Africa's growth trap: a political-economy model of taxation, R&D and investment

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Abstract: Why do so many African governments consistently impose high tax rates and make little investment in productive public goods when alternative policies could yield greater tax revenues and higher national income? We posit and test an intertemporal political economy model in which the government sets tax and R&D levels while investors respond with production. Equilibrium policy and growth rates depend on initial cost structure. We find that in many (but not all) African countries, low tax/high investment regimes would be time-inconsistent. For pro-growth policies to become sustainable, commitment mechanisms or new production techniques would be needed.

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I. Introduction

This paper presents and tests a model of the interaction between government policymakers and private investors, aimed at helping to explain why some countries are able to sustain policies that foster high levels of investment and rapid economic growth, while others remain at near-subsistence activity levels for long periods of time. This question is of particular urgency in Africa, where numerous countries have experienced a succession of harsh policy regimes inviting little new investment and fostering no productivity growth. Persistent stagnation seems to be widespread but not inevitable: since independence at least a dozen African countries have adopted more favorable policies and experienced real income growth (Rodrik 1998), and variation in growth rates is greater in Africa than in any other region.[1] In this paper we use the variation in growth rates within Africa to ask, can African countries’ economic performance be explained in terms of their governments’ policy choices? And if so, can those choices be explained as rational policymakers’ responses to observable conditions?

Our goal is to identify those conditions under which governments are most likely to adopt and sustain pro-growth regimes. The first section of the paper presents the theory, in the form of a political-economy model where policy (taxation and investment in public goods) and production (private investment) result from an equilibrium between optimizing policymakers and investors. The second part of the paper presents empirical results, testing hypotheses derived from the model using data on African levels of agricultural taxation, agricultural R&D, and economywide growth. Appendices describe and present the data.

II. Theory

Empirical studies often find that policy differences account for a large fraction of cross-country differences in the level and growth rate of per-capita income (e.g. Hall and Jones 1999, Sachs and Warner 1997). Such findings beg the question of why some governments adopt policies that foster growth, while others adopt anti-growth policies—occasionally imposing such high tax rates, and making such small investments in public

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[1] . Long-run growth rates for the 1965-95 period across African countries ranged from -2.3 to +5.7 percent, with a coefficient of variation of 2.7 percent. The next- highest variability was in East Asia and Latin America. See Appendix Table 1 for details.

goods, that tax revenues shrink (McMillan 2000) and productivity falls over time (Fulginiti and Perrin 1997). It is particularly puzzling to see serial and spatial correlation in policy choice, as neighboring countries have similar regimes that persist over time (Easterly and Levine 1998). Instead of learning from experience, it appears that governments in the same situation consistently implement the same policies. Why might otherwise rational policy-makers continue to make seemingly irrational policy choices?

Many analyses of African policy-making focus on social conflict, and the use of state instruments to enrich favored groups (e.g. Bates 1981). But over time African policies have been so destructive to African economies that even politically favored groups have suffered. Our goal is to help explain how such counter-productive policies can arise and persist even if policy-makers are well informed. To formulate an intuitively plausible, politically relevant and empirically testable model of policy formation, we focus on two specific instruments – output taxation and investment in public goods -- and treat economic growth as the equilibrium outcome of an infinitely-repeated game between government officials and the private sector. The model is aimed at specifying a mechanism through which an optimizing, fully-informed government could consistently choose to maintain confiscatory taxes and very low R&D investments, despite knowing that lower tax rates and higher investment levels would yield higher tax revenues over time. The mechanism we use generates such a policy failure when producers expect (or fear) that policymakers will not sustain low tax rates in the future. Our model builds on analyses of time-consistency in pricing policies by Besley (1997), McLaren (1996) and Gilbert and Newbery (1994), adding interaction with public investment in R&D so as to construct a mechanism whereby policy choice underpins changes in total factor productivity and economywide growth.

The model's structure could apply to any sort of economic activity, but our empirical application is specific to agriculture. This case is empirically tractable because of past efforts to collect internationally comparable data on commodity tax rates, production costs and agricultural R&D. The farm sector looms large in the economywide performance of low-income countries, where agriculture tends to be the dominant employer and farmland provides a large fraction of the capital stock. And public R&D is a key factor in agricultural productivity growth, as many important technologies are nonrival, nonexcludable public goods such as the genes embodied in open-pollinated crops. Within Africa, Lusigi and Thirtle (1997) find that R&D spending with a six year lag accounts for between 1.8 and 3.1 percent of agricultural output growth. Thus, agricultural R&D as well as economic policy proves to be a major determinant of per-capita income growth, and although the model itself is quite general a focus on agriculture is well merited. For simplicity, then, we will henceforth refer to all producers as farmers, all public goods as agricultural R&D, and all products as crops.

To specify the model, we begin with farmers' investment and production choices. We then specify the government's options, and derive the conditions under which repeated interactions between optimizing farmers and optimizing policymakers result in persistent stagnation, and those which sustain high levels of investment and productivity growth.

Farmers

In the model, farmers choose between remaining at subsistence and producing for market, where they can earn positive profits but are exposed to taxation. The total cost of producing for market, *c*, varies across farmers continuously from [0, c_{max}], representing variation in distance to market and/or agro-climatic conditions. These costs can be divided into sunk costs, *s*, and harvesting costs, *h*, which also vary continuously across farmers.

Each farmer chooses q_t to maximize the present value of profits or,

$$\pi_t = \sum_{t=0}^{\infty} \delta^t (P_t^f - c) q_t (P_t^f)(1+\gamma(rd_{t-1})) \tag{1}$$

where,

δ^t is the farmer's discount rate,

P_t^f is the farmer's price received at the market,

q_t is the farmer's investment level (normalized, for example, to one unit of land), and

$\gamma(rd_{t-1})$ is the productivity gain generated by investment in public R&D in the previous five-year period, determined by its productivity (γ) and the government's spending level (rd_{t-1}).

Thus, in a competitive sector where subsistence yields zero profits, farmers plant as long as the farmgate price covers the total cost of production.

The Government

The government cannot itself undertake production, perhaps because supervision costs would be prohibitive. But it does control the marketplace, and is the only provider of R&D. The government sets the tax wedge between the price paid to farmers, P^f, and the price received from consumers which for simplicity (and realism, in a small-country setting) we assume to be an exogenous world price, P^w. We assume that policymakers have an infinite time horizon, and seek to maximize the present discounted value of some social welfare function which is a weighted sum of tax revenue and producer surplus given by,

$$W_t = \sum_{t=0}^{\infty} \beta^t \left\{ (P_t^w - P_t^f) \int_0^{P^f} q_t(c)(1+\gamma(rd_{t-1}))dc + \alpha \int_0^{P^f} (P_t^f - c_t) q_t(c)(1+\gamma(rd_{t-1}))dc - rd_t \right\} \tag{2}$$

where β^t is the government's discount rate, and α is the relative weight placed by policymakers on producer's surplus relative to tax revenue. To simplify notation, we define the following terms,

$$\int_0^{P^f} q_t(c)dc = Q_t(P^f) \quad and \quad \int_0^{P^f} cq_t(c)dc = Z_t(P^f) \tag{3}$$

which gives us the following expression for social surplus,

$$W_t = \sum_{t=0}^{\infty} \beta^t \left\{ P_t^w - P_t^f) Q_t(P_t^f)(1+\gamma(rd_{t-1})) + \alpha P_t^f Q_t(P^f)(1+\gamma(rd_{t-1})) - \alpha Z_t(P^f)(1+\gamma(rd_{t-1})) - rd_t \right\} \tag{4}$$

