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Foreign Aid Policy and Sources of Poverty:
A Quantitative Framework

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Abstract

The econometric literature has been unable to establish a robust association between foreign
aid and growth and poverty reduction. In this paper we argue that aid effectiveness must be
assessed using methods that go beyond cross-country regressions. We calibrate a dynamic
general equilibrium model that is capable of generating large income gaps between rich and
poor countries. The model quantifies three sources of poverty: (i) lack of access to
international capital, (ii) low schooling and high fertility (a poverty trap), and (iii) antigrowth
domestic fiscal policy. We analyze policies designed to address each source of poverty and
estimate and compare the aid cost of implementing the different policies. The policies differ
dramatically in the extent and timing of their growth effects, and in the aid cost of their
implementation.

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written in part while Rangazas was a visiting scholar at the IMF Institute. We thank participants
at an INS Seminar and Lupin Rahman for useful comments and suggestions on an earlier draft.

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I. INTRODUCTION

A key challenge facing the international community is how to increase the effectiveness of foreign aid in poverty-reduction efforts around the world. Despite large amounts of foreign aid—and several countries that were able to successfully utilize foreign assistance in their development and poverty-alleviation strategies—the effectiveness of foreign aid remains in doubt. Econometric methods have not identified a robust correlation between aid and growth (e.g., Easterly, Levine, and Roodman, 2004). Several surveys of the evidence conclude that aid has not led to increased growth and may have even worsened the economic performance of the countries receiving aid (e.g., Easterly,2001; and Stiglitz, 2003). Recent studies continue to paint a mixed picture (see Isard and others, 2006). For example, Radelet, Clemens, and Bhavnami (2006) report robust evidence that aid targeted to infrastructure has quick growth payoffs. On the other hand, Rajan and Subramanian (2005) find that aid may have adverse long-run effects, by worsening a country's competitiveness.[2]

One fundamental reason for the lack of consensus regarding the effectiveness of foreign aid is professional ignorance about the sources of growth (e.g., Azariadis and Stachurski, 2004, p.1; and Rodrik, 1999, 2004) and the policies that are most likely to generate growth (Feldstein, 1998; and Pronk 2001). It is clear that quantitative assessments of the impact of foreign aid policy on growth and poverty reduction must go beyond standard econometric approaches. A promising research strategy is to investigate the effectiveness of foreign aid using calibrated dynamic general equilibrium models. This approach has been used extensively to evaluate domestic fiscal policy (e.g., Auerbach and Kotlikoff , 1987) and trade policy (e.g., Deardorff and Stern, 1990). The advantages of a dynamic computational general equilibrium models include the ability to (i) assess longer-run growth effects, (ii) identify causal mechanisms, (iii) link microeconomic data and estimates to the macroeconomy, (iv) consider welfare effects, and (v) evaluate policy reforms that have never been attempted or have been attempted too infrequently to conduct an econometric analysis.

In this paper, we investigate the effects of aid in specific computational general equilibrium model. Our model satisfies four principles that, we believe, *any* computational model used to assess aid policy should follow.

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[2] Radelet, Clemens, and Bhavnami (2006) base their conclusions on the findings of Clemens, Radelet, and Bhavani, (2004), who argue that one reason for the lack of correlation is the aggregation of different types of aid into one composite measure. They find that aid designed to stimulate growth within a short time horizon (e.g., aid for budget support or infrastructure investment) does have a robust positive correlation with growth in regressions using four-year panel data across countries. However, they express doubts about the ability of econometric methods to identify the effects of aid designed to achieve growth over longer horizons (e.g., aid for health and schooling, or even the supply-side effects of larger infrastructure projects).

First, before jumping to policy evaluation, the underlying model *should be able to explain (replicate) significant growth experiences* such as the gradual steady growth of Western countries for over a century (including the economic transformation and demographic transition), the explosive growth miracles of some developing countries after World War II, and the huge differences in worker productivity across rich and poor countries today. Confidence in policy recommendations stem directly from the performance of the underlying model from which they are derived. The current academic standard for development models is that they be able to explain one or more of the growth experiences mentioned above. Since all of these growth experiences have proved difficult to replicate, following this principle will significantly narrow the candidate models that will be used to evaluate aid policy.

Second, *the fundamental sources of poverty, or the barriers to growth, should be identified*. It is not enough to identify the "proximate" or immediate sources of poverty—such as a lack of factor accumulation or technological adoption. The most important and deepest causes of poverty, the reasons factors are not accumulated or technologies adopted, must be identified to focus policy efforts effectively. This requires that one uncover the microeconomic foundations of poverty. Explicit microeconomic foundations also allow welfare effects to be computed.

Third, *the aid cost of achieving growth through alternative polices should be estimated*. Some sources of poverty are likely to be easier to eliminate than others. Pro-poor, pro-growth reforms favored by donors are likely to be resisted by domestic interest groups in low-income countries. Such groups exert decisive influence over government policy objectives in many countries, leading to political-economic equilibria characterized by inefficient policies. Whether because of direct reform conditions stipulated in aid policies, or because of the indirect response to the aid policy, domestic policy will change when aid is extended. Thus, to calculate the cost of successfully implementing reforms, the model must take a stance on how existing government policies are set. One can then determine how much aid is necessary to convince governments to adopt and support particular reform recommendations that they would otherwise oppose.

Fourth, *some insight should be provided on the reasons why regression analysis has been unable to estimate a robust positive correlation between aid and growth.* As indicated above, regression studies seem to indicate that aid policies have had mixed success at best in improving economic growth. The absence of an aid-growth correlation in regression studies is a stylized fact in itself which models should attempt to explain.

Below we present a model that follows these four principles. While the model is primarily put forth as a prototype of how the principles can be implemented, it also generates some insights for the formation of aid policy. The model satisfies the four principles in the following ways.

First, the basic features of the model are taken from a growth model that replicates worker productivity, fertility, interest rates, and schooling in United States from 1800 to 2000 (Lord and Rangazas, 2005). In addition, the model can generate large differences in worker productivity across countries today.

Second, three fundamental sources of low worker productivity are identified: (i) a closed economy, (ii) a poverty trap that keeps schooling low and fertility high, and (iii) a selfish government that sets taxes and government investment to maximize its own consumption.

Third, we examine three reform policies that address the three sources of low incomes in poor countries. In each case we take into account the domestic government's willingness to adopt the policy, which shapes its policy response to the conditions attached to foreign aid. The first policy simply opens the economy to trade and external capital flows. The second is a policy that provides funds to subsidize families for some of the forgone income associated with sending their older children to school, similar to Mexico's Progresa program.[3] The third policy aims to reform domestic fiscal policy so as to increase growth by lowering taxes and increasing public investment.

Fourth, we identify reasons why aid policies may produce disappointing outcomes as measured by regression techniques. The failures relate to the high cost of aid required to induce certain reforms and the professional ignorance about what policies best promote growth.

Section II compares our approach to others that use computational models to analyze the effects of aid. Section III presents the model. Section IV calibrates the model and demonstrates its ability to generate large income differences across countries. Section V analyzes three development policies. Section VI estimates the aid cost of implementing each of the policies from section V. Section VII discusses why some aid polices might not be positively correlated with growth. Section VIII suggests some extensions to the prototype model that are needed for it to be taken seriously as the basis for policy evaluation.

