

TARIFFS, TAXES, GOVERNMENT AND GROWTH

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ABSTRACT

Cross-section and time-series data show that as nations develop, they substitute income taxes for tariffs and increase the relative size of their public sectors. This chapter confronts these observations within the context of a two-country open-economy endogenous growth model with productive public expenditure that is subject to congestion. Public spending is financed by a tariff and an income tax that is subject to administrative costs. The model is calibrated to the data and is shown to yield time paths for the optimal tariff, optimal income tax rate, and optimal share of government spending in output that are consistent with the data.

Keywords: Optimal Tariffs, Optimal Taxes, Optimal Government Expenditures, Growth

INTRODUCTION

Two commonly accepted features of economic development are that nations rely less on trade taxes on more on other forms of indirect taxation as output rises and the share of public spending in output rises with output, a result usually referred to as “Wagner’s Law.” Tables 1 and 2 provide cross-section evidence of these relationships while Figures 1 – 3 do the same using time-series evidence.² Table 1 provides data for 1998 on the percent of government revenue raised from four categories of taxes: (i) tariffs; (ii) income, profits, and capital gains;

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² Other studies providing cross-section evidence of the first relationship include Mourmouras (1991), Burgess and Stern (1993), and Easterly and Rebelo (1993). Examples providing time-series evidence of the same include Easterly and Rebelo (1993), Polley (2000), and Tanzi and Zee (2000). As for evidence on Wagner’s Law, the literature contains numerous cross-section studies. See, for example, the papers in Lybeck and Henrekson (1988) and Tanzi and Schuknecht (2000). Bird (1971) questions whether cross-section data in fact provides evidence of the result arguing instead that only time series data suffices. Some of the many examples of this type of study include Ram (1987), Bohl (1996), and Ghate and Zak (2002).

(iii) social security; and (iv) goods and services. Table 2 does likewise for government consumption as a percentage of GDP, this time using data for 1999. The values in the two tables 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.³ An inverse relationship between the share of tariff revenue and per capita income is evident from Table 1. As for the positive relationship between other forms of indirect taxation and per capita income, such a relationship is seen to hold for two of the three types of taxes considered as well as for the sum of the three. A rising share of government consumption in GDP, Wagner's Law, is evident in Table 2.

**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

**Table 2: Government Final Consumption Expenditure as Percent of GDP
(Average Value within Income Groups)**

Income Group (#)	G/Y
Low (21)	12.8
Lower Middle (24)	14.0
Upper Middle (20)	15.7
High (24)	19.2

Covering the years 1975 – 2000, 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 GDP per capita in 1996 dollars (thin line) for a sample of 32 low- and middle-income nations for which sufficient data is available.⁴ For the same sample of countries, but covering 1960 – 2000, Figure 3 plots the average value of government consumption as a percentage of output (bold line) against average real GDP per capita in 1996 dollars (thin line). Consistent with the prevailing view and the cross-section

³ 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 the number of countries per group. The Data Appendix also includes the data sources used in constructing Tables 1, 2, and A1, Figures 1, 2, and 3, and the countries belonging to the cross-section and time-series samples sorted by income groups.

⁴ Note that after 1994 the data set is somewhat incomplete as there are two or more missing observations for seven nations: Brazil, Burkina Faso, Cameroon, Egypt, Korea, Malaysia, and Morocco.

data, Figures 1 and 2 show that the general movement over time in the share of tariff revenue is falling and in the share of income tax revenue plus goods and services tax revenue is rising as per capita income increases. As for Figure 3, it is consistent with the prevailing view and the cross-section data over the 1960 – 1986 period inasmuch as the share of government consumption in GDP generally rises along with real GDP per capita over this period. After 1986, the time series evidence is inconsistent with Wagner’s Law as the ratio of government consumption to GDP falls from 1986 to 1995 and then rises from 1995 to 2000 despite real GDP per capita generally increasing over the entire time period. Thus, the time series evidence at lower levels of income is supportive of Wagner’s Law, but is less so at higher levels of income. Despite being somewhat inconclusive, these results are, however, in line with what is reported in Ram (1987), Bohl (1996), and Ghate and Zak (2002).

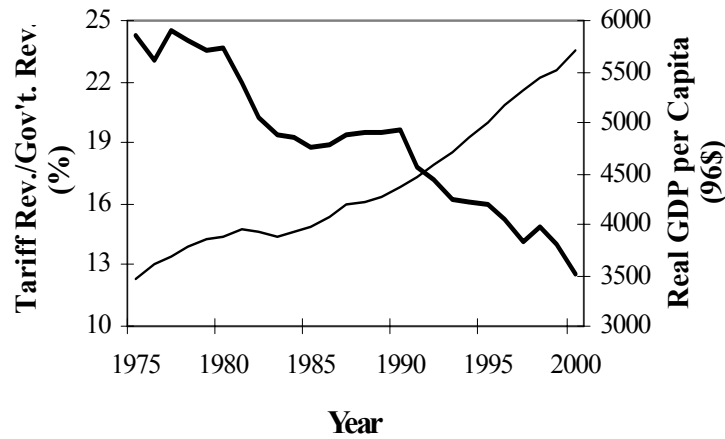


Figure 1: Share of Tariff Revenue in Government Revenue versus Real GDP per Capita

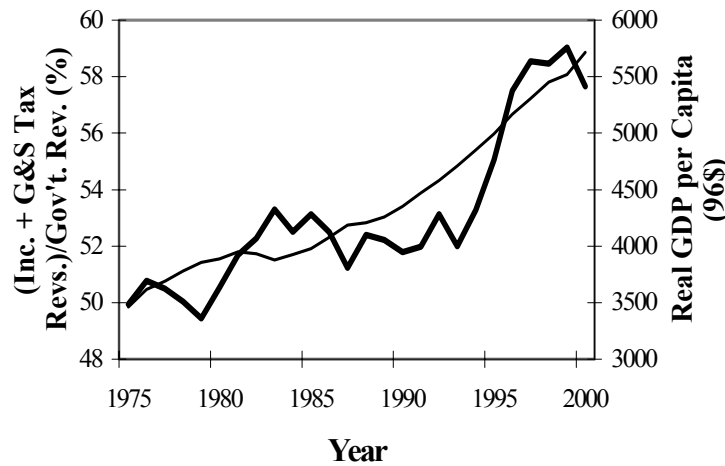


Figure 2: Share of Income Tax and Goods & Services Tax Revenues in Government Revenue vs. Real GDP per Capita

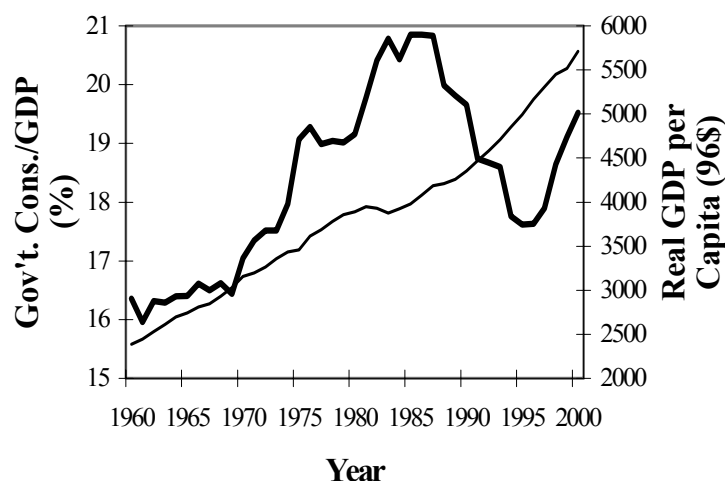


Figure 3: Share of Government Consumption in GDP versus Real GDP per Capita

One explanation that is commonly offered for why developing countries rely on tariffs (other forms of indirect taxation) to a greater (lesser) extent than do developed countries is that tariffs effectively have zero administrative costs whereas for most other forms of indirect taxation these costs are not only positive, but on a per-unit-of-revenue-collected basis are also inversely related to income.⁵ It then follows that as income levels rise, there is an incentive to substitute away from tariffs towards other forms of indirect taxation (given an unchanged time path for public spending). Furthermore, if the positive growth and level effects of decreasing tariffs dominate the negative growth and level effects of increasing the income tax rate, say, as certain classes of open-economy, endogenous-growth models predict, then a developing economy will not only see its level of output rise, but ultimately will also see its steady-state rate of growth increase. Since high-tariff/low-income countries often have low rates of growth while low-tariff/high-income countries often have high(er) rates of growth, the suggested benefits that derive from substituting an income tax for tariffs may well hold in practice.

Despite there being some question as to its empirical support, modern theories of Wagner's Law nevertheless abound. Typically, these explanations are reformulations or refinements of Wagner's (1890) original idea that increased political pressures will accompany economic development and so lead to an expansion in the relative size of the public sector. Among the various theories offered include (i) extensions of voting rights reduced the income of the median voter and so increased transfers; (ii) increased centralized decision making; (iii) increased government monitoring of private activity is needed in a more complex economy; and (iv) an aging population brought about an increase in transfers.⁶ Rather than add to this literature, in what follows I view Wagner's Law as an empirical regularity that my model needs to reproduce as part of its transitional dynamics. To this end, I model government expenditure (or more precisely its ratio to output since congestion costs

⁵ This argument has been made in one form or another by Mourmouras (1991), Burgess and Stern (1993), Bearnse, Glomm, and Janeba (2000), Polley (2000), Tanzi and Zee (2000), and Atolia (2003), among others.