Optimal policy

In pursuing its objective the government has two policy instruments, the farmgate price and spending on R&D. To constrain the policymaker's problem in a realistic way we rule out nondistorting lump-sum taxes, and require each year's spending on R&D to not exceed the government's tax revenues. Hence, the government's problem is the following,

$$\underset{P_t^f, rd_t}{\mathrm{Max}} W_t = \sum_{t=0}^{\infty} \beta^t \left\{ (P_t^w - P_t^f) Q_t(P_t^f)(1+\gamma(rd_{t-1})) + \alpha(P_t^f Q_t(P_t^f)(1+\gamma(rd_{t-1})) - \alpha Z_t(P_t^f)(1+\gamma(rd_{t-1})) - rd_t \right\}$$

$$\text{s.t.} \quad \left\{ (P_t^w - P_t^f) Q_t(P_t^f)(1+\gamma(rd_{t-1})) \geq rd_t \right\} \tag{5}$$

For well-behaved functions, the optimality condition with respect to rd_t is:

$$\beta \, d\gamma \left[(P_{t+1}^w - P_{t+1}^{f*}) Q_{t+1} + \alpha P_{t+1}^{f*} Q_{t+1} - \alpha Z_{t+1} \right] = d\, rd_t \lambda_t \tag{6}$$

where λ is the Lagrange multiplier on the government budget constraint. Interpreting, the optimal level of R&D spending equates the marginal benefit of additional R&D spending to the marginal cost of additional taxation. If the constraint is binding, then $\lambda > 0$ and the distortions associated with raising government funds raise the R&D's marginal costs, requiring it to be more productive.

The first order condition with respect to P_t^f is;

$$\frac{dQ_t}{dP_t^f} \left[P_t^w - P_t^f(\lambda + \alpha - 1) \right] + Q_t(P_t^f)(\lambda + \alpha - 1) - \alpha \frac{dZ_t}{dP_t^f} = 0 \tag{7}$$

Rearranging terms and recognizing that $dQ_t/Q_t \div dP^f_t/P^f_t$ is equal to the farmgate price elasticity of supply yields the following solution for the optimal farmgate price,

$$\left(\frac{P^f}{P^w}\right)^*_t = \frac{1}{(1-\alpha+\lambda)(1+\frac{1}{\varepsilon^s})+\frac{\alpha\tilde{Z}'_t}{\tilde{Q}_t\varepsilon^s}} \tag{8}$$

where, $\tilde{Z}_t = Z_t(1+\gamma)$
$\tilde{Q}_t = Q_t(1+\gamma)$

Equation 8 implies that in the extreme case in which α=0 and policymakers place no value on producer surplus, the tax that maximizes their objective function is the revenue maximizing tax. As α approaches 1, the government's optimal tax approaches a value that depends on λ and ε^s.[2] A feature of the model structure is that the γ terms cancel, and the welfare maximizing tax is independent of the level of spending on R&D. But given that tax revenue, if the budget constraint is binding, and α lies between zero and one, the constraint may justify a tax higher than the otherwise optimal tax.

Equilibrium policy

The equilibrium tax would be the optimal one if it were to affect production immediately. But in the context of sunk costs and a delay in farmers' price response, the optimal tax would still be an equilibrium only if there were a commitment mechanism by which government could promise to sustain announced tax rates. In the absence of such a commitment mechanism, a government whose value of α is less than unity may be tempted to announce low taxes to induce investment, then raise taxes after sunk costs are incurred to expropriate the resulting economic rent. Farmers may, with experience, learn to doubt the government's announcements, fearing to lose their sunk costs. Thus observed investment and tax levels will be part of a repeated game between policymakers and farmers, whose equilibrium depends on the incentives available in deviation (or defection) from the optimal (or cooperative) policy.

To specify these incentives, we begin by assuming that farmers have no recourse against expropriation other than to retreat from the market. Following Besley (1997), if government deviates from optimal tax rates, farmers revert to subsistence farming for *k* periods. The length of *k* could be infinite, if subsistence production never generates enough surplus to support another experiment in market production, or it could be just one period. Given that expropriation of farmers' sunk costs would lead to *k* periods of no new investment, the government's net gain from expropriation is given by,

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[2] This is because when α=1,$Z'_t/Q_t\varepsilon^s$ simplifies to dQP^f/dZ and this term evaluated at P^{f*}_t is equal to one.

$$\hat{W}_t = \sum_{t=0}^{T}\left[(P_t^w - h_t^*)\tilde{Q}_t + \alpha(h_t\tilde{Q}_t - \tilde{Z}_t)\right] + \sum_{t=T+k+1}^{\infty} W_t \tag{9}$$

Equation (9) is derived assuming that the government must continue to pay some marginal harvesting cost, *h*, to some farmers for *T* periods in order to obtain the fruits of past investment and h_t^* is the solution to dW/dh. Hence the government saves on sunk costs and R&D. Implicitly, we assume crop rotation where some new planting occurs every year, and *T* represents the length of time over which the crop continues to produce without having to reinvest in sunk costs. This ranges from zero for crops that are replanted every year such as cereals, to several years or decades for long-lived crops such as coffee and cocoa. Since *k* represents the number of periods for which output equals zero because no new planting takes place, after expropriation farmers begin to plant again in period *T*+*k*+1.

For government the value of not deviating from the optimal policy is given by,

$$W_t = \sum_{t=0}^{\infty}\beta^t\left\{(P_t^w - P_t^f)\tilde{Q}_t + \alpha(P_t^f\tilde{Q}_t - \tilde{Z}_t) - rd_t\right\} \tag{10}$$

and as long as (10) remains greater than (9) the optimal policy is sustainable.

Conditions for the time-consistency of optimal policy

Subtracting (9) from (10) yields the following condition under which the optimal policy is a sustainable equilibrium:

$$\left[(1-\alpha)\frac{s^*}{P^{f*}}\right] \le \frac{\beta^{T+1} - \beta^{T+k+1}}{\beta - \beta^{T+1}}\left[\left(\frac{P^w}{P^{f*}} - 1\right) - \frac{rd}{P^{f*}\tilde{Q}}\right] + \frac{rd}{P^{f*}\tilde{Q}} \tag{11}$$

The left-hand side of inequality (11) is the ratio of sunk costs to total costs, weighted by government's relative valuation of farm income as opposed to tax revenue. It thus represents the government's short-run gains available in defection away from the low-tax, high-growth path. The right hand side of inequality (11) is the present discounted value of the long-run costs of deviating from the high-growth path: once farmers' profits are expropriated by high taxation, they revert to subsistence farming for *k* periods and the government loses the present discounted value of the foregone tax revenue adjusted for productivity increases owing to continued spending on R&D.

Equation (11) provides the testable hypotheses of the model. The factor highlighted in our model that is generally omitted from other analyses is s^*/P^{f*}, the observed ratio of sunk to total costs. The higher is this sunk/total cost (STC) ratio, the greater is the government's incentive to undertake predatory taxation after investment occurs. The STC ratio is largely a physical characteristic of production technology, and is relatively high for perennials and production systems requiring a heavy up-front investment in irrigation or field preparation. African countries tend to have a comparative advantage in these products, particularly tree crops, perhaps because the African environment, like the tropics more generally, offers less of a concentrated summer growing season with less available moisture and generally poorer soils than temperate regions. By favoring crops requiring heavy preharvest investment, the physical environment itself can be said to make farmers relatively more vulnerable to predatory taxation, thus inhibiting growth unless governments can commit to low-tax/high R&D policies.

Two other variables, α and β, formalize the role of political conditions that are often discussed in previous studies: α reflects the degree to which the government is representative of farmers as opposed to those who benefit from tax revenue, and β reflects the degree to which the government is impatient and discounts future tax revenues. For example, Hall and Jones (1999) argue that poor policies could be due to the limited political accountability associated with nondemocratic traditions, as would be captured by the parameter α. Similarly, Easterly and Levine (1997) argue that African countries' poor policy choices may be due to their internal ethnolinguistic divisions and frequent political conflict, hence high discount rates as captured by parameter β.

