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Mining Revenue and Inclusive Development in Guinea

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Mining Revenues and Inclusive Development in Guinea^{*}
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ABSTRACT: What are the potential benefits of increasing the taxation of a foreign extractive sector? This paper applies this question to the case of Guinea by using a multi-sector macro-inequality model with heterogeneous agents. We quantify the long-run equilibrium impact of additional taxation when the proceeds are invested in human capital, inclusive infrastructure, and social transfers. Our analysis focuses on the response of GDP, labor formalization, poverty rates, Gini coefficients, rural/urban inequality and sectoral reallocation. The three forms of investment are complementary. Infrastructure investments favor formal production in the urban area while growth and government transfers boost the demand for food. These effects help support the rate of return to education, protecting job formalization through higher wages and prices of informal goods, as the education policy boosts labor supply in rural and urban areas.

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Introduction

As Guinea prepares for its transition back to democratic elections, it continues to face a number of challenges for economic development and social inclusion. Guinea consistently ranks among the lowest 12 countries worldwide in the World Bank’s Human Capital Index (HCI) without meaningful improvements over the past decade (see Figures A1-A2 in Appendix 1) and, in health and education, it lags behind the average Sub-Saharan African country and behind the average Low-Income Country (LIC) (see Figures A3-A4, Appendix 1).

However, these challenges are not devoid of opportunity. Guinea’s mining sector embodies revenue potential that could generate substantial fiscal space in the short and long run. Mining accounted for 84 percent of Guinea’s total exports and 21 percent of its GDP as of end-2021. With an estimated 7.4 billion tons, Guinea has the world’s largest reserves of the bauxite mineral, which is an essential input for producing aluminum.¹ How could any additional revenues from mining translate into more inclusive economic growth and social development? This paper seeks to quantify the potential impacts of plausible development policies that could be financed with the additional fiscal space generated by mining revenues in Guinea, including the following policies:

- Human capital formation through early and basic education;
- Inclusive infrastructure investments; and
- Social protection via cash transfers.

The educational human capital policies we consider are key for our research because we can incorporate them in a simple way into our model and calibrate their impact and costs to well-established empirical returns measures. Furthermore we can use the educational policy as a rough stand-in for other fundamental human capital policies such as those improving child mortality, nutrition, health and longevity indicators. We leave a precise analysis of health investments in Guinea for future work.

The infrastructure investment we consider is inclusive because it impacts the total factor productivity for a broad set of economic activities. Our baseline assumptions for the productivity of infrastructure investments contrast starkly with the infamous “white elephant” investments that have conspicuously, albeit occasionally affected African economies during times of abundant financing. In fact, we base our assumptions on the sectoral impact of infrastructure on

¹In the short-run, the adoption of more transparent pricing schemes by multinationals can generate substantial revenue. In the long-run, applying the existing mining code to new contracts while limiting corporate income tax exemptions for mining producers would raise substantial revenues for the country. See Mogues (2021) for further discussion.

panel regressions employing broad year and country samples. Finally, our social protection via cash transfers policy emphasize the ease of implementation: a lump sum transfer to all households. While targeted transfers are desirable we also leave their detailed analysis to future work and qualify our analysis being conservative regarding the extent to which means-tested programs can be easily implemented.

These development policies are evaluated through their impact on a number of indicators that seek to gauge changes in the country's economic performance, social inclusion and development. The indicators are:

- Poverty rates, poverty depth, and the Gini coefficient of household-level consumption expenditures;
- GDP per capita, government surplus and tax revenue;
- Rural/urban inequality; and
- Sectoral reallocation and diversification of the economy, including its reliance on food imports.

Our methodology consists of performing stylized policy reforms within a model of Guinea's economy and use the outcomes of those policies to generate lessons that can be taken into account by real-life policymakers. These lessons are not necessarily policy advice, they rather aim to enrich the policy debate from the perspective of a self-consistent frame of reference provided by the model.

Our analysis shows that revenues from mining can be crucial for long run development. We also show that education and infrastructure policies are complementary: without education, infrastructure policy has a small and ambivalent impact on poverty and inequality; yet without infrastructure, more education erodes the returns from education even leading to more informality in rural areas.

The remainder of the paper is structured as follows. The next subsection reviews literature relevant to this analysis. Section 1 describes the model and its equilibrium conditions. Section 2 describes the calibration of our model to match the Guinea economy. Section 3 then describes the policies to be analyzed and their calibration to the data. Section 4 discusses the functioning of the calibrated model under the baseline equilibrium. Section 5 describes the modeled policy outcomes. Finally, we conclude with a summary of our main findings, based on the results of Section 5.

Related Literature

This paper builds on the work of a small number of studies that have applied quantitative macro models with heterogeneity to analyze the macro-inequality consequences of different policy regimes in LICs.²

In this vein, Gibson and Rioja (2020) focus on quantifying the effect of infrastructure on growth, inequality and welfare. Their results show large and desirable impacts of reasonable infrastructure policies and emphasize differences in distributional impacts that arise from different financing schemes. In contrast to our work, their framework does not take into account the role of foreign extractive industries as a potential source of fiscal space to finance the reforms, and does not consider a connection between education policy and infrastructure.

Mendes-Tavares et al. (2021) analyze the impact of fiscal revenue generation in a model economy roughly similar to ours. Our main contribution in this dimension is to take into account how development policy can interact with the generation of additional revenue. In particular, our infrastructure reform can substantially expand the revenue potential from the foreign extractive sector because the productivity of the mining sector is enhanced, counteracting the curvature of the sector's Laffer curve with respect to mining tax rates. This is a consequence of the inclusive nature of our infrastructure investment.³

Fabrizio et al. (2017) examine the distributional effects of combinations of tax policies and investment reforms that have been identified as growth-promoting in low-income developing countries (LIDCs). Their analysis highlights the differences in the distributional impact of different tax policies. On the expenditure side they argue that more and better infrastructure can boost growth and diminish inequality, that financial sector reforms can exacerbate inequality under certain conditions and that reforms that boost agricultural output can worsen income inequality under certain conditions.