⁶ Ram (1987) and Ghate and Zak (2002) provide numerous references. See also Holsey and Borcharding (1997).

are assumed present) as an input to production.⁷ Consequently, an increase in public spending raises the marginal productivity of other factors of production and this in turn increases both the ratio of government spending to output along the transition to steady-state and the steady-state growth rate of output, *ceteris paribus*.

The goal of this chapter is to confront the negative (positive) relationship between tariff revenue (revenue from other forms of indirect taxation) and real GDP per capita and Wagner's Law that are observed in Figures 1 – 3 within the context of an open-economy, endogenous-growth model. In particular, the growth model constructed below seeks to replicate these relationships as part of its transitional dynamics. This is accomplished by adding an income tax that is subject to administrative costs and productive government expenditures that are subject to congestion costs to a discrete-time, two-country version of Ben-David and Loewy's (1998) open-economy growth model. In their model, physical capital is absent and the labor input is exogenous so that growth is driven only by the accumulation of knowledge, an input that itself is a function of trade volume and hence of tariff and income tax rates. These assumptions are maintained here. In addition, Ben-David and Loewy assume that tariff rates are set exogenously and tariff revenue is returned to private agents lump sum. In contrast, I assume that the government optimally (in the sense of Ramsey, 1927) chooses the tariff rate, income tax rate, and share of its spending in output and that the revenue that these taxes raise finances both its expenditures and the administrative costs of the income tax.⁸

Consistent with the justification offered for the first two empirical relationships documented above, administrative costs are modeled such that their ratio to income tax revenue declines as the tax base (namely output) rises. This feature of the model, plus the assumptions of no physical capital and exogenous labor input, implies that the only distortion that the income tax causes operates through administrative costs. Although these assumptions are rather strong, they permit the analysis to focus exclusively on the role that administrative costs play in deriving results that are consistent with Figures 1 and 2. As will be seen below by means of a simulation, the solution to the government's problem implies that it substitute the income tax for the tariff as income rises. Moreover, because increases in the share of government expenditure in output raise the productivity of knowledge, in the simulation this share rises as income increases yielding Wagner's Law. In the steady state, the tariff goes to zero while the income tax rate approaches the share of government expenditure in income. In addition, the steady state value of the latter is consistent with Barro (1990) and others who show that the optimal share of government expenditure in output equates the marginal benefit of government spending to its marginal cost. These results jointly imply that in the steady state the economy achieves the highest rate of growth that is consistent with financing the optimal share of government spending in output.

Although there exist a number of researchers who suggest in passing that administrative costs of taxation may be the reason for the inverse relationship between level of development and reliance on tariffs, few of them have sought to model this argument. Two notable examples where explicit theorizing of this link does take place are Polley (2000) and Atolia

⁷ See, for example, Barro (1990) and Barro and Sala-i-Martin (1992, 2004).

⁸ A model similar to the one developed here also appears in Loewy (2004). In this related paper, I confront the same relationships between tariffs, income taxes, and real GDP per capita considered here, but treat the share of government expenditure in output as exogenous and so do not consider the ratio to be an input to production.

(2003). 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. Furthermore, should producer income be sufficiently large or the marginal cost of auditing producer income be sufficiently small, then Polley shows that the optimal tariff equals zero.

While these results can be viewed as explaining the inverse relationship between tariff revenue and economic development, since Polley's model is static and so only provides a link from income to optimal tariffs and taxes, they are perhaps just suggestive of it. As the model developed in this chapter 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 chapter is not only a model of optimal tariffs and taxes, but one of economic growth as well.

Atolia (2003) analyzes 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 chapter is as follows. Section 2 lays out the open-economy endogenous growth model and the administrative cost function. 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 the resultant time path for shares of government revenue derived from the tariff and the income tax are shown to capture features of the data seen in Figures 1 and 2 while the time path for the share of government expenditure in output is suggestive of Figure 3. Section 6 summarizes and offers some concluding remarks.

THE MODEL

The model to be developed in this chapter is a discrete time, two-country version of Ben-David and Loewy's (1998) open-economy, endogenous-growth model. In their model, output is taken to be a function of inelastically supplied labor and knowledge. Physical capital, and hence aggregate saving, is absent. To this model, I add two features, an income tax along with its associated administrative costs (as in Loewy, 2004) and productive government purchases. The admittedly strong assumptions of no physical capital and perfectly inelastic supply of labor permit the analysis to focus on the role that optimal tariff and income tax rates play in the knowledge accumulation process and thus on their impact on economic growth.⁹ In

⁹ Given that the engine of growth in Ben-David and Loewy (1998) is the accumulation of knowledge, if physical capital were included in their model, then the steady-state rate of growth of physical capital would be proportional to that of knowledge as Ben-David and Loewy (2003) show. Therefore, the absence of physical capital as an accumulating factor in the current model may be unsettling, but is inconsequential for its main

addition, the absence of physical capital allows an analysis of both the economy's steady state and its transitional dynamics. Since the goal of the chapter is to show how the presence of administrative costs influences the optimal choices of tariff and income tax rates as income rises, not to mention how adding government expenditures to the production function can yield Wagner's Law, the ability to study the model's transitional dynamics is vital.

Following Dollar, Wolff, and Baumol (1988), 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, along with increases in the level of government expenditures, serve as sources of growth in output per capita. To the extent that tariff and income tax rates can and do impact trade, the government's optimal choice of these tax instruments determines not just the economy's level of income per capita, but its rate of growth as well. If trade is absent, then the model reduces to a neoclassical growth model with productive government spending in which the rate of technical progress corresponds to what is now an exogenous rate of knowledge accumulation.

Consider 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 labor 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 . Assuming all agents in country i are identical, then the aggregate utility of the agents in country i , U_i , is given by

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

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

For each country $i = 1, 2$, let good i denote that country's distinct output. Good i is produced using labor, knowledge, and government purchases. Following Barro and Sala-i-Martin (1992), government services are rival, but not excludable and therefore are subject to congestion.¹⁰ A common way to model this is to assume that the ratio of government expenditure to output enters into the production function. Given the absence of physical capital and the public nature of knowledge, the production function also must be constant returns to scale in labor. In light of these features, the production function for country i may be written as

$$Y_{i,t} = L_{i,t} \left(G_{i,t} / Y_{i,t} \right)^{\theta_i} H_{i,t}^{\varepsilon_i} \quad (2)$$

where $Y_{i,t}$ is aggregate output, $G_{i,t}$ is aggregate government purchases, $H_{i,t}$ is the aggregate stock of knowledge in country i at time t , $\theta_i > 0$, and $\varepsilon_i > 0$. Dividing both sides by $L_{i,t}$ to

results. For a further defense of this approach, see Stokey (1988). As for the exogeneity of labor, admittedly this simplification does rule out the presence of a potentially interesting substitution effect associated with changes in the income tax rate and implies that the income tax is equivalent to a uniform commodity tax. This equivalence is also inconsequential for the model's main results.

¹⁰ Given that a large share of government expenditure in both developing and developed countries takes the form of infrastructure, such an assumption seems warranted. See the discussion in Barro and Sala-i-Martin (1992).

obtain output per capita, $y_{i,t}$, on the left-hand side and denoting the ratio of government purchases to output as $\gamma_{i,t}$, it follows that eq. (2) may be written more usefully as

$$y_{i,t} = \gamma_{i,t}^{\theta_i} H_{i,t}^{\varepsilon_i}. \quad (3)$$

As is to be expected with a specification such as this, in the steady state $\gamma_{i,t}$ must equal a constant. Hence, in the steady state output per capita grows at a rate that depends upon rate of accumulation of knowledge. However, since ε_1 need not equal ε_2 , the steady-state rates of growth in the two countries need not be the same even though it is shown below that the two steady-state rates of knowledge accumulation must 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 rate on good j at time t and $\sigma_{i,t}$ be country i 's time t labor income tax rate, it follows that the time t per capita budget constraint for country i is given by

$$c_{ii,t} + \frac{p_{j,t}}{p_{i,t}}(1 + \tau_{ij,t})c_{ij,t} = (1 - \sigma_{i,t})y_{i,t} \quad (4)$$

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, $(p_{j,t}/p_{i,t})\tau_{ij,t}c_{ij,t} + \sigma_{i,t}y_{i,t}$, is used to finance the sum of government expenditure per capita, $g_{i,t} = \gamma_{i,t}y_{i,t}$, and the per capita administrative costs of collecting these revenues.