The remaining two variables, expected future world prices and the productivity of R&D, have also been said to differ systematically between Africa and the rest of the world. Deteriorations in the terms of trade may be as frequent as improvements, and the relatively low historical levels of R&D investment in Africa make it hard to identify its payoff. But recent projections of Africa's terms of trade (Hertel et al. 1998) suggest continued high demand for African farm products, and studies of the productivity of African agricultural research suggest that it is at least as productive as research elsewhere (Masters et al., 1999).

Consequences of agricultural policy for economywide growth

The political-economy model described above provides testable predictions about which countries will adopt what policies. To generate predictions as to the consequences of those policies for the economy as a whole we need to control for other major determinants of growth. Following the conditional-convergence approach to empirical growth of Barro (1991) and Barro and Sala-i-Martin (1995), we assume that our agricultural sector is embedded in a Cobb-Douglas aggregate economy for which growth is a transitional process from its randomly determined initial income (y_0) to its steady-state potential income (y^{ss}) determined by resource endowments and their productivity, and the time path of income follows:

$$\ln y_t = (1-e^{bt})\ln y^{ss} + e^{bt}\ln y_0 \tag{12}$$

where *b* is the speed of convergence to the steady-state. In this context, growth will be faster for countries with lower levels of initial income or higher levels of steady-state income. Differentiating (12) with respect to time we obtain the following:

$$\frac{d\ln y_t}{dt} = b\,e^{bt}y_0 - b\,e^{bt}y^{ss} \ , \quad where \quad b<0 \tag{13}$$

In the cross-country empirical implementation, we first ask whether policy choices are in fact correlated with material conditions as predicted by equation (11) – looking particularly for an effect of cross-country differences in the *STC* ratio when controlling for differences in other factors that influence policy. Then, we ask whether our measures of agricultural taxation and R&D investment are significant correlates of growth, raising the steady state income level in equation (13) controlling for its other possible determinants.

III. Empirical Application

Equation (11) is a condition for sustaining optimal policy. The model predicts that, if condition (11) is met, we will observe low taxes, high investment, and high rates of economic growth. If the condition is not met we expect to observe high taxes and low investment associated with the Nash equilibrium growth trap. Specifically, the model suggests that the low-tax, high-growth equilibrium will be harder to sustain: (a) the larger the share of sunk costs in total costs, (b) the smaller are expected future profits from a particular investment, (c) the greater the government's discount factor and, (d) the lower is expected future productivity of R&D spending. In deriving our estimating equations we will avoid needing to measure α, the weight on producer surplus, which we will treat as an unobservable variable taking on country-specific values.

To simplify notation, we rename each of the variables we are interested in testing. The sunk to total cost ratio is called *STC*. The government's discount factor is $\delta(T,k)$, where $\delta(T,k) = (\beta^{T+1}-\beta^{T+k+1})/(1-\beta^{T+1})$. It is expressed as a function of T and k to remind us that its value will depend on the length of punishment, k and on the type of crop, T, as well as on the pure time-preference factor β. The expected future profit margin is $PROF^e$. The expected productivity of R&D spending is $R\&D^e$. Rewriting equation (11) with the new variable names gives the following condition for sustaining the "high-growth" equilibrium,

$$STC\ (1-\alpha) \le \delta(T,k)(PROF^{\ e} - R\ \&\ D^{\ e}) \tag{14}$$

Our empirical strategy is to construct a direct test of the model followed by a variety of alternative formulations and robustness tests. Taken literally, the model implies that countries make discrete jumps from one regime to the other. Thus the direct test requires us to classify countries in terms of whether the observed tax rate is higher than the optimal tax implied by equation (8). In the absence of information on α, we classify as high-tax only those governments whose tax rates exceed the revenue-maximizing tax, computed using long-run elasticities following McMillan (2000). This is the highest tax that *any* government might consider optimal, as a lower rate would increase revenues for both government and producers.This model-based classification of tax regime differs substantially from the prespecified cutoffs used in other studies to differentiate between favorable and unfavorable policy environments, such as the 30 percent tax rate used by Jaeger (1992). We also classify countries into low- and high-growth regimes, based on whether per-capita growth rates were negative or positive.

Using the regime classifications we conduct a direct test of the model, asking whether the variables in inequality (14) are statistically relevant predictors of regime type in a probit specification. The advantage of taking the model literally in this way is that, if it were the true model, these parameter estimates would be precise. But we also wish to test the robustness of our observed correlations to alternative model specifications. In particular, we would like to use the tax and growth variables in a continuous OLS specification, to retain any information implicit in the magnitude of these variables, and to ensure that our results are directly comparable to others' work in the empirical-growth literature. The relevant estimating equations are derived below, first for the limited-dependent-variable probit specification and then for the linear OLS regression.

The limited dependent variable model

Up to this point, we have ignored α, the government's weight on producer surplus. We expect it to vary from country to country so we give it a subscript, α_i. The net benefit of a low-tax policy, y_i^*, depends on this unobserved variable,

$$y_i^* = STC_i(1-\alpha_i) - \delta(T,k)_i(PROF_i^e - R\&D_i^e). \tag{15}$$

What we observe is only which policy regime prevails, corresponding to the sign of (15): the dependent variable y_i is set equal to one if a low-tax regime prevails and zero otherwise. It is defined by,

$$y_i = \begin{cases} 1 & if \quad y_i^* \le 0 \\ 0 & if \quad y_i^* > 0. \end{cases} \tag{16}$$

Thus, the probability that a low-tax/high-growth regime prevails is,

$$prob(y_i = 1) = prob(y_i^* \le 0) = prob[(1-\alpha_i) \le \delta(k)_i(PROF_i^e - R\&D_i^e)/STC_i]. \tag{17}$$

Estimating this equation requires an assumption about the distribution of 1-$\alpha_{i.}$ Recall that the unobserved variable, α_I, is the weight that the government places on producer surplus relative to its own. Hence, it lies between negative infinity and one and is likely to be grouped between zero and one. It is reasonable to assume that the distribution of 1-α_i is log normal with mean μ and variance $\sigma^{2.}$ Hence,

$$prob\ (y_i = 1) = \Phi[\frac{\mu}{\sigma} + \frac{1}{\sigma}(\log(\delta(T,k)_i (PROF_i^e - R\,\&\,D_i^e)/STC_i)]. \tag{18}$$

where Φ is the cumulative distribution function of the normal distribution with mean 0 and standard deviation one, and μ and σ account for the fact that log(1-α_i) may have a normal distribution with a mean other than zero and variance not equal to one. Rewriting equation (18) in log-linear form yields the following estimating equation[3]:

$$prob(y_i = 1) = \Phi\ [\gamma_0 + \gamma_i \ln(\delta(T,k)_i) + \gamma_2 \ln(PROF_i^e - R\,\&\,D_i^e) + \gamma_3 \ln(STC_i)]. \tag{19}$$

Linear models

For OLS estimation we use inequality (14) informally, as a guide to the variables that might be important in determining policy levels rather than regime type. Here our dependent variables are the original continuous measures of taxation and spending on research and development in agriculture. Specifically, we estimate the following two equations:

$$taxation_{it} = \beta_0 constant + \beta_1 STC_{it} + \beta_2 PROF_{it}^e + \beta_3 \delta(T,k) + \varepsilon_{it} \tag{20a}$$

$$rd_{it} = \beta_0 constant + \beta_1 STC_{it} + \beta_2 PROF_{it}^e + \beta_3 \delta(T,k) + \varepsilon_{it} \tag{20b}$$

Then, to evaluate consequences of these policies for growth, we use equation (13) to generate the following estimating equation:

$$growth_{it} = \beta_0 constant + \beta_1 initial\ income + \beta_2 \text{determinants of steady state income} + \varepsilon_{it} \tag{21}$$

Data

Details of the data used, along with summary statistics for the entire data set and also for each estimation sample, are provided in the data appendix. The unpublished data on research and development expenditures for 19 African countries over the period 1961-1991 are provided in appendix Table 7. Key features of the time period and sample sizes are summarized here.