II. RELATED LITERATURE

Several recent studies use calibrated dynamic general equilibrium models to examine aid-related issues. These works differ from ours across three dimensions. First, there are differences in focus. Our goal is to link the analysis of aid to the academic study of economic development in general and to the policies that may eliminate poverty traps or speed transitional growth. In our study, aid is secondary to the task of identifying effective pro-growth policies. Other studies have instead focused more directly on aid with an emphasis on sectoral and distributional effects of aid (Adam and Bevan, 2004 and Agénor, Bayraktar, and El Aynaoui, 2004), the volatility of aid (Arellano and others, 2005), and the comparison of tied and untied aid (Chatterjee, Sakoulis, and Turnovsky, 2003; and Chatterjee and Turnovsky, 2004, 2005). In this sense, the different studies are complementary.

Second, there are significant differences in the models used that are largely driven by the differences in focus. Our objective requires the model to contain a mechanism of the basic determinants of long-run growth, such as savings, education, and fertility. A model of physical capital accumulation alone, as in Arellano and others (2005) and the papers by

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[3] Programa de Educación, Salud y Alimentación.

Chatterjee and his coauthors, does not suffice because of the well-known fact that physical capital differences do not explain large productivity differences across time and space (e.g., King and Rebelo, 1993; and Parente and Prescott, 2000). In addition, we need to identify the barriers to growth: poverty traps and anti-growth policies. In our initial attempt at these tasks we abstract from the sectoral and distributional issues that are the primary focus of Adam and Bevan (2004) and Agénor, Bayraktar, and El Aynaoui (2004). In turn, they must compromise by having exogenous sources of growth and exogenous domestic fiscal policy.

Finally, there are differences in methodology or modeling principles. In our view, models of aid effectiveness should (i) identify why the aid recipients are poor to begin with; and (ii) demonstrate that the proposed sources of poverty are quantitatively important. Following these principles will serve to discipline the analysis by narrowing the range of aid models down to those that are the most empirically relevant. It will also help to narrow the types of policies that can effectively address the specific sources of poverty that have been identified. While existing models of aid contain many important insights, it is hard to gauge their empirical importance because these principles are not being followed.

As an example, in Adam and Bevan (2004) the sources of poverty are (i) low saving rates and skill levels in the household sector, (ii) a lack of public infrastructure, and (iii) an inefficiently low share of the workforce employed in the export sector, where a learning-by-doing externality resides. These are potentially interesting sources of poverty, but the reasons why poor countries differ from rich countries in these respects are not explained within the model (saving rates, skill levels, public capital, and rural-to-urban migration are all exogenous variables). Furthermore, there is no demonstration that these sources of poverty lead to large worker productivity differences between rich and poor countries under their calibration.

III. THE MODEL

We first describe the behavior of the private sector in the poor country and then turn to the government.

A. Households

In our model, households live for three periods, each of which lasts twenty years. The three periods correspond to one period of childhood and two periods of adulthood. Households make saving, fertility, and schooling decisions. They value their consumption over the two periods of adulthood (c_t^y, c_{t+1}^o) and the adult earnings ($w_{t+1}h_{t+1}$) of all their children (n_{t+1}). Earnings are the product of the after-tax market rental rate for skills (w_{t+1}) and the embodied skills, or human capital (h_{t+1}), of the worker. Preferences are given by

$$U_t = \ln c_t^y + \beta \ln c_{t+1}^o + \psi \ln\left(n_{t+1} w h_{t+1}\right),$$

where $0 < \beta < 1$ and $\psi > 0$ are preference parameters. This preference specification is a simple way of capturing the idea that parents value both the quantity and the quality of their children. It has been use extensively in the literature on fertility and growth (e.g., Galor and

Weil, 2000; Greenwood and Seshadri, 2002; Hazan and Berdugo, 2002; Lord and Rangazas, 2005; and Moav, 2005).

Adults inelastically supply one unit of labor when young and zero units when old. Children have an endowment of $T < 1$ units of time that they can use to attend school (s_t) or work ($T - s_t$). Children have less than one unit of time to spend productively because early in childhood they are too young to either attend school or to work, and in the middle years they do not have the mental or physical endurance to school or work as long as an adult.

While children may work as they become older, they are also expensive to care for and feed. To raise each child requires a loss of adult consumption equal to a fixed fraction τ of the adult's first period wages.

The government decrees that younger children receive some education during their early years. So each child invests at least $\bar{s}$ units of time into learning during the first portion of their childhood.[4] This gives older children $\gamma \bar{h}_t = \gamma \bar{s}^{\theta}$ units of human capital that can be used in production during the later years of childhood, where $0 < \theta < 1$ is a parameter that gauges the effect of schooling on human capital accumulation and $0 < \gamma < 1$ reflects the fact that children lack relative physical strength or experience in applying knowledge to production compared to an adult. Adult human capital of the same person in the next period is $h_{t+1} = s_t^{\theta}$. Thus, a person is more productive in adulthood than in childhood because of greater strength and experience ($1 > \gamma$) and additional schooling ($s_t \geq \bar{s}$).

The household maximizes utility subject to the lifetime budget constraint,

$$c_t^y + \frac{c_{t+1}^o}{1 + r_{t+1}} + n_{t+1} \tau w_t h_t = w_t h_t + n_{t+1} w_t \gamma \bar{h} (T - s_t).$$

In addition to the standard first order conditions for life-cycle consumption, the choices of n_{t+1} and s_t yield

$$\frac{\psi \theta}{s_t} \leq \lambda_t n_{t+1} w_t \gamma \bar{h} \tag{1a}$$

$$\frac{\psi}{n_{t+1}} = \lambda_t \left[\tau w_t h_t - (T - s_t) w_t \gamma \bar{h} \right], \tag{1b}$$

where λ_t is the Lagrange multiplier.

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[4] Alternatively $\bar{s}$ may be interpreted as a minimum amount of schooling needed for the child to be productive.

Equation (1a) says the marginal utility of additional child quality must be equated to the marginal value of consumption lost from allowing children of working age to attend school. The strict inequality holds when the marginal cost of educating children beyond the schooling received in their early years, $\bar{s}$, exceeds the marginal benefit. In this case, parents are content to set $s_t = \bar{s}$.

Equation (1b) says the marginal utility of additional children must be equated to the marginal value of lost consumption. Consumption is lost from having additional children because we assume the cost of children exceeds the earnings that older children bring to the household.

Solving the model gives us the following demand functions for children, schooling, and financial assets for retirement (a_{t+1})

$$n_{t+1} = \frac{\psi}{(1 + \beta + \psi)\left(\tau - \gamma(T - s_t)(\bar{s}/s_{t-1})^\theta\right)} \tag{2a}$$

$$s_t = \max\left[\frac{\theta\left(\tau(s_{t-1}/\bar{s})^\theta - \gamma T\right)}{\gamma(1-\theta)}, \bar{s}\right] \tag{2b}$$

$$a_{t+1} = \left[\frac{\beta}{1 + \beta + \psi}\right] w_t h_t. \tag{2c}$$

Assuming that s_{t-1} is sufficiently high, a dynamic results that causes economic growth and a demographic transition. Greater schooling raises adult earnings relative to older children's earnings. This raises the net cost of having children, so fertility declines. Lower fertility and greater consumption lower both the quantity and the value of forgone earnings from schooling children, and so schooling rises further. Thus, the sole factor driving fertility down is the rise in schooling. It is also important to note that the dynamics is independent of the country's conventional fiscal policy. The after-tax factor prices or rental rate on physical and human capital are the only variables that are affected by conventional fiscal policy.