With regard to administrative costs, Yitzhaki (1979), Polinsky and Shavell (1982), Kaplow (1990), Mayshar (1991), and Slemrod and Yitzhaki (1996) suggest that they are likely to be an increasing function of the tax base and/or the tax rate. The latter also argue that a higher tax rate reduces administrative costs per unit of revenue collected. Finally, Mourmouras (1991), Burgess and Stern (1993), Bearse, Glomm, and Janeba (2000), Polley (2000), Tanzi and Zee (2000), and Atolia (2003), among others, suggest that administrative costs per unit of revenue collected decrease with income. Beyond these rudimentary ideas, the literature offers little other guidance as to how administrative costs ought to be modeled and so leaves the door open to a number of possible approaches that can be followed.

I assume that because tariffs can be applied "at the port," they do not entail any administrative costs and so only the income tax is assumed to bear this cost.¹¹ Loewy (2004) offers a specification for administrative costs per capita that satisfies the criteria mentioned above, namely $\sigma_{i,t}y_{i,t}^{\psi}/(1 + \sigma_{i,t})$ where $0 < \psi < 1$. While the first two criteria hold for any positive value of ψ , note that the upper bound on ψ is needed to guarantee that average

Moreover, to assume otherwise implies that there will exist a scale effect, a features that at best is weakly supported by the data (see, for example, Barro and Sala-i-Martin, 2004 and Jones 1995, 1999).

¹¹ 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.

administrative costs per unit of revenue collected decline as per capita income increases.¹² Combining the tariff and income tax revenue terms from the per capita budget constraint, eq. (4), with the expenditure and administrative costs terms described above, it follows that the time t government budget constraint for country i in per capita terms is

$$\frac{p_{j,t}}{p_{i,t}} \tau_{ij,t} c_{ij,t} + \sigma_{i,t} y_{i,t} = g_{i,t} + \frac{\sigma_{i,t}}{1 + \sigma_{i,t}} y_{i,t}^{\psi} \quad (5)$$

Given that the rate of growth in the model is ultimately governed by the rate of growth of knowledge, consider next the means by which knowledge accumulates. Lucas (1988) suggests that knowledge accumulation in country i exhibits constant returns to scale in country i 's level of knowledge. I extend this formulation by assuming, as Ben-David and Loewy (1998, 2003) do, that knowledge accumulation in country i exhibits 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.

Consider first the notion of accessibility. Let $v_{ij,t}$ denote the time t share of country j 's knowledge that is accessible to country i . As in Grossman and Helpman (1991), this share is assumed to be an increasing function of the volume of trade between countries i and j . In particular, $v_{ij,t}$ is taken to be the ratio of country i 's total trade per capita with country j (bilateral imports plus bilateral exports) to country i 's output per capita. Thus,

$$v_{ij,t} = \frac{\frac{p_{j,t}}{p_{i,t}} c_{ij,t} + \frac{L_{j,t}}{L_{i,t}} c_{ji,t}}{y_{i,t}} \quad (6)$$

Consider next the notion of applicability. Let $a_{ij,t}$, $0 \leq a_{ij,t} \leq 1$, 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.¹⁴ As in Ben-David and Loewy (2003), I assume that $a_{ij,t}$ increases as $H_{i,t}$ and $H_{j,t}$ become more nearly equal to one another. Note that "become more nearly equal" need not imply that the two knowledge stocks are becoming nearly identical. Rather, the phrase should be construed more generally as meaning the two sets of knowledge stocks are becoming more comparable in terms of their levels of technology. When this is the case, each country is in a better position to obtain knowledge spillovers from the other. To see why this

¹² Although the requirement of an upper bound on ψ may appear restrictive, in practice it is not since, as will be shown below, the calibrated value for ψ does in fact lie between 0 and 1.

¹³ Both eqs. (4) and (5) assume that the government does not issue debt. While this is certainly 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% while the world average for debt and interest payments as a percentage of GDP was 3.12%. By comparison, the 1998 world average for total government expenditure as a percentage of GDP was 27.9%. Thus, the assumption of budget balance, and hence of no government debt, is reasonable.

¹⁴ In a certain sense, $a_{ij,t}$ can be thought of as measuring Abramovitz's (1986) concept of "social capability," namely the ability of a country to utilize existing technologies.

should be, suppose first that $H_{j,t}$ 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 . Conversely, if $H_{i,t}$ greatly exceeds $H_{j,t}$, then presumably there is little in country j 's knowledge stock that is relevant to advancing knowledge in country i .

Suppose, as the above discussion suggests, that $a_{ij,t}$ (and hence $a_{ji,t}$) is maximized when $H_{i,t} = H_{j,t}$. What then of the relationship between $a_{ij,t}$ and $a_{ji,t}$ when the two knowledge stocks differ? Since one can reasonably argue that this inequality can run either way, I follow Ben-David and Loewy (2003) and assume that $a_{ij,t} = a_{ji,t}$ always. Given this assumption, $a_{ij,t}$ is defined as follows:

$$a_{ij,t} = A \left(\frac{H_{j,t}}{H_{i,t}} \right) = \begin{cases} \left(\frac{H_{j,t}}{H_{i,t}} \right)^\mu & \text{if } 0 < \frac{H_{j,t}}{H_{i,t}} \leq 1 \\ \left(\frac{H_{j,t}}{H_{i,t}} \right)^{-\mu} & \text{if } 1 < \frac{H_{j,t}}{H_{i,t}} \leq \infty \end{cases} \quad (7)$$

where $0 < \mu$. Notice that the larger is μ , the smaller is the share of country j 's accessible knowledge that country i can utilize for any given value of $H_{j,t}/H_{i,t}$. Therefore, larger values of μ tend to reduce the rate of knowledge accumulation, and hence the rate of growth, in each country.

With these two definitions now in hand, I write as the accumulation of knowledge in country i as

$$H_{i,t+1} = \phi a_{ij,t} v_{ij,t} H_{j,t} + (1 + \phi - \delta) H_{i,t} \quad (8)$$

where $\phi \geq \delta > 0$ and represent a productivity parameter and rate of knowledge depreciation that are common to both countries. Note that in autarky $v_{ij,t} = 0$ which implies that the rate of knowledge accumulation is now exogenous and satisfies $H_{i,t+1}/H_{i,t} = 1 + \phi - \delta$. Given eq. (3), it then follows that in a world without trade, output per capita in country i grows in steady state at the (gross) rate of $(1 + \phi - \delta)^{\epsilon_i}$ since the share of government spending in output equals a constant in this case. Furthermore, because the steady-state rate of growth is exogenous, it follows that in autarky 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, in fact $(1 + \phi - \delta)^{\epsilon_i}$ represents the greatest lower bound on the steady-state rate of growth. In addition, since the levels of imports and exports are functions of the optimal tariff and tax rates, these values affect the common steady-state rate of knowledge accumulation and hence each country's steady-state rate of growth of output per capita.¹⁵

¹⁵ Since the ratio of government purchases to output is constant in the steady state, its value can only have a level effect on steady-state output per capita. On the other hand, since the ratio is changing along the transition to steady state, it and the accumulating knowledge stock jointly determine the rate of growth in this case.

PRIVATE AGENT AND GOVERNMENT PROBLEMS

Consider first the choice problem of the private agents of Country 1 (with that of Country 2 being symmetric). Suppose, as Lucas (1988) does, that private agents are atomistic and so treat the time path of knowledge and the share of government spending as being beyond their control. Hence, these agents take $H_{1,t}$ as given at time t . Since there is no private saving in the model, this in turn implies that these agents 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 to choose $c_{11,t}$ and $c_{12,t}$ to maximize $\alpha_{11} \ln c_{11,t} + \alpha_{12} \ln c_{12,t}$ subject to eq. (4). Solving this problem yields $c_{11,t} = \alpha_{11}(1 - \sigma_{1,t})y_{1,t}$ and $c_{12,t} = \alpha_{12}(1 - \sigma_{1,t})y_{1,t}p_{1,t}/p_{2,t}(1 + \tau_{12,t})$ with $p_{1,t} \equiv 1$.

Consider next the choice problem of the government of Country 1 (with that of Country 2 again being symmetric). Note first that because the production function is Cobb-Douglas, it follows that choosing the level of per capita government spending, $g_{1,t}$, is equivalent to choosing government's share of output, $\gamma_{1,t}$. Since employing the second variable simplifies the analysis, henceforth I assume this to be the case. Second, 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 1 solves a dynamic problem in which it chooses sequences for $\tau_{12,t}$, $\sigma_{1,t}$, and $\gamma_{1,t}$ to maximize private agents' lifetime indirect utility subject to the government budget constraint and the two laws of motion for knowledge given the current values of the two knowledge stocks, $H_{1,t}$ and $H_{2,t}$. If it cannot, then because it now takes the two laws of motion for knowledge as given, the government effectively solves a static problem in which it chooses $\tau_{12,t}$, $\sigma_{1,t}$, and $\gamma_{1,t}$ to maximize private agents' time t indirect utility subject to the government budget constraint, eq. (5).¹⁶ 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. In other words, the government treats the linkages between its current and future policy decisions as beyond its control.¹⁷

Let the government of Country 1 behave as just described. Substituting the above expressions for $c_{11,t}$ and $c_{12,t}$ into the time t private utility function and again for $c_{12,t}$ in the time t government budget constraint, eq. (5), 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 $y_{1,t}$, is given by

$$\max_{\tau_{12,t}, \sigma_{1,t}, \gamma_{1,t}} \ln(1 - \sigma_{1,t}) + \ln \gamma_{1,t} - \alpha_{12} \ln(1 + \tau_{12,t}) \text{ subject to}$$

¹⁶ For similar types of set-ups see Heller and Shell (1974), Mayshar (1991), Dubravko (1992), Polley (2000), and especially Yitzhaki (1979).

