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Abstract

We analyze the costs of trade restrictions for a small developing economy. Capital goods are only introduced on the market if it is profitable to do so. The economy evolves to a balanced growth path in which income, welfare, and the share of introduced capital goods increase if trade restrictions fall. The adjustment path is asymmetric: an increase in trade restrictions will slow-down economic growth, while a decrease may give rise to a rapid catch-up process. The static costs of trade restrictions are smaller than the dynamic costs if, and only if, it changes the share of introduced capital goods.

Key words: growth, development, static and dynamic costs, trade restrictions, new goods

JEL codes: E, F, O

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1 Introduction

Empirically, developing countries are largely dependent on R&D efforts undertaken in the industrial countries for access to newly developed products and services and the availability of quality improvements for existing goods and services, see Coe, Helpman, and Hoffmaister (1997). A few years earlier, Romer (1994) already incorporated this aspect of a developing economy in a static model, where he argued that the costs of unexpected increases in trade restrictions (estimated using Harberger triangles) are smaller than the costs of expected increases in trade restrictions (estimated using Harberger and Dupuit triangles), because the latter affects the range of goods available in the developing economy.

We provide a dynamic extension of this framework in an endogenous growth setting, see Romer (1986, 1990), Grossman and Helpman (1991), and Aghion and Howitt (1992).[1] We analyze a small developing economy which depends on R&D undertaken in the rest of the world and introduced on its market for an extension of the available range of (intermediate) capital goods. Using the variety approach, the introduction of new capital goods is associated with a positive production externality. The providers of the capital goods have market power and are therefore able to charge a mark-up over marginal costs, allowing them to enjoy positive operating profits *if* they introduce their capital good on the market in the developing economy. They will only do so if the discounted operating profits are larger than the introduction costs for their particular variety. In general, therefore, only a fraction of all newly invented goods in the rest of the world will actually be introduced on the market in the developing economy. We analyze how changes in trade policy and various parameters affect the share of actually introduced capital goods. This set up enables us to explain the level of economic development in a dynamic setting and analyze the static and dynamic costs of trade restrictions.

Two implications of our model are worth emphasizing from the start. First, the estimated static costs of trade restrictions are smaller than the dynamic costs of trade restrictions if, and only if, the increase in trade restrictions reduces the *share* of invented capital goods introduced on the market. In this dynamic setting it is therefore not the fact that we ignore the Dupuit triangles of newly invented goods in estimating the effects of an increase in trade restrictions, as it is in the Romer (1994) model, but the fact that an increase in the trade restrictions affects the share of newly invented goods not introduced on the market. Second, as a result of the sunk-cost nature of the introduction costs, there is an asymmetric adjustment path of the developing economy after a change in trade restrictions. An increase in the level of trade restrictions will slow-down economic growth and put the economy on a transition path to a new balanced growth rate. If the new level of trade restrictions exceeds a critical value, the new growth rate will be zero and stagnation occurs. If trade restrictions fall, the developing economy may embark on a rapid catch-up process of economic growth by benefiting from the backlog of previously-invented-but-not-yet-introduced capital goods which may now, as a result of the increase in operating profits resulting from the decrease in trade restrictions, be introduced on the market in the developing economy.

We believe that the second implication of our model, that a decline in prosperity following increases in trade restrictions is more gradual than the potential increase in prosperity following reductions in trade restrictions, is in accordance with empirical observations. In the period 1973-1991, for example, Maddison (2003) estimates per capita GDP in the North Korean economy to be stagnant at $2,841 (in 1990 international Geary-Khamis dollars). Arguably, this stagnation is caused by the high level of trade restrictions, which makes it unprofitable to introduce newly invented goods and services on the North Korean market. Since the rest of the world continues to grow in this same time period (by investing in capital, schooling, and R&D to develop new goods and varieties or discover quality improvements for existing goods), North Korea's level of income per capita relative to the world average gradually declines from 69 percent in 1973 to 55 percent in 1991. The South Korean economy, in contrast, continues to rapidly open up to the world economy in this period and experiences an impressive increase in GDP per capita relative to the world average, namely from 69 percent in 1973 to 184 percent in 1991. In the absence of extreme terms of trade effects and catastrophes, such as

[1] See van Marrewijk (1999) for an overview.

wars, floods, and famines, it appears that a relative decline in production occurs more gradually than seems to be possible in the catch-up process of a relative increase in production. For example, seven countries (mostly the 'Asian Tigers') have experienced an increase of more than 100 percent in per capita income relative to the world average within a 20 year period at least once in the last decade of the 20^{th} century.[2] Although a similar decrease also occurred seven times, this is never due to the size of the contraction of economic production, but always the result of a large negative terms of trade effect, namely in the price of oil.[3]

Section 2 provides the basic structure of the model. Section 3 determines the range of invented capital goods actually introduced on the market in the developing economy. Sections 4 and 5 focus on the balanced growth path and the long-run implications of changes in trade restrictions. Sections 6-8 analyze the asymmetric transition dynamics and the static and dynamic costs of trade restrictions, followed by a brief discussion in section 9 and a general summary and conclusions in section 10.

2 The model

Our analysis focuses on a small developing economy which at time t uses labor $L(t)$ and a range (indexed by i) of different types of capital goods $x(i,t)$ to produce a final good $Y(t)$. The set of available capital goods at time t is denoted by $A(t)$. We use the term capital goods in a broad sense to refer to intermediate goods and services used in the production of final goods, that is we employ the Ethier (1982) interpretation of a continuous representation of the Dixit-Stiglitz (1977) constant elasticity of substitution variety function (a generalization of Romer, 1994). It is well-known that, given the claim on real resources, an increase in the number of varieties available in the economy will lead to higher productivity through a positive externality effect, see van Marrewijk (2002, chs 10, 16). Since our focus is on the introduction of new capital goods, we keep the level

[2] The countries are: Norway, Ireland, Japan, South Korea, Taiwan, Hong Kong, and Singapore.
[3] The countries are: Venezuela, Iraq, Kuwait, Qatar, Saudi Arabia, United Arab Emirates, and Gabon

of employment constant, that is $L(t) = L$. It is, however, straightforward to allow for changes in employment. This brings us to the following aggregate production function:[4]

(1) $$Y(t|.) = L^{1-\alpha} \int_{i \in A(t)} x(i,t)^{\alpha} \, di \, ; \quad \alpha \in (0,1)$$

The ultimate objective is to explain the level of economic development in a dynamic setting and illustrate various types of welfare costs of imposing trade restrictions or other impediments to economic interaction with the rest of the world. To do this, we have in mind a Romer (1990) or Grossman and Helpman (1991) type endogenous growth model giving rise to an ever expanding variety of capital goods in the rest of the world. Since the economy we are analyzing is only a small developing economy, we make two simplifying assumptions, namely (i) this economy cannot influence the economic growth rate in the rest of the world and (ii) this economy does not engage in any R&D activity to develop new types of capital goods.

Assumption (ii) implies that the small developing economy depends on R&D activity in the rest of the world for introducing new types of capital goods, which is in accordance with the empirical results of Coe, Helpman, and Hoffmaister (1997). Assumption (i), in combination with the assumption that the rest of the world is on a positive balanced growth path, implies that the world's growth rate of knowledge (measured by the total range of invented capital goods $N(t)$) is equal to a constant $g > 0$, that is:

(2) $$N(t) = N(0)e^{gt} \equiv N_0 e^{gt} \, ; \quad \dot{N}(t)/N(t) = g > 0 \, ; \quad \textit{where } \dot{x} \equiv dx/dt$$

$$N(t) = N(0)e^{gt} \equiv N_0 e^{gt}$$

In general, the range of invented capital goods available to producers in the *developing* country is a *subset* of the total range of invented goods (assumed to be a measurable set), see equation (3). The core of this paper is to determine the size of this subset as a function

[4] The notation $t|.$ signals that the income level may depend on historical developments, see the sequel. See Berden and van Marrewijk (2001) for a similar structure to determine active and non-active firms.

of trade restrictions and the costs of introducing the capital good on the market of the developing country in a small general equilibrium model.

(3) $A(t) \subseteq [0, N(t)]$

Given the range of available capital goods $A(t)$, the production function exhibits constant returns to scale in L and $x(i,t)$. This allows us to model the production of final goods in the developing economy as perfectly competitive, where the producers face wage rate $w(t)$ for the use of labor and prices $p(i,t)$ for the use of capital goods $x(i,t)$. In equilibrium, profits by the final goods producers are zero, labor's share of income will be equal to $1-\alpha$, and in the aggregate the share of income paid for the use of all capital goods will be equal to α, see equation (4). Moreover, the price elasticity of demand for individual capital goods by final goods producers is equal to a constant $\varepsilon > 1$, see equation (5).