Our paper complements their analysis by honing in on the country case of Guinea and exploring the synergy policymakers can attain when allocating scarce investment resources across three key policies: education, infrastructure and social transfers. In addition, we seek to deepen our quantitative understanding of the role that foreign extractive sectors like Guinean mining play in LIDCs. One of our broader policy messages is that seeking for alternative sources of revenue

²Some theoretical foundations of the macro impact of infrastructure are outlined in Glomm and Ravikumar (1994), while the relationship between education, growth and distribution is explored in Benabou (2002). For a representative application of education in heterogeneous agent models for the United States, see Restuccia and Urrutia (2004).

³In comparison with them, we model the foreign extractive sector and consider the role of the Laffer curve of foreign extractive sectors for revenue mobilization and fiscal consolidation, in contrast to only focusing on tax revenues. Additionally, we include the impact of food imports on the behavior of food prices, the impact of the public services sector on the economy, and we allow a semi-open instead of a closed economy in terms of capital flows.

besides traditional consumption, income and profit taxation is important when searching for fiscal space. In the context of policy-relevant representative-agent dynamic macro models, Buffie et al. (2020) explore the complementarity among several government policies, including education and infrastructure.

To our best knowledge, this paper’s contribution is twofold: (i) we provide a framework to quantitatively analyze the connection between foreign extractive sectors, growth and distribution; and (ii), we quantitatively address the interplay between the paramount triad of development policies, namely education, infrastructure and transfers in a general equilibrium semi-open economy macro-inequality framework.

1 Model

Our model is an infinitely lived economy where urban and rural households experience independent idiosyncratic histories of exogenous labor productivity. Rural households can work formally for large “farmtrepreneurs” or for foreign mining firms. Urban households can work formally for the manufacturing firms or for government service enterprises. Households’ remaining time is spend in informal production of food and services in the rural and urban areas, respectively. The external sector exports capital services, commodities, mining goods, and manufactured goods while it imports capital services, food and manufactured goods. The households consume food, services and manufactured goods while saving in a riskless capital asset that they can rent to manufacturers and foreigners.

The foreign mining sector employs low skilled workers and imports capital services (which also embed managerial and consulting labor services) exports all output, and pays taxes. The manufacturing sector rents capital services from the local households or from abroad, hires urban labor, produces, and pays taxes. The government service sector uses capital accumulated by the government at an exogenous rate together with urban labor to produce services that compete with ththose supplied informally by the households.

The educational policy uses government resources to increase the labor productivity of households while the infrastructure policy accumulates stocks of transportation, communications and energy that impact TFP for all productive activities, including the informal work. Finally, the government can give out lump-sum transfers of the same magnitude to all households. These government expenditures are financed via consumption taxes (VAT), taxes to corporate revenues (CIT) and taxes to labor income (PIT).

More specifically the model features three sets of consumers broadly representative of the country’s economy: urban households, rural households and “farmtrepreneurs,” that represent

the set of large family-run farms in the agricultural sector. We refer to each set of consumer as as type $j = 1, 2, 3$, respectively. Each set comprises a share μ_j of the population, in which the sum of the shares equals 1, the size of total population. We assume that there is a very large number of households (tending towards infinity) and that each household represents a tiny part of the population. We further assume that every household and the farmtrepreneurs are independent and different from each other. Unless otherwise noted, in what follows, all variables defined pertain to any single atomistic consumer unit.

1.1 Household Behavior

Each year, every household chooses a basket with three types of final consumption goods: food, services and manufactured goods. We denote the basket by the vector array $c = (c_f, c_{sv}, c_m)$. The annual utility that a given household derives from a particular consumption basket is denoted $u(c)$. The cost of the consumption basket is paid from the household's income net of taxes plus available financial assets. Households then save any remaining resources for the next year. These savings are denoted a' .

At the beginning of each year, the household observes its existing stock of savings a and its productivity z . Then, the household chooses s , the share of time spent supplying formal labor. Once all annual income is accrued, the household chooses c , the basket of annual consumption, and; a' , its savings for next year.⁴ Function $y(z, l, s, w_l)$ gives the formal labor income of a household with productivity z in location l formally working a share s of its available time, when local wages are w_l . Function $y^*(z, l, 1 - s, w_l)$ gives the informal labor income of such household. Note that the disposable time not spent in formal work, $1 - s$, is devoted to informal work in its entirety.⁵ Function $T(l, c, y, p)$ gives the total taxes paid by the household. Taxes can depend on location l , consumption basket c and its price p , and on formal income y . The taxes are net of any government transfers. Functions y , y^* and T are specified below.

We can describe the dynamic utility maximization problem faced by each and every household in either location $l = \{rural, urban\}$ using the basic language of dynamic programming that

⁴The product $a(1+r)$ in the budget constraint denotes the household's total financial wealth at the beginning of the year, including savings from last year and interest accrued at rate r on those savings.