¹⁷ Although this is a strong assumption about government behavior, it serves to convert the government's problem from a dynamic one whose solution, if it can be solved for at all, typically can only be found in the steady state to a static one whose entire transitional dynamics can be simulated. Since this last feature is needed to confront the data, assuming away these dynamic linkages seems to be the simplest approach to follow.

$$\frac{\tau_{12,t}}{1+\tau_{12,t}}\alpha_{12}(1-\sigma_{1,t})+\sigma_{1,t}=\gamma_{1,t}+\frac{\sigma_{1,t}}{1+\sigma_{1,t}}y_{1,t}^{\psi-1}. \quad (9)$$

Allowing for the possibility that either the tariff or the tax rate might be negative and assuming an interior solution for the ratio of spending to output, the first-order conditions for this problem are

$$1+\tau_{12,t}=\lambda_{1,t}(1-\sigma_{1,t}), \quad (10)$$

$$\frac{1}{1-\sigma_{1,t}}=\lambda_{1,t}\left[1-\frac{\tau_{12,t}\alpha_{12}}{1+\tau_{12,t}}-\frac{y_{1,t}^{\psi-1}}{(1+\sigma_{1,t})^2}\right], \quad (11)$$

$$1=\lambda_{1,t}\left[\frac{\gamma_{1,t}}{\theta_1}+(\psi-1)\frac{\sigma_{1,t}}{1+\sigma_{1,t}}y_{1,t}^{\psi-1}\right] \quad (12)$$

where $\lambda_{1,t}$ is the Lagrange multiplier associated with the time t Country 1 government budget constraint and $\partial y_{1,t}/\partial \gamma_{1,t}=\theta_1 y_{1,t}/\gamma_{1,t}$ has been used in deriving eq. (12). Using eq. (10) to solve for $\lambda_{1,t}$ and substituting the result into eqs. (11) and (12) implies that the time t optimal tariff, tax rate, and ratio of government purchases to output, $\tau_{12,t}^*$, $\sigma_{1,t}^*$, and $\gamma_{1,t}^*$, are the solutions to

$$(1+\tau_{12,t})\left[1-\frac{\tau_{12,t}\alpha_{12}}{1+\tau_{12,t}}-\frac{y_{1,t}^{\psi-1}}{(1+\sigma_{1,t})^2}\right]=1, \quad (13)$$

$$\frac{1+\tau_{12,t}}{1-\sigma_{1,t}}\left[\frac{\gamma_{1,t}}{\theta_1}+(\psi-1)\frac{\sigma_{1,t}}{1+\sigma_{1,t}}y_{1,t}^{\psi-1}\right]=1, \quad (14)$$

and the form of the government budget constraint appearing in eq. (9) with $y_{1,t}=\gamma_{1,t}^{\theta_1}H_{1,t}^{\varepsilon_1}$. By symmetry, a similar triple of expressions determines $\tau_{21,t}^*$, $\sigma_{2,t}^*$, and $\gamma_{2,t}^*$.

To complete the description of the model at time t , it suffices to solve for the market-clearing price of good 2, $\bar{p}_{2,t}$. Focusing on good 1, say, market clearing requires that private and public spending plus administrative costs exhaust output per capita, $c_{11,t}+\frac{L_{2,t}}{L_{1,t}}c_{21,t}+g_{1,t}+\frac{\sigma_{1,t}}{1+\sigma_{1,t}}y_{1,t}^{\psi}=y_{1,t}$. Note that this expression, along with the private and government budget constraints, eqs. (4) and (5), 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 $\bar{p}_{2,t}$ and using eq. (3) yields

$$\bar{p}_{2,t}=\frac{\alpha_{12}(1-\sigma_{1,t}^*)L_{1,t}(\gamma_{1,t}^*)^{\theta_1}H_{1,t}^{\varepsilon_1}/(1+\tau_{12,t}^*)}{\alpha_{21}(1-\sigma_{2,t}^*)L_{2,t}(\gamma_{2,t}^*)^{\theta_2}H_{2,t}^{\varepsilon_2}/(1+\tau_{21,t}^*)}. \quad (15)$$

With $\bar{p}_{2,t}$ being a function of the optimal tariffs, tax rates, and spending ratios (which are themselves functions of the two current stocks of knowledge), it follows that these values affect the time t equilibrium quantities of imports and exports. Therefore, eqs. (6), (7), and (8) imply that the time $t+1$ stocks of knowledge are themselves determined. Specifically,

$$H_{1,t+1} = A \left(\frac{H_{2,t}}{H_{1,t}} \right) \cdot \frac{2\phi\alpha_{12}(1-\sigma_{1,t}^*)}{1+\tau_{12,t}^*} \cdot H_{2,t} + (1+\phi-\delta)H_{1,t} , \quad (16)$$

$$H_{2,t+1} = A \left(\frac{H_{1,t}}{H_{2,t}} \right) \cdot \frac{2\phi\alpha_{21}(1-\sigma_{2,t}^*)}{1+\tau_{21,t}^*} \cdot H_{1,t} + (1+\phi-\delta)H_{2,t} .^{18} \quad (17)$$

STEADY-STATE ANALYSIS

Inspection of eqs. (9), (13), and (14) suggests that it is not a priori obvious that along the transition to the steady state optimal tariffs decrease while optimal tax rates and government shares of output increase. Inasmuch as these are the key features of the data that the model needs to confront, it follows that the model's implications are best determined by means of a calibration. Before doing so in the next section, it is instructive to consider first the model's steady state since its properties do not directly depend upon the calibration. By definition, a steady state for this model is such that the tariff rate, income tax rate, and ratio of government spending to output in each country must equal a constant, and output in each country must grow at a constant rate.

Let a hat over a variable denote its value in the steady state. For those variables that are constant in the steady state, I henceforth suppress the time subscript to simplify the notation.

Since $0 < \psi < 1$, eq. (13) implies that the only steady-state solution for the tariff is $\widehat{\tau}_{ij}^* = 0$.¹⁹

Given this, eq. (9) then implies that $\widehat{\sigma}_i^* = \widehat{\gamma}_i^*$. What, then, can be said of $\widehat{\gamma}_i^*$? Substituting the

two previous steady-state values into eq. (14), it follows that $\widehat{\gamma}_i^* = \theta_i / (1 + \theta_i)$. To gain some

further insight into this result, notice that eq. (2) implies that $Y_{i,t} = (G_{i,t}^{\theta_i} H_{i,t}^{\varepsilon_i})^{\frac{1}{1+\theta_i}}$ which in turn

implies that

$$\frac{\partial Y_{i,t}}{\partial G_{i,t}} = \frac{\theta_i}{1+\theta_i} \frac{Y_{i,t}}{G_{i,t}} = \frac{\theta_i}{1+\theta_i} \frac{1}{\gamma_{i,t}} . \quad (18)$$

¹⁸ Since preferences are log linear, the price level, and therefore the optimal ratio of government spending to output, does not appear in eqs. (16) and (17). The optimal tariff and the optimal tax rate remain in these expressions since they directly enter into the demands for the two imported goods.

¹⁹ Therefore, the steady state exhibits complete free trade. Results in Polley (2000) are suggestive of a similar result.

Therefore, in the steady state, the marginal benefit of government spending, the right-hand side of eq. (18), equals its marginal cost, namely one. The condition $\partial Y_{i,t} / \partial G_{i,t} = 1$ is exactly the result that Barro (1990) and others have shown must apply in order that the level of government spending is optimal. One important difference here is that because the present model exhibits transitional dynamics while the one in Barro (1990), for example, does not, here the efficiency condition for government spending only holds in the steady state. Along the transition, marginal benefit exceeds marginal cost since, as will be demonstrated below, the share of government spending in output rises over time.