Our measure of initial income is GDP per capita in purchasing power parity dollars in 1965, from the Penn World Tables version 5.6. Growth is measured as the average annual change in the natural logarithm of GDP per capita between 1965 and

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[3] Note that two testable restrictions on these coefficients, namely $\gamma_0 = 0$ and $\gamma_1 = \gamma_2 = -\gamma_3$ are implied by the model but rejected in it is empirical application with the available data.

1990. Agricultural R&D is measured in real per-capita terms, and is derived from the work of Pardey et al. (1998). R&D expenditures are available on an annual basis for a total of 19 countries over a period of 30 years, 1961-1991. Agricultural taxation is measured in the product markets as one minus the nominal protection coefficient (NPC), the farmgate to border price ratio, as a measure of the divergence between what farmers could get if they sold their product directly to world markets and what they actually get due to government intervention. These data are derived from the work of Jaeger (1992), extended by McMillan (2000), and are available for a total of 56 crops and 32 countries for various years. For the cross-country regressions, the crop specific variables (eg tax rates and ratios of sunk to total costs) are aggregated up to national levels using production weights. All of these variables are computed annually, then averaged up to four sub-periods, 1970-74, 1975-79, 1980-84 and 1985-89 to take account of variation in world commodity prices and economic conditions.[4] Statistical tests are performed both for the individual sub-periods and then for the pooled data.

VI. Results

Tables 1 and 2 reports estimation of equation (19) using standard probit techniques, first for the tax regime and then for the growth regime as the dependent variable. Each column uses a different measure for the government's discount factor, starting with the measure developed by McMillan (2000) and then testing the major variables for political conditions reported in the Barro-Lee data set.

The signs of the estimated coefficients on all explanatory variables are as predicted by our model in all regressions, although the political variables are statistically significant in only three of the eight regressions. In the tax-regime regressions of Table 1, the STC ratio is by far the most strongly significant regressor; in the growth-regime regressions of Table 2, it is the net profitability variable. From Table 1, countries whose production systems require higher levels of sunk costs are more likely to have confiscatory agricultural tax regimes, and also to not grow – this is consistent with the model, as it is the taxation of these sunk costs which might tempt the government into deviation from the optimal policy. From Table 2, countries whose agricultural production is very profitable are particularly likely to experience growth, and also to have low tax regimes. Again this is consistent with the model, as it is the pursuit of these expected profits which induces the government to sustain the optimal policy.

Tables 3 and 4 report regression results for equations (20a) and (20b) respectively. The signs of the estimated coefficients are again as expected, and here the political variables are significant in five of the eight regressions. Although there is a much smaller sample size for regressions explaining R&D, significance levels are similar for the two dependent variables. In this context the magnitudes of the coefficients can be interpreted directly, and

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[4] These sub-periods are similar to the sub-periods used by Bevan, Collier and Gunning (1993) in a comparative analysis of Tanzania and Kenya and the impact of the boom in coffee prices.

the importance of the STC ratio is clearly visible in the results. Table 5 reports results for growth rates in a comparable way, revealing that a ten percent higher STC ratio is associated with a one percent lower growth rate.

Tables 6 and 7 report regressions estimating equation (21), using a cross section of the long-run data and then a panel of the five-year averages. The first column of both tables establishes the correlation between growth rates and our two agricultural policy instruments (taxation and R&D) plus their interaction. In both cases the predicted correlations are strong and significant. The Table 6 formulation permits us to include controls for three economywide policy measures that have achieved prominence in the empirical-growth literature: aggregate government savings as a measure of fiscal prudence, the openness of policy to foreign trade as a measure of rent-seeking and distortions in the external sector, and the quality of institutions as a measure of rent-seeking and distortions in the domestic sector. None of these controls has much influence on the results. Adjusted R-square values are high and unchanged, and coefficients are uniformly large and significantly different from zero—except for the taxation variable when controlling for the external openness, which may be due to similarities in the types of policies these two variables pick up. In any case, R&D levels remain a highly significant correlate of growth and long-run productivity, confirming the association between R&D and economywide growth in this context.

Table 7 provides the same regressions using panel data, allowing controls for unobservable influences on growth rates in particular countries or time periods. Column (1) gives results without controls for any such fixed effects. Column (2) allows for period-specific fixed effects, column (3) checks for both period- and country fixed effects, and column (4) drops the initial-income variable which, as a lagged value of the dependent variable could bias the panel results. As before the correlations between R&D and taxation with growth are highly robust to these controls. Results for each variable are similar to those using the long-run growth data in Table 6, although model R-square values are lower due to the presence of business cycles, terms of trade shocks, weather disturbances and other noise.

Finally, to provide results that are fully comparable to many other studies and provide a different sort of robustness test, Table 8 presents regressions that use our agricultural-policy measures as controls in a standard growth-accounting context. The first column of Table 8 takes the growth-accounting specification identified as empirically important on a worldwide basis by Sachs and Warner (1997), and replicates it for our within-Africa sample. Columns 2 and 3 do the same, discarding the variables which lose their significance in this context, for both the resticted Sachs-Warner sample and the larger sample for which the data are available. Columns 3a, 3b and 3c then add three alternative measures of taxation, and columns 3a', 3b' and 3c' do so with the R&D variable as well. Results are consistent across all three taxation measures: Columns 3a and 3a' use the dummy variable constructed by Deaton and Miller (1995) to indicate whether a country paid producers a relatively high proportion of the world price during the period 1970-1975, constructed using a weighted average of the country's most important exports. Columns 3b and 3b' use a similar dummy constructed by McMillan (2000) covering the period 1970-1979. Columns 3c and 3c' use the same continuous measure as in the previous tables, namely the average nominal protection coefficient, or ratio of domestic producer price to world price. Once again the R&D variable overshadows tax policy as a correlate of growth. This may be because its effect is stronger, but it could also be due to other factors such as having less measurement error than the tax variable.

IV. Conclusions

This paper presents and tests a model of policy choice aimed at explaining why so many (but not all) African governments adopt self-defeating predatory policies towards the private sector, when pro-growth reforms would yield greater incomes for both government and the private sector.

The theory is a political-economy model in which the government sets the level of taxation and R&D in a strategic game with domestic producers who produce output. One equilibrium has the government commit to low taxes with investment in R&D, so as to elicit high and growing levels of production. Another possible equilibrium involves high tax rates and no investment, to which the economy responds with low and stagnant levels of production and perhaps a retreat to subsistence.

Without an institutional mechanism for commitment to a particular strategy, the government can credibly be expected by farmers to sustain high-growth policies only if material conditions make it consistently in government's favor to do so. This requires that the sector's share of sunk costs in total costs be relatively small (yielding a low potential payoff to exploitation by a rent-seeking government), the government's discount rate be relatively low (leading to a high value on the future costs of exploitation in the present), high expected future profitability and high relative weight on farmers' as opposed to government's own income.

Empirical tests of these hypotheses find considerable support for the model, particularly for the relevance of the sunk-to-total-cost ratio in determining policy choice. Our preliminary conclusion is that one factor contributing to African economic performance could be that African policy-makers are trapped in a low-growth equilibrium of opportunistic policies and low investment, induced by high levels of sunk costs in the production system. Changes in technology or institutions that enable producers to escape taxation or retaliate against it, as well as changes enabling governments to make credible pro-growth commitments, are thus likely to have a high payoff in promoting a more favorable policy environment.

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Table 1.