(4) $w(t)L = (1-\alpha)Y(t); \quad \int_{i \in A(t)} p(i,t)x(i,t)\,di = \alpha Y(t)$

(5) $x(i,t) = \alpha^{\varepsilon} L\, p(i,t)^{-\varepsilon}; \quad \varepsilon \equiv 1/(1-\alpha) > 1$

To determine the range of invented capital goods actually introduced on the market of the developing economy, we have to confront the costs and benefits of doing this to the inventor of a particular capital good. Starting with the latter, we will assume that the monopolistic producer of a capital good (who has the sole property rights to selling this good) can produce a unit of the capital good at a constant marginal cost of 1. To enable us to investigate the dynamic effects of trade restrictions, we will assume that the government of the developing country requires a payment of tariff T for the imports of foreign goods.[5] The foreign producers of capital goods take this tariff rate as given and assume that it will be applied indefinitely. As a result of the additively separable structure of the production function, the demand for a particular capital good *if* it is introduced on the market in the developing economy is stable over time, see equation (5) and Romer (1994). Since the price elasticity of demand is constant, the price of introduced capital

[5] Equivalently, the domestic government could impose a tax on goods produced by foreign companies.

goods is a constant mark-up over marginal costs and does not change over time, see equation (6). Obviously, an increase in the tariff rate leads to a higher price charged for the use of capital goods and thus a lower quantity demanded. The equilibrium quantity demanded for actually introduced varieties can be easily determined by substituting the optimal price (eq. 6) into market demand (eq. 5), see equation (7).

(6) $p(i,t) = (1+T)/\alpha \equiv p(T); \quad p'(T) = 1/\alpha > 0$

(7) $x(i,t) = \alpha^{2\varepsilon} L (1+T)^{-\varepsilon} \equiv x(T); \quad x'(T) = -\varepsilon\, x(T)/(1+T) < 0$

As a result of the above, instantaneous operating profits π for the providers of capital goods actually introduced on the market are constant over time, see equation (8). This means that the present value of operating profits of a capital good introduced at time t and discounted at the interest rate $\rho > 0$ is equal to the instantaneous operating profits divided by the interest rate, see equation (9).

(8) $\pi(T) \equiv p(T)x(T) - (1+T)x(T) = (1-\alpha)\alpha^{2\varepsilon-1} L (1+T)^{1-\varepsilon}$

$\pi'(T) = -(\varepsilon - 1)\pi(T)/(1+T) < 0$

(9) $\int_t^{\infty} e^{-\rho(\tau - t)} \pi(T)\, d\tau = \pi(T)/\rho$

Before the owner of capital good i invented at time t can reap the benefits of discounted operating profits from the market of the developing economy she has to introduce this good to the market at a fixed introduction cost $c(i,t)$. This can be the cost of setting up a service and parts supply network or the costs of setting up a local branch consulting office, etc. We assume these introduction costs may vary for the various producers of intermediate goods varieties from a minimum of a to a maximum of b. More specifically, we will assume that these costs are drawn independently from a cumulative distribution function F, without mass points and with support $[a,b]$ (where $0 < a < b$), see equation (10). The decision on whether or not to introduce the newly invented capital good on the market in the developing economy is now simple. The answer is yes if the discounted value of operating profits is larger than the costs of introduction. Otherwise, the answer is no. This decision process is summarized by the indicator function $I(i,t)$ defined in equation (11), see also (3').

(10) $c(i,t)\ iid\ with\ cdf\ F(x)$; $x \in X = [a,b]$, $F(a) = 0, F(b) = 1,$

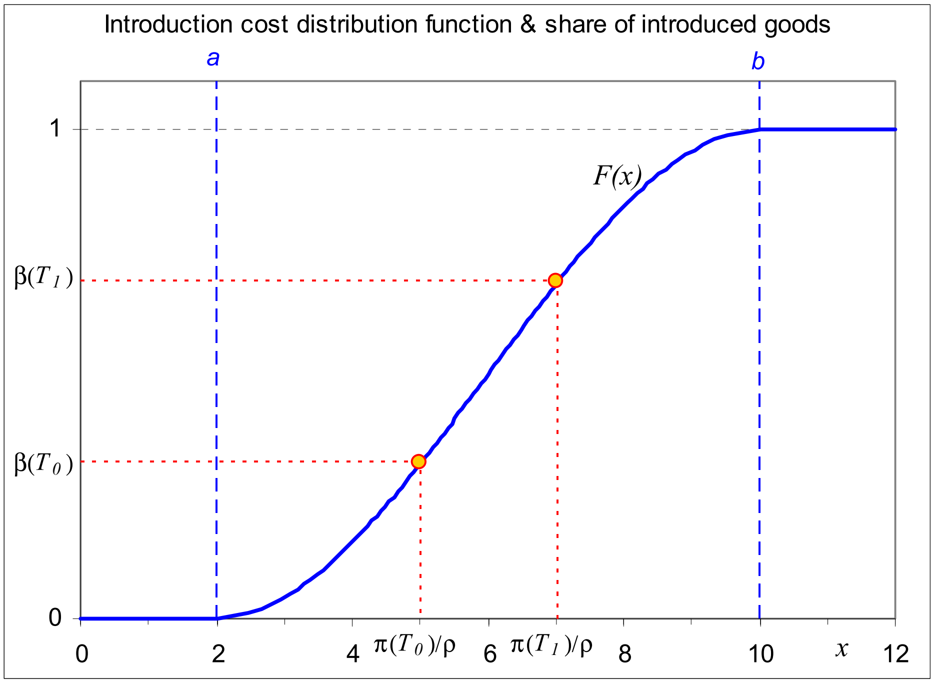
(11) $$I(i,t) = \begin{cases} 1, & if\ \pi(T)/\rho > c(i,t) \\ 0, & otherwise \end{cases}$$

(3') $A(t) = \{ i \in [0, N(t)] \mid I(i,.) = 1 \}$

3. The range of introduced capital goods

We are now in a position to determine the range of capital goods introduced on the market in the developing economy relative to the total range of invented goods in the rest of the world as a function of the trade restrictions T, as summarized by the introduction decision of equation (11). At each point in time, the growth rate of new capital goods invented in the rest of the world is g, implying that $gN(t)$ new goods become available for introduction on the market in the developing economy. Clearly, if the discounted value of operating profits $\pi(T)/\rho$ is smaller than the minimum introduction costs a *none* of the new capital goods will be introduced on the market in the developing economy. Similarly, if the discounted value of operating profits is higher than the maximum introduction costs b *all* of the new capital goods will be introduced on the market. The more interesting case occurs, therefore, if the discounted value of operating profits is in between these two extremes, that is $\pi(T)/\rho \in X$. Since the introduction costs are drawn independently from the same distribution function, the law of large numbers, which holds in this continuous specification over the number of capital goods and time, ensures that a stable *fraction*, β say, of the newly invented capital goods will actually be introduced on the market in the developing economy. At each point in time, therefore, $\beta gN(t)$ new capital goods will be available in the developing economy.

Figure 1 Distribution function F and share of introduced goods β



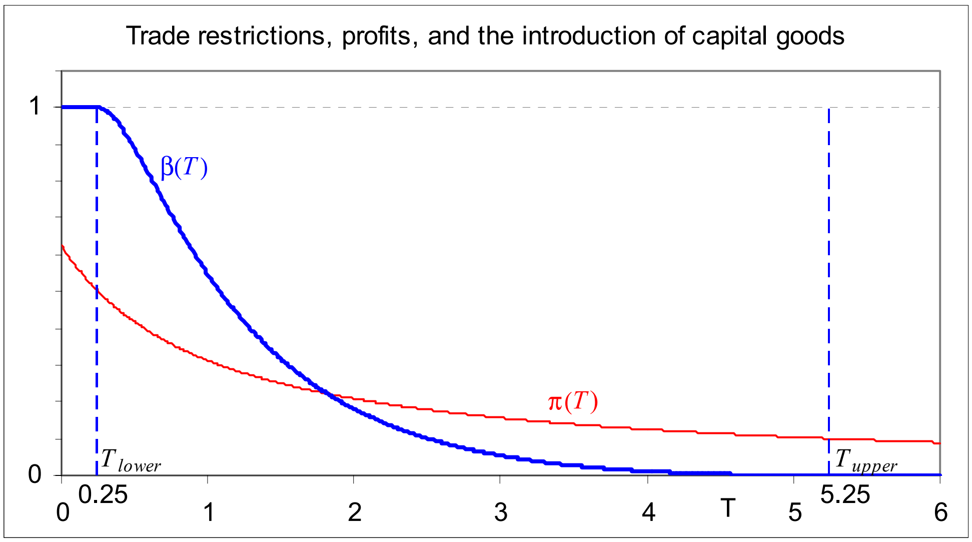
The illustrated cdf is a beta distribution with support [2,10] and parameters equal to 2.