Consider next the steady-state rate of growth of knowledge and therefore of output per capita in each country. From eqs. (16) and (17), steady-state growth is governed by the system

$$\begin{bmatrix} \widehat{H}_{1,t} \\ \widehat{H}_{2,t} \end{bmatrix} = \begin{bmatrix} 1 + \phi - \delta & A\left(\frac{\widehat{H}_{2,t}}{\widehat{H}_{1,t}}\right) \cdot 2\phi\alpha_{12} (1 - \widehat{\gamma}_1^*) \\ A\left(\frac{\widehat{H}_{1,t}}{\widehat{H}_{2,t}}\right) \cdot 2\phi\alpha_{21} (1 - \widehat{\gamma}_2^*) & 1 + \phi - \delta \end{bmatrix} \begin{bmatrix} \widehat{H}_{1,t} \\ \widehat{H}_{2,t} \end{bmatrix}. \quad (19)$$

This system is conceptually the same as the one introduced by Ben-David and Loewy (1998). They show that the steady-state growth rate of knowledge equals the system's maximum eigenvalue minus one and that the ratio of knowledge stocks in the steady state, $\widehat{H}_{1,t} / \widehat{H}_{2,t}$, corresponds to the ratio of elements of the associated eigenvector. After a bit of algebra, the steady-state rate of growth of knowledge, $\widehat{\rho}_H$, can be shown to equal

$$\phi - \delta + \left(\frac{\widehat{H}_{1,t}}{\widehat{H}_{2,t}}\right)^\mu \cdot 2\phi \left[\alpha_{12}\alpha_{21} (1 - \widehat{\gamma}_1^*) (1 - \widehat{\gamma}_2^*) \right]^5 \quad (20)$$

where it is assumed without loss of generality that $\widehat{H}_{1,t} / \widehat{H}_{2,t}$ is less than one.²⁰

From eqs. (3) and (20), the steady-state rate of growth of output per capita in country i , $\widehat{\rho}_{y_i}$, satisfies $1 + \widehat{\rho}_{y_i} = (1 + \widehat{\rho}_H)^{\varepsilon_i}$. 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 in general will not equal each other. To see why, suppose that $\varepsilon_1 = \varepsilon_2 = \varepsilon$. Results in Ben-David and Loewy (1998) then imply that the

eigenvector associated with $1 + \widehat{\rho}_H$ satisfies $\frac{\widehat{H}_{1,t}}{\widehat{H}_{2,t}} = \left(\frac{v_{12}}{v_{21}}\right)^5 = \left(\frac{\alpha_{12}(1 - \widehat{\gamma}_1^*)}{\alpha_{21}(1 - \widehat{\gamma}_2^*)}\right)^5$. Substituting

this expression into the measure of relative income determined by eq. (3) implies that steady-

²⁰ If not, then the ratio of knowledge stocks must be taken to the $-\mu$ power. This, of course, leaves the value of $\widehat{\rho}_H$ unchanged.

state relative income satisfies $\frac{\widehat{y}_{1,t}}{\widehat{y}_{2,t}} = \left(\frac{\widehat{\gamma}_1^{\theta_1}}{\widehat{\gamma}_2^{\theta_2}} \right) \left(\frac{\alpha_{12}(1-\widehat{\gamma}_1^*)}{\alpha_{21}(1-\widehat{\gamma}_2^*)} \right)^{.5\varepsilon}$. Therefore, if $\alpha_{12} \neq \alpha_{21}$ and/or

$\theta_1 \neq \theta_2$ (which implies that $\widehat{\gamma}_1^* \neq \widehat{\gamma}_2^*$), then relative income will not typically equal one. Moreover, since $\widehat{\gamma}_1^*$ is itself an increasing function of θ_1 , it follows that an increase in θ_1 , say, has countervailing effects on relative income. On the one hand, such an increase raises $\widehat{\gamma}_1^*$ which in turn raises output because public spending is productive. On the other hand, a higher value of $\widehat{\gamma}_1^*$ necessitates a higher income tax rate (recall that the steady-state tariff equals zero) which in turn negatively impacts trade and hence knowledge accumulation. Last, since $\widehat{\gamma}_1^* < 1$, an increase in θ_1 implies that the productivity of public spending is lower for any given value of $\widehat{\gamma}_1^*$ which is income reducing. These issues notwithstanding, in the calibration 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 on-going increase in $y_{1,t}/y_{2,t}$ along the transition will ultimately imply that $\alpha_{12} = \alpha_{21}$ and $\theta_1 = \theta_2$.

CALIBRATION

To illustrate the behavior of the model along the transition to the steady state, I consider a simulation in which the behavior 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 calibration, at each point in time, I place each of the model's two countries 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 the theory section, I again let Country 1 be the "poor" economy and Country 2 be the "rich" economy. In particular, I classify Country 2 as High Income 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.

To determine when Country 1 transitions from one income group to another, I use the data in Table A1. Although the figures in the table are for the year 2000 rather than 1999, I use relative income to determine when a switch occurs. Thus, the difference in reference years is not problematic. 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. Thus, when Country 1's income per capita relative to that of Country 2 reaches 2.7% ($\$756/\$27,510$), 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% ($\$2996/\$27,510$) and then as High Income when its relative income per capita reaches 33.7% ($\$9266/\$27,510$).

Next, I use data contained in Table 4.9 of the *WDI 2001* to calibrate values for α_{12} and θ_1 for the lower and two middle-income groups and for α_{21} and θ_2 for the High Income group. Table 3 provides the source data drawn from *WDI 2001* Table 4.9 for 1999. In the table, **c**, **i**, and **g** represent the average 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 (to proxy for a balanced budget in the model).²¹ These data must 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, but investment (both private and public) is absent.

Table 3: WDI Data on Structure of Demand (% of GDP)

	Low Income	Lower Middle Income	Upper Middle Income	High Income
c	68	57	61	62
i	22	26	22	22
g	11	14	15	16
m	25	29.5	26	21.5

To calibrate the three values of α_{12} and the single value of α_{21} I instead determine the α_{11} 's and α_{22} and subtract the computed value from one. To derive each of the α_{ii} 's I first normalize **c**, **i**, and **g** by dividing each by the sum of the three in order to impose trade balance. Denote these ratios as \mathbf{c}^{bal} , \mathbf{i}^{bal} , and \mathbf{g}^{bal} . Second, I assume that the shares of \mathbf{c}^{bal} , \mathbf{i}^{bal} , and \mathbf{g}^{bal} derived from domestically produced goods (rather than from imports) is equal to $1 - \mathbf{m}$ times each term. Thus, let the share of domestic consumption in income, \mathbf{c}^{dom} , be defined as $\mathbf{c}^{\text{dom}} = (1 - \mathbf{m})\mathbf{c}^{\text{bal}}$ with \mathbf{i}^{dom} and \mathbf{g}^{dom} defined similarly. It then follows that $\mathbf{c}^{\text{dom}} + \mathbf{i}^{\text{dom}} + \mathbf{g}^{\text{dom}} + \mathbf{m} = 1$. Third, because investment is absent in the model, \mathbf{c}^{dom} , \mathbf{i}^{dom} , and \mathbf{m} are adjusted for this absence by dividing each by $1 - \mathbf{i}^{\text{dom}}$, the share of output that does not go to domestic investment. The resulting measure of the share of domestic consumption in investment-adjusted income, $\mathbf{c}^{\text{dom}}/(1 - \mathbf{i}^{\text{dom}})$, can be taken as the empirical counterpart to $c_{ii}/y_i = \alpha_{ii}(1 - \sigma_i)$ (where the time subscript has been dropped to simplify the notation). Therefore, if an estimate for σ_i can be obtained, then α_{ii} is determined.

Recall that the income tax rate is a choice variable for the government. Hence, its value cannot be pinned down except in the steady state where it equals the steady-state share of government spending in output, $\widehat{\gamma}_i^*$. This, of course, merely shifts the calibration problem from one of pinning down $\widehat{\sigma}_i^*$ to one of pinning down $\widehat{\gamma}_i^*$. Given the discussion in the previous paragraph, a natural approach to take here is to calibrate $\widehat{\gamma}_i^*$ to the share of domestic government spending in investment-adjusted income. Thus, $\widehat{\sigma}_i^* = \widehat{\gamma}_i^* = (\mathbf{g}^{\text{dom}})/(1 - \mathbf{i}^{\text{dom}})$. Substituting this expression into the one for c_{ii}/y_i , setting it equal to $\mathbf{c}^{\text{dom}}/(1 - \mathbf{i}^{\text{dom}})$, and simplifying implies that

²¹ In the WDI, the difference between exports' and imports' shares of output vary between one and three percentage points.

$$\alpha_{ij} = 1 - \frac{\mathbf{c}^{\text{dom}}}{\mathbf{c}^{\text{dom}} + \mathbf{m}}. \quad (21)$$

Last, since $\widehat{\gamma}_i^* = \theta_i / (1 + \theta_i)$, calibrated values for θ_i follow directly from those of $\widehat{\gamma}_i^*$. Table 4 provides the computed values for α_{ii} , α_{ij} , $\widehat{\gamma}_i^*$, and θ_i for each of the four World Bank Income Groups.

