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Optimal tariffs, optimal taxes and economic development

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Abstract

Cross-section and time-series data suggest that nations substitute income taxes for tariffs as they develop. This paper confronts the data within the context of a two-country open-economy endogenous growth model in which public expenditure is financed by an optimal tariff and income tax. When the latter is subject to administrative costs, the model predicts that the government will optimally substitute the income tax for the tariff as output rises along the transition. The model is calibrated and a simulation yields time paths for the shares of total government revenue derived from the tariff and the income tax that are consistent with the data.

Keywords

Optimal tariffs, optimal taxes, growth

1. INTRODUCTION

A generally accepted feature of economic development is that reliance on trade taxes declines while reliance on other forms of indirect taxation rises. Table 1 offers cross-section evidence of these relationships while Figures 1 and 2 do the same using time-series evidence. Table 1 provides data for 1998 on the percentage of government revenue raised from four categories of taxes: (i) tariffs; (ii) income, profits and capital gains; (iii) social security; and (iv) goods and services. The values in the table are drawn from an 89-country sample that is first partitioned by per capita income into the four income groups defined by the World Bank and is then averaged across the countries in each group.[1] For the period 1975–1995, Figures 1 and 2 plot the average value of tariff revenue (income tax revenue plus goods and services tax revenue) as a percentage of government revenue (bold line) and average real income per capita (thin line) for a sample of 32 low- and

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middle-income countries for which sufficient data are available.[2] The inverse relationship between per capita income and share of tariff revenue is evident in Table 1 and Figure 1. As for the positive relationship between other forms of indirect taxation and income, it holds for two of three indirect taxes listed in Table 1 as well as for the sum of the three and for the sum of the two taxes considered in Figure 2. These results are consistent with evidence provided by other researchers.[3]

One explanation that is offered for why developing countries rely on tariffs (other forms of indirect taxation) to a greater (lesser) extent than do

Table 1 Percent of government revenue by type of tax (average value within income groups)

Income Group (#)	*Tariffs*	*Inc., Prof., Cap. Gains*	*Soc. Sec.*	*Gds. & Serv.*	*Sum Cols. 3–5*
Low (21)	24.52	20.43	5.95	31.19	57.57
Lower Middle (24)	12.33	21.63	12.84	36.29	70.13
Upper Middle (20)	8.75	22.00	18.84	33.50	72.4
High (24)	0.63	32.00	23.17	29.67	84.83

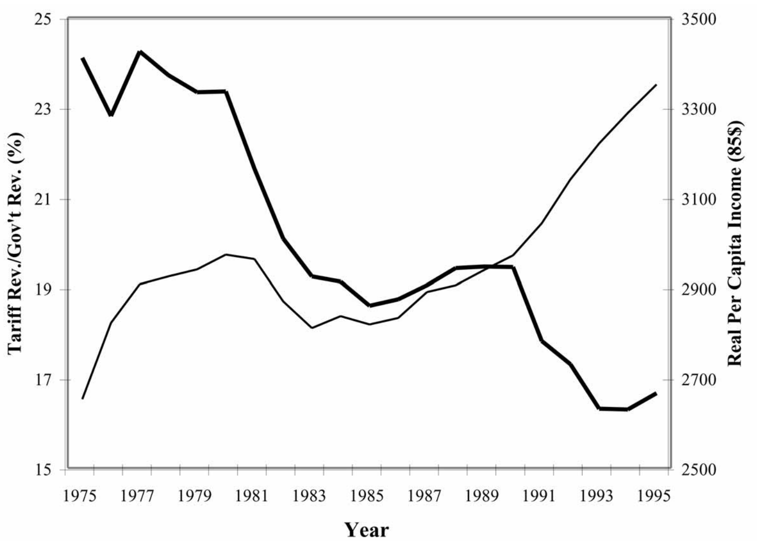

Figure 1 Relationship between percent of tariff revenue and real per capita income (32 low- and middle-income countries)

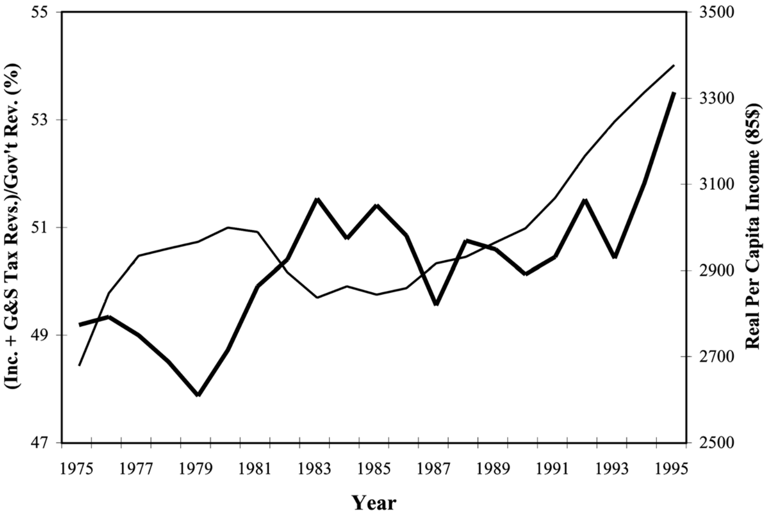

Figure 2 Relationship between percent of income and goods and services tax revenue in government revenue and real per capita income (32 low- and middle-income countries)

developed countries is that tariffs effectively have zero administrative costs whereas for most types of indirect taxes these costs are positive and on a per-unit-of-revenue-collected basis are inversely related to income.[4] Hence, as an economy develops, there is an incentive to substitute indirect taxes for tariffs (given an unchanged time path for public spending). In addition, if the growth and level effects of decreasing tariffs dominate the growth and level effects of increasing the tax rate on income, say, as certain classes of open-economy endogenous-growth models predict, then a developing country will not only see its level of output rise, but will ultimately see its steady-state rate of growth increase as well. That high-tariff/low-income countries often have low rates of growth while low-tariff/high-income countries often have high(er) rates of growth suggests that this may well be the case.

The goal of this paper is to show that adding an income tax (which serves as a proxy for various forms of indirect taxation other than tariffs), which is subject to administrative costs, to an open-economy endogenous growth model is sufficient to generate behaviour in the model's transitional dynamics that is consistent with what is documented in Figures 1 and 2.[5] Specifically, I use a discrete time, two-country version of Ben-David and Loewy's (1998) open-economy growth model. In this model, the capital stock is assumed to be fixed and the labour input is exogenous so that growth is driven solely by the accumulation of knowledge, which in turn is a function of trade volume and hence of tariff rates. Whereas Ben-David and Loewy assume that tariffs are exogenously set and tariff revenue is returned to private agents lump sum, here I assume that the government chooses optimal tariff and income tax rates (in the sense of Ramsey, 1927) and the revenue raised is used to finance both government expenditures and the administrative costs of the income tax.

Consistent with the explanation described above, administrative costs are modelled such that their ratio to income tax revenues declines as the tax base (namely output) rises. This feature of the model, coupled with the assumptions of fixed capital stock and exogenous labour input, imply that the only distortion that the income tax causes operates through administrative costs. Although these assumptions may appear to be extreme, they permit the analysis to focus exclusively on the role that administrative costs play in deriving results that are consistent with what is seen in Figures 1 and 2. As will be seen below by means of a simulation, the solution to the government's problem implies that it substitutes the income tax for the tariff as income rises. In the steady state, the tariff goes to zero while the income tax rate approaches the share of government expenditure in income. This result yields the highest possible steady-state rate of growth that is consistent with financing the given share of government spending in output.

Despite there being a number of researchers who suggest in passing that administrative costs of taxation may be a rationale for the inverse relationship between level of development and reliance on tariffs, few of them have attempted to formalize of this argument. Two notable exceptions are Polley (2000) and Atolia (2002). In contrast to the approach taken here, Polley considers a static model and assumes that administrative costs take the form of an auditing cost. Such costs arise because private agents' revenues are unobservable to the government in the absence of an audit. When the cost of auditing the income of producers is sufficiently greater than the cost of auditing the revenue of importers, Polley shows that the optimal tax system includes both a positive tariff and a positive income tax rate. Moreover, should producer income be sufficiently large or the marginal cost of auditing producer income be sufficiently small, then the optimal tariff is shown to equal zero.