⁵Traditionally, time-use models include some leisure, we follow Mendes-Tavares et al. (2021) and abstract from leisure. We acknowledge that leisure is important in developed economies. For Guinea we consider that lack of opportunity dominates the desire for quiet enjoyment. Therefore we interpret informal production time $1 - s$ as including idle time. We consider that people who are not working are still attempting to "make ends meet" continually, albeit at a low productivity rate. Also we acknowledge that a continuous time choice with perfectly elastic demand can be too flexible compared to real life. On one hand we note that our choice reflects time aggregation over the activities performed over a full year, and on the other hand it reflects aggregation across all working-age family members.

says that households choices lead to the optimal value of expected discounted utility:

$$V_l(a, z) = \max_{s, c, a'} [u(c) + \beta E[V_l(a', z')|z]]. \quad (1)$$

subject to the time use constraint:

$$0 \leq s \leq 1.$$

and the budget constraint:

$$a(1 + r) + y(z, l, w_l, s) + y^*(z, l, w_l, 1 - s) - T(l, c, y, p) \geq p \cdot c + a'.$$

Equation 1 is the optimal value function for location l . For a household with initial assets a and productivity z , Equation 1 gives the optimized expected value of utility measured at the beginning of the year. Variables s, c, a' are chosen by the household with the goal of maximizing the sum of current-year utility $u(c)$ plus all future expected utility $E[V_l(a', z')|z]$, discounted at rate $\beta < 1$.⁶

The choice of s, c, a' cannot violate the time use constraint or the budget constraint. The time use constraint says that the share of time used to work in the formal labor market has to be between zero and one. The budget constraint says that the total sources of wealth have to be less than or equal to the total uses of wealth. Finally, we define $p \cdot c = p_a c_a + p_{sv} c_{sv} + p_m c_m$ to denote total consumption expenditures before taxes, i.e. the sum of the element-wise product of vectors p and c .

We note that the functions describing income and taxes (y, y^*, T) are explicitly defined below, while function $V_l(a, z)$ is endogenously determined by the solution of the functional equation in Equation 1, via the principle of dynamic programming. Intuitively, the V_l on the left hand side of the functional equation can be thought of the infinite sum of optimized future utility flows. The max operator determines how decisions (s, c, a') must be made in the current year, taking into account their expected impact on future years, assuming that the household will continue to make optimal decisions in future years.

⁶Future utility depends on the chosen future assets a' and on the outcome of the random shock z' . The equation assumes that future choices will be optimal from next year onwards, as the value starting next period is also given by function V_l . The expected value E is taken by averaging $V_l(a', z')$ over all the possible outcomes of the productivity shock z' . The weights for averaging each z' come from the conditional probability distribution of z' given z . Note that we assume that the z shocks follow an AR(1) process so that the probability of having shock productivity z' next period depends on the current productivity, denoted z . For simplicity, we now assume the shock takes discrete values and the probability of observing the sequence z, z' in two consecutive years is given by the joint distribution $\pi(z', z)$.

1.2 Determination of Income and Taxes

Taxes paid by urban and rural households consist of a flat tax on consumption (VAT) and a flat labor income tax (PIT) which are identical across regions. For each type of tax, there is a tax gap such that effective taxes collected from households are:

$$T(l, c, y, p) = \tau_{income}(1 - gap_{income})y + \tau_{cons}(1 - gap_{cons})c^{formal} \cdot p - g \quad (2)$$

Equation 2 simply states that total taxes are the sum of the PIT and VAT levied on the final consumption goods produced in the formal sector, i.e. formal consumption (denoted c^{formal}). The third term g denotes any government transfers.

While find the optimal decision rules c and a' numerically using the computer, while we can find an analytical solution for time share at formal work, s as a function of z and w_l . We first define formal income as the product of effective labor supply $z \times s$ and the wage rate so that

$$y(l, z, s, w_l) = w_l z s,$$

and we define informal income as a concave function of effective informal labor $z(1 - s)$ times the unit price of informal goods so that

$$y^*(l, z, 1 - s, p) = p_l \varepsilon [z(1 - s)]^\alpha.$$

Net labor income is thus given by

$$y^* + y - y\hat{\tau} = p_l \varepsilon [z(1 - s)]^\alpha + z w_l s (1 - \hat{\tau}), \text{ with } 0 < \alpha < 1 \text{ and } \varepsilon > 0$$

where $\hat{\tau}$ is shorthand notation for the effective income tax rate $\tau_{income}(1 - gap_{income})$ and p_l is defined to represent the price of the good that is produced by the informal sector in region l .

Because s is an intratemporal decision, it can be chosen to maximize household income, in the following auxiliary problem:

$$\max_s p_l \varepsilon [z(1 - s)]^\alpha + z w_l s (1 - \hat{\tau})$$

subject to the time use constraint:

$$0 \leq s \leq 1.$$

The auxiliary problem allocates a share s of discretionary time to market work and a share $1 - s$ to informal work. Marginal informal income from putting a unit of time in the job market is fixed at $z w_l$ times one minus the effective tax rate. *Informal* marginal income from a unit of

time in informal work is strictly decreasing and equal to $\alpha \varepsilon z^\alpha (1 - s)^{\alpha-1}$.⁷ The solution, as a function of the household's state, taking wages, prices and tax rates as parameters, is:

$$s_l(z, a) = \max \left(0, 1 - \frac{1}{z} \left(\frac{\alpha \varepsilon p_l}{w_l (1 - \hat{\tau}_{income})} \right)^{\frac{1}{1-\alpha}} \right) \quad (3)$$

Equation 3 implies that a corner solution with zero formal work is possible. We can see that formal labor time s is increasing in wages and in the households skill z , and decreasing in the tax rate and the price of the informally supplied good. This simple static decision problem will be at the heart of our model's reaction to changes in relative prices, regional wages, and shocks. For households providing positive formal work, the behavioral reaction to a small increase in skill z is to formal work time. This implies that, keeping wages fixed, effective labor supply increases when all agents experience a productivity increase (like in the case of our educational reform). Since wages and informal goods prices p_l also affect formal labor supply, the labor supply effect of an economy-wide increase in skills z may well be positive or negative, depending on the equilibrium reaction of wages and sectoral prices p_l , which we cannot characterize analytically. Interestingly we will observe how some of our reforms have opposing effects in the rural and urban areas.