Table 4: 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
$\widehat{\gamma}_i^*$	0.098	0.125	0.136	0.152
θ_i	0.109	0.143	0.157	0.179

As noted previously, in order that steady-state relative income be well defined it must be the case that $\varepsilon_1 = \varepsilon_2 = \varepsilon$. Therefore, to complete the specification of the model, it remains to assign values to ε , ϕ , δ , ψ , and μ as well as to determine the economy's two initial values, $H_{1,0}$ and $H_{2,0}$. To calibrate ε , ϕ , and δ , I first utilize the result that the model implies income convergence in the long run since eventually Country 1 enters the High Income group and so satisfies $\alpha_{12} = \alpha_{21}$ and $\gamma_1^* = \gamma_2^*$. Using data in Easterly and Yu (2000), I set this common steady-state rate of growth of income per capita equal to 2.53%. This corresponds to the average rate of growth over the 1979 – 1999 period of the ten most-open countries that in 1979 had an income relative to the U.S. in excess of 34% and so would have qualified (by year 2000 standards) as a High Income country.²² By excluding the years 1960 – 1979, a period during which many of these nations may have been experiencing faster growth associated with transitional dynamics, the 1979 – 1999 period offers a plausible estimate of the steady-state rate of growth of a group of relatively open, high-income economies. From eq. (20) we then have that

$$\left[1 + \phi - \delta + 2\phi\alpha_{21} \left(1 - \widehat{\gamma}_2^* \right) \right]^\varepsilon = 1.0253$$

where convergence implies that $\widehat{H}_{1,t} = \widehat{H}_{2,t}$. Second, I utilize the result that initially Country 2 will be growing at very nearly the autarky rate of $(1 + \phi - \delta)^\varepsilon$ because the large gap in initial knowledge stocks implies that $a_{12} = a_{21} \approx 0$. Since the United States has the lowest

²² The countries included are Austria, the Bahamas, Barbados, Belgium, Hong Kong, Ireland, Israel, Luxembourg, the Netherlands, and Singapore. Between 1979 and 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%. Data source: Easterly and Yu (2000). Using 1979 rather than 2000 as the year determining whether a country qualifies as High Income eliminates the type of bias described by De Long (1988). If the year 2000 were to be used, then Austria and Israel would be replaced by Malta and Taiwan. This raises the average rate of growth to 3.13% and the average ratio of total trade to GDP to 1.66.

average ratio of total trade to GDP of any High Income country over the 1979 – 1999 period, namely 21%, I assume that the initial rate of growth of output per capita in Country 2 equals 1.60%, the average value of per capita growth for the United States over the period 1979 – 1999.²³ It follows that $(1 + \phi - \delta)^\varepsilon = 1.0160$. Third, I calibrate the rate of growth of knowledge in autarky, $\phi - \delta$, by setting it equal to the average rate of growth in the number of U.S. patents issued to U.S. residents over the 1979 – 1999 period. Using data from the U.S. Patent and Trademark Office (2002), this value is found to equal 4.15%.²⁴ Solving these three restrictions simultaneously, I find that $\varepsilon = 0.3905$, $\phi = 0.0471$, and $\delta = 0.0055$.

To calibrate ψ I equate the $t = 0$ ratio of tariff revenue to total government revenue for Country 1,

$$\chi_{1,0} = \frac{\tau_{12,0}^* \alpha_{12} (1 - \sigma_{1,0}^*) / (1 + \tau_{12,0}^*)}{\sigma_{1,0}^* + \tau_{12,0}^* \alpha_{12} (1 - \sigma_{1,0}^*) / (1 + \tau_{12,0}^*)}, \quad (22)$$

to the 1998 share of tariff revenue in total government revenue of the World Bank's South Asia group. I opt to use the South Asia group rather than the Low Income group since there does not exist any government revenue data for the Low Income group (see *WDI 2001* Table 4.13). This substitution is not problematic since the 1999 per capita incomes of the two groups are roughly equal, \$440 vs. \$420.

WDI 2001 Table 4.13 provides 1998 data on the shares of total government revenue derived from five types of taxes plus nontax revenue.²⁵ To obtain an empirical counterpart to $\chi_{1,0}$, suppose, as was done above, that total government revenue equals total government spending. Next, since nontax revenue is fundamentally different from the other five revenue sources, I do not include it the calibration of $\chi_{1,0}$. Hence, I take the empirical counterpart to eq. (22) to be the ratio of taxes on international trade to the sum of taxes on income, profits, and capital gains plus social security taxes plus taxes on goods and services plus taxes on international trade plus other taxes.²⁶ From *WDI 2001* Table 4.13 it follows that $\chi_{1,0} = 0.257$.²⁷ Given this value, the values of α_{12} , ε , and $y_{1,0}$, the value of θ_1 for the Low

²³ Data source: Easterly and Yu (2000).

²⁴ Although the U.S. is not in autarky with regard to issuing patents any more than it is in autarky with regard to international trade, I restrict matters to U.S. residents to be consistent with the notion that the U.S. growth rate corresponds to the autarky growth rate. When the number U.S. patents issued to foreigners are included, then the average growth rate of patents rises to 4.98%, a reflection of the growing share of patents issued to non-residents. This issue notwithstanding, whether patents represent a reasonable proxy for knowledge is open to debate. See the comments of Jones (2002, p. 91) for example.

²⁵ The five types of taxes are (i) taxes on income, profits, and capital gains; (ii) social security taxes; (iii) taxes on goods and services; (iv) taxes on international trade; and (v) other taxes.

²⁶ Since the model only includes tariffs and income taxes, this approach clearly overstates the share of income taxes in government revenue, $1 - \chi_{1,0}$. This difference does not change the descriptive aspects of the simulation, however.

²⁷ 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 1995-7 data on tax revenue by type as a percentage of GDP for a different group of developing countries. Making comparable calculations of $\chi_{1,0}$ 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 $\chi_{1,0}$ are quite consistent with one another.

Income group, the production function, government budget constraint, first-order conditions, and definition of $\chi_{1,0}$, eqs. (3), (9), (13), (14), and (22), can be solved simultaneously for $\tau_{12,0}^*$, $\sigma_{1,0}^*$, $\gamma_{1,0}^*$, $H_{1,0}$, and ψ . In particular, $\psi = 0.541$. By substituting in the relevant parameters for Country 2, these same equations, less eq. (22), are used to obtain $\tau_{21,0}^*$, $\sigma_{2,0}^*$, $\gamma_{2,0}^*$, and $H_{2,0}$.

The law of motion for Country 1's knowledge stock, eq. (16), is used to calibrate μ . Examination of the equation shows that the only value that is as yet unknown (save for μ of course) is $H_{1,1}$. This value is found by first calibrating a value for the initial growth rate of Country 1 income per capita and then using it to determine a value for $y_{1,1}$. Once this value is known, eqs. (3), (9), (13), and (14) are used to obtain a value for $H_{1,1}$ (among other things).

Consider, then, calibrating Country 1's initial growth rate. Recall that Country 1 is taken to be a "poor" country that starts liberalizing trade in period 0. Thus, one estimate of its initial rate of growth is to use the average rate of growth of countries that were "poor" in 1960 and experienced substantial increases in their degrees of openness since this time. Using data in Easterly and Yu (2000), I first calculate (wherever possible) the average ratio of total trade to GDP for 1960 – 1979 and for 1979 – 1999 and then take the difference. Second, I consider the ten countries with the largest differences that have incomes in 1960 that are at most 20% of that of the U.S.²⁸ Third, I 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, namely one associated with it now being more open. This value, 4.52%, is then taken to be the initial growth rate of Country 1 and implies that $y_{1,1} = 439$. Solving the system of equations listed above for $H_{1,1}$ and substituting the value into eq. (16) implies that $\mu = 0.9003$. Therefore, the share of accessible Country 2 knowledge that Country 1 can utilize increases almost linearly. This in turn implies that Country 1's income per capita will converge to that of Country 2 quite slowly.

Figure 4 shows the evolution of the optimal tariff and income tax rates in Country 1. Figure 5 shows the rate of growth for both countries while Figures 6 and 7 plot for Country 1 the share of tariff revenue and income tax revenue in government expenditure as a function of Country 1's income per capita relative to that of Country 2. Given the initial values of income per capita for the two countries, $y_{1,0} = 420$ and $y_{2,0} = 26440$, and the calibrated value of ψ , it follows that $\tau_{12,0}^* = 8.84\%$, $\sigma_{1,0}^* = 7.21\%$, $\tau_{21,0}^* = 1.03\%$, and $\sigma_{2,0}^* = 14.96\%$. Note that consistent with the discussion in Section 4, Country 2's high initial level of income per capita implies that its optimal tariff and income tax rate are nearly equal to their steady-state values of 0% and 15.2%. This implies that Country 2 initially raises just 1.73% of its government revenue through the tariff. On the other hand, as Figure 6 shows, Country 1 initially raises 25.7% of its revenue through the tariff (per the calibration) and this share falls (with one exception) as Country 1 develops.

²⁸ The ten countries in the sample 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%. Moreover, their average share of U.S. income in 1960 equals 13%. Although the choice of 20% is arbitrary, it is roughly midway between the switch points from Lower Middle to Upper Middle Income, 10.9% and from Upper Middle to High Income, 33.7%. In addition, data limitations for many of the poorest countries preclude reducing my upper bound much below 20%. Data source: Easterly and Yu (2000).