Since the effect of schooling has a diminishing effect on human capital formation and wages, the transition equation given by (2b) would exhibit the standard properties of neoclassical growth if not for one additional feature. Children receive a minimum level of schooling or learning ($\bar{s}$) while they are young and unable to work. This creates a non-convexity in the transition equation, where the schooling during childhood must be greater than or equal to $\bar{s}$.

Figure 1 sketches the schooling transition equation. The vertical intercept of the graph is at $-\theta T/(1-\theta)$, rather than its usual position at the origin. This implies that the graph intersects the 45-degree line twice, at *A* and *B*. For schooling to increase over time, the schooling level for parents, when they were children, must be to the right of *A*. Starting to the right of A will cause schooling to rise, but in relatively small increments. As the level of schooling rises, the

increments in schooling across generations become larger, until the economy nears the stable steady-state at *B* when the increments converge to zero. So, *provided that schooling is sufficiently high initially*, the model predicts relatively small increments in schooling initially, an acceleration of schooling in the middle of the transition, and then a slowdown as the steady-state is approached. Lord and Rangazas (2005) show that this model fits the qualitative pattern observed over the last two centuries of United States history.

Figure 1. Dynamics of Schooling
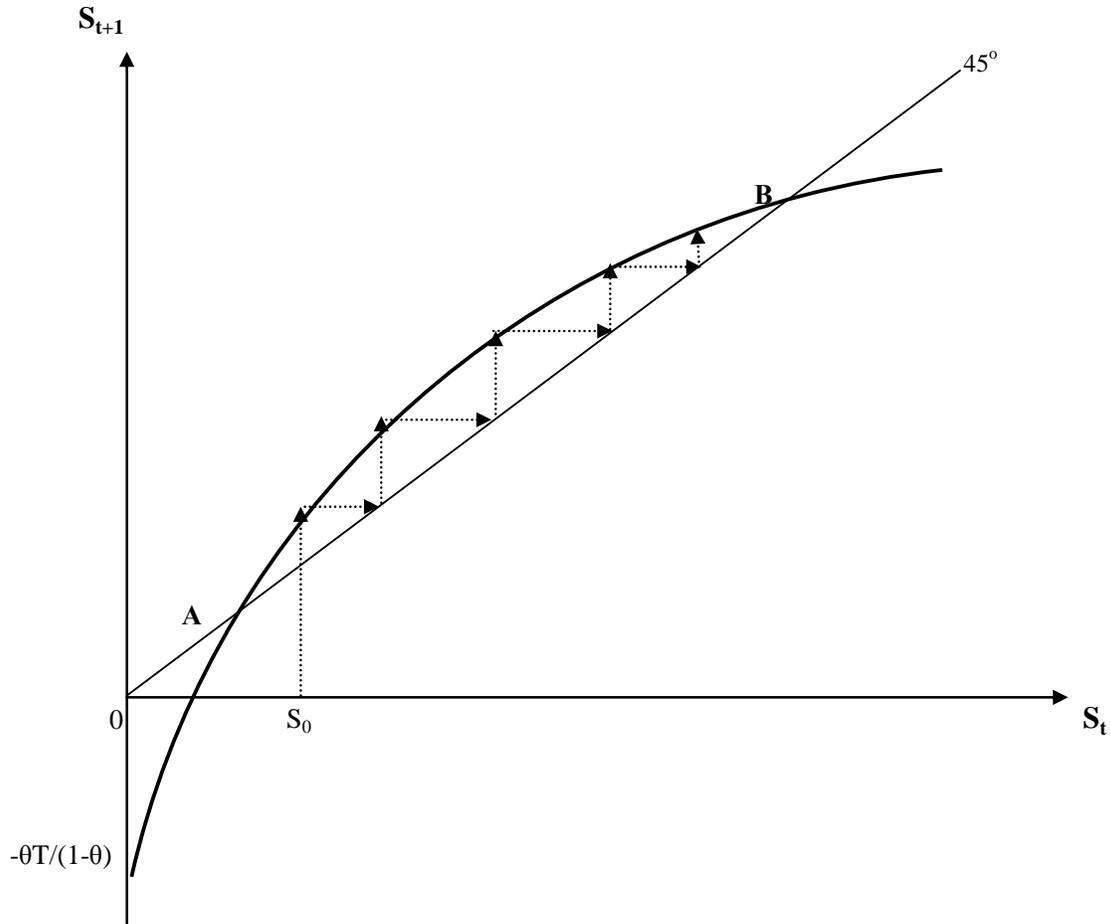
B. Firms

Production takes place within standard neoclassical firms that combine physical capital (K_t) and human capital (H_t) to produce output from a Cobb-Douglas technology

$$Y_t = K_t^\alpha \left(D_t H_t\right)^{1-\alpha},$$

(3)

where D_t is a productivity variable associated with production in firms.

The productivity variable, *D*, is a function of disembodied technology, *A*, and government capital per adult worker, *G*, and is given by

$$D_t = A_t^{1-\mu} G_t^{\mu}, \tag{4}$$

where $0 < \mu < 1$ is a constant parameter. We assume that A progresses at the exogenous rate q. This specification of the impact of government capital is similar to Aschauer (1989) and Clarida (1993).

Firms operate in perfectly competitive factor and output markets. This implies the profit-maximizing factor mix must satisfy

$$r_t + \delta = (1 - \sigma_t)\alpha g_t^{\mu(1-\alpha)} k_t^{\alpha-1} \tag{5a}$$

$$w_t = (1 - \sigma_t)(1 - \alpha)A_t g_t^{\mu(1-\alpha)} k_t^{\alpha}, \tag{5b}$$

where δ is the rate of depreciation on physical capital, σ is the income tax rate (net of transfers back to the private sector), $g \equiv G/A$, and $k \equiv K/AH$.

C. Capital Market Equilibrium

The firm's demand for private physical-capital intensity is given by (5). The supplies of private capital comes from the household's asset demand for retirement assets and the human capital they rent to the market,

$$K_{t+1} = a_{t+1} N_t \tag{6a}$$

$$H_t = h_t N_t + \gamma \bar{h}_t (T - s_t) N_{t+1} \equiv N_t h_t^A, \tag{6b}$$

where $h_t^A \equiv h_t + \gamma \bar{h}_t (T - s_t) n_{t+1}$. Substituting (2c), (5b), and (6b) into (6a), gives the equilibrium difference equation for physical-capital intensity,

$$k_{t+1} = \left[\frac{\beta}{1+\beta+\psi}\right] \frac{(1-\sigma_t)(1-\alpha)g_t^{\mu(1-\alpha)} k_t^{\alpha} h_t}{(1+q)n_{t+1}h_{t+1}^A}. \tag{7}$$

D. Government

We assume that the government officials who determine fiscal policy are some fraction, ε, of the population of private households, N_t. Government officials value their own consumption (c_t^g) as well as the welfare of the representative citizen according to the period utility function, $\ln c_{t+i}^g + \phi U_{t+i}$, where ϕ is a positive preference parameter that gauges the relative weight the government places on the welfare of private households. We assume that the current government also cares about the government as an ongoing institution (i.e., they

care about the future operations of the government and the welfare of future government officials) and the welfare of the country's future citizens. The preferences of the government are given by

$$\sum_{i=0}^{\infty} \beta^i \left(\ln c_{t+i}^g + \phi U_{t+i} \right), \tag{8}$$

The government budget constraint, per young household, is

$$c_{t+i}^g \varepsilon N_t = \sigma_{t+i} Y_{t+i} - G_{t+i+1} N_{t+1}. \tag{9}$$

The left-hand side gives the government's consumption expenditures. The right-hand side is the difference between government tax revenue, net of transfers, and government expenditures on public capital. Public capital evolves according to the equation

$$G_{t+1} = I_t^g + (1 - \delta^g) G_t, \tag{10}$$

where I_t^g is government investment and δ^g is the rate of depreciation of government capital.