1.3 Farmtrepreneurs

The farmtrepreneurs make up the third type of consumer. These agents have the same preferences for consumption as households; however, farmtrepreneurs differ from rural households in two key ways. First, farmtrepreneurs do not face idiosyncratic risk, reflecting their size and our model's focus on the lower end of the income distribution, rather than the top. Second, farmtrepreneurs can hire labor in rural areas to produce two different types of goods: (i) the same food produced informally by rural households, or (ii) an export commodity. Producing the export commodity requires capital and labor, while producing food requires only labor (and, implicitly, land). We assume farmtrepreneurs cannot borrow in financial markets capital so they gradually accumulate the capital required to produce the export commodity. This restriction highlights the limited depth of financial markets in many LIDCs. The optimization problem of farmtrepreneurs is given by:

$$V_f(k) = \max_{c, k'} [u(c) + \beta V_f(k')] \quad (4)$$

⁷Note that marginal informal income falls within the range $[\alpha \varepsilon z^\alpha, \infty]$ for parameter α values between 0 and 1 while formal income is fixed. This guarantees that solutions will have the property that *formal* work s is strictly less than one, although it can take the value zero, while *informal* work is always positive.

subject to the budget constraint:

$$k(1 - \delta) + \pi(w_{rural}) + \pi^*(k, w_{rural}) - T_f(R_1^*, R_2^*) \geq c \cdot p + k' \quad (5)$$

R_1^* and R_2^* in the budget constraint (Equation 5) are the optimal revenues from food and export commodity sales of the farmtrepreneur and π and π^* are the optimal profits from farming and production of agricultural export commodities, respectively. Every year, the farmtrepreneur chooses a consumption basket c and the capital stock for next year, k' . Optimal profits depend on the accumulated stock of capital k and wages w_{rural} per unit of effective labor. In particular, the profits from food production are given by:

$$\pi(w_{rural}) = \max_{n_1} R_1(n_1) - w_{rural}n_1$$

where $R_1 = p_f \varepsilon_1 n_1^{\alpha_1}$ is the sales revenue from food sales by the farmtrepreneur. Also, the profits from export commodities, given capital, are given by:

$$\pi^*(k, w_{rural}) = \max_{n_2} R_2(k, n_2) - w_{rural}n_2$$

where $R_2 = p^* \varepsilon_2 (k^\zeta n_2^{1-\zeta})^{\alpha_2}$ is the sales revenue from export commodity sales by the farmtrepreneur. This problem includes new parameters, ε_1 and ε_2 , which are productivity constants; the two α_2 parameters, controlling returns to scale; and parameter ζ , controlling capital and labor shares. Note that, for simplicity, all of the farmtrepreneur's capital is assumed to be used for production of export commodities so they cannot save in the financial market. This completes the specification of farmtrepreneurs in our model. The taxes on optimal revenues are specified as follows: $T_f(R_1^*, R_2^*) = \hat{\tau}_f R_1^* + \hat{\tau}_{fx} R_2^* - g$ where the two τ parameters are effective revenue tax rates on food and export commodities revenues, and g are lump sum government transfers that are also received by farmtrepreneurs.

1.4 Extractive Multinational Sector

Our model of extractive multinationals in Guinea's mining sector features a single firm that uses foreign capital and local unskilled labor under a Cobb-Douglas technology with decreasing returns to scale. We assume the global market for extractive export goods is competitive in the sense that Guinean output does not affect the world market price.⁸

⁸We note that, in practice, vertical integration leads many extractive multinationals to engage in "transfer pricing," or when a firm sells to its partner firms or affiliates. When the parties put in place a price level to reduce their taxable income, transfer pricing can be considered abusive. This practice has been previously analyzed in Guinea's mining sector. For example, Mogues (2021) uses an IMF mining forecasting model to assess the

We follow Schmitz (2005) and Greenwood and Weiss (2018) and assume a smooth technology and a unit elasticity of substitution between labor and capital. We thus also employ a Cobb-Douglas production function.⁹

Our model features decreasing returns to scale.¹⁰ This assumption allows us to match the observed elasticity of supply, which will determine the impact of government policy on the size of the foreign extractive sector, generating a behavioral response consistent with the views of the Guinean authorities that basically says that more taxes imply less business. In particular, the behavioral response generates a Laffer curve by which increased taxation increases the share of the pie obtained by the government, but only at the expense of making the total pie (e.g. mining output) smaller and smaller.

We use the x subscript for all variables and parameters related to this sector, for convenience:

$$Y_x = A_x (K_x^{\alpha_x} L_x^{1-\alpha_x})^{\gamma_x}$$

The problem of extractive multinationals, given the effective tax rate $\hat{\tau}_x^*$, the rural area wage rate w_{rural} and the international price of mining commodities, is to choose the capital and labor to maximize profits:

$$\pi_x = \max_{K_x, L_x} p_x (1 - \hat{\tau}_x) A_x (K_x^{\alpha_x} L_x^{1-\alpha_x})^{\gamma_x} - w_{rural} L_x - (r^* + \delta_x) K_x.$$

Parameter r^* is the opportunity cost of capital faced by the foreign firms and δ_x is the depreciation rate for mining equipment. The solution to this optimization problem is:

$$L_x^* = \left[\frac{(1 - \alpha_x)(1 - \hat{\tau}_x)\gamma_x p_x A_x}{w_{rural}} \left(\frac{\alpha_x}{1 - \alpha_x} \frac{w_{rural}}{r^* + \delta_x} \right)^{\alpha_x \gamma_x} \right]^{\frac{1}{1-\gamma_x}}$$

$$K_x^* = \frac{\alpha_x}{1 - \alpha_x} \frac{w_{rural}}{r^* + \delta_x} L_x^*.$$

Using this solution we can calculate several statistics that can be helpful for calibrating the

revenue gains from carrying out modest reforms to select mining companies. The results of this analysis serve as a useful benchmark and quantitative guide for our model. We maintain the profit-maximization framework from quantitative economics in order to evaluate the behavioral and the equilibrium impact of policies, as well as the feedback effect of other human capital investments and cash transfers on the mining sector. Our model can also be used to analyze the impact of changes in the world market price of mining output.