While these results can be viewed as explaining the inverse relationship between tariff revenue and economic development, because Polley's model is static and so only provides a link from income to optimal tariffs and taxes, they are perhaps only suggestive of it. Since the model developed in this paper is dynamic, it not only captures the link found in Polley's paper, but also addresses the reverse linkage from optimal tariffs and tax rates back to income. In this sense, the present paper is not only a model of optimal tariffs and taxes, but one of economic growth as well.

Atolia (2002) analyses a model of tax evasion within an overlapping generations framework in which tax revenues finance the purchase of public capital. In his model, if the risk of being caught evading taxes is uninsurable, then reducing tariffs and raising income taxes need not be Pareto improving.

This in turn implies that current generations will resist moves to reduce tariffs. Moreover, since this 'reluctance' is stronger at low levels of income than at higher levels, Atolia's model is consistent with the one here in that it too predicts an inverse relationship between income and reliance on tariffs.

The remainder of the paper is as follows. Section 2 lays out the open-economy endogenous growth model and the specification of administrative costs. Section 3 solves the household and the government's problems and Section 4 describes the economy's steady state. In Section 5, the model is calibrated and then simulated. The resultant time paths for shares of government revenue derived from the tariff and the income tax are shown to capture features of the data seen in Table 1 and Figures 1 and 2. Section 6 summarizes and offers some concluding remarks.

2. THE MODEL

I consider a discrete, two-country version of Ben-David and Loewy's (1998) open-economy growth model to which I add an income tax and its associated administrative costs. In their model, output is taken to be a function of labour, physical capital, and knowledge with physical capital normalized to unity and the supply of labour taken to be perfectly inelastic. These assumptions, which are maintained here, allow the analysis to focus on the role that optimal tariff and income tax rates play in the knowledge accumulation process and hence on their impact on economic growth.[6] Moreover, setting physical capital to a constant permits an analysis of both the economy's steady state and its transitional dynamics. Given that the goal of this paper is to show how the presence of administrative costs influences the optimal choices of tariff and income tax rates as income rises, an ability to study transitional dynamics is key.

What then of the role that optimal tariffs and taxes play in the accumulation of knowledge? Following Rivera-Batiz and Romer (1991a, b), Grossman and Helpman (1991, 1995), and others, trade is assumed to serve as a conduit for knowledge flows. In the presence of international trade, these knowledge flows serve as the source of growth of output per capita. To the extent that tariff and income tax rates can and do impact trade, the government's optimal choices of these tax instruments determines not just the economy's level of income per capita, but its rate of growth as well. Were trade to be absent, the model reduces to a type of neoclassical growth model in which the rate of technical progress corresponds to what is now an exogenous rate of knowledge accumulation.

Consider then a two-country world. In what follows, it is useful to think of one country as being 'poor', Country 1 say, and the other, Country 2, as being 'rich'. Let $L_{i,t}$ be the time t population (and, for simplicity, the labour input) of country i, n_i be that country's population growth rate, and $c_{ij,t}$ be the time t real consumption per capita of good j in country i. Taking all agents in country i to be identical, the aggregate utility of the agents in country i, U_i, is given by

$$U_i = L_{i,0} \sum_{t=0}^{\infty} \beta^t (1 + n_i^t)[\alpha_{i1} \ln c_{i1,t} + \alpha_{i2} \ln c_{i2,t}] \tag{1}$$

where $\alpha_{i1} + \mathrm{a}_{i2} = 1$ and β is the common discount rate that is assumed to satisfy $\beta(1 + n_i) < 1$ for $i = 1, 2$. In what follows, the initial population of each country, $L_{i,0}$, is normalized to one.

For each country $i = 1, 2$, let good i be that country's distinct output. Good i is produced using labour, physical capital, and knowledge. Assuming that the production function is constant returns to scale in labour and given that physical capital is normalized to one, write this relationship in per capita terms as

$$y_{i,t} = H_{i,t}^{\varepsilon_i} \tag{2}$$

where $y_{i,t}$ and $H_{i,t}$ are output per capita and the aggregate stock of knowledge in country i at time t, and $\varepsilon_i > 0$. As this specification makes clear, the rate of knowledge accumulation determines the rate of economic growth. However, since ε_1 need not equal ε_2 , the same is not true for steady-state rates of growth even though the two steady-state rates of knowledge accumulation are shown to be equal to one another.

The government in country i raises revenue through a combination of a tariff on the imported good and an income tax. Letting $\tau_{ij,t}$ be country i's tariff on good j at time t and $\sigma_{i,t}$ be country i's labour income tax rate at time t, it follows that the time t per capita budget constraint for country i is

$$c_{ii,t} + \frac{p_{j,t}}{p_{i,t}}(1 + \tau_{ij,t})c_{ij,t} = (1 - \sigma_{i,t})y_{i,t} \tag{3}$$

where $p_{i,t}$ is the price of good i in terms of good 1, the numéraire good. The revenue raised by the tariff and the income tax, $(p_{j,t}/p_{i,t})\ \tau_{ij,t}c_{ij,t} + \sigma_{i,t}\gamma_{i,t}$, is used to finance the sum of government expenditure and the administrative costs of operating the income tax.

Government expenditure is assumed to be a fixed share, γ_i, of time t output and to enter agents' utility function in an additively separable form. Since γ_i is a constant and, as will be seen below, $y_{i,t}$ is given at time t, it follows that the level of government spending is taken as given by private agents. Therefore, I opt to disregard it when writing private agents' utility function, equation (1).[7]

Turning to the modelling of administrative costs, one aspect of these costs mentioned by a number of researchers is that they are likely to be an increasing function of the tax base and/or the tax rate.[8] Slemrod and

Yitzhaki (1996) suggest a second aspect, namely that a higher tax rate reduces administrative costs per unit of revenue collected. Third, as noted earlier, some have suggested that administrative costs per unit of revenue also decrease with income. The literature contains little other guidance and so leaves open a number of possible approaches to modelling administrative costs.

For present purposes, I assume that because tariffs can be applied 'at the port', they do not entail any administrative costs. Thus, only the income tax bears this cost.[9] Since income tax revenue equals $\sigma_{i,t}y_{i,t}$, one specification for administrative costs that focuses only on the income tax and satisfies the three criteria mentioned above is $\sigma_{i,t}y_{i,t}^{\psi}/(1+\sigma_{i,t})$ where $0 < \psi < 1$.[10] Combining the tariff and income tax revenue terms from the per capita budget constraint, equation (3), with the expenditure and administrative costs terms described above, it follows that the time t per capita government budget constraint for country i is[11]

$$\frac{p_{j,t}}{p_{i,t}}\tau_{ij,t}c_{ij,t} + \sigma_{i,t}y_{i,t} = \gamma_i y_{i,t} + \frac{\sigma_{i,t}}{1+\sigma_{i,t}}y_{i,t}^{\psi}. \tag{4}$$

Given the production function, per capita growth in country i is solely derived from the accumulation of knowledge. Lucas (1988) suggests that knowledge accumulation in country i is constant returns to scale in country i's level of knowledge. As in Ben-David and Loewy (1998), this idea is extended here by assuming that knowledge accumulation in country i is constant returns to scale in the level of knowledge of both countries. However, the extent to which country j's stock of knowledge is able to contribute to the growth of knowledge in country i depends upon (i) the extent to which country i can access country j's knowledge stock and (ii) the extent to which country i can absorb and utilize the accessible part of country j's knowledge.