The government chooses sequences of tax rates and government capital to maximize the discounted utility of government officials and private households, given by (8), subject to the budget constraint and capital accumulation equation given above.[5] In addition, the government takes into account how their policy choices affect all private sector decisions. This includes only (7), since (2a) and (2b) are independent of fiscal policy.[6] Finally, to obtain analytical solutions, we assume $\delta = \delta^g = 1$, so that over our twenty-year periods, the capital stocks fully depreciate.

The solution to the government's problem is (see the Appendix):

$$\sigma_t = \sigma = \frac{(1 - \alpha\beta)(1 + \beta\mu\phi(1 - \alpha)\Gamma)}{1 + (1 - \alpha\beta)\phi\Gamma}, \tag{11a}$$

$$g_{t+1} = \frac{\beta\mu(1 - \alpha)}{(1 + q)n_{t+1}} k_t^\alpha g_t^{\mu(1 - \alpha)} h_t^A, \tag{11b}$$

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[5] An important extension of our approach (left for future work) is to assess the aid cost of reform using calibrated dynamic general equilibrium models that also incorporate optimal government debt or monetary policy.

[6] In setting up the government's problem, we assume that they can commit to their policy choices in advance. For a discussion of commitment issues in regard to the setting of fiscal policy see Lundquist and Sargent (2004, Chapter 22).

$$k_{t+1} = \frac{\beta(1-\sigma)(1-\alpha)}{(1+\beta+\psi)(1+q)n_{t+1}} \frac{k_t^\alpha g_t^{\mu(1-\alpha)} h_t}{h_{t+1}^A},$$

(11c)

where $\Gamma \equiv 1 + \beta + 1 + (\psi/\beta) + (\beta\alpha(1+\beta) + \beta(\alpha-1) + \psi\alpha)/(1-\alpha\beta)$.

One can show that the constant tax rate σ is decreasing in ϕ. From (11b), the public saving rate out of national income is a constant, $\beta\mu(1-\alpha)$. Thus, a more selfish government, with a lower ϕ, will collect more in taxes but invest *a smaller fraction of tax revenue* in public capital—so as to maintain the *same* investment rate out of national income.

It is important to note that the model is recursive. The private sector schooling and fertility dynamics can be solved independently of fiscal variables and physical capital intensity. The fertility-schooling dynamic then plays a role in determining the dynamics of government and private capital intensity, for a given optimal tax rate.

E. Steady-State Equilibria

A country with sufficiently high initial schooling will experience growth and converge to a steady-state as determined by (2) and (11). However, if $s_{t-1} = \bar{s}$, it may be the case that $\frac{\theta(\tau - \gamma T)}{\gamma(1-\theta)} < \bar{s}$. If this is true, then $s_t = \bar{s}$ and the economy is in a poverty trap where neither schooling nor fertility changes over time. For an economy with this initial condition, the only possible dynamics stem from the government and private physical capital accumulation in (11). Thus, initial conditions may cause economies with identical structures to come to rest at very different steady-state equilibria; with one steady-state having higher values of *h*, *g* and *k*, and lower levels of *n*, than the other.

It is also possible that economies differ in terms of the weight, ϕ, that their governments place on household welfare in setting fiscal policy. Economies with higher ϕ will have higher private capital-labor ratios and higher levels of public capital. This will cause higher worker productivity, even if the steady values of *s* and *n* are the same.

Thus worker productivity may differ either because of a poverty trap or because of policy differences. The next question is whether these sources of income differences are quantitatively important.

IV. CROSS-COUNTRY INCOME DIFFERENCES

To investigate the potential of the model to generate income difference across countries, consider the following two steady-state equilibria, where *s*, *n*, *g,* and *k* are constant. The "poor-country" equilibrium is characterized by (i) a poverty trap, $s_t = \bar{s}$ and (ii) a relatively selfish government, $\phi^{poor} < \phi^{rich}$. The "rich-country" equilibrium is characterized by: (i) $s = T$ (full-time schooling); and (ii) $n = 1$ (one child per parent) and (iii) a government that

sets net tax rates in manner similar to the United States at the end of the 20th century, i.e., $\sigma = 0.15$.

A. Calibration

To quantify the model's predictions about income differences across these two equilibria, we calibrate the parameters to the rich country steady-state. The physical capital income share, α, is set to the standard value of 1/3. The output elasticity for public capital, μ, is set to 0.30 somewhat less than the values estimated by Aschauer (1989) and Clarida (1993). However, the values of α and μ place $\mu(1-\alpha)$ at 0.2, an intermediate value of the estimates surveyed by Glomm and Ravikumar (1997). Based on Lord and Rangazas (2005), we set $\gamma = 0.28$ and $T = 0.50$. This implies potential earnings of a child that are about 14 percent of an adult's earnings. The annualized after-tax return to capital is set to 4 percent, the after-tax real rate of return to capital in the United States at the end of the 20th century (Poterba, 1997, Table 1). The annualized rate of growth of exogenous technological change, q, is set to 1.0 percent (Rangazas, 2002, 2005). This is intended to reflect a worldwide, transferable, component of exogenous technological change.

The remaining parameters are set to match certain targets. We set ϕ^{rich} to match $\sigma = 0.15$, about the ratio of government purchases to GDP in the United States.[7] In the rich equilibrium steady-state, we targeted $n = 1$, $s = 0.5$ (children spend all their available time in school, similar to the current value in the United States), and a value of k consistent with an annualized after-tax return of 4 percent.

In the poor country equilibrium, we targeted $n = 3.5$, which implies 7 children per couple. Despite the fertility decline in Africa over the last two decades, many of its poorest countries have total fertility rates of 7 children per female (Bongaarts, 2002). In addition, the parameter settings must to be consistent with an optimal schooling level below $\bar{s}$. The minimal schooling level for young children is set to 0.08. This value implies that children in the rich country spend 6.25 times as much time in school over their childhoods than children from poor countries. If poor children spend 2 years in school, then rich children spend 12.5 years in school (assuming school years of equal length). Finally, we set ϕ^{poor} in the poor country so that $\sigma = 0.35$.

Table 1 gives examples of poor countries (1/10 of U.S. worker productivity, denoted by y^{US}, or less) with levels of $\sigma = $ G/Y that are at least double those of the United States.[8] Table 2 summarizes the parameter settings.

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[7] The values of G/Y for the United States and the poor countries are from the Penn World Tables, where government purchases are defined as government consumption only. So the values for G/Y are actually low for both the United States and the poor countries.

[8] There is also the issue of differences in the tax base across rich and poor countries. Poor countries have much larger informal sectors that go untaxed. This causes poor countries to

Table 1. Selected Low-Income Countries with Large Governments (1985)

Country	*G/Y*	$y^{US} / y^{country}$
Angola	0.36	11
Burkina Faso	0.29	33
Central African Republic	0.44	17
Comoros	0.49	10
Ethiopia	0.28	40
Gambia	0.37	17
Mozambique	0.31	33
Uganda	0.28	33
Average	0.32	24

Source: Alan Heston, Robert Summers, and Bettina Aten, Penn World Table Version 6.1, Center for International Comparisons at the University of Pennsylvania, October 2002.