⁹In comparing our model to Schmitz's, our formulation is consistent with the inclusion of a non-substitutable, Leontief, materials input. So long as such materials input is tradeable, as noted in Greenwood and Weiss (2018), its price will be fixed and its ultimate role will be to renormalize the productivity parameter A_x by a fixed proportion. Our calibration of this parameter is independent of the non-substitutable materials parameter, so we omit it (see Section 3 for further details).

¹⁰This feature of the model differs from Schmitz because we are not analyzing a structural transformation of the industry or a change in competition.

parameters of the production function. The share of revenue paid to labor is:

$$\frac{w_{rural}L_x}{p_xY_x} = (1 - \alpha_x)(1 - \hat{\tau}_x)\gamma_x$$

while the mining supply elasticity with respect to prices is:

$$\frac{d \log Y_x}{d \log p_x} = \frac{\gamma_x}{1 - \gamma_x}.$$

The share of the labor force and the share of output to GDP can also be directly calculated, as $\frac{p_xY_x}{GDP}$. Finally the tax rate on revenues is given by:

$$\hat{\tau}_x = \tau_x(1 - gap_x).$$

1.5 Food Imports

Guinea is defined as a low-income food-deficit country (LIFD) by the Food and Agriculture Organization of the UN (FAO), meaning that it relies on food imports to stabilize its food supply but remains vulnerable to domestic and external shocks that could affect the nutritional status of its vulnerable populations. We thus follow the empirical literature that estimates the trade elasticity to changes in the relative price. In particular, we adopt the following reduced form equation, which is widely used and estimated in the literature:

$$m_f = \left(\frac{p_f}{p_f^*(1 + \hat{\tau}_f)} \right)^\varepsilon$$

Where parameter ε is the trade elasticity, we assume the foreign price of food is p_f^* , the local price of food is p_f , and the import price of food is m_f . Hillberry and Hummels (2013) review the models that give rise to this type of equation as well as the empirical literature that estimates the parameter ε .

1.6 Manufacturing Sector

A competitive manufacturing firm rents capital from households and foreign financial markets at interest rate r , pays for depreciation, and sells manufacturing goods in the combined domestic and international markets. Profit maximization is thus given by:

$$\max_{K_m, L_m} (1 - \hat{\tau}_m)p_m A_m K_m^{\alpha_m} L_m^{1-\alpha_m} - w_{urban}L_m - (r + \delta)p_m K_m$$

Due to the assumption of constant returns to scale, the solution specifies the optimal combination of capital and labor to be employed by the manufacturing firm, given the prices of inputs and outputs. The size of the sector depends on the equilibrium conditions, which dictate that wages be such that this sector has to absorb all the urban formal labor supply not demanded by the government while it rents its desired amount of capital at international rate r .

1.7 Public Service Sector

The public services sector can absorb some of the additional labor supply generated by educational reforms and enhances the supply of services as the economy expands. The provision of public services follows three assumptions. First, the government invests a fixed share of GDP ζ in capital for service enterprises. Second, government services are perfect substitutes with services provided informally by the urban households. Third, the government hires labor competitively in the urban labor market in an efficient proportion to its capital stock. We add the subscript e to all variables related to the public service sector. If all capital is composed of manufactured goods and the depreciation of public enterprise capital is δ_e , the law of motion for public capital is $K_{e,t+1} = \zeta GDP/P_m + (1 - \delta_e)K_{e,t}$, so the steady-state public service capital is $K_e = \frac{\zeta_e GDP}{\delta_e P_m}$. The optimal profits of the public enterprise, given the capital stock, are:

$$\pi_e^*(w_{urban}, K_e) = \max_{L_e} p_{sv} A_e K_e^\alpha L_e^{1-\alpha_e} - w_{urban} L_e - \delta_e P_m K_e.$$

The first order condition for optimality is $w_{urban} = (1 - \alpha_e) p_{sv} A_e K_e^\alpha L_e^{1-\alpha_e}$. From this condition, we solve for the public service sector's demand of labor as a function of GDP and other variables, given by

$$L_e = \left(\frac{A_e P_{sv} (1 - \alpha_e)}{w_{urban}} \right)^{\frac{1}{\alpha_e}} \frac{\zeta_e}{\delta_e P_m} GDP.$$

From this solution we derive two statistics that allow us to calibrate parameters A_e and α_e upon knowledge of investment parameter ζ and depreciation δ_e . First, the ratio of the public service sector revenue to GDP given by

$$\frac{P_{sv} Y_e}{GDP} = P_{sv} A_e^{1/\alpha} \left(\frac{P_{sv} (1 - \alpha_e)}{w_{urban}} \right)^{\frac{1-\alpha_e}{\alpha_e}} \frac{\zeta_e}{\delta_e P_m},$$

and, second, the public payroll to GDP ratio, given by

$$\frac{w_{urban} L_e}{GDP} = w_{urban} \left(\frac{A_e P_{sv} (1 - \alpha)}{w_{urban}} \right)^{\frac{1}{\alpha_e}} \frac{\zeta_e}{\delta_e P_m}.$$

1.8 Government

Government surplus is defined as the difference between government revenues and government expenses *excluding* the government's consumption of manufacturing. Government revenues equal the sum of all tax revenues (including taxes from mining) and the profits (or losses) of public service enterprises. Government expenses equal the sum expenses in development policies (education, infrastructure and social transfers), the government's consumption of services, the government's investment in capital for public service enterprises and interest payments on existing debt. In our model development policies, government consumption of services and investments in capital for public services and the exogenous level of existing debt are specified as fixed proportions of nominal GDP.

In the definition of equilibrium, below, the government's consumption of manufactures is set equal to government surplus, as defined above, to balance the government's revenues and expenses every year.