Figure 1 illustrates how the fraction of introduced capital goods β depends on the trade restrictions T as a function of the operating profits π, the rate of discount ρ, and the distribution function F. Suppose the import tax is initially T_0, leading to discounted operating profits $\pi(T_0)/\rho$. Given enough observations, a fraction $F\left(\pi(T_0)/\rho\right)$ of the randomly drawn introduction costs will be below the discounted operating profit threshold $\pi(T_0)/\rho$. All these capital goods will be introduced on the market. Similarly, a fraction $1-F\left(\pi(T_0)/\rho\right)$ will be above the discounted operating profit threshold $\pi(T_0)/\rho$. All these capital goods will not be introduced on the market. If the trade restriction falls, say to $T_1 < T_0$, the discounted operating profit threshold will rise to $\pi(T_1)/\rho$ and a larger share of newly invented capital goods $F\left(\pi(T_1)/\rho\right)$ will actually be introduced on the market, see Figure 1. To summarize, the share of capital goods actually introduced on the market in the small developing economy is equal to:

$$\text{(12)} \qquad \beta(T) \equiv \begin{cases} 0, & \text{if } 0 < \pi(T)/\rho < a; \quad \beta' = 0 \\ F\left(\pi(T)/\rho\right), & \text{if } a \le \pi(T)/\rho \le b; \quad \beta' = F'\pi'/\rho < 0 \\ 1, & \text{if } b < \pi(T)/\rho < \infty; \quad \beta' = 0 \end{cases}$$

The crucial point is, of course, that the range of introduced new capital goods depends negatively on the trade restrictions T, which allows us to investigate both dynamic and static welfare costs in the analysis below. This is illustrated in Figure 2, where it is assumed that in the absence of trade restrictions ($T = 0$) all newly invented capital goods will actually be introduced on the market in the developing economy.

Figure 2 Trade restrictions, profits, and the introduction of new capital goods



Note: $\alpha = 0.5, L = 10, \rho = 0.05$, for the distribution function see Figure 1.

An increase in the level of trade restrictions immediately implies a higher price charged for the use of capital goods (eq. 6), a lower quantity of capital goods used (eq. 7), and lower profits for the producers of capital goods (eq. 8 and Figure 2). Despite the lower profit level, however, the inventors of new capital goods will still introduce all of them on the market, provided the trade restrictions are not too high. Beyond a critical value of trade restrictions, equal to 25 per cent ($T = 0.25$) in Figure 2, some inventors of new capital goods will decide that the costs of introducing the capital goods on the market in the developing economy are higher than the discounted value of operating profits. The share of actually introduced capital goods then starts to decline gradually until a second critical value is reached, equal to 525 per cent ($T = 5.25$) in Figure 2, beyond which no newly invented capital goods will be introduced on the market. These critical values are, of course, determined by the support limits a and b of the distribution function in conjunction with discounted profits, see equation (12). For ease of reference we will call these critical values T_{upper} and T_{lower}, defined as follows:

- $T_{upper} \equiv \pi^{-1}(\rho a); \quad T \geq T_{upper} \Rightarrow \beta(T) = 0$
- $T_{lower} = \begin{cases} 0, & if\ \pi(0)/\rho < 1 \\ \pi^{-1}(\rho b), & otherwise \end{cases} ; \quad 0 \leq T \leq T_{lower} \Rightarrow \beta(T) = 1$

4. Government revenue and welfare

This section focuses on government revenue and welfare as a function of trade restrictions under the assumption that the same policy has been operative indefinitely. We therefore assume that the same fraction of capital goods as dictated by the function $\beta(T)$ of equation (12) has also been introduced at time 0. The next section analyzes transitory dynamics if government policy is changed. Under the simplifying assumption above, the share of actually introduced capital goods is constant over time. More specifically, if $M(.)$ is the Lebesgue measure, it follows that:

(13) $$M(A(t)) = \beta(T)N(t); \quad \beta(T) > 0 \Rightarrow \dot{M}(A(t))/M(A(t)) = \dot{N}(t)/N(t) = g$$

The growth rate of newly available capital goods in the developing economy is therefore equal to the growth rate g in the rest of the world for all time periods. This allows us to explicitly determine the level of output at any point in time as a function of the level of trade restrictions by using equations (7), (12), and (13), see equation (1'). Since both the use of capital goods x is a declining function of T and the share of new capital goods introduced on the market is a non-increasing function of T, the output level is a decreasing function of the level of trade restrictions.

(1') $$Y(t|T) = L^{1-\alpha}M(A(t))\,x(T)^{\alpha} = L^{1-\alpha}x(T)^{\alpha}\,\beta(T)N_0\,e^{gt} \equiv Y(T)\,e^{gt}$$

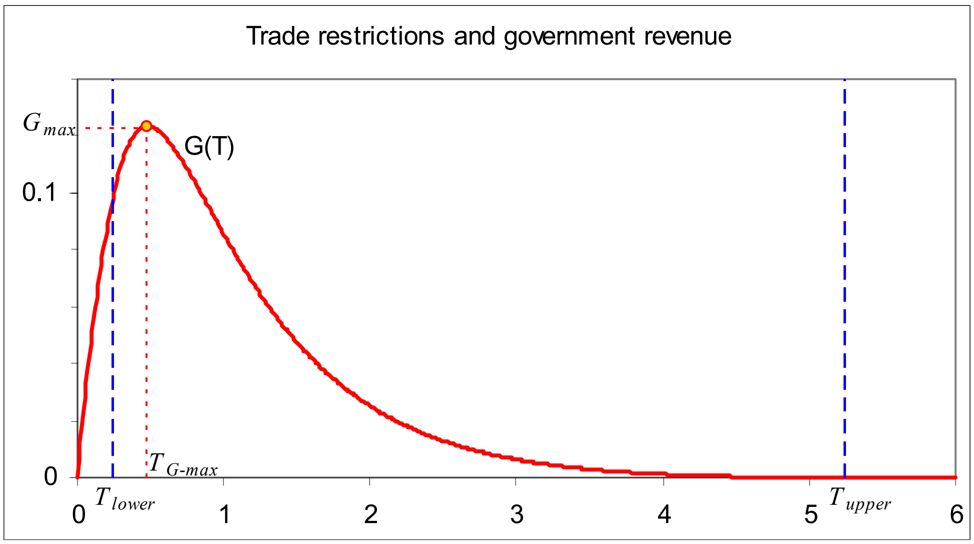
$$Y'(T) = \left[(\beta'/\beta) - \alpha\varepsilon/(1+T)\right]\,Y(T) < 0$$

In the absence of an efficient tax collecting system, which requires detailed information on the inhabitants of a country, their income level, etc., as well as public servants gathering and processing information, the governments of many developing nations are tempted to collect tax revenue by imposing trade restrictions on the import of goods and services.[6] Total government revenue G is equal to the tariff T multiplied by the import of capital goods x and the measure of active firms $M(A(t))$. As with the income level given in equation (1'), this implies that government revenue increases exponentially and depends on the level of trade restrictions as follows:

(14) $$G(t|T) = M(A(t))T\,x(T) = \beta(T)T\,x(T)N_0\,e^{gt} \equiv G(T)\,e^{gt}$$

$$G'(T) = \beta\,x\,N_0 + \left[(\beta'/\beta) - \varepsilon/(1+T)\right]\,G(T);\quad G(0) = G(T_{upper}) = 0;\quad G'(0) > 0$$

Figure 3 Trade restrictions and government revenue



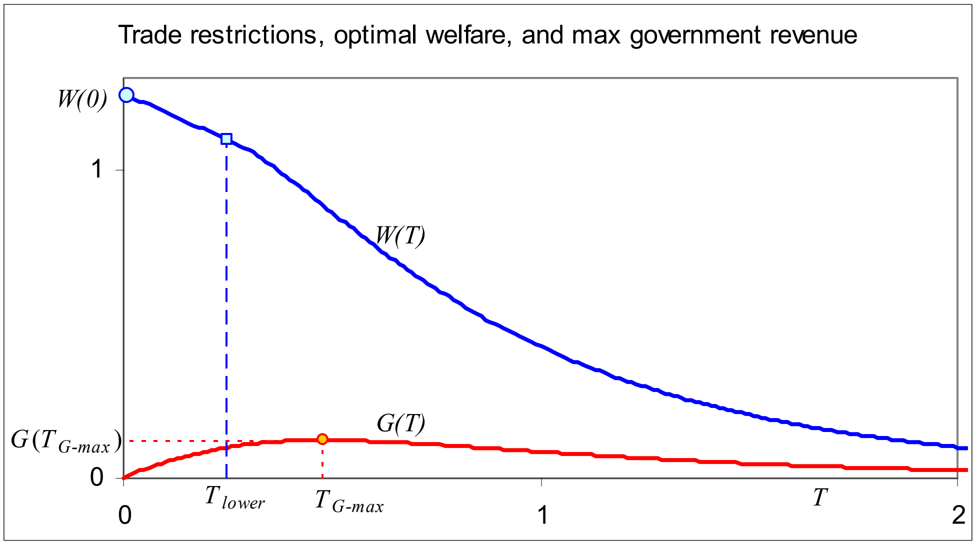
Note: $N_0 = 1$, for the other parameter values see Figure 2.