Table 2. Calibrated Parameter Values

Parameter		Target
γ	0.2800	relative child's earning
T	0.5000	relative child's earnings
τ	0.1646	steady state fertility (poor)
θ	0.4049	steady state schooling (rich)
α	0.3333	standard value for capital share
μ	0.3000	intermediate empirical estimate
ψ	0.2956	steady state fertility (rich)
β	0.4999	steady state return to capital (rich)

B. Worker Productivity Differences

Table 3 presents the steady-state worker productivity ratio, across rich and poor countries, generated by the model. The features included in the model cause the rich country to be over 28 times richer than the poor country. The decomposition of the worker productivity ratio in Table 3 is based on the following expression for worker productivity,

$$y_t = \frac{k_t^\alpha A_t g_t^{\mu(1-\alpha)} h_t^A}{1 + n_{t+1}(T - s_t)} . \tag{12}$$

The poverty trap causes the term $h_t^A / (1 + n_{t+1}(T - s_t))$, average human capital per worker, to be 3.7 times higher in the rich country for two reasons. First, since $s_t = 0.5$ in the rich-

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collect a small fraction of output in taxes with the same tax rate. An informal sector is needed to capture this and other important features of poor economies. We discuss this extension in the conclusion.

equilibrium and $s_t = \bar{s} = 0.08$ in the poor-equilibrium, adult human capital differs across countries. This causes output per worker in the rich country relative to that in the poor country to be 2.10, a value similar to that estimated by Hall and Jones (1999) using a much different approach. Second, the high fertility in the poor country implies that their workforce contains a sizable fraction of young workers, who are less productive than adult workers due to less strength and experience (captured by $\gamma = 0.28$). This causes worker productivity to be 1.75 times higher in the rich country. This determinant of low worker productivity has been overlooked in previous studies.

Table 3. Steady-State Worker Productivity Differential: Rich vs. Poor Countries

Rich to Poor Ratios	Model Prediction
k^α	3.68
$g^{\mu(1-\alpha)}$	2.09
$h^A / [1 + n(T - s)]$	3.68
y	28.25

The poverty trap also causes low values of k and g. High population growth increases the size of next period's workforce relative to the current period's savers.[9] This spreads saving and capital accumulation more thinly across workers in the future, lowering k. Lower values of k and h^A also lower the tax base and reduce public investment for any given tax rate. Differences in ϕ raise tax rates and further reduce private saving and private capital formation. Indirectly, this also lowers public capital formation by reducing the level of national income and the tax base. These various effects that serve to lower public and private physical-capital intensities cause worker productivity to be 7.7 times higher in the rich country. This is over four times as high as the productivity ratio that Hall and Jones (1999) attribute to differences in capital intensity. There are several reasons why the estimate in Table 3 is higher.

In Table 3 we are assuming that the poor country is a perfectly closed economy. In the next section, we open the economy to international capital flows. This reduces the differences in capital intensity across rich and poor countries, although not completely. Since the typical poor country is neither perfectly open nor perfectly closed, our estimates would bound the Hall and Jones (1999) estimates, if not for other considerations that suggest their estimates may be too low.

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[9] The large effects on worker productivities are accentuated in a three-period model. With only three periods, the population of households that are saving compared to the future workforce is unrealistically small. In addition, the high fertility rate, without a high rate of mortality, will imply a large increase in the size of the future workforce. Both these features cause the capital accumulation financed by the current period's saving to be more thinly spread over the next generation of workers than in a model with many periods of work (and saving) and with the high death rates that mediate population growth in poor countries.

Pritchett (2000) estimates that the actual capital stock in poor countries is only between 57 percent and 75 percent of the officially measured stock. Thus, in poor countries government consumption is underestimated and investment is overestimated. This causes estimates of productivity differences that are based on direct estimates of the capital stock differences to be too small.

The Hall and Jones (1999) approach also treats private and public investment as perfect substitutes in production. The estimates of the output-elasticity of public capital suggest that this is not the case; the elasticity for public capital is less than two-thirds the elasticity for private capital (Glomm and Ravikumar, 1997). Since poor countries have relatively more public capital, the perfect-substitutes assumption overstates the productivity of the capital stock in poor countries. This, in turn, lowers the estimated role of capital differences in explaining worker productivity differences.

V. POLICY EXPERIMENTS

The previous section identified some potentially important sources of income differences across countries. The question now is whether there are aid policies that can effectively eliminate the sources of poverty. We consider three policies: opening the economy to international capital flows, an education subsidy aimed at eliminating the poverty trap, and a policy reform aimed at eliminating anti-growth domestic fiscal policy.

A. Opening the Economy

Section III assumes that the poor country's economy is perfectly closed. What happens if the economy is opened to trade and international capital flows? What will be the effect on different generations of households in the poor country? Will opening the economy make the poor country's government better off, or will the government oppose the policy?

To answer these questions, the model must first be re-solved under the assumption that the economy is open and that private capital flows will equate the poor country's interest rate to the exogenous world interest rate (which we take to be the steady-state interest rate in the rich country). Next, the dynamic path under the open economy assumption is computed as the economy goes through the transition from the initial closed economy steady-state to the open economy steady-state. Unlike most neoclassical growth models, the "small" poor economy will *not* adjust to the new steady-state in a single period when interest rates are equalized in an open world capital market. This is because the government's *public* capital accumulation will adjust *gradually* to the opening of the economy. Equation (5a) shows that interest rates can be equalized due to private capital adjustments alone. Finally, welfare comparisons are made to see who benefits and who loses from opening the economy, an analysis that includes computing the welfare effect on the poor country's government itself.

After the economy is opened, the poor country's r will converge to the world interest rate, r^w, which we take to be the steady-state interest rate of the rich country. The equilibrating force is assumed to be private capital mobility. The poor country's private capital intensity will then be determined by substituting r^w in (5a) and then solving for the new value of k. Note that this does not mean that k is equated across rich and poor countries because g may

differ across countries. Smaller values of g lower the marginal product of k and imply that smaller values of k are needed to drive the return to physical capital down to the world interest rate.

With k determined internationally, the government's optimal policy will change. The government now maximizes (8) not subject to (7), as in the closed economy, but subject to the k determined by international capital markets as described above. The optimal policy in an open economy becomes (see the Appendix for the derivation)

$$\sigma = \frac{\beta(1-\alpha)}{\beta + \phi[\psi + \beta(1+\beta)]} \tag{13a}$$

$$g_{t+1} = \frac{B\sigma}{(1+q)n_{t+1}} \left(\frac{\alpha(1-\sigma)}{1+r^w} \right)^{\frac{\alpha}{1-\alpha}} g_t^\mu h_t^A, \tag{13b}$$

where $B = \dfrac{\mu\beta + \phi\mu(\beta(1+\beta)+\psi)}{1+\phi\mu(\beta(1+\beta)+\psi)}$. The coefficient B represents the share of the government budget that is invested in public capital. The product $B\sigma$ is the share of national output that is invested in public capital.