1.9 Definition of Equilibrium

Given the external prices of agricultural commodities, food, manufactures and mining goods; given the international interest rate and the investment rates for government service enterprises, government infrastructure, education; given the investment rate for social transfers; given the opportunity cost of capital for mining multinationals; given the effective tax rates on food consumption, manufacturing consumption, labor income, commodity exports, food imports, mining revenue, manufacturing revenue, formal food revenue and commodity exports, *an equilibrium is defined as:* (i) a set of domestic prices for food and services, wage rates for urban and rural labor and a value of GDP; (ii) optimal decision rules for consumption, saving and formal work for urban and rural households; (iii) optimal value functions for urban and rural households; (iv) a cross sectional joint distributions of individual productivity and asset holdings for urban and rural households; (v) decision rules for capital accumulation, consumption, and production of food and agricultural commodities for farmpreneurs and government consumption of manufactures such that the following conditions hold:

1. Optimality.

- **Households.** Given prices, the value functions are consistent with the optimal decision rules and the value functions solve the Bellman equations (Equation 1) for urban and rural households.

- **Farmtrepreneurs.** Given the taxes rates food revenue and commodity export revenue the domestic price of food and the external price of commodity exports, the decisions rules for capital accumulation, production of food and commodity exports and consumption, solve the Bellman equation (Equation 2).
2. **Stationarity.** The cross sectional joint distributions of individual productivity and asset holdings are jointly generated by the household's decision rules and the stochastic process for individual productivity. Furthermore, these distributions are time-invariant.
3. Market Clearing:
- **Agricultural Commodities.** The exports of agricultural commodities equals their production by farmtrepreneurs.
 - **Mining.** The export of mining goods equals its production by foreign multinationals.
 - **Manufactures.** Given the tax rate on manufacturing revenue, domestic manufacturing firms hire labor to equate its marginal product and marginal cost, given the urban wage rate and the international interest rate.
 - **Absorption.** The net exports of manufactures equal domestic production minus domestic absorption. Domestic absorption equals the sum of investment in manufacturing firms, government enterprises and government infrastructure plus private and government consumption.
 - **Food.** Given the effective tax rates on consumption of food, the tax rates on formal food production and the domestic and foreign prices of food, the total food demand by households and farmtrepreneurs equals the imports of food plus the sum of formal and informal domestic production of food.
 - **Capital.** Given the international interest rate and the GDP value, the inflow of capital services equals the demand of capital services by manufacturing firms minus the supply of savings by households.
 - **Services.** Given the GDP value, the domestic price of services and the urban wage rate, the government's demand for services plus the private consumption of services equals the informal production of services by urban households plus the production of services by government enterprises.
4. Government Budget:
- Given GDP, any positive government surplus (as defined above) is devoted to consumption of manufacturing so that government revenue and expenditure are balanced every period.

- The GDP value assumed has to equal the sum of the output of farmtrepreneurs, informal production (of food, services and agricultural commodities) by households and farmtrepreneurs, the output of manufacturing firms, the output of the public service enterprises and the output of the foreign mining sector, times their respective prices.

First, we make some restrictions on international trade that simplify our abstraction. We assume that food is not exported while agricultural commodities are exported. Food can be imported. Services cannot be imported or exported. Because of a limited elasticity of import supply, the domestic price of food can differ from the foreign price. Manufactured goods can be exported and imported; in addition, their price always equals the foreign price.

The aggregate supply of formal labor in both the rural and urban area is defined as the sum total of every household's supply of effective labor zs , which equals the time spent in market work s times the labor productivity of the household, z . The demand for formal labor is also measured in units of effective labor.¹¹ While the savings of urban and rural households can be invested in the formal urban sector or in the foreign financial sector at the interest rate, farmtrepreneurs need to finance their own productive enterprises through savings.

Total government revenues consist of (i) the revenue tax on formal firms (i.e. manufacturing firms, farmtrepreneurs producing food and commodity exports, and foreign extractive firms),¹² (ii) the VAT, whereby consumption expenditures on food and manufactured goods are taxed at flat rates;¹³ and (iii) flat taxes on formal labor income.

Government expenditures consist of (i) interest payments to households holding domestic government debt (for simplicity, we abstract from modeling foreign debt), (ii) transfers to households, (iii) payments to the educational system (iv) investment in public infrastructure (v) investments in capital for the public service sector.

2 Computation

Our model is solved using a standard value function iteration method. The optimal decision rules for savings are computed at each iteration using the intratemporal Euler equation. The

¹¹Aggregation across households requires employing the endogenous stationary (cross sectional) distribution of households over individual state (a, z) which returns the share of households that fall in a subset of the space of all possible states. See Sargent and Ljungqvist (2004), chapter 16-17 for an introduction to heterogeneous agent models and the stationary distribution.

¹²The corporate taxes are modeled as flat tax on total revenue and thus have effects on marginal revenues, input demand and output.

¹³The consumption of services is not taxed as it is modeled primarily as an informal good.

value functions and their derivatives as well as the period utility function are represented by one dimensional splines.

The intra-temporal decision problem that determines the time spent in formal work and the period utility from consumption expressed as a function of total expenditure (rather than a basket of three goods) are pre-computed in discrete grids prior to solving the dynamic programming problem. We iterate by applying the value function operator repeatedly until we obtain approximate convergence of the decision rules.

The simulation of equilibrium distributions is carried out by setting up discrete grids for the joint distributions and iterating on the mass allocated across discrete points, until convergence, by forward application of the decision rules.

Finally, the process for ability shocks is numerically approximated by constructing a Markov chain using a discrete approximation to the lognormal AR(1) known as a Tauchen method.

The equilibrium is computed by searching for equilibrium prices using a Fortran version of the Matlab FSOLVE routine designed to find the zero of systems of nonlinear equations.¹⁴

Further details are available from the authors upon request.