Following Grossman and Helpman (1991), the time t share of country j's knowledge stock that is accessible to country i, what I denote as $v_{ij,t}$, is assumed to be an increasing function of the volume of trade between countries i and j. Specifically, $v_{ij,t}$ is taken to be the ratio of country i's total trade with country j (bilateral imports plus bilateral exports) to country i's aggregate output. Thus,

$$v_{ij,t} = \frac{L_{i,t}\frac{p_{j,t}}{p_{i,t}}c_{ij,t} + L_{j,t}c_{ji,t}}{L_{i,t}y_{i,t}}. \tag{5}$$

Turning next to the question of applicability, let $a_{ij,t}$, $0 \leqslant a_{ij,t} \leqslant 1$, be the time t share of country j's accessible knowledge stock that country i is in fact able to utilize as part of its own knowledge stock.[12] To model this idea, I use a functional form due to Ben-David and Loewy (2003), namely

$$a_{ij,t} = A\left(\frac{H_{j,t}}{H_{i,t}}\right) = \begin{cases} \left(\frac{H_{j,t}}{H_{i,t}}\right)^{\mu} \text{ if } 0 < \frac{H_{j,t}}{H_{i,t}} \leq 1 \\ \left(\frac{H_{j,t}}{H_{i,t}}\right)^{-\mu} \text{ if } 1 < \frac{H_{j,t}}{H_{i,t}} \leq \infty \end{cases} \tag{6}$$

where $0 < \mu$. By design, this specification allows $a_{ij,t}$ to depend upon the similarity of $H_{i,t}$ and $H_{j,t}$ where 'similarity' is taken to mean that the more nearly equal are $H_{i,t}$ and $H_{j,t}$, the more comparable (in terms of their levels of technology) are the two countries' knowledge stocks (as opposed to being nearly identical sets of knowledge). In particular, the more similar are the two countries' knowledge stocks, the better position each is in to obtain knowledge spillovers from the other.[13] While this discussion implies that $a_{ij,t}$ is maximized (at one) when $H_{i,t} = H_{j,t}$, it leaves open the question of whether $a_{ij,t}$ exceeds or is less than $a_{ji,t}$ when the two knowledge stocks differ. As one can reasonably argue that this inequality can run either way, equation (6) imposes $a_{ij,t} = a_{ji,t}$ always. Finally, note that when $H_{i,t} \neq H_{j,t}$ an increase in μ decreases $a_{ij,t}$. Therefore, larger values of μ reduce the rates of knowledge accumulation and growth in both countries.

Given the definitions of $v_{ij,t}$ and $a_{ij,t}$, the accumulation of knowledge in country i satisfies

$$H_{i,t+1} = \phi a_{ij,t} v_{ij,t} H_{j,t} + (1 + \phi - \delta) H_{i,t} \tag{7}$$

where ϕ and δ represent the common productivity parameter and rate of knowledge depreciation and satisfy $\phi \geqslant \delta > 0$. Note that in the absence of trade, knowledge accumulation is exogenous and satisfies $H_{i,t+1} / H_{i,t} = 1 + \phi - \delta$. Given equation (2), it then follows that in a world without trade, output in country i grows at the (gross) rate $(1 + \phi - \delta)^{\varepsilon_i}$. Since this rate is also exogenous, in autarchy the model collapses to a type of neoclassical growth model. However, since trade will always exist in equilibrium due to the choice of the utility function, $(1 + \phi - \delta)^{\varepsilon_i}$ represents the greatest lower bound on the rate of growth that will be observed both along the transition and in the steady state. Moreover, since the levels of imports and exports are functions of the optimal tariff and tax rates, these values affect the common rate of knowledge accumulation and therefore each country's rate of growth of output per capita.

3. PRIVATE AGENT AND GOVERNMENT PROBLEMS

Consider the problem being solved by the private agents of Country i. Suppose, as Lucas (1988) does, that private agents are atomistic and so treat the time path of knowledge as being beyond their control. Hence, $H_{i,t}$ is taken as given at time t. Since physical capital is normalized to one, this in turn implies that the private agents of Country i effectively solve a sequence of static problems wherein they allocate their after-tax income between purchases of the home and the imported good. At time t this problem is written as

$$\max_{c_{i1,t},\, c_{i2,t}} \alpha_{i1} \ln c_{i1,t} + \alpha_{i1} \ln c_{i2,t} \text{ subject to equation (3)}$$

Solving this problem yields $c_{ii,t} = \alpha_{ii}(1 - \sigma_{i,t})y_{i,t}$ and $c_{ij,t} = \alpha_{ij}(1 - \sigma_{i,t})y_{i,t} \times p_{i,t}/p_{j,t}(1 + \tau_{ij,t})$ with $p_{1,t} \equiv 1$.

Consider next the government's problem. In defining this problem, it matters greatly whether or not the government is assumed able to internalize the effects that its current actions have on its choices of future actions. If it can, then the government of Country i solves a dynamic problem in which it chooses sequences for $\tau_{ij,t}$ and $\sigma_{i,t}$ to maximize private agents' lifetime indirect utility subject to the government budget constraint and the two laws of motion for knowledge.[14] If it cannot, then because it now takes the two laws of motion as given, the government solves a simpler problem in which it chooses $\tau_{ij,t}$ and $\sigma_{i,t}$ to maximize private agents' time t indirect utility subject to its budget constraint. In what follows, I assume that political realities in each country are such that the government cannot commit to more than a one-period planning horizon. As a result, the government takes as given the linkages between its current and future policy choices.[15]

Let the government of Country 1 behave as just described and so solve a series of static problems rather than a single dynamic problem. Substituting the above expressions for $c_{11,t}$ and $c_{12,t}$ into the time t private utility function and again for $c_{12,t}$ into the time t government budget constraint, equation (4), it follows that the government's problem, after dropping constants and terms taken as given (among which is the world price $p_{2,t}$) and dividing the constraint by $y_{1,t}$, may be written as

$$\max_{\tau_{12,t},\, \sigma_{1,t}} \ln(1 - \sigma_{1,t}) - \alpha_{12}\ln(1 + \tau_{12,t}) \text{ subject to } \frac{\tau_{12,t}}{1 + \tau_{12,t}}\alpha_{12}\ (1 - \sigma_{1,t}) + \sigma_{1,t} = \gamma_1 + \frac{\sigma_{1,t}}{1 + \sigma_{i,t}} y_{1,t}^{\psi - 1} \tag{8}$$

Allowing for the possibility that either the tariff or the income tax rate could be negative, the first-order conditions for this problem are

$$1 + \tau_{12,t} = \lambda_{1,t}(1 - \sigma_{1,t}) \tag{9}$$

$$\frac{1}{1 - \sigma_{1,t}} = \lambda_{1,t}\left[1 - \frac{\tau_{12,t}}{1 + \tau_{12,t}}\alpha_{12} - \frac{y_{1,t}^{\psi - 1}}{(1 + \sigma_{1,t})^2}\right] \tag{10}$$

where $\lambda_{1,t}$ is the Lagrange multiplier associated with the time t government budget constraint. Eliminating the multiplier between equations (9) and (10) implies that the optimal tariff and tax rates are the solutions to

$$(1-\alpha_{12})\frac{\tau_{12,t}}{1+\tau_{12,t}}-\frac{y_{1,t}^{\psi-1}}{(1+\sigma_{1,t})^2}=0 \tag{11}$$

and the form of the government budget constraint appearing in equation (8).[16] Using equation (11) to eliminate $\frac{\tau_{12,t}}{1+\tau_{12,t}}$ in equation (8), it follows that the optimal value of the income tax rate, $\sigma_{1,t}^*$ must satisfy

$$\left[\frac{\alpha_{12}}{1-\alpha_{12}}(1-\sigma_{1,t}^*)-\sigma_{1,t}^*(1+\sigma_{1,t}^*)\right]y_{1,t}^{\psi-1}+(\sigma_{1,t}^*-\gamma_1)(1+\sigma_{1,t}^*)^2=0 \tag{12}$$

If a solution to equation (12) exists, then equation (11) determines the optimal value of the tariff, $\tau_{12,t}^*$. By symmetry, a similar pair of expressions determines $\tau_{21,t}^*$ and $\sigma_{2,t}^*$. Assuming this is the case, total differentiation of equations (11) and (12) shows the signs of $\partial\tau_{ij,t}^*/\partial y_{i,t}$ and $\partial\sigma_{i,t}^*/\partial y_{i,t}$ to be ambiguous. Since the data show the former to be negative and the latter to be positive, any further progress along this line requires calibrating the model and then simulating it. This will be taken up in Section 5.