As shown in Figure 5, Country 1 initially grows at the calibrated rate of 4.52% while Country 2 initially grows at the autarky rate of 1.60% since $A(H_{1,0}/H_{2,0}) \approx 0$. This difference allows Country 1's income to rise relative to that of Country 2. At period 20, this ratio now exceeds 2.7%, the value at which Country 1 switches from the Low Income group to the Lower Middle Income group. From Table 4 this implies that its share of after-tax income spent on imported goods, α_{12} , rises sharply as does its income elasticity of public spending, $\theta_1/(1 + \theta_1)$. Given the rise in this elasticity, and hence the rise in the steady-state ratio of government spending to output, $\widehat{\gamma}_1^*$, both the tariff rate and the income tax rate increase with $\tau_{12,t}^*$ rising from 5.7% to 6.3% and $\sigma_{1,t}^*$ increasing from 8.1% to 10.3% (see Figure 4). For the same reason, Figure 8 shows that the ratio of public spending to output, $\gamma_{1,t}^*$, increases sharply. As is to be expected, the rise in the tariff and tax rates imply that Country 1 temporarily experiences an increase in its share of government revenue derived from tariffs, $\chi_{1,t}$, from 16.8% to 17.8%.

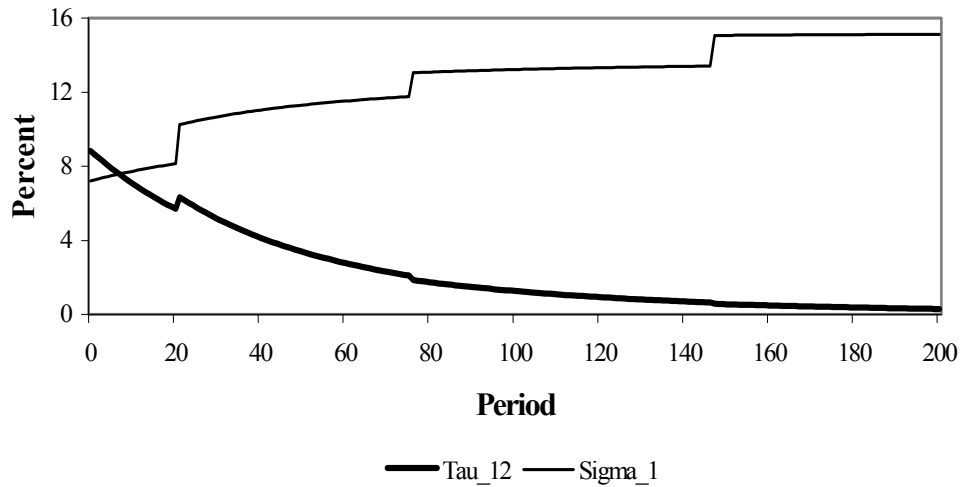


Figure 4: Country 1 Tariff and Income Tax Rates

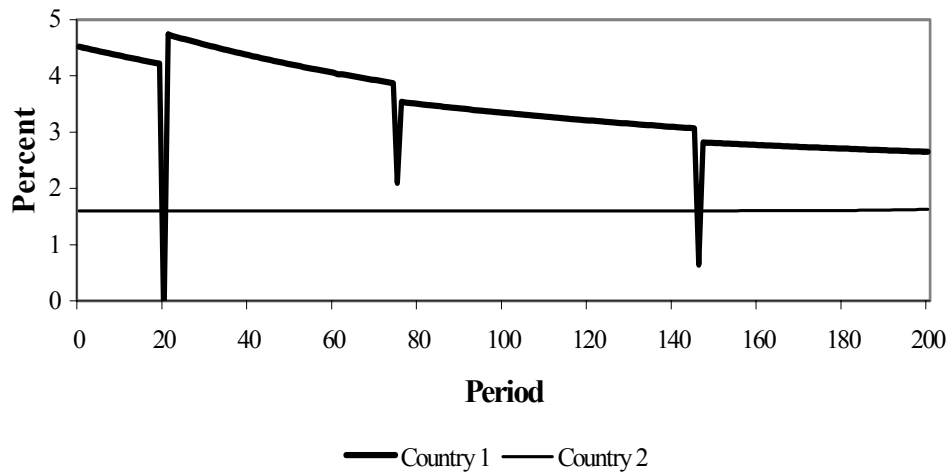


Figure 5: Rates of Growth

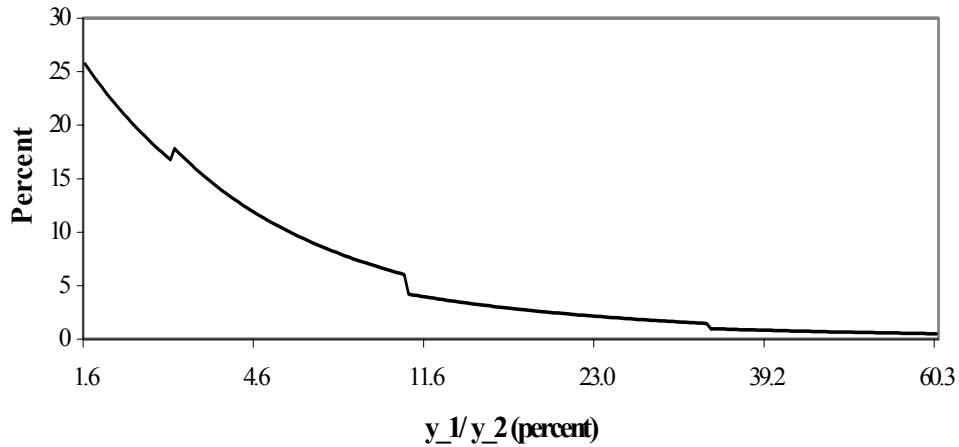


Figure 6: Country 1 Tariff Revenue as Share of Government Revenue

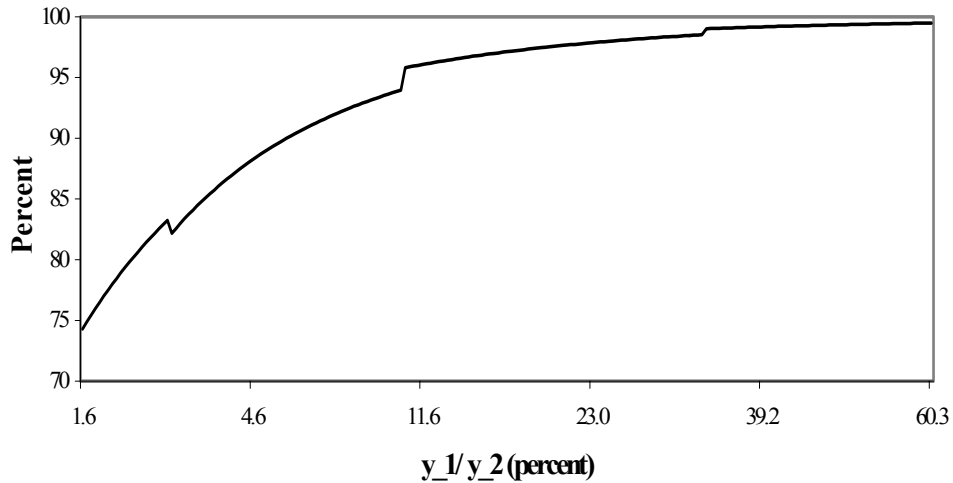


Figure 7: Country 1 Income Tax Revenue as Share of Government Revenue

Returning to Figure 5, although the increases in $\tau_{12,t}^*$ and $\sigma_{1,t}^*$ are both growth reducing since they each decrease trade while the increase in α_{12} is growth enhancing since it increases trade, the negative spike in the growth rate of Country 1 is in fact due to the sharp rise in θ_1 . Specifically, even though $\gamma_{1,t}^*$ rises which increases output *ceteris paribus*, the increase in θ_1 reduces output because $\gamma_{1,t}^*$ is less than one. In this instance, the second effect is large enough to cause Country 1's income to actually fall in the period in prior to when the switch takes place because growth in period t is measured as $y_{1,t+1}/y_{1,t} - 1$. Concentrating on behavior on either side of the spike (since it is idiosyncratic to the model), Country 1's rate of growth rises from 4.22% in period 19 to 4.73% in period 21 since the strong growth-enhancing effect of the rise in α_{12} more than offsets the growth-reducing effect of the rise in $\tau_{12,t}^*$ and $\sigma_{1,t}^*$. On the other hand, since μ equals 0.90, knowledge spillovers from one country to another are

negligible when Country 1's relative income is small. Thus, Country 2 continues to grow at roughly the autarky rate of 1.60%.