From the properties of the government revenue function, it follows that there exists a strictly positive level of trade restrictions, $T_{G-\max} \in (0, T_{upper})$ say, which maximizes the present discounted value of government revenue.[7] This is illustrated in Figure 3. Note that for the parameter setting used in Figure 2 the level of government revenue maximizing trade restrictions $T_{G-\max}$ is higher than the level for which the share of introduced capital

[6] The government of Swaziland, for example, relied on import duties to collect 55 per cent of total tax revenue in 2000 (World Bank Development Indicators CD-Rom 2003).
[7] Alternatively, myopic government revenue maximization (which takes the measure of active firms as given) leads to $T_{myopic} = 1/(\varepsilon - 1)$, which in general is larger than $T_{G-\max}$ due to the term β'/β in (14).

goods starts to decline ($T_{lower} > 0$). In general, this depends on the specific parameters and $0 < T_{G-\max} < T_{lower}$ is also possible.

Figure 4 Trade restrictions, optimal welfare, and maximum government revenue



Same parameter values as used in Figure 3.

Instantaneous welfare W for the small developing economy is the sum of government revenue (eq. 14) and labor income (eq. 4), see equation (15). As explained below the equation, given t instantaneous welfare is a declining function of trade restrictions T, where the first inequality follows from ignoring some negative terms, after which we use sequentially $(1-\alpha)\varepsilon = 1$, the fact that βN_0 is equal to the Lebesgue measure of active firms at time 0 in conjunction with the second part of equation (4) while simultaneously using equations (6) and (7), and again the optimal pricing rule given in equation (6), leading eventually to the conclusion that $W'(T) < 0$.

(15) $$W(t|T) = G(t|T) + (1-\alpha)Y(t|T) = \left[G(T) + (1-\alpha)Y(T)\right] e^{gt} \equiv W(T)e^{gt}$$

$$\begin{aligned} W'(T) &= \beta x N_0 + (\beta'/\beta)W(T) - \varepsilon G(T)/(1+T) - \alpha\varepsilon(1-\alpha)Y(T)/(1+T) < \\ &< \beta x N_0 - \alpha\varepsilon(1-\alpha)Y(T)/(1+T) = \beta x N_0 - \alpha Y(T)/(1+T) = \\ &= x M(A(0)) - p x M(A(0))/(1+T) = x M(A(0))\left[1 - 1/\alpha\right] < 0 \end{aligned}$$

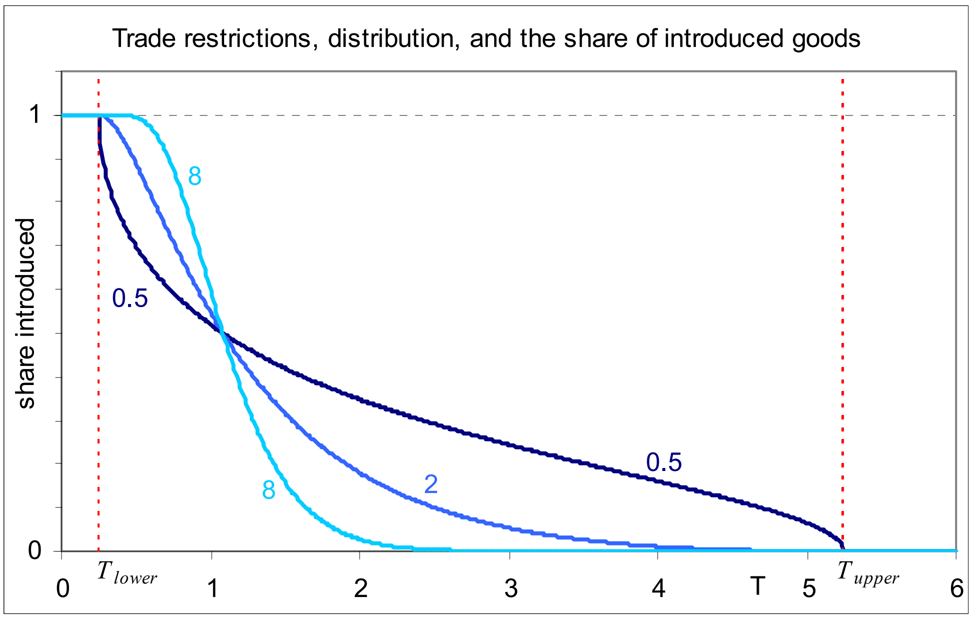
Since total welfare is just the discounted value of instantaneous welfare, the optimal policy is to impose no trade restrictions at all, leading to total welfare $W(0)/(\rho - g)$. As follows from equation (14) and is illustrated in Figure 4, however, a government maximizing the discounted value of government revenue would choose the level of trade restrictions $T_{G-\max} > 0$, leading to a sub-optimal outcome in terms of welfare. In general, therefore, any government assigning a disproportionate weight to the importance of obtaining government revenue from trade restrictions will impose a too high level of trade restrictions. In the thought experiment of this section, which ignores transition dynamics, the increase in the number of new goods, which is equal to the growth rate of the economy, is dictated by progress in the rest of the world and equal to g for all time periods. The next section briefly discusses the long-run implications of policy changes along this balanced growth path. Sections 6-8 demonstrate not only that the economy will indeed evolve over time towards the balanced growth path, but also that the deviation in economic growth rate and the level of income can be substantial if we allow for changes in government policy and incorporate transition dynamics. Proposition 1 summarizes the main analytic results derived so far.

Proposition I. The balanced growth path of the economy regarding income, government revenue, and welfare is given in equations (1'), (14), and (15), respectively. Income, welfare, and the share of capital goods introduced on the market in the developing economy increase if the level of trade restrictions falls.

5. Long-run implications of policy changes[8]

As discussed in sections 6-8 below, the economy will adjust from one balanced growth path to another after a change in government policy, where the speed of adjustment depends on the size of the policy change as well as its direction. The long-run implications of the policy change are, however, determined by the new balanced growth path, which was characterized in sections 3 and 4, see equations (1') and (12)-(15). The discussion and exposition in section 4 emphasizes the implications of a change in the level of trade restrictions. An increase in trade restrictions (i) increases the price of capital goods, (ii) decreases the quantity demanded, (iii) decreases the profit level, (iv) decreases the share of capital goods introduced on the market in the developing economy, (v) reduces the income level, and (vi) reduces the welfare level. The effect of an increase in trade restrictions on government revenue is ambivalent. We now briefly review the impact of other parameter changes.

Figure 5 Effect of changes in the shape of the distribution function on β



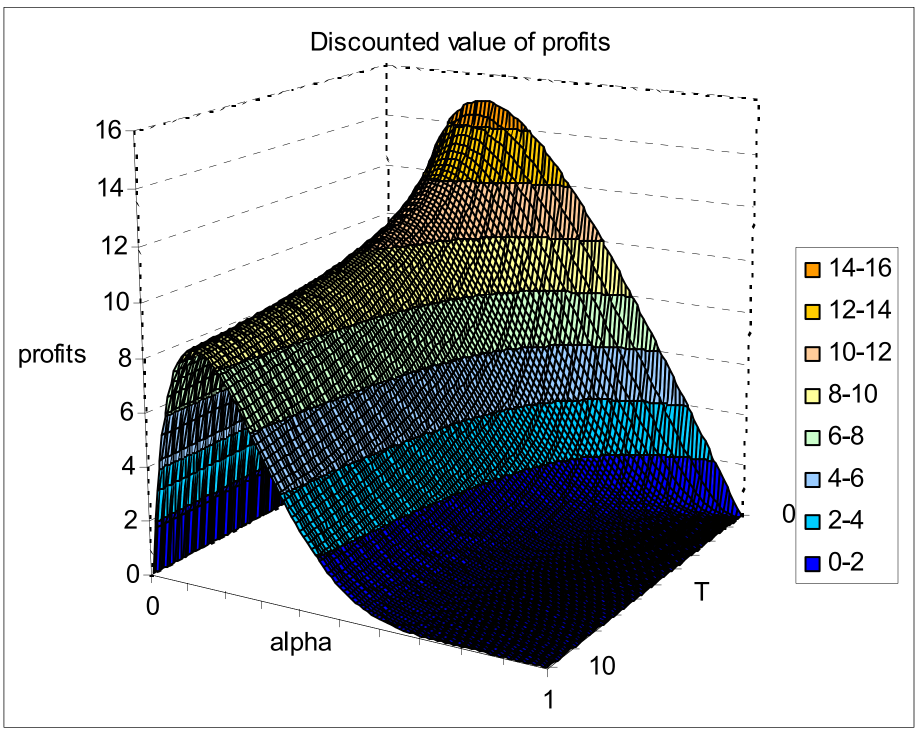
Beta distribution function parameters are 0.5, 2, and 8; for other parameters see Figure 3.