Fiscal Policy in an Open Economy

One can compare the effect of opening the economy on the fiscal policy of the poor country. Consider the extreme case where $\phi = 0$. We then have $B^{open} \equiv \beta\mu > \beta\mu \dfrac{1-\alpha}{1-\alpha\beta} \equiv B^{closed}$,

$\sigma^{open} \equiv 1-\alpha < 1-\alpha\beta \equiv \sigma^{closed}$, and $(B\sigma)^{open} = \beta\mu(1-\alpha) = (B\sigma)^{closed}$, where all inequalities hold when future utility is discounted, i.e., when $\beta < 1$. Thus, opening the economy raises the portion of the budget that is invested and lowers the tax rate, but leaves the fraction of national output invested the same.

The fiscal policy differences are due to the *timing* of the impact of fiscal policy on private capital formation in open versus closed economies. In a closed economy, government policy affects private capital formation by affecting the after-tax wage of savers that fund the *next* period's private capital intensity. In an open economy, government policy affects private capital intensity by affecting the marginal product of private investments in the poor country—reducing it with higher tax rates and raising it with higher public capital intensity. International capital flows will anticipate and respond to these changes in private returns to investment, until the after-tax return to investment are equalized across countries. Thus, in an open economy, government policy has a more *immediate* effect on private capital formation—this period's policy affects *this* period's capital intensity rather than this period's saving flow and *next* period's capital intensity (as in a closed economy). With discounting of the future ($\beta < 1$), the cost of high taxes and low public investment, in lowering private capital intensity, is smaller in the closed economy due to the one-period delay in effect. In this sense, opening the economy makes private capital formation more responsive to policy

changes. The government reacts to the new environment by choosing a more "pro-growth" fiscal policy stance.

Table 4 gives the fiscal policies in open and closed economies for the calibration in Table 2 where $\phi = 0.7461$.

Table 4. Fiscal Policy in the Closed and Open Economy

Fiscal Parameter	Closed Economy	Open Economy
σ	0.35	0.26
B	0.29	0.31
σB	0.10	0.08

The result with $\phi = 0.0$ extends to a higher values of ϕ; taxes are lower and the fraction of the government budget invested is higher in an open economy. However, the share of national output that is invested in public capital is lower in the open economy when $\phi > 0$, as B rises less than σ falls when the economy is opened. Thus, opening the economy lowers the economy's rate of investment in public capital.

Growth Effects of Opening the Economy

Table 5 gives the effects on economic growth in worker productivity of opening the economy. Rapid growth occurs in the first period as capital inflows narrow the gap in private capital intensity between rich and poor countries. The gain in the tax base offsets the fact that the rate of investment in public capital is lower. This causes the public capital intensity to rise over time to a new, lower steady-state value. The rise in the public capital intensity raises the marginal product of private capital and causes the private capital intensity to increase further. The modest additional increases in public and private capital intensities keeps the growth rate in worker productivity above the exogenous rate of technological change until period 4, when the economy has approximately converged to its new physical capital intensities.

Table 5. Growth in Worker Productivity: The Effect of Openness[1]

Period	1	2	3	4	5
Growth Rate	6.5	1.3	1.1	1.0	1.0

[1] The values are the average annualized percentages over 20 years.

The extent to which inflows of private capital narrow productivity differences is given in Table 6; the counterpart to Table 4 in a perfectly open, rather than perfectly closed, economy. Comparing Table 6 to Table 3, one sees that worker productivity gaps are narrowed by opening the economy. The rich country's advantage in worker productivity is now less than one-third of what it was in a closed economy setting, although a ninefold difference still remains.

Table 6. Steady-State Worker Productivity Differential: The Effect of Openness

Rich to Poor Ratios	Model Prediction
k^{α}	1.41
$g^{\mu(1-\alpha)}$	1.73
$h^A / \left[1 + n(T-s) \right]$	3.68
y	8.98

Welfare Effects of Opening the Economy

There are clear gains in worker productivity from opening the economy. However, not all generations benefit from the opening. The policy affects the welfare of households by affecting factor prices. Households prefer higher current wages for themselves and higher future wages for their children. They also benefit from higher interest rates on their life-cycle saving. Opening the economy will raise wages and lower interest rates as capital flows into the economy. For *most* generations, there is a net gain in utility from these factor price adjustments (the effect of higher wages is greater than the effect of lower interest rates). This is *not* true for the initial generation of young households who are alive at the time the policy is introduced. Their current wages are unaffected by the capital inflows (since the initial capital intensity is fixed) and yet their interest rates are significantly lowered. The sharp drop in interest rates with no change in current wages causes their welfare to fall. Thus, welfare falls for the first generation and rises for all others.

The government in the poor country enjoys an increase in public consumption each period— the increase in the tax base from capital inflows offsets the drop in tax rates. The gain in the public consumption, along with the discounted gain in utility to all future generations, are larger than the loss in welfare of the initial generation. Thus, the poor government would want to open the economy, on economic grounds, in our setting.

This finding is obviously sensitive to the particular calibration chosen. If the initial capital intensities were smaller, or if the poor country's government had a higher rate of time preference, then one might find that the poor country opposes the opening. We plan to investigate these possibilities in future work.

B. Eliminating the Poverty Trap

Schooling is low in the poor country because the value of forgone earnings associated with sending older children to school is high. The value of forgone earnings is high because households have many children and because parental earnings are low. The poverty trap can be removed if parental earnings are increased relative to the earnings of older children. This would make it more costly to have many children (because of the forgone wages and consumption of parents associated with child rearing) and it would lower the relative value of children's work in total family income.

Using aid to encourage poor countries to increase the schooling of *younger* children (i.e., to increase $\bar{s}$) will increase earnings but will not remove the poverty trap.[10] This policy would not raise the earnings of parents *relative* to those of older children (since they both receive the higher levels of education when they are young children). What is needed is more schooling of *older* children, so that when they become parents their earnings (based on $s_t > \bar{s}$) sufficiently exceed the earnings of their older children (based only on $\bar{s}$)—thereby making children more costly and relatively less important in generating family income.[11]

One policy that can remove the poverty trap is similar to Mexico's Progresa program.[12] Governments would subsidize the forgone earnings of older children who attend school. A sufficiently high subsidy would raise s_t sufficiently higher than $\bar{s}$, so that a transitional dynamic would result, sending the poor country to point *B* in Figure 1. The potential advantage of identifying and eliminating poverty traps is that aid need not be ongoing. Once sufficient aid has been provided to eliminate the poverty trap, no further aid is necessary.

To begin the analysis of the subsidy policy, introduce the policy parameter η that indicates the fraction of forgone earnings of older children that the government returns to the household. This introduces the expression $\eta w_t \gamma \bar{h}_t (s_t - \bar{s}) n_{t+1}$ on the right-hand side of the household lifetime budget constraint from section I. In face of the subsidy, household behavior becomes

$$n_{t+1} = \frac{\psi}{(1 + \beta + \psi)\left(\tau - \gamma(T - s_t + \eta(s_t - \bar{s}))(\bar{s}/s_{t-1})^\theta\right)} \tag{14a}$$

$$s_t = \max\left[\frac{\theta\left(\tau(s_{t-1}/\bar{s})^\theta - \gamma T + \gamma\bar{s}\eta\right)}{\gamma(1-\theta)(1-\eta)}, \bar{s} \right]. \tag{14b}$$

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[10] Of course, using aid to increase human capital spending on young children can be defended on other grounds. Due to imperfect intergenerational capital markets, the rate of return to investments in the human capital of young children may be quite high (e.g., Rangazas, 2002, 2005).

[11] It is important to remember that by older children, we mean children of working age. Working age may reasonably be interpreted as children age 10 or older.