Tax Regime Modeled as Probit Specification

Dependent variable: =1 if tax<revenue-maximizing tax and 0 otherwise

Explanatory Variables	(1)	(2)	(3)	(4)
Sunk-to-Total-Cost ratio	-4.72	-9.01	-8.81	-6.01
	(1.56)***	(3.07)***	(3.11)***	(1.81)***
Net profitability	0.53	0.74	0.67	0.27
	(0.38)	(0.33)**	(0.31)	(0.26)
Imputed Discount Rate	0.19			
	(0.11)*			
Political Instability		-1.17		
		(1.19)		
Frequency Revolutions			-0.59	
			(0.35)*	
Political Rights				-0.18
				(0.16)
No. of obs.	128	62	62	84
Likelihood Ratio Test	19.94	8.86	9.81	14.22

Notes: Figures in parentheses are robust (Huber-White) standard errors. Significance levels are 99% (***), 95% (**), and 90 (*). Definitions, sources and descriptive statistics for all variables provided in the data appendix.Likelihood ratio tests are for the null hypothesis that the coefficients excluding the constant term are jointly zero for each model. Under the null, the test statistic is distributed as Chi-2(3). The null is rejected for values greater than 7.8 at the 5% level.

Table 2.

Growth Regime Modeled as Probit Specification

Dependent variable: =1 if growth>0 and 0 otherwise

Explanatory Variables	(1)	(2)	(3)	(4)
Sunk-to-Total-Cost ratio	-7.06	-3.12	-3.01	-3.18
	(3.70)***	(2.65)	(2.68)	(1.96)*
Net profitability	0.33	0.28	0.29	0.72
	(0.08)***	(0.09)***	(0.23)***	(0.19)***
Imputed Discount Rate	0.04			
	(0.03)			
Political Instability		-0.86		
		(0.86)		
Frequency Revolutions			-0.46	
			(0.26)*	
Political Rights				-0.08
				(0.14)
No. of obs.	96	56	56	76
Likelihood Ratio Test	20.97	14.09	13.47	16.88

Notes: Figures in parentheses are robust (Huber-White) standard errors. Significance levels are 99% (***), 95% (**), and 90 (*). Definitions, sources and descriptive statistics for all variables provided in the data appendix. Likelihood ratio tests are for the null hypothesis that the coefficients excluding the constant term are jointly zero for each model. Under the null, the test statistic is distributed as Chi-2(3). The null is rejected for values greater than 7.8 at the 5% level.

Table 3.

Tax Level Modeled as Linear OLS

Dependent variable: average nominal protection coefficient by crop & period, 1965-90

Explanatory Variables	(1)	(2)	(3)	(4)	(5)
Sunk-to-Total-Cost ratio	-2.01 (.362)***	-1.65 (.483)***	-1.65 (.398)***	-1.59 (.407)***	-1.93 (.463)***
Net profitability	-.032 (.010)***	-.036 (.010)***	-.023 (.016)	-.020 (.016)	-.024 (.016)
Imputed discount rate		.005 (.004)			
Political instability			-.186 (.132)*		
Frequency revolutions				-.091 (.052)**	
Political rights					-.049 (.037)
Constant	2.24 (.275)***	1.92 (.395)***	1.91 (.294)***	1.84 (.289)***	2.41 (.379)***
No. of obs.	128	128	62	62	84
Adj. R^2	0.24	0.25	0.23	0.22	0.27
Root MSE	.265	.263	.216	.218	.267

Notes: Figures in parentheses are robust (Huber-White) standard errors. Significance levels are 99% (***), 95% (**), and 90 (*). Definitions, sources and descriptive statistics for all variables provided in the data appendix.

Table 4.

Agricultural R&D Level Modeled as Linear OLS

Dependent variable: average per capita agricultural R&D levels by country & period, 1965-90

Explanatory Variables	(1)	(2)	(3)	(4)	(5)
Sunk-to-Total-Cost ratio	-.015 (.004)***	-.016 (.007)**	-.019 (.004)***	-.015 (.005)**	-.016 (.004)***
Net profitability	.0004 (.0002)**	.0004 (.0002)*	.0005 (.0001)***	.0005 (.0002)**	.0004 (.0002)**
Imputed discount rate		.0000 (.0001)			
Political instability			-.006 (.001)***		
Frequency revolutions				-.003 (.001)***	
Political rights					-.0009 (.0002)***
Constant	.014 (.003)***	.014 (.006)**	..017 (.002)***	.013 (.004)	.020 (.002)***
No. of obs.	44	44	32	32	44
Adj. R^2	.26	.24	.51	.28	.39
Root MSE	.002	.002	.002	.002	.002

Notes: Figures in parentheses are robust (Huber-White) standard errors. Significance levels are 99% (***), 95% (**), and 90 (*). Definitions, sources and descriptive statistics for all variables provided in the data appendix.

Table 5.

GDP Growth Level Modeled as Linear OLS

Dependent variable: five year average annual growth, 1965-90

Explanatory Variables	(1)	(2)	(3)	(4)	(5)
Sunk-to-Total-Cost ratio	-.113 (.004)***	-.113 (.004)***	-.102 (.061)***	-.101 (.044)***	-.088 (.051)***
Net profitability	.004 (.001)**	.004 (.001)**	.003 (.001)***	.003 (.001)**	.003 (.001)**
Imputed discount rate		-.001 (.011)			
Political instability			-.049 (.022)***		
Frequency revolutions				-.026 (.011)***	
Political rights					.004 (.003)***
Constant	.014 (.003)***	.014 (.006)**	.017 (.002)***	.013 (.004)	.020 (.002)***
No. of obs.	95	95	56	56	75
Adj. R^2	.26	.24	.51	.28	.39
Root MSE	.002	.002	.002	.002	.002

Notes: Figures in parentheses are robust (Huber-White) standard errors. Significance levels are 99% (***), 95% (**), and 90 (*). Definitions, sources and descriptive statistics for all variables provided in the data appendix.

Table 6.

GDP Growth on Policy using Long-Run Data

Dependent variable: average annual growth of real per capita GDP, 1965-90

Explanatory Variables	(1)	(2)	(3)	(4)
Initial income	-3.96	-3.11	-3.92	-3.32
	(.954)***	(1.05)**	(1.17)***	(1.37**
R&D	3.03	2.35	2.72	3.05
	(.646)***	(.687)***	(.773)***	(.786)***
taxation	6.28	6.31	2.84	12.9
	(1.62)***	(1.74)***	(3.64)	(6.85)*
R&D x taxation	1.18	1.11	.562	2.21
	(.350)***	(.352)***	(.641)	(1.16)*
Govt. savings		.096		
		(.056)		
Openness (Sachs-Warner index)			1.71	
			(1.74)	
Institutional quality (IRIS index)				.141
				(.317)
No. of obs.	19	19	18	15
Adj. R^2	0.67	0.71	0.62	0.60
Root MSE	1.098	1.039	1.15	1.18

Notes: Figures in parentheses are robust (Huber-White) standard errors. Significance levels are 99% (***), 95% (**), and 90 (*). Definitions, sources and descriptive statistics for all variables provided in the data appendix.

Table 7.

GDP Growth on Policy using Panel Data

Dependent variable: growth of real per capita GDP by five-year period, 1965-90

Explanatory Variables	(1)	(2)	(3)	(4)
Initial income	-.042 (.016)**	-.038 (.015)***	-.126 (.029)***	
R&D	.030 (.009)***	.031 (.008)***	.057 (.012)***	.039 (.009)***
taxation	.094 (.040)**	.118 (.031)***	.079 (.041)**	.151 (.046)***
R&D x taxation	.015 (.007)**	.019 (.005)***	.012 (.007)**	.022 (.007)***
Control Variables	none	time	time & country	time & country
No. of obs.	93	93	93	93
Adj. R^2	0.23	0.31	0.64	0.46
Root MSE	.038	.030	.035	.037

Notes: Figures in parentheses are robust (Huber-White) standard errors. Significance levels are 99% (***), 95% (**), and 90 (*). Definitions, sources and descriptive statistics for all variables provided in the data appendix.

Table 8.