The effect of a change in the discount rate ρ is straightforward. A decrease in the discount rate increases discounted profits and therefore the share of introduced capital goods. This, in turn, increases the income level, government revenue, and welfare. The effect of a change in the distribution function F is quite similar to a change in ρ, as it also only affects the equilibrium through the share of introduced goods. Other things equal, a decrease in the lower limit of introduction costs a or the upper limit of introduction costs b tends to increase the share of introduced goods, which is similar to a decrease in ρ. Changes of the distribution function itself (but not its limits) will affect the

[8] The terms ‘increases’ and ‘decreases’ as used in this section indicate ‘non-decreasing’ and ‘non-increasing’, respectively.

speed with which the share of introduced goods changes as the level of trade restrictions changes, but not the critical values T_{upper} and T_{lower}, see Figure 5. The share of introduced goods curve in Figure 5 could therefore have any smooth downward sloping shape, as long as it connects the points $(T_{lower},1)$ and $(T_{upper},0)$. In contrast to changes in the discount rate and the distribution function, changes in the labor force L affect the equilibrium not only through changes in the share of introduced goods but also through other economic variables. Since an increase in the labor force increases the demand for capital goods and hence instantaneous and discounted profits, this implies an increase in the share of introduced capital goods, the income level, government revenue, and welfare.

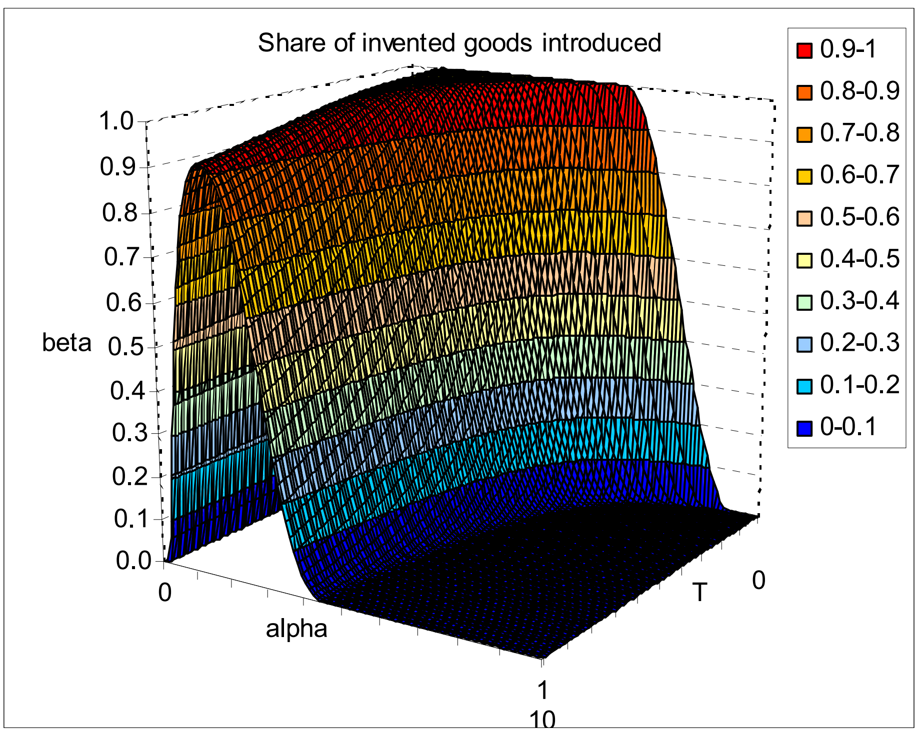
Figure 6 Effect of a change in α and T on profitability



Parameter values: $L = 10; \rho = 0.05$.

The effect of a change in α is a little more involved than the effect of a change in the other parameters. On the one hand, an increase in α increases the importance of capital goods in total production and raises the share of income spent on capital goods, thus raising profitability for the capital goods suppliers. On the other hand, an increase in α reduces the firm's market power, leading to a reduction in the mark-up of price over marginal cost and hence profitability. As illustrated in Figure 6, the first effect (increased importance of capital goods) dominates for low values of α, such that profits initially rise as α increases, while the second effect (reduced market power) dominates for higher values of α. In short, given T, there exists a critical value of α, say $\bar{\alpha}(T)$, such that a rise in α implies increasing profits as long as α is below $\bar{\alpha}(T)$ and falling profits thereafter. Calculations show that $\bar{\alpha}(0) \approx 0.28$, $\bar{\alpha}'(T) < 0$, and $\lim_{T\to\infty} \bar{\alpha}(T) = 0$. The effect of a change in α on the share of goods introduced on the market is basically a truncated translation of the level of discounted profitability, see Figure 7.

Figure 7 Effect of a change in α and T on the share of introduced goods



Parameter values: see Figure 1 and Figure 6

6. Policy changes and transition dynamics

A crucial aspect of this model is the sunk cost nature of the costs of introducing a capital good on the market of the developing economy, implying that once such a good is actually introduced it will continue to be supplied on the market independently of subsequent changes in the level of trade restrictions. This implies not only that the income level is path-dependent (hysteresis) but also that the response of changes in government policy is asymmetric. We will start our discussion of policy changes and transition dynamics with a simple thought experiment. Section 7 relates this to the static and dynamic costs of an increase in trade restrictions, section 8 analyzes a decrease in trade restrictions, followed by a brief discussion in section 9.

Policy change experiment

Suppose the government of the developing country imposes a tariff level T_0 from time 0 to time t_1. We assume that (i) within this time frame it is *expected* that this tariff level will be maintained indefinitely, (ii) initially a positive fraction of newly invented goods in the rest of the world is actually introduced in the developing country ($0 \le T_0 < T_{upper}$), and (iii) the economy is initially on a balanced growth path ($M(A(0)) = \beta(T_0)\,N_0 \equiv M_0$). At time period t_1, however, as the measure of active firms has increased to $M(A(t_1)) \equiv M_1$, the government unexpectedly changes its policy by imposing a tariff level T_1. We furthermore assume that (iv) the government henceforth actually maintains tariff level T_1 indefinitely and (v) it is (perhaps surprisingly) *immediately* expected from time period t_1 onwards that the new tariff level will be maintained indefinitely. Obviously, the new level of trade restrictions may be either higher or lower than the old level. To analyze the impact of policy changes in this thought experiment, the notation $|t_1^+$ will be used to indicate a rise in the level of trade restrictions ($T_1 > T_0$) and the notation $|t_1^-$ will be used to indicate a fall in the level of trade restrictions ($T_1 < T_0$).

Section 8 will focus on a decrease in trade restrictions. This section analyzes the impact of an *increase* in the level of trade restrictions. Initially, that is in between periods 0 and t_1, the economy is on a balanced growth path. The government levies tariff T_0, the active capital goods providers charge price $p(T_0)$, and the final goods producers demand quantity $x(T_0)$ of each capital good. This implies that the capital goods producers receive operating profits $\pi(T_0)$, which they expect to enjoy forever. Consequently, of the $gN(t)$ new capital goods that are invented each period in the rest of the world, a constant fraction $\beta(T_0)$ will be actually introduced in the developing economy, such that the income level and government revenue evolve according to (1') and (14), respectively.

Figure 8 Impact of an increase in trade restrictions on the economic growth rate

Parameter values: $\alpha = 0.8; L = 60; \rho = 0.05; g = 0.02; t_1 = 10; T_0 = 0.5; T_1 = 0.6$, combined with a beta distribution function with support [2,10] and parameters equal to 2.

From time period t_1 onwards, the government levies tariff $T_1 > T_0$, the active capital goods providers charge price $p(T_1) > p(T_0)$, and the final goods producers demand quantity $x(T_1) < x(T_0)$ of each capital good. The capital goods producers therefore receive operating profits $\pi(T_1) < \pi(T_0)$, which we assumed they expect to enjoy forever. Regarding the range of active capital goods producers we have to distinguish between two groups of producers.