[12] In 1997 Mexico began Progresa, a program designed to increase human capital in poor families by paying families to send their children to school and to visit health care providers. Grants are provided directly by the government to the mothers of children. The school grants cover about two-thirds of what the child would receive in full time work (Krueger, 2002).

The subsidy increases the optimal schooling level and, if it is sufficiently high, the optimal schooling level is pushed above $\bar{s}$. For a given level of s_t, fertility is also encouraged by the subsidy. However, if the subsidy raises s_t enough, then fertility will fall.

Of course, the subsidy must be financed out of tax revenues. In addition, as older children work less in order to attend school, the tax base shrinks. Government revenue is reduced by two factors in the first period—the subsidy payment and the decline in the tax base. This implies that government consumption and investment will fall initially, which may offset, or at least mediate, the early growth effects of the policy. As the stock of human capital rises and increases the tax base, government consumption and investment eventually rise.

Table 7. The Progresa Program: Schooling, Fertility, and Growth Effects[1]

Period	1	2	3	4	5	6	7	8	9	10
s	0.29	0.34	0.37	0.41	0.43	0.45	0.47	0.48	0.49	0.49
n	2.5	1.2	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
$\%\Delta y$	2.4	8.6	3.0	2.0	1.6	1.4	1.3	1.2	1.1	1.1

[1] Growth rates are the annualized value over twenty years.

Growth Effects of the Progresa Program

Table 7 gives the growth effects of the Progresa program with a subsidy, for a single period, that is similar in size to that offered in the Mexican Progresa program, $\eta = 0.67$. The relatively large one-period subsidy is more than enough to boost the economy out of the poverty trap and in fact creates something close to a "growth miracle." The large rise in schooling and fall in fertility creates strong direct (via human capital per worker) and indirect (via physical and public capital intensities) growth effects for a number of periods.

Welfare Effects of the Progresa Program

An advantage of the Progresa program is that no generation is hurt by the policy. Although the positive welfare gain is quite small for the first generation, because they do not directly benefit from the higher schooling, it is significant from the second generation on. With sizable welfare gains after the first period, combined with large increases in the tax base, the government's welfare increases due to the policy change.

C. Eliminating Anti-Growth Fiscal Policy

Attempting to reform conventional fiscal policy is a very common target for aid policy. We now consider the effects of imposing a fiscal policy in the poor country that would bring it in line with the fiscal policy of the rich country. In particular, we compute the effects of imposing the σ and B of the rich country, where the optimal values are 0.15 and 0.67, on the poor country, where the optimal values in the open economy are 0.26 and 0.31.

Growth Effects of Fiscal Policy Reform

The effect of fiscal policy reform on the growth rates of worker productivity are given in Table 8.

Table 8. Fiscal Reforms and Growth in Worker Productivity: No Aid[1]

Period	1	2	3	4	5
%Δy	1.78	1.13	1.01	1.00	1.00

[1] The values are the average annualized percentages over 20 years

The growth effects are relatively modest and short-lived. In part, this is due to the fact that we begin the policy experiment from a perfectly open economy. Opening the economy brings the fiscal policy of the poor government closer to that of the rich government (see Table 4). This has the effect of making the differences in tax policy less dramatic and the returns to accumulating private and public capital smaller (since capital intensities are higher in the open economy than in the closed economy). Since the poor economy is relatively close to the rich country's capital intensities to begin with (see Table 6) the transition to the new steady-state is short.

Welfare Effects of Fiscal Reform

There is a significant gain in utility of all generations from the fiscal reform. This is because of the growth effects highlighted in Table 8 and because of the direct effects of paying lower taxes. Of course, the welfare of the poor country's government falls significantly because they have been moved off their optimal fiscal policy.

VI. THE AID COST OF REFORM

We have examined three policies to promote growth in developing economies. The impact of the policies on growth differed significantly and so does their aid cost. The first two policies, openness and the Progresa-style education subsidy, increase the welfare of the poor country's government and thus should be readily accepted. Apart from not being aware of the policies and their benefits, a poor country should adopt these policies on its own *without aid*. In the case of these two policies, aid should simply take the form of "technical assistance"— informing the countries about the virtues of the policies and helping to facilitate their implementation. The domestic fiscal reforms, on the other hand, would be opposed by the poor country's government. Aid dollars would have to be used to "purchase" the fiscal reforms from the poor country's government, in compensation for its losses.

We can assess the aid cost of fiscal reform by calculating the minimum amount of aid needed to keep the poor country's government indifferent to the reforms. We compute the aid cost as a permanent flow of aid, expressed as a fraction of the poor government's budget. The aid flow must be permanent because the government will want to renege and revert back to its optimal fiscal policy as long as it stays in power. Of course, the aid flow will also change the amount that the government invests (while the government consumes most of the aid flow, some is invested) and thus the growth effects of the fiscal reforms will be larger than those

without aid—an added benefit of the aid that goes beyond purchasing the reforms per se. The growth effects are given in Table 9.

Table 9. Fiscal Reforms and Growth in Worker Productivity: The Effect of Aid[1]

Period	1	2	3	4	5
$\% \Delta y$	2.74	1.41	1.12	1.04	1.01

[1] The values are the average annualized percentages over 20 years.

The growth effects are higher than in Table 8 because the government chooses to invest some of the aid. The amount of aid required to purchase reforms is very high. Aid equal to over 87 percent of the poor country's budget is needed. Since the poor country's budget increases as the country grows, the absolute flow of aid must increase over time—long after the growth rate effects of the reforms have been exhausted.

VII. AID FAILURES

No robust correlation between aid and growth has been identified in the econometric literature (e.g., Easterly, Levine, and Rodman, 2004). There are several possible econometric reasons for the absence of a clear positive relationship; for example, *endogeneity of aid flows* (aid is targeted to slow-growing economies), *specification error* (the relationship between aid and growth is highly nonlinear), and *measurement error* (all aid, including aid not intended to generate growth, is lumped together in a single measure). Our analysis is consistent with two other possible reasons for the lack of correlation.

A. Ignorance about Growth Policies

Our results suggest that opening the economy to international capital flows and a Progresa-style subsidy have the *potential* to generate significant growth effects. The open economy computational experiment is consistent with econometric evidence which clearly identifies that countries with open economies grow faster than those with closed economies (e.g., Frankel and Romer, 1999). However, the profession is much more divided on the best *policies* for opening a previously distorted economy to international capital flows (e.g., Rodrik, 2004; and Rodriguez and Rodrik, 2001). Our experiment assumes that the poor country was initially closed by law (say, for political reasons) because it was unaware of the economic benefits on international investment. However, many poor economies are likely closed because of the indirect effects of chosen domestic or international policies. With the exception of anti-growth fiscal policy, our model contains no specific policy that prevents capital inflows and thus cannot provide guidance on the best policy reforms to open the economy. The best policy for opening the economy may be highly specific to the initial conditions of the economy that led it to be closed in the first place. The standard textbook advice of removing *all* possible trade barriers may not be convincing to the poor country's government. The key is to encourage international investment and how best to do this is not yet known.

The computational Progresa-style experiments are consistent with direct empirical evidence on the ground showing that the real-world Progresa experiment has been a success in Mexico (Krueger, 2002). Why wasn't this policy carried out earlier and in other countries? Probably

because no one had previously thought of it. Before Progresa was implemented, there was no formal analysis of its possible effects in the academic literature and it certainly has never been a required condition for receiving aid.