GDP Growth on Policy in a Growth-Accounting Model

Dependent variable:Growth of per capita ppp-adjusted GDP, 1965-90

Explanatory Variables		(1)	(2)	(3)	(3a)	(3b)	(3c)	(3a')	(3b')	(3c')
Initial Conditions	Income 1965	-1.76	-1.19	-1.08	-1.47	-1.48	-1.53	-2.24	-2.02	-2.12
		(.471)***	(.331)***	(.452)***	(.254)***	(.295)***	(.429)***	(.309)***	(.332)***	(.526)***
	Life 1965	.13	.11	.15	.16	.14	.13	.15	.14	.16
		(.051)***	(.052)***	(.038)***	(.037)***	(.038)***	(.056)***	(.046)***	(.034)***	(.069)***
	Primary 1970	0.59								
		(1.741)								
Policy Variables	Openness	26.21								
		(90.37)								
	Gov. Savings	.21	.21	.18	.17	.18	.18	.09	.14	.26
		(.046)***	(.027)***	(.029)***	(.019)***	(.024)***	(.059)***	(.037)***	(.046)***	(.094)***
	Institutions	.14								
		(.194)								
	Demography	4.21	2.73	2.03	1.28	1.82	2.21	1.39	1.48	4.14
		(1.536)***	(1.142)***	(.861)***	(.612)***	(.778)***	(1.503)	(1.139)	(1.243)	(2.168)
	Open*initial	-4.09								
		(6.932)								
	Taxation				-0.76	-0.73	2.34	-0.49	-0.02	1.15
					(.361)**	(.372)**	(1.059)**	(.557)	(.013)	(.982)
	R&D							1.22	1.18	1.69
								(.557)**	(.711)*	(.961)*
Immutable Characteristics	Tropics	.82								
		(.759)								
	Access	-0.84								
		(.464)*								
Adjusted R^2		0.76	0.76	0.66	0.69	0.67	0.44	0.78	0.76	0.39
No. of Countries		23	23	34	34	34	25	19	19	12

Notes: Figures in parentheses are robust (Huber-White) standard errors. Significance levels are 99% (***), 95% (**), and 90 (*). Definitions, sources and descriptive statistics for all variables provided in the data appendix.Columns denoted *a*, *b* and *c* use different measures of taxation, and the signs of the measure in *a* and *b* is opposite to that of *c*.

Data Appendix. Definition and Description of All Variables

Growth

Average annual change in real GDP per person from 1965 to 1990, from Sachs and Warner (1997). GDP data are from the Penn World Tables 5.6, and population data are from the World Bank's *WorldData* CD-ROM (1995).

Initial income

Log of real GDP per economically active person in 1965, from Sachs and Warner (1997), using GDP from Penn World Tables 5.6 and economically active population (defined as the population between the ages of 15-64) from the World Bank (1995).

Agricultural R&D

Log of average annual real R&D expenditure per capita in agriculture, from Pardey, Alston and Roseboom (1998). R&D expenditures include spending on personnel, operating expenses and capital expenditures in research and development for crops, livestock, forestry and fisheries, by public and semi-public agencies.

Agricultural taxation

Data on taxation of export crops in Sub-Saharan Africa were obtained from Jaeger for data through 1987, and updated to 1995 for the World Bank (Jaeger 1991, McMillan 2000). Jaeger uses the same methodology to estimate nominal protection coefficients (NPCs) used in Krueger, Schiff and Valdes (1988,1983) and recommended by Westlake (1987). And, where the country crop combinations are the same, Jaeger's estimates are practically identical to those reported in Krueger et al (1988,1993). All three of these studies point to the importance of properly adjusting international reference prices to reflect value-added and transport costs. Previous studies often looked only at the ratio of the farmgate price to the world price without accounting for processing and transport costs and hence grossly overestimated the rates of taxation. A better estimate of the level of taxation is the ratio of the farmgate price to the border price adjusted for transport and processing costs and is a measure of the divergence between what farmers could get if they sold their product directly to world markets and what they actually get due to government intervention. The tax rate is then one minus the NPC.

Calculation of the nominal protection coefficient requires data on prices paid to farmers, world prices, and an estimate of any value added to the crop between the time of pickup from farmers and export. Several sources including the Food and Agricultural Organization of the United Nations (FAO) and the World Bank now publishes data on prices paid to farmers and world prices. However, to estimate the true nominal protection coefficient, one must convert these farmgate prices into their equivalent in terms of the processed good and adjust the world price for transport and marketing costs.

For example, in 1986 farmers in Madagascar received the equivalent of \$0.89/kg. of dry robusta coffee cherries. The world price for roasted robusta coffee beans was \$2.57/kg.

Since 1 kg. of roasted coffee equals approximately 1.32 kgs. of dry cherries and because the world price is for dry cherries, first the farmgate price is converted to its international equivalent by multiplying .89 by 1.32 to get $1.17 per kg. We now adjust the world price for transport and processing charges by subtracting .27 per kg. and .10 per kg. to get $2.20 per kg. Hence, the NPC is 0.53 and the corresponding tax rate is 47%. Details of the conversion factors, transport costs, processing margins, and freight charges used by Jaeger are published in McMillan 2000.

Government Savings

Average central government surplus or deficit as a percent of GDP, 1970-90, as used by Sachs and Warner (1997) from World Bank (1995).

Openness (Sachs-Warner index)

The fraction of years during the period 1965-90 in which the country meets all of the following criteria: (a) nontariff barriers apply to less than 40 percent of trade, (b) average tariffs are less than 40 percent, (c) the black market foreign exchange premium was less than 20 percent, (d) the country is not classified as socialist and (e) major exports are not subject to monopoly trading, from Sachs and Warner (1997).

Institutional Quality (ICRG index)

Average rating for the rule of law, the quality of bureaucracy, the prevalence of government corruption, the risk of expropriation, and the repudiation of contracts by government. This index was used by Sachs and Warner (1997) and originally constructed by the Center for Institutional Reform and the Informal Sector (IRIS) from data printed in the International Country Risk Guide published by Political Risk Services.

Sunk-to-Total-Cost ratio

Computed from cost-of-production estimates for various crop years, as one minus the ratio of harvest cost to total cost from data and sources in McMillan (2000), appendix A.

Net profitability

Computed from data reported in McMillan (2000), and follows the recommendation of Deaton and Miller (1995) by estimating the expected future profit margin by taking an average of actual profits over the twenty-year period, 1970-1989.

Imputed discount rate

Defined as $\delta\,(T,k) = (\beta^{T+1}-\beta^{T+k+1})/(1-\beta^{T+1})$, where β is one minus one over the mean time in power for each country since the time of independence at each point in time, or the retrospective hazard rate for the probability that the present government will remain in power. For example, when Jerry Rawlings came to power in Ghana in 1981, the mean time in office for his predecessors was 3.14 years, so the probability that he would remain in power the following year was 31.45 percent. The imputed discount rate for government policy is this political discount rate, β, plus the time value of money at five percent per year.

Revenue Maximizing Tax Rates

Computed as one over one plus the elasticity of supply, the tax rate that maximizes total revenue. Elasticities of supply were obtained for each crop from a number of sources and are reported in McMillan (2000).

Political instability

Average over 1960-90 of the five-year averages reported by Barro and Lee.

Frequency of revolutions

Average over 1960-90 of the five-year averages reported by Barro and Lee.

Political rights

Average over 1960-90 of the five-year averages reported by Barro and Lee.

Variables used only in Table 8 (all from Sachs and Warner 1997)

Life Expectancy

Life expectancy at birth.

Primary

Primary-school enrollment rates.

Demography

Average annual growth of economically active population, minus average annual growth in the total population, for 1965-90.

Tropics

Fraction of land area subject to tropical climate

Access

Dummy variable set to 1 for landlocked countries.