3 Calibration

In this section, we specify the functional forms and parameter values of the economy. The first item in our calibration is the share of rural and urban households and the share of farmtrepreneurs.

3.1 Population Shares

According to the U.S. Agency for International Development, one-third of Guinea’s population is urban and the other two-thirds are rural¹⁵. Additionally, half of all farms are less than two hectares and two-thirds are less than three hectares, while the average farm is 9.8 hectares. Assuming that each rural family owns a farm and that farms larger than 50 hectares are owned by formal farmtrepreneurs, we then calculate the share of farmtrepreneurs among the rural population to be 2.37 percent. This means that our urban, rural and farmtrepreneur shares are $(\mu_1, \mu_2, \mu_3) = (0.33, 0.6463, 0.0237)$, respectively. Further we calculate the average sizes of informal and formal farms to be 1.38 and 238 hectares, respectively.¹⁶

¹⁴This package can be found online from various contributors of open source software.

¹⁵<https://www.land-links.org/country-profile/guinea>.

¹⁶We fit a right-pareto-lognormal distribution to these statistics provided by the U.S. Agency for International Development and obtain the following mean, standard deviation, and Pareto tail parameters:

3.2 Interest Rate and Debt

We set the real interest rate to 1.6 percent. This rate is calculated by subtracting the annual inflation rate of 11.78 percent from the average rate on 90 day t-bills and bonds of 13.4 percent recorded in March 2022 by the Central Bank of Guinea ¹⁷. Also, we set the domestic debt of the government to 15.2 percent of GDP, was reported by Guinea’s Ministry of Economy, Finance, and Planning at end-2021.

3.3 Tax System

According to the the KPMG Fiscal Guide for Guinea (KPMG 2019), the statutory rates for value added, corporate taxes on non-mining non-oil sectors and labor income taxes are 18, 25, and 29 percent, respectively. The labor tax combines wage tax and social security. For the mining sector, the statutory corporate tax rate is 30 percent. We employ these values to calibrate the statutory level of τ mentioned in Section 2. In order to set up the value of the tax gaps for each of these types of taxes, we consider data provided by Guinean the authorities that contains the breakdown of tax revenue, as a share of GDP for the mining sector and for indirect taxes. The average mining and indirect tax collection for the period 2015-19 are 2.16 percent and 6.02 percent, respectively. Assuming that mining contributes approximately 15 percent of GDP, expected tax collection, at a 30 percent rate, would give 4.5 percent of GDP. ¹⁸ This rough estimate produces a tax gap of $100(1 - 2.16/4.5) = 52$ percent Using our calculation for average private consumption to GDP, we estimate that the tax base for indirect taxes is 80 percent of GDP. Applying the statutory rate for VAT from of 18 percent to the approximate size of the base gives a total statutory revenue of 14.4 percent of GDP. Therefore, we calculate a

($-0.129, 1.225, 1.233$). In the context of this distribution, the share of rural households above a threshold of 50 hectares is only 2.1 percent. We thus fix the share of rural households to two thirds minus 2.1 percent and the population share of farmtrepreneurs to 2.1 percent. We then calculate the average size of small and large farms by taking the average size of the bottom 80 percent, which is 1.38 hectares. To calculate the average size of the large farm, we take the average size of the top 2.1 percent, which is 238.4 hectares. We have skipped the percentiles between the 80th and the 97.9th in order to capture the inequality in farm sizes adequately. In order to adjust our binary distribution so the average is still 9.8, we adjust the shares of large and small farms, by solving

$$x238 + (1 - x)1.38 = 9.8$$

$$x236.62 = (9.8 - 1.38)$$

$x = (9.8 - 1.38)/236.62 = 3.56$ percent of the rural population. That is, $0.0356 * 0.667 * 100 = 2.37$ percent of the total population.

¹⁷<https://www.bcr-guinee.org/satistiques/marche-monetaire-2/statistiques-du-marche-monetaire/>

¹⁸An analysis of Guinea’s tax potential over 1990-2019 estimates overall tax revenues and resources on average of a bout 7.3 and 5.0 percent of GDP higher than they were over the course of the last decade (Mogues 2021). The helps to calibrate our estimated tax gap that makes use of a statutory tax rate to ensure that it does not overstate the quantitative impact of additional mining revenues on various economic indicators.

tax gap for value added taxes of $gap_{cons} = 100(1 - 6.02/14.4) = 58.2$ percent. We approximate the tax gaps for other taxes as the midpoint between two gaps, that is 53.10 percent.

3.4 Preferences

The period utility function $u(c)$ is parameterized as follows:

$$u(c) = c_f^{\gamma_1} + \gamma_2 \log(c_{sv}) + \gamma_3 \log(c_m). \quad (6)$$

This specification allows for a declining share of food expenditure $p_f c_f$ in total expenditure $p \cdot c$ through the variable curvature on the c_f .¹⁹ To obtain the values of these parameters, we target three statistics published by Guinea’s 2018/2019 national household survey (see Institut National de la Statistique, 2020, Table 4.26). The targets are: (i) the ratio of the food share of expenditures measured for the bottom 20 percent of consumption expenditures to the average share of food in consumption expenditures; (ii) the share of service expenditure on total expenditure; and (iii) the share of manufacturing expenditure on consumption expenditures. Since the survey data report does not have the exact same expenditure categories of our model, we resort to a manual reclassification of the expenditures.²⁰ Under the reclassification, the targets are (1.05, 0.42, 0.12).