- The first group consists of all capital goods producers who entered the market of the developing economy *before* the policy change at time period t_1. Since the costs of introducing the capital good on the market are sunk costs, they will remain active despite the policy change which reduces the discounted value of operating profits. Consequently, some of these producers will *ex post* conclude that they have made the wrong decision by introducing the capital good on the market as the discounted value of operating profits turns out to be actually lower than the introduction costs.

- The second group consists of all capital goods producers who may enter the market of the developing economy *after* the policy change at time period t_1. They know their instantaneous profits are $\pi(T_1)$ and will enter the market if the discounted profits are higher than the introduction costs, as given in equation (12). Since at each point in time $g\,N(t)$ new capital goods are invented in the rest of the world, a fraction $\beta(T_1)$ of these will enter the market of the developing economy from time period t_1 onwards. This allows us to explicitly determine the range of active firms after the policy change:

$$M(A(t))\big|_{t\geq t_1} = M_1 + \int_{t_1}^{t} \beta(T_1)\, g\, N(\tau)\, d\tau = M_1 + \int_{t_1}^{t} \beta(T_1)\, g\, e^{g\tau}\, N_0\, d\tau =$$
$$= \beta(T_1)\, e^{gt} N_0 + \left[\beta(T_0) - \beta(T_1)\right] e^{gt_1} N_0$$

To summarize, we can now determine the range of active capital goods producers on the market of the developing economy, the income level, and the government revenue as a function of time if the government increases trade restrictions at time t_1:

(16) $$M(A(t)|t_1^+) = \begin{cases} M_0 e^{gt}\,, & if\ t \in [0, t_1) \\ \beta(T_1)\, e^{gt} N_0 + \left[\beta(T_0) - \beta(T_1)\right] e^{gt_1} N_0\,, & if\ t \in [t_1, \infty) \end{cases}$$

(17) $$Y(t|t_1^+) = \begin{cases} Y(T_0) e^{gt}\,, & if\ t \in [0, t_1) \\ L^{1-\alpha} x(T_1)^{\alpha}\, M(A(t)|t_1^+)\,, & if\ t \in [t_1, \infty) \end{cases}$$

(18) $$G(t|t_1^+) = \begin{cases} G(T_0) e^{gt}\,, & if\ t \in [0, t_1) \\ T_1\, x(T_1)\, M(A(t)|t_1^+)\,, & if\ t \in [t_1, \infty) \end{cases}$$

Note that, because of the sunk cost nature of the introduction costs, the measure of active firms does not jump at time period t_1. This does not mean that the number of active firms cannot jump, see section 8. After the policy change, the economy adjusts over time to a new asymptotic balanced growth path dictated by the new level of trade restrictions T_1. This implies an immediate fall in the economic growth rate, which then gradually rises back to its pre-policy change level, see Figure 8. The next section discusses the static and dynamic costs of trade restrictions based on the adjustment path given in equations (16)-(18). Proposition II summarizes the results of this section.

Proposition II. After an increase in the level of trade restrictions in accordance with the policy change experiment, the economy adjusts over time to a new balanced growth path. The transition dynamics regarding the number of active capital goods producers, the income level, and government revenue after an increase in trade restrictions are given in equations (16)-(18), respectively.

7 Static and dynamic costs of an increase in trade restrictions

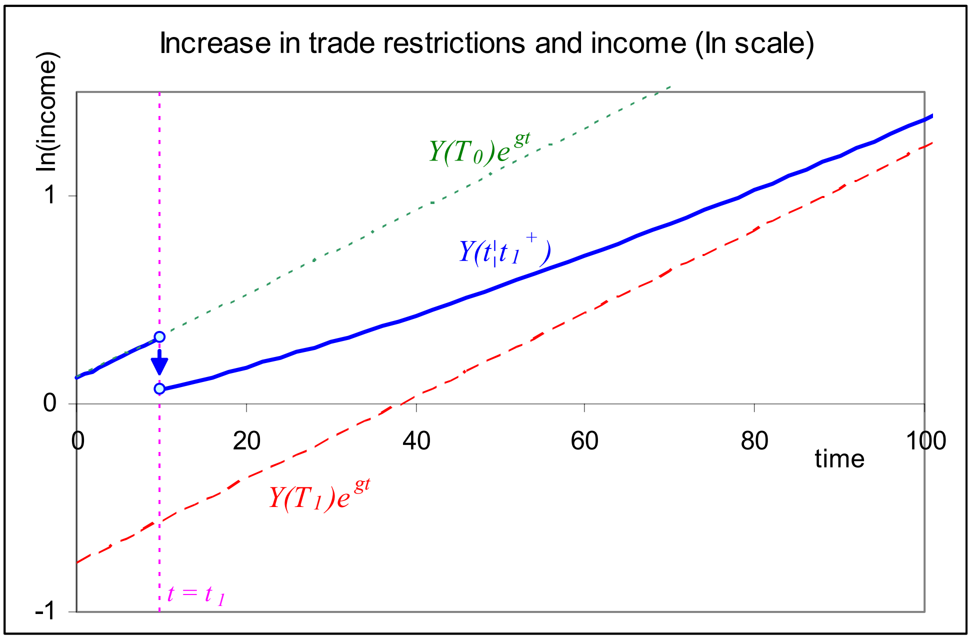
The main economic implications of the increase in trade restrictions are illustrated for the income level (a perfect measure of the real wage rate in our model) in Figure 9 using a logarithmic graph. At the time of the policy change there is an immediate reduction in the income level (indicated by the arrow in the figure), not because the number of capital goods firms active in the developing economy changes instantaneously, but because they all charge a higher price for the use of their goods (thus reducing demand and the income level). We will label this the *static* costs of increasing trade restrictions and we will measure it by calculating the reduction in income at time period t_1 as a percentage of income before the policy change. (This is, of course, the same as calculating the fall in discounted income under the *assumption* that the measure of active capital goods firms grows at the constant rate g after the policy change.) The static costs are equal to:

$$(19) \qquad Y_{static}^{costs}(t_1^+) \equiv 1 - \frac{Y(t_1|t_1^+)}{\lim_{t \uparrow t_1} Y(t_1|t_1^+)} = 1 - \left[\frac{1+T_0}{1+T_1}\right]^{\alpha\varepsilon}$$

After the policy change, the economy adjusts over time to a new asymptotic balanced growth path dictated by the new level of trade restrictions T_1, as illustrated in Figure 9. This implies that the economic growth rate falls instantaneously (to half its previous level in this case) at time period t_1 and increases gradually thereafter until the old growth rate g is reached asymptotically, see Figure 8. We will label the decrease of income in all time periods after the policy change the *dynamic* costs of increasing trade restrictions. We will measure these dynamic costs as the discounted value of the reduction in income after time period t_1 as a percentage of the discounted value of income from t_1 onwards without the policy change. With the use of the above equations the dynamic costs are:

$$(20)\quad Y_{dynamic}^{costs}(t_1^+) \equiv 1 - \frac{\int_{t_1}^{\infty} Y(t|t_1^+)e^{-\rho(t-t_1)}\,dt}{\int_{t_1}^{\infty} Y(T_0)e^{-(\rho-g)(t-t_1)}\,dt} = 1 - \frac{Y(T_1)}{Y(T_0)} - \frac{(\rho-g)[\beta(T_0)-\beta(T_1)]L^{1-\alpha}x(T_1)^{\alpha}N_0}{\rho Y(T_0)}$$

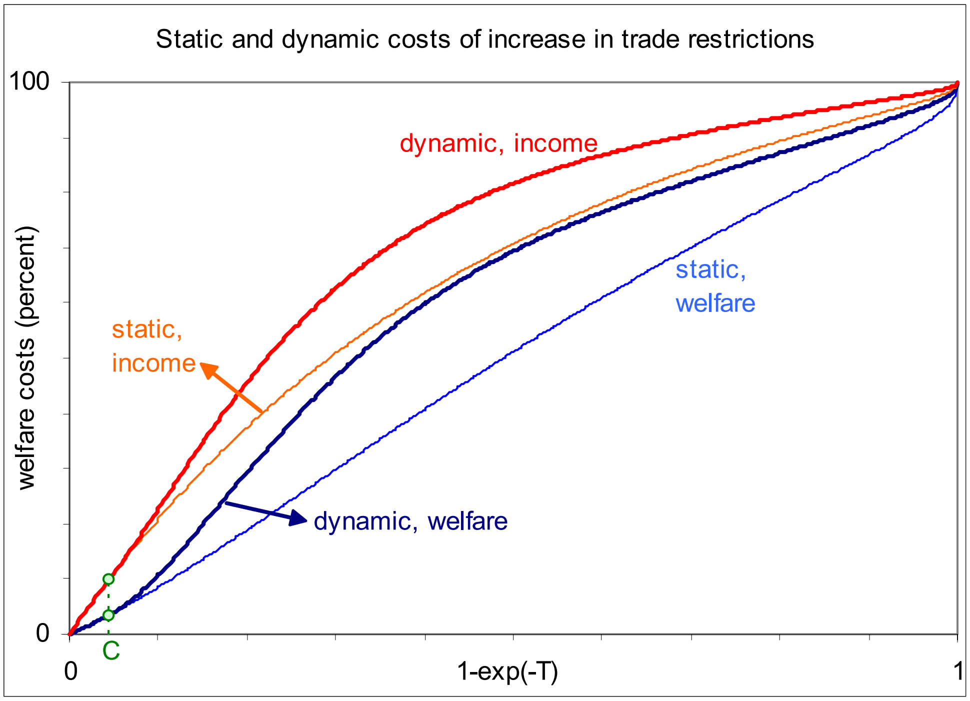
Figure 9 Dynamic effects of an increase in trade restrictions



Parameter values: see Figure 8.