APPENDIX TABLE A.1: SOME STATISTICS ON GROWTH

Cross-Section Data 1965-1995

Region	Coefficient of Variation[1]	Mean	Standard Deviation	Minimum	Maximum	Number of Obs.
Sub-Saharan Africa	2.66	0.67	1.78	-2.37	5.71	32
East Asia	0.42	4.96	2.06	1.39	7.41	8
South Asia	0.39	1.71	0.67	0.76	2.30	4
Latin America	1.66	0.86	1.43	-2.24	3.22	22
North Africa & Middle E.	0.46	2.14	.98	-0.01	2.92	7
OECD	0.33	2.66	0.87	0.97	4.66	22
Tropics	1.56	1.28	2.02	-2.37	7.39	63
Temperate	0.56	2.53	1.41	-0.25	7.41	32

Panel 1965-1995 Based on Five Year Averages

Region	Coefficient of Variation[1]	Mean	Standard Deviation	Minimum	Maximum	Number of Obs.
Sub-Saharan Africa	4.00	1.09	4.01	-8.02	17.09	238
East Asia	0.75	5.73	3.35	-3.74	13.31	84
South Asia	1.13	2.16	2.44	-2.07	7.75	33
Latin America	1.50	1.54	3.33	-7.39	9.92	135
North Africa & Middle E.	1.33	3.46	4.35	-8.56	14.63	61
OECD	0.67	3.18	2.15	-1.45	13.12	150
Tropics	2.00	1.99	3.91	-8.56	17.09	524
Temperate	1.00	3.17	2.89	-4.95	14.63	178

1/Coefficient of Variation is defined as the standard deviation divided by the absolute value of the mean.

APPENDIX TABLE A.2: SUMMARY STATISTICS FOR DATA USED IN TABLES 1, 2 AND 5

	Number of Obs.	Mean	Standard Deviation	Minimum	Maximum
avnpc	229	.6767717	.3165598	.015	1.986667
dscount	128	11.2202	7.89539	2.030303	23.99999
stc	128	.753125	.070563	.59	.87
netprof	128	2.377262	1.789646	0	11.33113
revol	171	.2083626	.3034599	0	1.8
pinstab	170	.111	.1563021	0	.93
prights	172	5.674593	1.325708	2	7
growth	99	.0079344	.0390853	-.0801642	.1709199

Correlation matrix for values used in estimation sample

	avnpc	dscount	stc	netprof	revol	pinstab	prights
avnpc	1.0000						
dscount	0.3584	1.0000					
stc	-0.4847	-0.7405	1.0000				
netprof	-0.1558	0.1167	0.0680	1.0000			
revol	-0.0979	-0.0940	-0.0143	-0.1976	1.0000		
pinstab	-0.0945	-0.0845	-0.0280	-0.2058	0.9977	1.0000	
prights	-0.2629	-0.1213	0.2681	-0.0754	0.1704	0.1634	1.0000
growth	0.1154	0.2022	-0.1639	0.1416	-0.3008	-0.2999	0.0653

Note: n= 62

APPENDIX TABLE A.3: SUMMARY STATISTICS FOR DATA USED IN TABLE 3

	Number of Obs.	Mean	Standard Deviation	Minimum	Maximum
All Observations					
avnpc	229	.6767717	.3165598	.015	1.986667
dscount	128	11.2202	7.89539	2.030303	23.99999
stc	128	.753125	.070563	.59	.87
netprof	128	2.377262	1.789646	0	11.33113
coup	180	.0498333	.1110864	0	.67
pinstab	170	.111	.1563021	0	.93
prights	172	5.674593	1.325708	2	7
Estimation Sample					
avnpc	128	.6489518	.3039305	.015	1.986667
dscount	128	11.2202	7.89539	2.030303	23.99999
stc	128	.753125	.070563	.59	.87
netprof	128	2.377262	1.789646	0	11.33113
coup	62	.0537097	.1206435	0	.67
pinstab	62	.13	.1845775	0	.93
prights	84	5.750833	1.192303	2	7
sample3	128	1	0	1	1

Correlation matrix for values used in estimation sample

	avnpc	stc	netprof	dscount	pinstab	coup	prights
avnpc	1.0000						
stc	-0.4677	1.0000					
netprof	-0.1932	0.0092	1.0000				
dscount	0.3356	-0.5911	0.1423	1.0000			
pinstab	-0.0945	-0.0280	-0.2058	-0.0845	1.0000		
coup	-0.1599	0.2193	-0.0669	-0.3486	0.4285	1.0000	
prights	-0.3035	0.2801	-0.0664	-0.1488	0.1634	0.1782	1.0000

Note: n= 128 for all variables except for pinstab and coup (n=62) and prights (n=84).

APPENDIX TABLE A.4: SUMMARY STATISTICS FOR DATA USED IN TABLE 4

	Number of Obs.	Mean	Standard Deviation	Minimum	Maximum
All Observations	(as for Table A3, except for R&D variable)				
rdagpop	114	.0063981	.0076084	.0001145	.0410093
Estimation Sample					
dscount	44	12.61891	8.498812	2.030303	23.99999
rdagpop	44	.003885	.002411	.0003956	.0082399
stc	44	.7372727	.0820766	.62	.87
netprof	44	2.622037	1.355139	.5868784	7.17088
coup	32	.0625	.1428737	0	.67
pinstab	32	.13625	.2020021	0	.93
prights	44	5.603182	1.016942	3	7
sample4	44	1	0	1	1

Correlation matrix for values used in estimation sample

	rdagpop	stc	netprof	dscount	pinstab	coup	prights
rdagpop	1.0000						
stc	-0.4950	1.0000					
netprof	0.1599	0.1179	1.0000				
dscount	0.4203	-0.8078	0.0196	1.0000			
pinstab	-0.4354	-0.1284	-0.0195	0.0097	1.0000		
coup	-0.3409	0.3151	0.0587	-0.4023	0.3236	1.0000	
prights	-0.3474	-0.0720	-0.0429	0.1993	0.1159	0.1232	1.0000

Note: n= 44 for all variables except coup and pinstab (n=32).

APPENDIX TABLE A.5: SUMMARY STATISTICS FOR DATA USED IN TABLE 6

	Number of Obs.	Mean	Standard Deviation	Minimum	Maximum
All Observations					
growth	42	.7288095	1.808697	-2.37	5.71
lnrd	19	-5.417179	.9748949	-7.35845	-3.495169
lnnpc	35	-.3651439	.4173538	-1.203973	.7419373
initial	42	7.3	.5698352	6.32	8.72
open	39	.0661538	.1775656	0	1
instqual	31	4.538065	1.196786	2.73	7
govsav	35	4.135143	5.252771	-3.34	20.86
Estimation Sample					
growth	19	.921579	1.914832	-1.99	5.71
lnrd	19	-5.417179	.9748949	-7.35845	-3.495169
lnnpc	19	-.2322986	.4571469	-1.203973	.7419373
initial	19	7.345263	.666503	6.32	8.72
open	18	.0983333	.2508398	0	1
instqual	15	4.877333	1.303481	2.73	7
govsav	19	3.327368	5.330188	-3.34	20.86

Correlation matrix for values used in estimation sample

	growth	initial	lnrd	lnnpc	govsav	open	instqual
growth	1.0000						
initial	-0.1688	1.0000					
lnrd	0.3316	0.8114	1.0000				
lnnpc	0.4363	0.2266	0.5083	1.0000			
govsav	0.6182	-0.1529	0.1850	0.0276	1.0000		
open	0.4679	0.4255	0.5358	0.5512	0.1545	1.0000	
instqual	0.3680	0.3229	0.5096	-0.2409	0.4674	0.3188	1.0000

Note: n=19 for all variables except open (n=18) and instqual (n=15).