To close the model, it suffices to solve for the market-clearing price, $\bar{p}_{2,t}$. Focusing on good 1, market clearing requires that $c_{11,t}+\frac{L_{2,t}}{L_{1,t}}c_{21,t}+\gamma_1 y_{1,t}+\frac{\sigma_{1,t}}{1+\sigma_{1,t}}y_{1,t}^{\psi}=y_{1,t}$. Note that market clearing, together with the private and government budget constraints, equations (3) and (4), implies that trade is balanced, namely $L_{1,t}p_{2,t}c_{12,t}=L_{2,t}c_{21,t}$. Solving this expression for yields

$$\bar{p}_{2,t}=\frac{\alpha_{12}(1-\sigma_{1,t}^*)L_{1,t}y_{1,t}/(1+\tau_{12,t}^*)}{\alpha_{21}(1-\sigma_{2,t}^*)L_{2,t}y_{2,t}/(1+\tau_{21,t}^*)} \tag{13}$$

With $\bar{p}_{2,t}$ being a function of the optimal tariffs and tax rates (which are themselves functions of the current stocks of knowledge), it follows that the optimal tariff and tax rates affect the time t equilibrium quantities of imports and exports. Therefore, equations (5), (6) and (7) imply that the stocks of knowledge for time $t+1$ are themselves determined. Specifically,

$$H_{1,t+1}=A\left(\frac{H_{2,t}}{H_{1,t}}\right).\frac{2\phi\alpha_{12}(1-\sigma_{1,t}^*)}{1+\tau_{12,t}^*}.H_{2,t}+(1+\phi-\delta)H_{1,t} \tag{14}$$

$$H_{2,t+1} = A\left(\frac{H_{1,t}}{H_{2,t}}\right).\frac{2\phi\alpha_{21}(1-\sigma^*_{2,t})}{1+\tau^*_{21,t}}.H_{1,t} + (1+\phi-\delta)H_{2,t} \tag{15}$$

4. STEADY-STATE ANALYSIS

Before calibrating and simulating the model, it is instructive to consider first the model's steady state since it does not directly depend upon the calibration. By definition, a steady state is such that both tariff rates and both income tax rates must equal constants and output per capita in each country must grow at a constant rate. Letting a hat over a variable denote its value in the steady state and suppressing the time subscript in those variables that are constant in the steady state, it follows from equation (12) that the only steady-state solution for the optimal income tax rate is $\hat{\sigma}^*_i = \gamma_i$ since output is rising at a constant rate and $0 < \psi < 1$. Given this, equation (11) implies that $\hat{\tau}^*_{ij} = 0$, the steady state exhibits free trade.[17]

Next, consider the steady-state rate of growth of knowledge, and therefore of output, in each country. From equations (14) and (15), steady-state growth is governed by the system

$$\begin{bmatrix} \hat{H}_{1,t+1} \\ \hat{H}_{2,t+1} \end{bmatrix} = \begin{bmatrix} 1+\phi-\delta & A\left(\frac{\hat{H}_{2,t}}{\hat{H}_{1,t}}\right)2\phi\alpha_{12}(1-\gamma_1) \\ A\left(\frac{\hat{H}_{1,t}}{\hat{H}_{2,t}}\right)2\phi\alpha_{21}(1-\gamma_2) & 1+\phi-\delta \end{bmatrix} \begin{bmatrix} \hat{H}_{1,t} \\ \hat{H}_{2,t} \end{bmatrix} \tag{16}$$

As shown in Ben-David and Loewy (1998), the steady-state growth rate of knowledge equals the maximum eigenvalue of equation (16) minus one while the ratio of steady-state knowledge stocks, $\hat{H}_{1,t}/\hat{H}_{2,t}$, corresponds to the ratio of elements of the associated eigenvector. After a bit of algebra, the steady-state rate of growth of knowledge, $\hat{g}_H$, can be shown to equal

$$\phi - \delta + \left(\frac{\hat{H}_{1,t}}{\hat{H}_{2,t}}\right)^{\mu} 2\phi[\alpha_{12}\alpha_{21}(1-\gamma)(1-\gamma_2)]^{0.5} \tag{17}$$

where it is assumed without loss of generality that $\hat{H}_{1,t}/\hat{H}_{2,t}$ is less than one.[18]

From equations (2) and (17), the steady-state rate of growth of output per capita in country i, $\hat{g}_{y_i}$, equals $(1+\hat{g}_H)^{\varepsilon_i} - 1$. Consequently, if both countries are assumed to possess the same income elasticity of knowledge, then their levels of output per capita in the steady state will grow at the same rate. Even so, these levels generally will not equal one another. To see why, notice that the eigenvector associated with $1+\hat{g}_H$ implies that

$$\frac{\hat{H}_{i,t}}{\hat{H}_{2,t}} = \left(\frac{\hat{v}_{12}}{\hat{v}_{21}}\right)^{0.5} = \left(\frac{\alpha_{12}(1-\gamma_1)}{\alpha_{21}(1-\gamma_2)}\right)^{0.5}.$$

Substituting this expression into equation (2) and setting $\varepsilon_1 = \varepsilon_2 = \varepsilon$ implies that relative steady-state income satisfies

$$\frac{\hat{y}_{1,t}}{\hat{y}_{2,t}} = \left(\frac{\alpha_{12}(1-\gamma_1)}{\alpha_{21}(1-\gamma_2)}\right)^{0.5\varepsilon}.$$

Consequently, the country with the smaller share of government expenditure in output and/or the larger share of imports in after-tax income will achieve the higher level of steady-state income. Be that as it may, in the simulation that follows, income per capita will converge in the steady state since (i) $\varepsilon_1 = \varepsilon_2 = \varepsilon$ is necessary in order that steady-state relative income be well-defined and (ii) the ongoing rise in $y_{1,t}/y_{2,t}$ along the transition will ultimately imply that $\alpha_{12} = \alpha_{21}$ and $\gamma_1 = \gamma_2$.

5. CALIBRATION AND SIMULATION

To illustrate the behaviour of the model along the transition to the steady state, I consider a simulation in which the behaviour of the model's parameters are, whenever possible, drawn from data in Easterly and Yu (2000) and the *World Development Indicators 2001*. For the purposes of the simulation, I classify the model's two countries by placing them into one of the four income groups defined by the World Bank, Low Income, Lower Middle Income, Upper Middle Income, and High Income.

As in Section 2, I take Country 1 to be the 'poor' economy and Country 2 the 'rich' economy. To this end, I place Country 2 in the High Income group and allow the classification of Country 1 to vary as its income relative to Country 2 rises along the transition. Using figures found in Table 1.1 of the *WDI 2001*, I set the initial income of Country 1, $y_{1,0}$, equal to the average income level of the Low Income group in 1999, \$420, and the initial income of Country 2, $y_{2,0}$, equal to the average income level of the High Income group in 1999, \$26,440.

Since the World Bank's income group classification data are only available for 2000, data for that year (rather than for 1999) are used to determine when Country 1 switches income groups. Specifically, Country 1's classification is assumed to rise by one level when its income relative to that of Country 2 reaches the minimum income for the next higher group divided by the average income in the High Income group. Therefore, when Country 1's income per capita rises to 2.7 per cent of that of Country 2 (\$756/\$27,510), Country 1 is reclassified as Lower Middle Income. Similarly, Country 1 is reclassified as Upper Middle Income when its relative income per capita reaches 10.9 per cent (\$2996/\$27,510) and then as High Income when its relative income per capita reaches 33.7 per cent (\$9266/\$27,510).

To calibrate values for α_{12} and γ_1 for the first three income groups and for α_{21} and γ_2 for the last income group, I use the data contained in *WDI 2001* Table 4.9 and which are provided in Table 2. In the table, *c, i* and *g* represent the shares of output allocated to household consumption, private investment, and government consumption while *m* corresponds to the mid-point between exports' share of output and imports' share of output. The mid-point is chosen as an estimate of what imports' share would equal under the model's maintained assumption of a balanced trade budget.[19] These data must then be adjusted since the model assumes that private consumption takes the form of domestically produced goods, c_{ii}, and imported goods, c_{ij}, that there exists government consumption, and that investment (both private and public) is absent.