In summary, some of the best policies for promoting growth are still out there to be discovered, and some of policies that we do recommend are misguided because they are too general and their effects have never been properly evaluated.

B. Aid Cost

Fiscal reforms are often part of the conditions for receiving aid. Our analysis suggests that reforms of domestic fiscal policy are likely to be the least successful of the three that we examined. First, the growth effects of fiscal reform are relatively modest and short-lived. Second, the aidcost of "buying" the reforms from the poor country's government are enormous. Unless the aid keeps flowing to the poor country in sufficient quantity, the domestic government will do what it can to revert back to a high-tax, low-investment regime. In fact, the cost of maintaining effective reforms will increase over time as the government's budget, and the potential to increase government consumption, grows. In practice, aid is likely to be far less than what is necessary to keep the government indifferent and thus fiscal reforms may be doomed from the beginning.

Even if the aid is carried out in sufficient amounts indefinitely, there will be little correlation between aid and economic growth in the data. The growth effects occur early on, while the aid continues into the future during periods where the growth effects have long since vanished. If aid is cut somewhat, rather than increased, then there will be a reversion in fiscal policy and growth. Thus, aid will be flowing to a country experiencing negative growth.

VIII. CONCLUSION

This paper proposes that dynamic general equilibrium models be used to help evaluate the conditions that are associated with aid to poor countries. In applying this method to development aid, we argue that four guiding principles should be followed.

- The underlying model must first be able to replicate important growth facts before it is used in analyzing aid policy.

- The microeconomics sources of poverty must be identified in order to sharpen policy remedies and to make welfare comparisons between alternative policies.

- The objectives of the domestic government must be modeled so that their policy responses to aid reforms can be accounted for and so their welfare effects can used to calculate the required aidcost of reforms.

- Some insight should be provided on why econometric methods have not been able to identify a robust positive correlation between aid and economic growth in the past.

The paper contains a very simple model that we use to illustrate how the four principles can be applied and to demonstrate their potential benefits. We do not feel that our prototype

model as yet satisfies the first principle to a sufficient degree to take its recommendations for aid policy too seriously. An important extension of the model would be to include an informal sector as in Lord and Rangazas (2005). Economic growth is almost uniformly associated with (i) an economic transformation from informal to formal methods of production, (ii) a demographic transition from high to low rates of fertility, and (iii) a rising share of government spending as a fraction of GDP—Wagner's Law. A two-sector model would allow us to directly address (i). While we capture (ii) to some degree with the current model, Lord and Rangazas (2005) shows that (i) and (ii) are likely connected. The inability of governments to effectively tax the informal sector is likely related to (iii).

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A. Optimal Fiscal Policy in a Closed Economy

Domestic fiscal policy is determined by maximizing (10) subject to the government budget constraint and the accumulation equations for private and public capital. The private household's indirect utility function may be written as

$$U_t = U_0 + \overline{U}_t + (1+\beta)\ln w_t + \beta\ln(1+r_{t+1}) + \psi\ln w_{t+1}, \tag{10}$$

where U_0 is a constant and $\overline{U}_t = (1+\beta)\ln h_t + \psi\ln n_{t+1} + \psi\ln h_{t+1}$ is independent of fiscal policy. For the purpose of setting optimal fiscal policy, the government can then be modeled as choosing tax rates and public capital to maximize,

$$\sum_{i=0}^{\infty} \beta^i \left(\ln c_{t+i}^g + \phi\{(1+\beta)\ln w_t + \beta\ln(1+r_{t+1}) + \psi\ln w_{t+1}\} \right) \tag{10'}$$

subject to (5) and (7)-(9).

Substituting the constraints into the objective function and collecting common terms yields the following equivalent problem

$$\max_{\{\sigma_{t+i},g_{t+i},k_{t+i}\}_{i=1}^{\infty}} \sum_{i=1}^{\infty} \beta^{i-1} \ln\left[\sigma_{t+i-1}k_{t+i-1}^{\alpha} g_{t+i-1}^{\mu(1-\alpha)} h_{t+i-1}^A - g_{t+i}(1+q)n_{t+i}\right]$$

$$+ \phi\sum_{i=1}^{\infty}\beta^{i-1}\{[\beta(\alpha-1)+\psi\alpha+\beta\alpha(1+\beta)]\ln k_{t+i} + \mu(1-\alpha)[(\beta+\psi)+\beta(1+\beta)]\ln g_{t+i}$$

$$+ [\beta+\psi+\beta(1+\beta)]\ln(1-\sigma_{t+i})\} +$$

$$\sum_{i=1}^{\infty}\lambda_{t+i}\left\{\left[\frac{\beta}{1+\beta+\psi}\right]\frac{(1-\sigma_{t+i})(1-\alpha)k_{t+i-1}^{\alpha}g_{t+i-1}^{\mu(1-\alpha)}h_{t+i-1}}{(1+q)n_{t+i}h_{t+i}^A} - k_{t+i}\right\},$$

where λ is the multiplier associated with the private capital accumulation constraint.

To solve this sequence problem, begin by differentiating to get the first-order conditions for $\sigma_{t+i}, g_{t+i}, k_{t+i}, \lambda_{t+i}$. Next, substitute into the first order conditions the "guess"

$(1+q)n_{t+i+1}g_{t+i+1} = B\sigma_{t+i}k_{t+i}^{\alpha}g_{t+i}^{\mu(1-\alpha)}h_{t+i}^A$, where B is an undetermined coefficient. Finally, solve the first order conditions for B, σ_{t+i}, g_{t+i}, and k_{t+i} to get (11).

B. Optimal Fiscal Policy in an Open Economy

In an open economy, the government's problems can be written so that it solves

$$\max_{\{\sigma_{t+i},g_{t+i}\}_{i=1}^{\infty}} \sum_{i=1}^{\infty} \beta^{i-1} \ln\left[\sigma_{t+i-1}\left(\frac{(1-\sigma_{t+i-1})\alpha}{1+r^w}\right)^{\frac{\alpha}{1-\alpha}} g_{t+i-1}^{\mu} h_{t+i-1}^A - g_{t+i}(1+q)n_{t+i}\right]$$

$$+ \phi[\psi + \beta(1+\beta)] \sum_{i=1}^{\infty} \beta^{i-1}\left\{\frac{1}{1-\alpha}\ln(1-\sigma_{t+i}) + \mu \ln g_{t+i}\right\}.$$

This problem differs from the closed economy problem because private capital intensity is now determined by international capital flows rather than domestic saving. In a closed economy, government policy affected private capital formation by affecting the after-tax wage of savers that funded the subsequent period's private capital intensity. Now government policy affects private capital intensity by affecting the marginal product of private investments in the poor country—reduced by higher tax rates and raised by higher public capital intensity. In an open economy, government policy has a more *immediate* effect on private capital formation—this period's policy affects *this* period's capital intensity rather than this period's saving flow and *next* period's capital intensity.

Differentiating with respect to σ_{t+i} and g_{t+i} generates first order conditions. As before guess a solution for g of the form

$$(1+q)n_{t+i+1}g_{t+i+1} = B\sigma_{t+i}\left(\frac{\alpha(1-\sigma_{t+i})}{1+r^w}\right)^{\frac{\alpha}{1-\alpha}} g_{t+i}^{\mu} h_{t+i}^A.$$

Substitute into the first order conditions and solve for σ_{t+i} and B to get the solution in the text.