Measuring the static or dynamic loss of an increase in trade restrictions in terms of income is equivalent to measuring the static or dynamic loss in terms of the real wage rate, see equation (4). However, these measures tend to overestimate the welfare loss to the small developing economy since the latter should take into consideration the change in government revenue from increasing the trade restrictions. The appendix therefore derives analogous static and dynamic welfare costs in terms of welfare.

Figure 10 Static and dynamic welfare and income costs; increase in trade restrictions



Parameter values: $\alpha = 0.7$; $L = 14$; $\rho = 0.05$; $g = 0.02$; $T_0 = 0$, combined with a beta distribution function with support [2,10] and parameters equal to 2.

Figure 10 illustrates the static and dynamic welfare costs, both in terms of income and in terms of welfare, starting from an initial position of no trade restrictions ($T_0 = 0$). A few things are worth noting. First, to illustrate these losses in a compact space, the horizontal axis depicts $1 - e^{-T}$, which ranges from 0 to 1; it is 0 if $T = 0$ and rises monotonically with increases in T to approach 1 as $T \to \infty$. Second, as already noted above, the static welfare costs are lower than the static income costs and the dynamic welfare costs are lower than the dynamic income costs. Third, there *may* be an initial range in which the static costs are equal to the dynamic costs, as is the case for the parameter setting illustrated in Figure 10 for $1 - e^{-T} \in [0, C]$. It should be noted that this is not necessarily true for all parameter settings. In particular, it holds only if $0 \leq T_0 < T_{lower}$, in which case $\beta'(T) = 0$ and all newly invented goods in the rest of the world are introduced on the market in the developing economy for all T within that range. Fourth, and most importantly, the dynamic costs of an increase in trade restrictions are larger than the static costs as soon as $T > T_{lower}$. This implies that the static costs of imposing trade restrictions, measured by estimating the size of Harberger triangles of actually introduced goods on the market, underestimate the actual (dynamic) costs of imposing trade restrictions as soon as an increase in these costs decreases the *share* of newly invented goods introduced on the market. In this dynamic setting it is therefore not the fact that we ignore the Dupuit triangles of newly invented goods in estimating the effects of an increase in trade restrictions, as it is in the Romer (1994) model, but the fact that an increase in the trade restrictions affects the share of newly invented goods not introduced on the market. As long as this share of introduced goods is not affected, as is the case for $1-e^{-T} \in [0, C]$ in Figure 10, the usually estimated static costs of an increase in trade restrictions are a perfect measure for the actual dynamic cost of an increase in trade restrictions.

Proposition III. After an increase in the level of trade restrictions in accordance with the policy change experiment, the estimated static costs of trade restrictions are smaller than the dynamic costs of trade restrictions if, and only if, the increase in trade restrictions reduces the share of invented capital goods introduced on the market.

8. Reducing trade restrictions: asymmetry in adjustment

The results discussed in sections 6 and 7 on the effects of an increase in trade restrictions would hold in *reverse* for a decrease in trade restrictions, that is lead to an increase in income and welfare gains mimicking the discussion in section 7, *if* we assume that capital goods producers can only enter the market of the developing economy at the moment the new capital good is invented, in which case equations (16)-(18) also hold for a decrease in trade restrictions. This, however, seems to be a too restrictive assumption. The crucial difference between an increase and a decrease in the level of trade restrictions is that capital goods producers will not decide to exit the market once they have entered it if restrictions increase (as operating profits are always positive), but may decide to enter the market if they earlier opted not to do so if restrictions decrease. This asymmetry has implications for the adjustment path of the economy.

Suppose that initially a strict fraction of newly invented goods is actually introduced on the market in the developing economy, that is $0 < \beta(T_0) < 1$. A decrease in trade restrictions $T_1 < T_0$ at time t_1 will ensure that from then on a larger fraction $\beta(T_1) > \beta(T_0)$ of all newly invented capital goods in the rest of the world will be introduced on the market in the developing economy. However, at time t_1 there is also a positive mass of capital goods owners who have decided not to introduce the good on the market because the introduction costs were too high compared to the discounted value of operating profits $\pi(T_0)/\rho$. Since at time t_1 the range of invented capital goods in the rest of the world is equal to $N_0 e^{gt_1}$, we know that $(1-\beta(T_0))N_0 e^{gt_1}$ of these goods are not available in the developing economy. At the moment of the policy change (at time t_1), a fraction $\beta(T_1)-\beta(T_0)$ of the total available capital goods (so $(\beta(T_1)-\beta(T_0))N_0 e^{gt_1}$ varieties) would decide to enter the market if they believed the new trade policy to be operative from then on, as we have assumed in section 6. This implies that the economy immediately jumps to a new balanced growth path if trade restrictions are decreased, see equations (16')-(18'). This asymmetry in adjustment is further discussed in section 9.

$$(16') \quad M(A(t)|t_1^-) = \begin{cases} \beta(T_0) N_0 e^{gt}, & \text{if } t \in [0, t_1) \\ \beta(T_1) N_0 e^{gt}, & \text{if } t \in [t_1, \infty) \end{cases}$$

$$(17') \quad Y(t|t_1^-) = \begin{cases} Y(T_0) e^{gt}, & \text{if } t \in [0, t_1) \\ Y(T_1) e^{gt}, & \text{if } t \in [t_1, \infty) \end{cases}$$

$$(18') \quad G(t|t_1^-) = \begin{cases} G(T_0) e^{gt}, & \text{if } t \in [0, t_1) \\ G(T_1) e^{gt}, & \text{if } t \in [t_1, \infty) \end{cases}$$

Proposition IV. After a decrease in the level of trade restrictions in accordance with the policy change experiment, the economy immediately jumps to a new balanced growth path, as summarized by equations (16')-(18').

9. Discussion

Although a policy thought experiment like that introduced in section 6 and analyzed thereafter is quite commonly used in economic analysis to better understand the structure and main implications of a model, it is clear that we should allow for some flexibility in interpreting the results. First, policy changes are usually not quite as abrupt as analyzed here but changed more gradually, leading to a more gradual transformation from one growth path to the other. Second, the assumption that the owners of capital goods are initially convinced that the imposed policy will be equal to T_0 indefinitely, at time t_1 are taken completely by surprise regarding the change in policy to T_1, and from then on are immediately convinced that it will remain T_1 indefinitely, is questionable. We should, of course, expect the owners of capital goods to form expectations regarding all future trade policies before introducing the good on the market in the developing economy. A significant change in trade restrictions will then only gradually shift their expectations regarding commitment of the government to the policy change. As this process takes time, we should again expect a more gradual transition process than depicted in Figure 9 and implied by equations (16)-(18) and (16')-(18').