To calibrate each α_{ij} I instead determine the value of α_{ii} and then subtract that value from one. The derivation of each α_{ii} proceeds as follows. First, *c, i* and *g* are normalized by dividing each by the sum of the three in order to impose trade balance. Denoting these ratios as c^{bal}, i^{bal} and g^{bal}, I next measure the share of each that is derived from domestically produced goods (rather than from imports) as $(1-m)$ times each term. Therefore, the share of domestic consumption in income, c^{dom}, equals $(1-m)c^{\text{bal}}$ with i^{dom} and g^{dom} defined similarly. It then follows that $c^{\text{dom}} + i^{\text{dom}} + g^{\text{dom}} + m = 1$. Third, since investment is absent in the model, c^{dom}, g^{dom} and m are adjusted for this absence by dividing each by $1 - i^{\text{dom}}$, the share of output that does not go to domestic investment. The resulting measure of the share of domestic consumption in investment-adjusted income, $c^{\text{dom}}/(1-i^{\text{dom}})$, is the empirical counterpart to $c_{ii}/y_i = \alpha_{ii}(1-\sigma_i)$. Therefore, if an estimate for σ_i can be obtained, then α_{ii} is determined.

Since the income tax rate is a choice variable for the government, it cannot be calibrated except in the steady state where it equals the share of government domestic spending in investment-adjusted income. Thus, $\hat{\sigma}_i^* = g^{\text{dom}}/(1-i^{\text{dom}}) = \gamma_i$. Substituting this ratio for σ_i in the expression

Table 2 WDI data on structure of demand (percentage of GDP)

	Low Income	*Lower Middle Income*	*Upper Middle Income*	*High Income*
c	0.68	0.57	0.61	0.62
i	0.22	0.26	0.22	0.22
g	0.11	0.14	0.15	0.16
m	0.25	0.295	0.26	0.215

Table 3 Calibrated spending parameters

	Low Income	*Lower Middle Income*	*Upper Middle Income*	*High Income*
α_{ii}	0.669	0.584	0.639	0.694
α_{ij}	0.331	0.416	0.361	0.306
γ_i	0.098	0.125	0.136	0.152

for c_{ii}/y_i, setting the resulting expression equal to $c^{\text{dom}}/(1 - i^{\text{dom}})$, and simplifying implies that

$$\alpha_{ij} = 1 - \frac{c^{\text{dom}}}{c^{\text{dom}} + m} \tag{18}$$

Table 3 provides the computed values for α_{ii}, α_{ij}, and γ_i for each of the four World Bank Income Groups.

Recall that for steady-state relative income to be well defined it must be the case that $\varepsilon_1 = \varepsilon_2 = \varepsilon$. Therefore, to complete the calibration of the model, it remains to assign values to ε, ϕ, δ, ψ, and μ as well as to determine the economy's initial values, $H_{1,0}$ and $H_{2,0}$. To determine ε, δ, and ϕ, I first utilize the result that the model implies growth (and income) convergence in the steady state since eventually Country 1 enters the High Income group and so satisfies $\alpha_{12} = \alpha_{21}$ and $\gamma_1 = \gamma_2$. As an estimate of this common steady-state rate of growth, I use the average rate of growth over the 1979–1999 period of the ten most-open countries over the same period that in 1979 had an income relative to the US that would have qualified them (by year 2000 standards) as High Income countries.[20] Using data in Easterly and Yu (2000), this value equals 2.53 per cent.[21] Note that because the years 1960–1979 may represent a period during which many of these nations were experiencing the fast growth associated with transitional dynamics, the 1979–1999 period appears to offer a plausible estimate of the steady-state rate of growth of a group of relatively open, high-income economies. From equations (2) and (17) we then have that $[1 + \phi - \delta + 2\phi\alpha_{21}(1-\gamma_2)]^{\varepsilon} = 1.0253$ since in the steady state we have that $\hat{H}_{1,t} = \hat{H}_{2,t}$.

Second, I use the result that Country 2 will initially grow at very nearly the autarchy rate of $(1 + \phi - \delta)^{\varepsilon}$ because the large gap in initial knowledge stocks implies that $\alpha_{12} = \alpha_{21} \approx 0$. This suggests calibrating $(1 + \phi - \delta)^{\varepsilon}$ to the growth rate of a large, developed country in which trade represents a small share of GDP (since no such country is truly in autarchy). Among High Income countries, the United States has the lowest average ratio of total trade to GDP over the 1979–1999 period, namely 21 per cent. Since the average rate of growth of output per capita for the United States over the period 1979 – 1999 equals 1.60 per cent, it follows that $(1 + \phi - \delta)^{\varepsilon} = 1.0160$.

Third, I calibrate the rate of growth of knowledge in autarchy, $\phi - \delta$, by assuming that it equals the average rate of growth in the number of US patents issued to US residents over the 1978 – 1998 period. The restriction to US residents is designed to proxy the growth of 'knowledge' in autarchy. Using data from the US Patent and Trademark Office (1998, 1999), this value is found to equal 4.12 per cent.[22] Solving these three restrictions simultaneously, it follows that $\phi = 0.0467$, $\delta = 0.0055$ and $\varepsilon = 0.3935$. Given this value of ε, the initial values of the two knowledge stocks are found by inverting equation (2) and substituting in the initial values of income per capita.

To calibrate ψ, I require that at $t = 0$ the ratio of tariff revenue to total revenue for Country 1,

$$\xi_{1,0} = \frac{\tau^*_{12,0}\alpha_{12}(1 - \sigma^*_{1,0})/(1 + \tau*_{12,0})}{\sigma^*_{1,0} + \tau^*_{12,0}\alpha_{12}(1 - \sigma^*_{1,0})/(1 + \tau*_{12,0})} \tag{19}$$

match the 1998 share of tariff revenue in total government revenue of the Low Income group. However, because the source data, *WDI 2001* Table 4.13, does not include government revenue data for the Low Income group, I instead use figures for the South Asia group since the 1999 per capita incomes of the two groups are roughly equal, \$440 versus \$420. Table 4.13 provides 1998 data on the shares of total government revenue derived from (i) taxes on income, profits, and capital gains, (ii) social security taxes, (iii) taxes on goods and services, (iv) taxes on international trade, (v) other taxes, and (vi) non-tax revenue. To obtain an empirical counterpart to $\zeta_{1,0}$, suppose, as was done above, that total government revenue equals total government spending. Since non-tax revenue is fundamentally different from the other five revenue sources, I take the empirical counterpart to equation (19) to be the ratio of taxes on international trade to the sum of the remaining four. Under this approach, the data in Table 4.13 implies that $\xi_{1,0} = 0.257$.[23] Given this value and the initial values for α_{12}, γ_1, and $y_{1,0}$, equations (4), (11) and (19) can be solved simultaneously for $\tau^*_{12,0}, \sigma^*_{1,0}$ and ψ. Doing so yields $\tau*_{12,0} = 0.0945, \sigma^*_{1,0} = 0.0763$, and $\psi = 0.5523$.

The law of motion for Country 1's knowledge stock in growth rate form, equation (14) divided by $H_{1,0}$, is used to calibrate μ. Given that Country 1's initial tariff and income tax rates are known, as are the initial knowledge stocks of both countries, in order to solve for μ, the initial growth rate for Country 1's knowledge stock must be determined. This is achieved by calibrating the initial rate of growth for Country 1 and then inverting equation (2). Since Country 1 is initially taken to be a 'poor' country that begins to liberalize trade in period 0, this suggests calibrating Country 1's initial rate of growth to the average rate of growth of countries that were 'poor' in 1960 and have since experienced substantial increases in their degrees of openness.

