*phi2*phi1+3*L2*phi2*phi1*λ
-L1*λ^3*phi2*phi1-3*L1*phi2*λ-3*L1*phi2*phi1*λ-3*L2*phi2*λ-L1*λ^3*phi2+3*L1*λ^2*phi2
+L2*λ^3*phi2*phi1-L2*λ^3+2*ρ*phi2+L2-L1)

c3:=(6*ρ*phi2*λ-2*L2*λ^3*phi1+2*L2*λ^3*phi2
+8*L1*λ^2-8*L1*λ*phi1-7*L1*λ+5*L2*λ+3*L1*phi1+6*ρ*phi1-10*ρ*λ*phi1-4*L2*λ^2
+7*L1*λ^2*phi1-3*L1*λ^3-2*L1*λ^3*phi1+4*ρ*λ^2*phi1+4*ρ*λ^2*phi2*phi1
+8*L2*λ^2*phi2*phi1-5*L2*λ^2*phi2-4*ρ*λ^2*phi2-4*L1*λ^2*phi2*phi1+7*L2*λ^2*phi1
-L1*phi2-2*L1*phi2*phi1-8*L2*λ*phi1+3*L2*phi1-L2*phi2+2*L2*phi2*phi1-7*L2*phi2*phi1*λ+L1*λ^3*phi2*phi1
+4*L1*phi2*λ+5*L1*phi2*phi1*λ+4*L2*phi2*λ+2*L1*λ^3*phi2-5*L1*λ^2*phi2-3*L2*λ^3*phi2*phi1
-4*ρ*phi2*phi1*λ+L2*λ^3-2*ρ*phi2-2*L2+2*L1)

c2=(-3*ρ*phi2*λ+L2*λ^3*phi1-L2*λ^3*phi2-8*L1*λ^2+8*L1*λ*phi1+6*L1*λ
-3*L2*λ-3*L1*phi1-6*ρ*phi1+9*ρ*λ*phi1+2*L2*λ^2-6*L1*λ^2*phi1+3*L1*λ^3+L1*λ^3*phi1
-3*ρ*λ^2*phi1-6*ρ*λ^2*phi2*phi1-8*L2*λ^2*phi2*phi1+3*L2*λ^2*phi2+3*ρ*λ^2*phi2
+2*L1*λ^2*phi2*phi1-6*L2*λ^2*phi1+L1*phi2*phi1+8*L2*λ*phi1-3*L2*phi1-L2*phi2*phi1+6*L2*phi2*phi1*λ
-2*L1*phi2*λ-3*L1*phi2*phi1*λ-2*L2*phi2*λ-L1*λ^3*phi2+3*L1*λ^2*phi2+3*L2*λ^3*phi2*phi1
+6*ρ*phi2*phi1*λ+L2-L1)

c1:=(L2*λ-L1*λ^3+L1*phi2*phi1*λ-4*L2*λ*phi1+4*L1*λ^2
-2*L2*phi2*phi1*λ+2*ρ*phi1+2*L1*λ^2*phi1+2*L2*λ^2*phi1-L1*λ^2*phi2+ρ*λ^2*phi1
+4*ρ*λ^2*phi2*phi1+L2*phi1-2*L1*λ-4*ρ*λ*phi1-L2*λ^2*phi2-L2*λ^3*phi2*phi1-4*L1*λ*phi1
-ρ*λ^2*phi2+4*L2*λ^2*phi2*phi1-2*ρ*phi2*phi1*λ+L1*phi1)

c0:=-L1*λ^2-L2*λ^2*phi2*phi1+L1*λ*phi1+L2*λ*phi1+ρ*λ*phi1-ρ*λ^2*phi2*phi1
```

The notation here uses '1' and '2' to indicate home and foreign variables, but otherwise it is identical to the notation in the text. Experiments with limited forms of asymmetry always produced intractable solutions such as this one.

27. These calculations were performed in Maple worksheet jacsym_E.mws.

28. It is simple to calculate the critical α (there are two solutions; only one that lies in the interval [0,1]), however the expression is too unwieldy to be very revealing.

29. Also, for any values of α, the eigenvalues are real for sufficiently low ϕ.

30. Note that $e_3=0$, if and only if $-b+(rad)^{1/2}=0$, and this holds if and only if c=0, since a>0.

31. One negative eigenvalue indicates that the stable manifold is one dimensional. Thus except in the degenerate case where the corresponding eigenvector is orthogonal to the θ_K axis, the two jumping state variables can jump onto the stable manifold for any perturbation of θ_K. The transversality condition tells us that L_I and L_I* will jump to the stable path, if they can.

32. At the critical ϕ, we have $b=(b^2-4ac)^{1/2}$. Simplifying and using the fact that a>0, we see that c=0 is a necessary and sufficient condition for $e_3=0$.

33. It is straightforward to demonstrate that this root lies in the interval [0,1] and the other root is always greater than unity. See calculations in Maple worksheet jacsym_E.mws.

34. Note that the Euler equation comes from the consumer's utility maximization problem, so it does not depend upon the lack of transitional dynamics. Also, the expression for E in (10) requires only perfect competition in the I sector and the consumer's temporal budget constraint. Log time differentiation of (10) with w=1, yields:

$$\frac{\dot{E}}{E} = \frac{-\dot{L}_I}{L-L_I}$$

This is the left-hand side of the transformed Euler equation. The right-hand side involves only r-ρ, and from the no-arbitrage condition, r equals π/P_K plus the growth rate of P_K. Using I-sector competition P_K=F, so with symmetry:

$$r = \frac{\pi}{F} - g$$

Now using (7) – which was derived using only the optimal pricing rule of X-firms and the temporal demand functions – and (3), we have:

$$r = \frac{2\alpha M(L-L_I)}{1-\alpha(\eta+M)} - 2L_I$$

Plugging these into the Euler equation yields the formula in the text.