It is relatively straightforward to incorporate expectations into the model. The crucial variable is, of course, the expected level at time t of all future trade restrictions, $T_e(\tau,t)$ say, for $\tau \geq t$. Using equation (8), we can then derive the expected instantaneous profits at time τ conditional on information available at time t, denoted $\pi_e(\tau,t)$:

(21) $$\pi_e(\tau,t) = (1-\alpha)\alpha^{2\varepsilon-1}L(1+T_e(\tau,t))^{1-\varepsilon} = \theta(1+T_e(\tau,t))^{1-\varepsilon}; \quad where\ \theta \equiv (1-\alpha)\alpha^{2\varepsilon-1}L$$

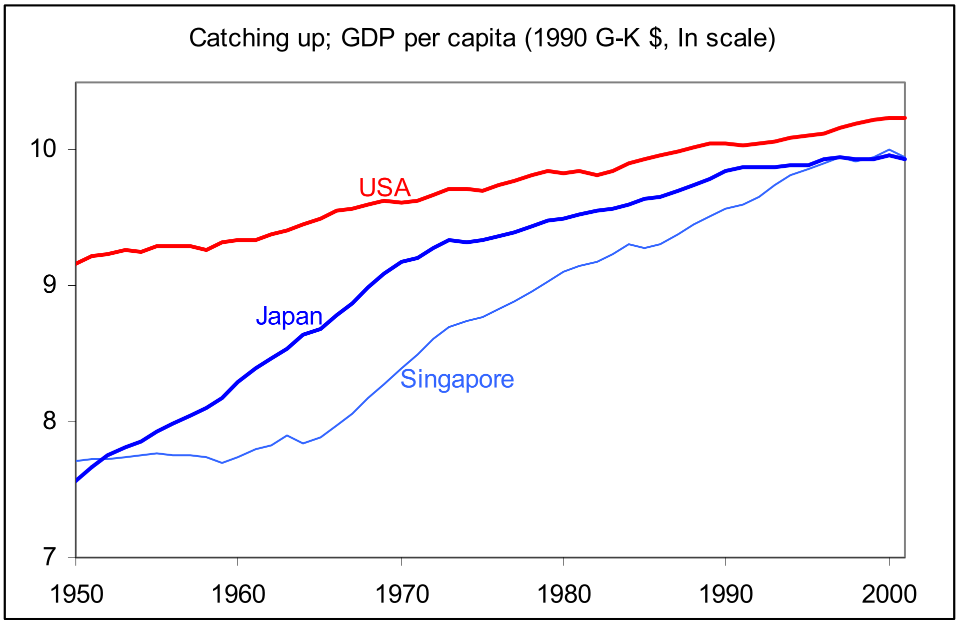
This allows us to calculate the expected discounted value of future profits, $\Pi_e(t)$ say, at time t, given the available information at that time. By differentiating with respect to t we can determine how this value evolves over time, as indicated below.

(22) $$\Pi_e(t) \equiv \int_t^\infty e^{-\rho(\tau-t)}\pi_e(\tau,t)\,d\tau = \int_t^\infty e^{-\rho(\tau-t)}\theta(1+T_e(\tau,t))^{1-\varepsilon}\,d\tau$$

$$\dot{\Pi}_e(t) = \int_t^\infty \rho\, e^{-\rho(\tau-t)}\theta(1+T_e(\tau,t))^{1-\varepsilon}\,d\tau + \int_t^\infty e^{-\rho(\tau-t)}\theta(1-\varepsilon)(1+T_e(\tau,t))^{1-\varepsilon}\,T_{et}'(\tau,t)\,d\tau +$$
$$-\theta(1+T_e(t,t))^{1-\varepsilon} = \rho\Pi(t) - \pi(t,t) - (\varepsilon-1)\theta\int_t^\infty e^{-\rho(\tau-t)}(1+T_e(\tau,t))^{1-\varepsilon}\,T_{et}'(\tau,t)\,d\tau,$$

where $T_{et}'(\tau,t)$ is the derivative of $T_e(\tau,t)$ with respect to t. If the level of trade restrictions is stationary, we get $\Pi(t) = \pi(t|t)/\rho$, see equation (9).

Figure 11 Catching up in economic prosperity



Data source: Maddison (2003)

The limitations above notwithstanding, some crucial implications will continue to hold in a flexible interpretation of the model. First, a permanent change in policy will imply a transition from one balanced growth path to another. The long-run implications of the policy change can therefore be deduced from changes in the balanced growth path, see section 5. Second, as long as the share of capital goods introduced on the market is affected by the policy change, the static welfare costs underestimate the actual (dynamic) welfare costs of an increase in trade restrictions. Third, an increase in trade restrictions leads to a welfare loss and a decrease to a welfare gain. Fourth, there is an asymmetry in adjustment with respect to increases and decreases in trade restrictions. An increase leads to a slow-down in economic growth during a prolonged period of time due to the sunk-cost nature of the introduction costs. In the most extreme case, no new capital goods are introduced on the market, the growth rate reduces to 0 and per capita income is stagnant. Arguably, this is what happened in North Korea in the 1970s and 1980s.[9] A decrease in trade restrictions may result in rapid increases in economic growth rates if the reduction is deemed structural and reliable. The primary reason is the availability of a pool of capital goods producers (owning $(\beta(T_1)-\beta(T_0))N(t_1)$ varieties) who previously deemed it unprofitable to introduce their good on the market in the developing economy and are now standing by to do so, enabling the economy to rapidly catch-up to its new balanced growth path.

Figure 11 depicts the rapid catch-up processes of Japan and Singapore in the second half of the 20th century relative to the benchmark level of the United States. We do not want to argue that the model is fully applicable to these two cases as other factors not explicitly modeled here have also contributed to their impressive economic growth performance, think of capital accumulation, schooling, and the size of the labor force (demographic transition).[10] However, all these other factors feed into the attractiveness of the economy for the catch-up process modeled here: as the labor force expands, as capital accumulates, and as schooling improves, the profitability for the providers of capital goods and intermediate services rises, such that a larger share of varieties will be introduced on the market, which leads to a virtuous cycle of rapid economic growth. We should expect that this process comes to a hold once the boundaries of the state-of-the-art knowledge are reached, as indeed it did in Japan and Singapore. In general, our model predicts that a decline in prosperity following increases in trade restrictions is more gradual than the possible increases in prosperity following reductions in trade restrictions.

10 Conclusions

We analyze the static and dynamic costs of a change in trade restrictions for a small developing economy which combines labor and (intermediate) capital goods in its final goods production process. The economy depends on successful R&D projects undertaken in the rest of the world and introduced on its market for an increase in the range of available capital goods. Any newly invented capital good is only introduced on the market in the developing economy if the (expected) discounted value of operating profits is larger than the costs of introduction. Since operating profits decline as the level of trade

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[9] Maddison (2003) reports stagnant per capita income in North Korea from 1973 to 1991. After 1991 income dropped sharply as a result of the collapse of the Soviet Union. No reliable data is available before 1973, although Maddison reports the South Korean estimates before this time period as a lower bound.

[10] It is also clear that both economies became increasingly active in their own R&D projects as income rose.

restrictions increases, the share of capital goods introduced on the market is a declining function of the level of trade restrictions.

The developing economy evolves over time to a balanced growth path in which income, welfare, and the share of capital goods introduced on the market in the developing economy increase if the level of trade restrictions falls. The optimal level of trade restrictions is therefore zero, while a government wishing to maximize government revenue will set a strictly positive level of trade restrictions. As a result of the sunk-cost nature of the introduction costs, there is an asymmetric adjustment path of the developing economy after a change in trade restrictions. An increase in the level of trade restrictions will slow-down economic growth and put the economy on a transition path to the new balanced growth rate. If the new level of trade restrictions exceeds a critical value, the new growth rate will be zero and stagnation occurs. During this process the estimated static costs of trade restrictions are smaller than the dynamic costs of trade restrictions if, and only if, the increase in trade restrictions reduces the share of invented capital goods introduced on the market. If trade restrictions fall, the developing economy may embark on a rapid catch-up process of economic growth by benefiting from the backlog of previously-invented-but-not-yet-introduced capital goods which may now, as a result of the increase in operating profits, be introduced after the fall in trade restrictions.

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Appendix

Defining the static and dynamic welfare costs of an increase in trade restrictions analogously to the static and dynamic costs in terms of income, see equations (19) and (20), and using (7), (16)-(18), and the definitions in (1'), (14), and (15), we get:

$$\text{(A1)} \quad W_{static}^{costs}(t_1^+) \equiv 1 - \frac{W(t_1|t_1^+)}{\lim_{t \uparrow t_1} W(t_1|t_1^+)} = 1 - \frac{T_1 x(T_1) + (1-\alpha)L^{1-\alpha} x(T_1)^{\alpha}}{T_0 x(T_0) + (1-\alpha)L^{1-\alpha} x(T_0)^{\alpha}}$$

$$\text{(A2)} \quad W_{dynamic}^{costs}(t_1^+) \equiv 1 - \frac{\int_{t_1}^{\infty} \left[(1-\alpha)Y(t|t_1^+) + G(t|t_1^+)\right] e^{-\rho(t-t_1)}\, dt}{\int_{t_1}^{\infty} W(T_0) e^{-(\rho-g)(t-t_1)}\, dt} =$$

$$= 1 - \frac{W(T_1)}{W(T_0)} - \frac{(\rho - g)\left[\beta(T_0) - \beta(T_1)\right] N_0 \left[T_1 x(T_1) + (1-\alpha)L^{1-\alpha} x(T_1)^{\alpha}\right]}{\rho W(T_0)}$$