Using data from Easterly and Yu (2000), I first calculate the average ratio of total trade to GDP for 1960–1979 and 1979–1999 and take the difference. Second, I limit the sample to the ten countries with the largest differences and with incomes in 1960 that were at most 20 per cent of that of the US.[24] I then calculate the group's average rate of growth of output per capita between 1960–1979, a period during which each of these countries was likely transitioning to a new steady-state growth path associated with it now being more open. This value, 4.52 per cent, is then taken to be the initial growth rate of Country 1. Substituting for $A(\cdot)$ in equation (14), setting $t = 0$, and dividing both sides by $y_{1,0}^{1/\varepsilon} = H_{1,0}$ implies that

$$(1.0452)^{1/\varepsilon} = \frac{2\phi\alpha_{12}(1-\sigma_{1,0}^{*})}{1+\tau_{12,0}^{*}}\left(\frac{y_{1,0}}{y_{2,0}}\right)^{(\mu-1)/\varepsilon} + 1 + \phi - \delta \qquad (20)$$

Substituting for the other parameters implies that $\mu = 0.8963$. Therefore, the share of accessible Country 2 knowledge that Country 1 can utilize increases nearly linearly, which tends to retard the rise in H_i as H_j rises. This in turn implies that Country 1's income per capita converges to that of Country 2 quite slowly.

Figures 3–6 illustrate some of the results of the simulation with the first two figures presenting the model's take on the data presented in Table 1 and Figures 1 and 2. In particular, Figures 3 and 4 show that the model implies that the share of tariff revenue falls and the share of income tax revenue rises as Country 1 develops. These results suggest that the addition of administrative costs that have a declining average cost per unit of revenue

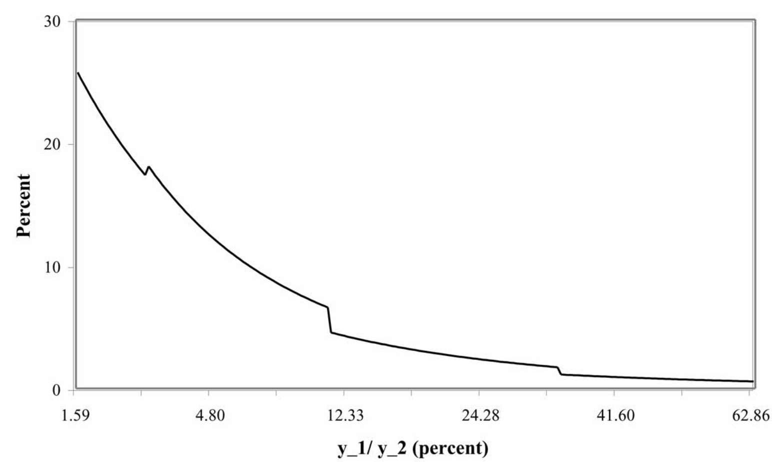

Figure 3 Country 1 tariff revenue as share of government revenue

to an open-economy endogenous growth model is sufficient for the model to explain the inverse relationship between share of tariff revenue and level of income seen in the data. Given the model's strong assumptions regarding saving and labour supply, this conclusion may not carry over to other specifications and illustrates why no claim of necessity is being made.

In Figure 3, Country 1's share of tariff revenue in government revenue is seen to start at 25.7 per cent, its calibrated value, and then it quickly decreases towards zero, its steady-state value. Given that any revenues not raised by tariffs must come from income taxes, it follows that Figure 4 exhibits the opposite behaviour of Figure 3. This in turn implies that Figure 4 quantitatively overstates the evidence provided in Figure 2. For example, in 1998, countries worldwide earned, on average, 58 per cent of government revenue from these other sources versus only 19 per cent from income taxes (see *WDI 2001* Table 4.13).

When Country 1's relative income reaches 2.7 per cent, its share of tariff revenue experiences an upward jump whereas in all other periods it declines. This jump, which occurs in period 21, arises as Country 1 moves from the Low Income group to the Lower Middle Income group. When this switch occurs, there are sharp rises in the share of after-tax income spent on imported goods, α_{12}, and share of output going to the public sector, γ_1. In particular, the combination of the latter and a low level of income cause the optimal tariff rate to rise from 6.17 per cent to 6.70 per cent and the optimal income tax rate to rise from 8.39 per cent to 10.60 per cent (see Figure 5). The rise in the tariff rate then causes the share of tariff revenue to increase. Simultaneous with the rise in tariff revenue, Country 1's growth rate jumps from 4.20 per cent to 4.74 per cent because in this case the trade-, and hence,

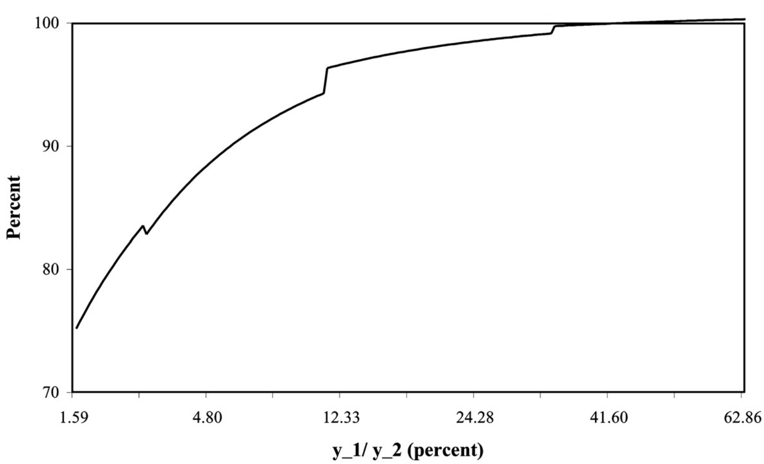

Figure 4 Country 1 income tax revenue as share of government revenue

growth-enhancing effect of the rise in α_{12} more than offsets the trade-, and hence, growth-reducing effects of the higher tariff and tax rates (see Figure 6).

Country 1 remains in the Lower Middle Income group until period 75 at which time it enters the Upper Middle Income group. Although this switch

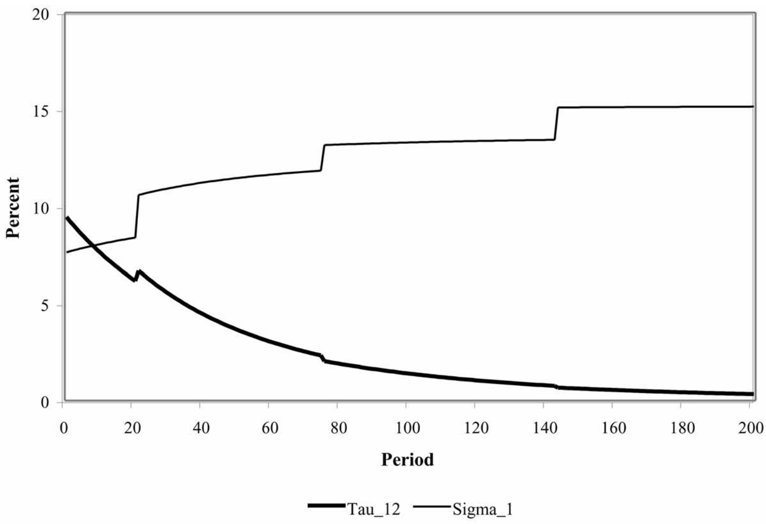

Figure 5 Country 1 tariff and income tax rates

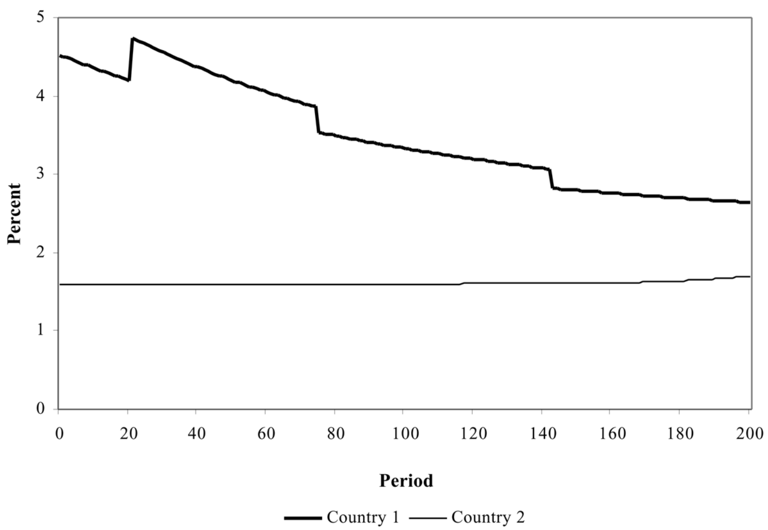

Figure 6 Rates of growth

again implies a rise in the share of the public sector, the share of imports in after-tax income now falls causing Country 1's optimal tariff rate to fall from 23.30 per cent to 20.40 per cent and its optimal income tax rate to rise from 11.84 per cent to 13.16 per cent (see Figure 5). These in turn cause the share of tariff revenue to fall as seen in Figure 3. Given the negative growth effect of the decline in α_{12}, Figure 6 shows that Country 1's growth rate now drops from 3.86 per cent to 3.56 per cent.