APPENDIX TABLE A.6: SUMMARY STATISTICS FOR DATA USED IN TABLE 7

	Number of Obs.	Mean	Standard Deviation	Minimum	Maximum
All Observations					
growth	238	.011335	.0399167	-.0801642	.1709199
initial	254	6.72006	.6059545	5.517453	8.668712
lnnpc	229	-.5272161	.6213797	-4.199705	.6864582
lnrd	114	-5.594466	1.090045	-9.075287	-3.193956
Estimation Sample					
growth	93	.0131501	.0425218	-.0688716	.1709199
initial	93	6.752922	.5770551	5.517453	8.267449
lnnpc	93	-.5268534	.8419937	-4.199705	.6864582
lnrd	93	-5.694964	1.019065	-9.075287	-3.273539

Correlation matrix for values used in estimation sample

	initial	lnrd	lnnpc
initial	1.0000		
lnnpc	0.0131	1.0000	
lnrd	0.8214	0.1912	1.0000

Note: n= 93

Appendix Table A.7
Total agricultural research expenditures (million 1985 PPP dollars)

	1961	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**
Botswana	0.182	0.289	0.406	0.532	0.668	1.136	1.374	1.565	1.603	2.543
Burkina Faso	1.613	1.580	1.805	1.819	2.186	2.483	2.494	2.553	2.835	3.687
Cote d'Ivoire	18.038	20.925	22.994	24.848	26.067	28.059	28.028	27.614	29.921	30.497
Ethiopia	1.900	2.420	2.680	3.300	3.858	4.750	6.359	10.337	8.723	9.087
Ghana	12.152	12.607	13.368	14.484	16.209	16.161	16.598	17.237	18.439	20.001
Kenya	22.364	23.387	24.341	25.914	25.680	31.625	35.533	35.943	40.914	41.731
Lesotho	0.248	0.372	0.495	0.619	0.743	0.743	0.954	1.171	1.392	1.620
Madagascar	17.889	19.451	22.840	22.725	27.060	25.691	26.817	28.154	29.138	27.711
Malawi	8.114	8.623	9.082	9.542	10.513	10.666	14.442	18.225	18.259	17.880
Mauritius	3.200	3.501	3.802	4.103	4.680	5.072	5.555	6.020	6.467	6.898
Niger	1.993	2.249	2.505	2.761	3.017	3.324	3.529	3.785	4.041	4.336
Nigeria	42.151	58.252	59.201	64.828	88.667	87.347	83.379	82.652	86.555	82.661
Rwanda	1.969	2.363	2.757	3.151	3.545	3.938	3.876	3.813	3.751	3.688
Senegal	17.819	17.819	18.231	18.638	19.059	19.494	19.944	20.411	20.896	21.423
South Africa	75.490	82.394	84.519	94.046	103.104	109.037	110.184	115.180	116.274	126.077
Sudan	12.992	13.475	16.998	19.368	19.479	23.793	23.875	24.168	25.981	32.533
Swaziland	1.052	1.239	1.441	1.657	1.889	2.139	2.611	2.372	2.135	1.898
Zambia	4.379	4.850	5.453	5.388	7.234	8.936	10.357	10.968	11.331	12.676
Zimbabwe	13.609	14.718	15.827	16.936	17.304	20.470	20.588	19.975	20.338	25.197
Total (19)	257.153	290.514	308.743	334.658	380.958	404.862	416.497	432.144	448.993	472.142

	1971	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**
Botswana	2.673	2.960	3.542	5.432	3.276	4.060	4.499	6.026	6.790	9.795
Burkina Faso	2.851	3.613	3.921	4.122	4.573	5.045	5.600	6.085	6.690	6.964
Cote d'Ivoire	34.690	35.765	35.041	33.770	34.856	34.982	34.395	37.459	38.695	36.939
Ethiopia	9.194	11.941	10.820	14.079	11.998	15.518	15.603	17.260	17.916	18.968
Ghana	17.915	20.577	21.401	22.080	20.440	21.363	20.886	20.490	17.682	14.340
Kenya	49.689	59.096	59.838	51.172	53.045	53.051	56.073	65.884	66.427	57.673
Lesotho	1.852	2.101	2.542	2.485	2.629	2.764	2.890	3.008	3.118	3.375
Madagascar	29.279	30.171	28.885	17.649	16.094	17.663	16.466	18.632	18.152	16.008
Malawi	17.360	21.054	20.564	18.436	17.527	18.370	18.178	22.911	20.918	26.475
Mauritius	7.589	7.752	7.796	7.844	7.750	7.515	8.115	8.231	8.354	8.521
Niger	4.308	5.129	2.850	3.017	3.087	6.003	8.952	9.693	10.652	9.693
Nigeria	92.074	111.534	132.060	126.266	180.647	209.383	240.957	169.264	164.057	177.753
Rwanda	3.626	3.407	3.188	2.969	2.750	3.160	4.372	4.837	5.275	5.458
Senegal	25.478	22.648	23.449	24.997	29.063	33.132	33.290	35.006	32.608	31.742
South Africa	137.950	127.475	113.764	119.294	129.596	123.118	130.210	131.300	110.858	110.538
Sudan	34.936	38.176	38.290	37.643	36.587	36.156	35.503	32.413	29.613	49.402
Swaziland	2.867	2.660	2.453	2.246	2.039	1.832	2.488	2.866	1.692	1.787
Zambia	17.688	15.915	14.412	14.203	17.220	18.653	18.333	18.093	17.475	19.358
Zimbabwe	26.434	27.876	29.451	27.829	29.560	29.298	29.796	28.225	28.537	27.976
Total (19)	518.452	549.849	554.268	535.533	602.737	641.065	686.607	637.682	605.508	632.764

Appendix Table A.7

Total agricultural research expenditures (million 1985 PPP dollars)

	1981	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
Botswana	10.839	13.938	11.722	12.366	11.371	12.030	10.941	8.672	8.164	8.639	9.821
Burkina Faso	7.108	7.314	7.578	8.957	10.598	10.648	10.701	10.908	12.649	15.863	19.130
Cote d'Ivoire	39.388	39.063	37.521	34.059	33.053	35.019	35.138	37.084	38.508	39.017	37.607
Ethiopia	21.141	22.085	21.419	25.263	25.441	32.314	50.002	54.007	48.686	49.370	40.530
Ghana	13.544	11.778	9.872	12.642	19.584	28.668	34.082	32.530	33.988	34.514	32.517
Kenya	62.277	64.440	66.230	66.237	65.320	67.659	73.527	80.299	81.105	83.126	95.971
Lesotho	3.490	3.595	3.690	3.810	4.166	2.824	2.975	3.350	3.064	2.714	3.123
Madagascar	11.451	10.655	14.001	17.961	12.548	12.952	14.243	12.581	17.421	16.015	15.627
Malawi	21.954	23.454	26.576	26.697	21.272	24.720	33.383	27.681	28.622	28.199	27.308
Mauritius	9.629	9.307	9.957	11.976	11.600	11.238	10.905	11.033	10.811	10.845	12.625
Niger	8.036	8.130	11.131	10.868	10.812	12.254	11.766	14.812	15.554	11.825	9.829
Nigeria	211.858	188.401	154.023	122.686	110.887	109.054	82.171	93.566	80.981	82.154	86.902
Rwanda	5.765	5.081	5.950	6.214	6.937	10.995	15.354	16.776	19.880	10.086	10.027
Senegal	37.362	30.495	40.385	44.827	59.273	43.246	35.705	34.325	28.567	26.456	23.850
South Africa	141.395	138.201	136.388	151.196	158.625	162.416	156.179	151.839	166.885	158.125	166.194
Sudan	39.903	37.087	33.305	31.504	26.690	23.676	37.308	26.487	22.221	23.288	21.463
Swaziland	3.526	10.870	11.970	10.864	9.571	8.445	8.286	7.165	7.179	5.744	5.885
Zambia	19.815	24.256	23.864	24.747	20.212	18.690	17.866	20.658	20.903	16.947	24.013
Zimbabwe	33.646	32.462	28.774	34.074	35.564	39.813	41.525	41.975	43.196	46.411	43.252
Total (19)	702.127	680.612	654.357	656.946	653.524	666.662	682.059	685.751	688.384	669.338	685.675

Source:International Food Policy Research Institute