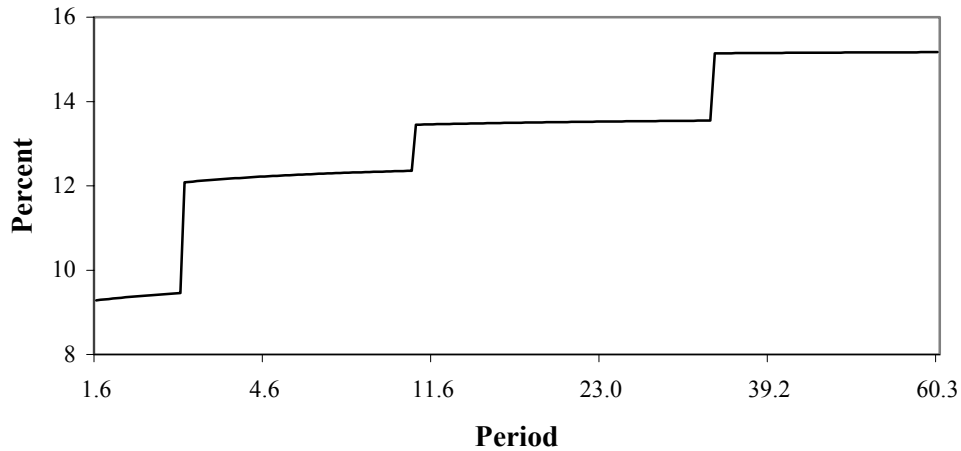


Figure 8: Country 1 Government Spending as Share of Output

Country 1 remains in the Lower Middle Income group until period 75 at which time its relative income surpasses 10.9% and it enters the Upper Middle Income group. Although the steady-state size of Country 1's public sector once again rises, its income level is now sufficiently high that its optimal tariff rate nevertheless drops from 2.10% to 1.85%. As expected, this necessitates an increase in the income tax rate from 11.76% to 13.05% (see Figure 4). Since the Upper Middle Income group devotes a smaller share of its after-tax income to imports than does the Lower Middle Income group, Figure 5 shows Country 1's rate of growth dropping from 3.87% in the period before the spike to 3.54% in the period following the spike with the source of the spike as before. Once again, given the relatively slow rate at which accessible knowledge spills over from one country to another, Country 2 continues growing at roughly 1.60%. Naturally, the rise in Country 1's tax rate coupled with the drop in its tariff rate reduces $\chi_{1,t}$ from 6.04% to 4.19% (see Figure 6). Last, Figure 8 shows that the rise in the income elasticity of the government's share of output causes a second jump in the actual share with $\gamma_{1,t}^*$ rising from 12.35% to 13.45% – that is from slightly less than its Lower Middle Income steady state value to slightly less than its Upper Middle Income steady state value.

Country 1's declining rate of growth coupled with the low rate of knowledge spillovers implies that it is not until period 146 that Country 1 enters the High Income group. At this point, it is identical to Country 2 save for its income level and hence its optimal tariff, income tax rate, and share of government spending. This switch again entails a decline in α_{12} coupled with an increase in θ_1 and therefore in $\hat{\gamma}_1^*$. Figures 4 and 8 show that Country 1 again experiences a decline in its tariff rate, from 0.645% to 0.575%, an increase in its income tax rate, from 13.41% to 15.06%, and an increase in its share of government spending, from 13.56% to 15.14%. Since Country 1's import sector falls and this effect dominates the effects of the changes in the tariff and tax rate, Figure 5 shows that its rate of growth drops from

3.07% in the period prior to the negative spike to 2.82% in the period following the spike.²⁹ There is also a modest decline in the share of government revenue derived from the tariff, from 1.47% to 0.98% (see Figure 6).

If the simulation continued beyond period 200, Country 1's relative income would be seen to continue rising, albeit slowly, a result that is consistent with simulations that Lucas (2002, ch. 4) reports.³⁰ However, as this ratio increases, eq. (7) implies that both countries will begin to experience increasing knowledge spillovers.³¹ In particular, these spillovers ultimately cause Country 2's rate of growth to increase. In the limit, incomes and growth rates converge and, as shown in Section 4, $\widehat{\sigma}_1^* = \widehat{\gamma}_1^* = \widehat{\sigma}_2^* = \widehat{\gamma}_2^* = 0.152$, $\widehat{\tau}_{12}^* = \widehat{\tau}_{21}^* = 0$, and $\widehat{H}_{1,t} / \widehat{H}_{2,t} = 1$. From eq. (20) it follows that the steady-state rate of growth of knowledge in each country equals 9.51% and hence that the steady-state growth rate of output per capita equals its calibrated value of 2.53%. Since this value exceeds that of autarky, 1.6%, it follows that both countries benefit from Country 1 opening itself to trade.

Empirically, the key results of the calibration are shown in Figures 6, 7, and 8. These figures show that the model is qualitatively consistent with the evidence presented in Tables 1 and 2 and Figures 1 – 3. In particular, Figure 6 shows that the model delivers the inverse relationship between tariffs' share of government revenue and per capita income that is evident in column 2 of Table 1 and in Figure 1.

Figure 7 shows that the model also delivers the positive relationship between the share of non-tariff indirect taxes in government revenue and per capita income seen in column 6 of Table 1 and in Figure 2. Note that this share is much larger in the calibration (at least 75%) than in the data (between 18% and 30%). As pointed out in footnote 26, this difference reflects the inclusion of four more revenue sources in the data than in the model. For example, in 1998 countries worldwide earned, on average, 58% of government revenue from all of these sources together versus 19% from income taxes alone (see *WDI 2001* Table 4.13).

Consider next the model's take on Wagner's Law. Figure 8 is consistent with the data presented in Table 2 and with what appears in Figure 3, at least through 1986, the point in time where the time-series evidence on Wagner's Law becomes questionable. Moreover, Figure 8 shows that the share of government purchases in output rises not just with a switch in income group (which brings about a rise in θ_1), but also with the level of income *within* each of the income groups. This feature is particularly visible in the Low and Lower Middle Income groups.

²⁹ As before, the negative spike reflects the effect of the increase in θ_1 on the current level of output, and hence on the growth rate, that dominates the effect of the increase on $\gamma_{1,t}^*$.

³⁰ Lucas (2002, ch. 4) simulates a closed-economy growth model in which the initial rate of growth of a "poor" country is a decreasing function of its initial income relative to that of the leading country at the time that the poor country begins to develop. See, in particular, Lucas's Figure 4.3 and its associated discussion (pp. 102-103).

³¹ Although not visible in the figure, in fact the rate the growth of Country 2 has increased to 1.63% by period 200. That there is so little increase over 200 periods is due to the very slow rate of increase in spillovers caused by μ nearly being equal to one.

CONCLUSION

Both cross-section and time-series data suggest that as their level of income per capita rises, developing nations find it optimal to substitute various types of indirect taxation for tariffs and increase the relative size of their public sectors. A common explanation for the first of these behaviors, and one that is utilized here, is that non-tariff forms of indirect taxation such as income taxes are subject to administrative costs that for low-income countries are prohibitively high at the margin. If administrative costs per unit of revenue collected decline with income, then as these nations grow they will find it optimal to substitute an income tax for tariffs. The second of these behaviors, what is commonly referred to as Wagner's Law, is thought to be the result of political economy considerations. Since these considerations are beyond the scope of this chapter, Wagner's Law is instead viewed as being a consequence of the productivity of government spending on goods and services that are subject to congestion costs.

This chapter confronts the data using a two-country endogenous-growth model in which growth is driven by knowledge accumulation that in turn depends upon the tariff rate and income tax rate of both countries. In the model, neither government is assumed able to internalize the impacts that its current choices of tariff and tax rates have on its future decisions. Under this and other strong assumptions regarding saving and labor supply, each government's choices of tariff and income tax rates is shown to be the solution to an optimal taxation problem where the government must raise sufficient revenue to cover both its expenditures and the administrative costs of the income tax. In addition to considering the model's steady state, a calibration of the model using data drawn from Easterly and Yu (2000) and the *World Development Indicators 2001* is used to analyze the model's transitional dynamics. The calibration produces a time path for the share of government revenues derived from the tariff and from the income tax, and for the share of government spending in output that match what is found in the data.

It is now well documented that there exists little empirical evidence in support of (absolute) convergence among the nations of the world. Growth models such as the one considered here suggest that a factor contributing to the absence of convergence is the high tariff rates seen in low-income countries. This chapter carries this line of argument one step further by suggesting that it may in fact be optimal for low-income nations to choose to impose high tariffs (despite their negative consequences for growth) since to do otherwise is too costly at the margin. Therefore, the model implies that not only are high tariffs part of the reason that low-income nations are poor, but also that because they are poor, these countries find it optimal to rely on high tariffs. These conclusions suggest that low-income countries find themselves in a sort of trap. However, this is not necessarily the case. Since the model also implies that given sufficient time (and according to the calibration, this could be several hundred years), the substitution of an income tax (or other forms of indirect taxation) for tariffs will bring about a rise in relative income and with it, convergence. Thus, the model's predictions for convergence are consistent with results that Lucas (2002, ch. 4) reports.

DATA APPENDIX

Table A1: World Bank Income Groups (2000\$)

	Low Income	Lower Middle Income	Upper Middle Income	High Income
Income Range	≤ \$755	\$756 – \$2995	\$2996 – \$9265	\$9266 ≤
Average Income	\$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 2: % G/Y; *World Development Indicators 2001*, Table 4.9

Table A1: *World Development Indicators 2001* database

Figures 1 – 3: % Tariff Rev., % Income, Profits, and Capital Gains Tax Rev., % Goods and Services Tax Rev.; *Government Finance Statistics Yearbook* (various issues) and Easterly and Yu (2000)

% G/Y, Real GDP per Capita; Heston, Summers, and Aten (2002)

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:

Brazil, Chile, Costa Rica, Korea (South), Malaysia, Mauritius, Mexico, Panama, South Africa, Turkey, Uruguay, Venezuela

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