Country 1's declining rate of growth, coupled with its low rate of knowledge spillovers, implies that it is not until period 143 that its relative income surpasses 33.7 per cent and it enters the High Income group. At this point, Country 1 is identical to Country 2 save for its income level and hence its optimal tariff and tax rates. As with previous moves from one group to another, the move into the High Income group entails a decline in α_{12} and a rise in γ_1. In Figure 5 these changes are seen to cause Country 1's optimal tariff rate to fall from 0.76 per cent to 0.67 per cent and its optimal tax rate to rise from 13.44 per cent to 15.11 per cent. Since Country 1's trade sector again decreases, the share of revenue derived from the tariff falls from 1.73 per cent to 1.13 per cent and its rate of growth drops from 3.07 per cent to 2.82 per cent (see Figures 3 and 6).

Consistent with the discussion in Section 4, Country 2's high initial level of income per capita implies that its initial optimal tariff and income tax rates of 1.15 per cent and 15.04 per cent are nearly equal to their steady-state values of 0 per cent and 15.2 per cent. Not surprisingly, these imply that Country 2 initially raises just 2 per cent of its government revenue through the tariff with the remainder coming from the income tax. The large gap in income between the two countries combined with Country 1's low level of knowledge implies that Country 2 grows at approximately the autarchy rate of 1.60 per cent and continues to do so until well after Country 1 enters the High Income group. However, as Figure 6 shows, eventually Country 1's relative income and knowledge stock rise sufficiently that Country 2 eventually begins to experience non-trivial knowledge spillovers. As a result, Country 2's rate of growth begins to increase by non-trivial amounts. Indeed, by period 200 where the simulation ends, Country 2's growth rate has risen to 1.70 per cent.

Were the simulation to continue beyond period 200, one would observe Country 1's relative income continuing to rise, albeit at an ever-decreasing rate. In the limit, incomes and growth rates converge with $\hat{\sigma}^*_{1,t} = \hat{\sigma}^*_{2,t} = \gamma_2 = 0.152$, $\hat{\tau}^*_{12,t} = \hat{\tau}^*_{21,t} = 0$ and $\hat{H}_{1,t}/\hat{H}_{2,t} = 1$.[25] From equation (17) it follows that the steady-state rate of growth of knowledge in each country equals 6.56 per cent and hence that the steady-state growth rate of output per capita equals its calibrated value of 2.53 per cent. Since this value exceeds that of autarchy, 1.6 per cent, it follows that both countries benefit from Country 1 having become more open.

6. CONCLUSION

Both cross-section and time-series data suggest that as their level of income rises, nations find it optimal to substitute income taxes for tariffs. One explanation offered for this behaviour is that revenue sources such as income taxes are subject to administrative costs that for low-income countries are prohibitively high at the margin. If these costs decline with income, then as these nations grow they should find it optimal to substitute income taxes for tariffs. This paper investigates whether administrative costs constitute a sufficient condition for matching the inverse relationship between share of tariff revenue and level of income seen in the data. Thus, the paper considers a two-country, open-economy growth model in which knowledge represents the only accumulating factor and knowledge flows are affected by tariffs and income tax rates. The model imposes strong assumptions regarding saving, labour supply, and government behaviour so that attention may be focused on how the lone distortion due to administrative costs impacts the government's optimal decisions. Under these restrictions, administrative costs are shown to be sufficient. No claim of their necessity is made, however.

It is now well known that there is little evidence of (absolute) convergence among the nations of the world. Models such as the one considered here suggest that one factor contributing to this lack of convergence is the high tariff rates seen in low-income countries. This paper carries that story one step further by suggesting that low-income countries may be choosing to use tariffs (despite their low growth consequences) because it is too costly at the margin to raise income tax rates. Thus, the model implies not only that high tariffs are part of the reason that low-income countries are low income, but also that because their income is low, these countries find it optimal to rely on high tariffs. These results suggest that low-income/high-tariff countries find themselves in a sort of trap. However, the simulation shows that this is not necessarily the case. Instead, the model implies that given sufficient time (and given the calibration this could take several hundred years), the ongoing substitution of the income tax for the tariff and concomitant rise in relative income will eventually bring about convergence, a conclusion that is consistent with results reported by Lucas (2002: ch. 4).

ACKNOWLEDGEMENTS

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DATA APPENDIX

Table A1 World Bank Income Groups (2000$)

	Low Income	*Lower Middle Income*	*Upper Middle Income*	*High Income*
Per Capita Income	$\leqslant$ $755	$756 – $2995	$2996 – $9265	$9266 $\leqslant$
Group Average	$420	$1140	$4620	$27,510
Number of Countries	63	54	38	52

Data Sources

Table 1: % Income, Profits, and Capital Gains Tax Rev., % Social Security Tax Rev., % Goods and Services Tax Rev., % Tariff Rev.; *World Development Indicators 2001*, Table 4.13

Table A1: *World Development Indicators 2001* database

Figures 1, 2: % Tariff Rev., % Income Tax Rev., % Goods and Services Tax Rev.; *Government Financial Statistics* Yearbook (various issues) and Easterly and Yu (2000)
Real GDP per Capita; Easterly and Yu (2000)

Countries in Cross-Section Sample (89)

Low Income:

Azerbaijan, Burundi, Cameroon, Côte d'Ivoire, Georgia, Guinea, India, Indonesia, Kenya, Kyrgyz Republic, Lesotho, Madagascar, Moldova, Mongolia, Nepal, Pakistan, Sierra Leone, Tajikistan, Vietnam, Yemen, Zimbabwe

Lower Middle Income:

Albania, Algeria, Belarus, Bolivia, Bulgaria, China, Colombia, Dominican Republic, Egypt, El Salvador, Iran, Jordan, Kazakhstan, Latvia, Lithuania, Papua New Guinea, Peru, Philippines, Romania, Russia, Sri Lanka, Syria, Thailand, Tunisia

Upper Middle Income:

Argentina, Botswana, Brazil, Chile, Costa Rica, Croatia, Czech Republic, Estonia, Hungary, Korea (South), Lebanon, Malaysia, Mauritius, Mexico, Poland, Slovak Republic, South Africa, Turkey, Uruguay, Venezuela

Upper Income:

Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovenia, Spain, Sweden, Switzerland, United Arab Emirates, United Kingdom, United States

Countries in Time-Series Sample (32)

Low Income:

Burkina Faso, Cameroon, Democratic Republic of the Congo, Ethiopia, India, Indonesia, Nepal, Nicaragua, Pakistan

Lower Middle Income:

Columbia, Dominican Republic, Egypt, Iran, Morocco, Paraguay, Peru, Philippines, Sri Lanka, Tunisia, Thailand

Upper Middle Income:

Bahrain, Brazil, Chile, Costa Rica, Malaysia, Mauritius, Mexico, Panama, South Africa, Turkey, Uruguay, Venezuela

NOTES

1 Table A1 in the Data Appendix provides the ranges of 2000 Gross National Income per capita that define the World Bank's four income groups, the average income per capita within each group, and number of countries per group. The Data Appendix also contains the data sources used in constructing Tables 1 and A1, Figures 1 and 2, and the countries appearing in the cross-section and time-series samples sorted by income group.

2 I do not include high-income group countries in the time series sample since doing so skews the results further in the direction of low tariffs and high indirect taxes being associated with high income and hence weakens the argument that is being made. Social Security taxes are excluded due to a lack of sufficient data.

3 Examples of studies providing cross-section evidence include Mourmouras (1991), Burgess and Stern (1993), and Easterly and Rebelo (1993). Examples providing time-series evidence include Gardner and Kimborough (1989), Tanzi (1992), Easterly and Rebelo (1993), Polley (2000), and Tanzi and Zee (2000).

4 This argument has been made in one form or another by Gardner and Kimbrough (1989, 1992), Mourmouras (1991), Burgess and Stern (1993), Bearse *et al.* (2000), Polley (2000), Tanzi and Zee (2000), and Atolia (2002), among others.

5 This is not to say, however, that the addition of administrative costs is necessary to obtain such behaviour. Whether or not this is the case is an open question that is the subject of current work.

6 Given that the engine of growth in the model is the accumulation of knowledge, if physical capital were included in the model, then in the steady state it would simply grow at a rate that is proportional to that of knowledge (see, for example, Ben-David and Loewy, 2003). Thus, its absence, although perhaps

unsettling, is rather inconsequential for the model's main conclusions. For an early example of an endogenous growth model that includes human capital, but not physical capital, and includes an argument in support of this approach, see Stokey (1988). As for the exogeneity of labour, this simplification does preclude the presence of a (potentially interesting) substitution effect associated with the income tax and, as will be seen below, implies that the income tax is equivalent to a uniform commodity tax. This equivalence is also inconsequential for the model's main conclusions.

7 Since I assume that the time path of government spending is 'given' while the optimal mix of taxes needed to finance it are endogenous, the approach taken here follows that of Ramsey (1927). Mourmouras (1991) proceeds in a like manner. Alternatively, one can proceed as Barro (1990) and Barro and Sala-i-Martin (1992) do and include government expenditures in the production function. This approach is taken up in Loewy (2004) who, in a model similar to the one used here, assumes that government's share of output, γ_i, is productive and is a choice variable for the government. Loewy shows that primary results of this paper are unchanged by the addition of this feature.

8 See, for example, Yitzhaki (1979), Kaplow (1990), Mayshar (1991), and Slemrod and Yitzhaki (1996).

9 Mourmouras (1991) makes a similar assumption. Along the same lines, Polley (2000) assumes that the marginal monitoring cost for imports is significantly less than that for domestically produced goods.

10 Note that the condition on ψ guarantees that the third condition holds. In an addendum available from the author upon request, I argue that if $\psi \geqslant 1$, then the model does not necessarily possess an economically relevant solution. Moreover, Section 5 shows that the calibrated value of ψ does in fact satisfy the stronger restriction.

11 Both equations (3) and (4) assume that the government does not issue debt. While this is clearly an oversimplification, data contained in Table 4.11 of the *World Development Indicators 2001* show that in 1998 the world average for overall government budget deficit as a percentage of GDP was 1.5 per cent while the world average for debt and interest payments as a percentage of GDP was 3.12 per cent. By comparison, the 1998 world average for total government expenditure as a percentage of GDP was 27.9 per cent. Thus, the assumption of budget balance, and hence of no government debt, is not unreasonable.

12 In a certain sense, $a_{ij,t}$ captures Abramovitz's (1986) concept of 'social capability', the ability of a country to utilize existing technologies.

13 To see why this should be, suppose that $H_{i,t}$ greatly exceeds $H_{j,t}$. In such a case, presumably there is little in country *j*'s knowledge stock that is germane to country *i*. Conversely, if $H_{j,t}$ greatly exceeds $H_{i,t}$, then the level of development in country *i* is sufficiently low that it will not possess the capability to utilize knowledge spillovers from country *j*.

14 Specifically, the Bellman equation for the government of Country 1 satisfies: $v(\mathrm{H}_2 = \max_{\sigma_{1,t},\tau_{12,t}} \{\ln(1-\sigma_{1,t}) - \alpha_{12}\ln(1+\tau_{12,t}) + \beta v(\mathrm{H}_{t+1})\}$ subject to $\frac{\tau_{12,t}}{1+\tau_{12,t}} \alpha_{12}(1-\sigma_{1,t}) + \sigma_{1,t} = \gamma_1 + \frac{\sigma_{1,t}}{1+\sigma_{1,t}}(H_{1,t}^{\varepsilon_1})^{\psi-1}$ where $\mathrm{H}_t = (H_{1,t}, H_{2,t})$ and the two elements of H_{t+1} are determined by equation (7). Assuming that a solution to this problem and the comparable one for Country 2 can be found (an outcome that is made all the more difficult by the presence of both controls, via the $v_{ij,t}$ terms, in both laws of motion) only the behaviour of the system in the steady state can be determined.

15 Admittedly, this is a strong assumption to make. However, because the transitional dynamics of the model are germane to the question at hand and a

static, rather than a dynamic, government problem allows for the simulation of transitional dynamics, assuming away these dynamic linkages appears to represent the most direct route to follow.

16 Note that I am using the term 'optimal' in the sense of Ramsey (1927) inasmuch as the government is choosing these values to maximize the indirect utility function of the representative agent taking prices, here the terms of trade, $p_{2,t}$, as given. Clearly, the term 'optimal', especially when applied to tariffs, takes on a very different interpretation when the terms of trade effects are internalized in the government's problem.

17 It should be noted that these two steady-state results are not necessarily robust to making capital and/or labour endogenous. For example, if labour were endogenous, then an additional distortion enters into the government's first-order condition for the tax rate. This distortion need not approach zero in the steady state.

18 If not, then the ratio of knowledge stocks must be taken to the $-\mu$ power. This, of course, leaves the value of $\hat{g}_H$ unchanged.

19 In the *WDI*, the difference between exports' and imports' shares of output vary between one and three percentage points.

20 Openness is measured as the average over 1979 – 1999 of the ratio of total trade to GDP. The relative income threshold of 27 per cent follows from the ratio of the minimum per capita income level in 2000 needed to qualify as High Income, \$9266, to US per capita income in 2000, \$34,260.

21 The countries included are Austria, the Bahamas, Barbados, Belgium, Hong Kong, Ireland, Israel, Luxembourg, the Netherlands and Singapore. For the period 1979 – 1999, these nations have an average ratio of total trade to GDP of 1.55 as compared to a world average of 0.79 and, in 1979, have an average relative income of 58 per cent. Note that the choice of 1979 rather than 2000 as the determinant of whether a country qualifies as High Income eliminates the type of bias described by DeLong (1988). If the year 2000 were used, then Austria and Israel would be replaced by Malta and Taiwan. This raises the average rate of growth to 3.13 per cent and the average ratio of total trade to GDP to 1.66. Data source: Easterly and Yu (2000).

22 Since the US is not truly in autarchy when it comes to patent issue either, the average growth rate in the total number of patents issued over the same period is 4.93 per cent, a reflection of the growing share of patents issued to non-US residents. Whether patents represent a reasonable proxy for knowledge is debatable. See the comments of Jones (2002: 91) for example.

23 Burgess and Stern (1993: Table 5) provide 1989 data on tax revenue by type as a percentage of total taxes for a group of developing countries. Likewise, Tanzi and Zee (2000: Table 2) provide 1995 – 1997 data on tax revenue by type as a percentage of GDP for a different group of developing countries. Making comparable calculations of $\zeta_{1,0}$ using these two data sets implies estimates of 0.264 (Burgess and Stern) and 0.206 (Tanzi and Zee). Given the differences in group composition and time periods covered across these two estimates as well as the one I report using *WDI* data, it appears that these various estimates of $\zeta_{1,0}$ are quite consistent with one another.

24 The countries included are Guyana, Jamaica, Lesotho, Malaysia, Malta, Paraguay, Singapore, Swaziland, Taiwan, and Tunisia. Comparing across the two periods, these nations have an average increase in their ratios of total trade to GDP of 43 per cent. Moreover, their average share of US income in 1960 equals 13 per cent. Although the choice of 20 per cent is arbitrary, it is roughly midway between the switch points from Lower Middle to Upper Middle

Income, 10.9 percent, and from Upper Middle to High Income, 33.7 per cent. Moreover, data limitations for many of the poorest countries preclude reducing my upper bound much below 20 per cent.

25 These results are generally consistent with those that Lucas (2002: ch. 4) reports using a closed-economy growth model in which the initial rate of growth of each poor country is a decreasing function of its initial income relative to that of the leading country at the time the former begins to develop. See, in particular, his Figure 4.3 and the associated discussion.

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