3.5 Output Shares

The output shares of different sectors in the model are controlled by the following: (i) average productivity parameters in each sector, called $\varepsilon_{rural}, \varepsilon_{urban}$ which control the productivity of informal production for rural and urban households; (ii) $\varepsilon_1, \varepsilon_2$ which control the productivity of agricultural and export commodities for farmpreneurs; and (iii) A_x, A_m which controls the productivity of the foreign extractive sector and the formal manufacturing sector, respectively. For simplicity, we assume $\varepsilon_{rural} = \varepsilon_1$. Then we target agriculture, services, commodity exports, mining and manufactures output as a share of GDP to calibrate the remaining five independent parameters. The values of our targets, in the same order, are (0.23, 0.39, 0.008, 0.15, 0.22). These

¹⁹Other work has historically employed logarithmic preferences with a subsistence minimum consumption for food. This causes the food share of expenditure to drop with total expenditure. Since we are investigating an economy with poverty and heterogeneous agents, we require that utility be defined for very low values of expenditure. The CES specification that we employ can only be solved numerically, posing a technical hurdle, but we solve for the optimal consumption bundle at different levels of expenditure and approximate the smooth utility function and its derivative using numerical splines. We employ the approximate derivative of the splines to solve the Bellman equations using the Euler equation that holds for the right hand side of the Bellman equation.

²⁰The replication materials are available from the authors upon request.

shares were obtained by averaging the value added by sector from Guinean national accounts over 2015-2019 and then reclassifying the 12 value added categories into the five categories in our model. The share of the export commodity sector was then adjusted so that the non-mining share of imports is equal to 5 percent of total exports. The reclassification weights were chosen by IMF staff based on country-level analysis and are available from the authors upon request.

3.6 Government Consumption and Trade

To close the macroeconomic identity in our model, we require the output to be equal to investment, plus private and net public consumption, plus net exports. This needs to be done for each of good in the economy: agricultural, services and manufactured goods.

First, we close the equation for manufactured goods by calculating the average value of public consumption as a share of GDP from the national accounts for 2015 to 2019 to be 17 percent of GDP. We then make the assumption that, out of this 17 percent, 11 percent are manufactured goods. We then set total investment for the economy at 10 percent of GDP, equal to the value of private and public capital consumption to GDP in national accounts over the same period. Third, we assume that all investment is composed of manufactured goods. Under these three assumptions, the net imports of manufactured goods total to 9 percent of GDP.

Second, we close the macroeconomic identity for services. Comparing output at 39 percent of GDP and private consumption at 36 percent of GDP, we set the government consumption of services to to 6 percent of GDP, which results in net imports of zero. We maintain the net imports of services at zero throughout our analysis. This assumption produces a total government consumption of 17 percent of GDP, to mimic the national accounts.

Third, we set the exports of mining equal to the total output of the mining sector, which is 15 percent of GDP. We then do the same for the export commodity sectors. Finally, we compare the consumption of agricultural products to the production of agricultural products and obtain net imports equal to 13 percent of GDP. Note that total imports are 9 percent of GDP in manufactured goods plus 13 percent in agricultural products, while the exports consist of 15 percent of GDP in mining plus 0.8 percent of GDP in agricultural commodities. This leads to a permanent deficit of 7 percent of GDP. To guarantee the balance of the current account in the long run, we simply adjust the government consumption of manufactured goods from 11 percent of GDP to 4 percent of GDP. This adjustment of the national accounts completes our characterization of the sectoral composition of Guinea's macroeconomy.

3.7 Inequality Indicators

The inequality targets for our calibration are the poverty rate, the Gini coefficient of consumption, and the share of wealth held by the top 10 percent in rural and urban areas. To generate these values within an equilibrium of the model, we adjust the poverty line as well as the variance and persistence parameters of the z shock process. We also adjust the value of the highest shock (superstar shock) proportionally to the persistence of the shock, in order to target the share held by the top 10 percent. The values for our targets are a poverty rate of 43.7 percent and a Gini coefficient of 50 (somewhat above the 33.7 reported in the latest measurement available from the World Bank’s World Development Indicators (WDI) but consistent with common sense and Gini coefficients of similar countries), and a wealth share of 90 percent held by the richest 10 percent of consumers. Since we do not have wealth data for Guinea, we guide our target with the wealth held by the top 10 percent calculated for South Africa by Chatterjee, Czajka and Gethin (2021). To the best of our knowledge, this is the closest point of reference to the Guinean economy for which we can obtain reliable wealth distribution data.

3.8 Informality

We choose the value of the economies of scale parameters $\alpha_{rural} = \alpha_{urban} = 0.3$ arbitrarily, but we keep in mind obtaining a reasonable approximation to the total share of work time that is devoted to informality work - which is 95 percent, according to the national household survey (Institut National de la Statistique 2019).

3.9 Mining Sector

We start by the elasticity of mining output to the foreign price of mining which helps us pin down the curvature and height of the Laffer Curve. Caldara et al (2016, see Table 3) presents a range of elasticities between 0.021 and 0.081 across methodologies for the full sample and a top estimate of 0.212 for Saudi Arabia only. In order to attain a conservative estimate for the potential revenues, we adopt the highest estimate of 0.21. We use this elasticity to pin down γ , the parameter controlling decreasing returns to scale. This elasticity value gives a parameter value $\gamma_x = 0.1749$. Using this parameter value and the effective tax rate of 0.1440 (resulting from a statutory assumption of 30 percent combined with a tax gap of 52 percent, calculated above), we can back out the value of the share parameter for the Cobb-Douglas production using the share of revenue paid to labor. Feyrer et al. 2017 estimate the labor share of Oil and

Mining output to be between 8 and 24 percent.²¹ From this range we pick a conservative value of 8 percent to pin down the share parameter of the Cobb-Douglas:

$$\alpha_x = 1 - \frac{0.08}{\gamma_x(1 - \hat{\tau})} = 0.466$$

The opportunity cost of capital for foreign miners is set to r is set at 12.8 percent, the average return to oil investors calculated available from the Return on Equity by Sector database maintained by Aswath Damodaran at the NYU Stern School of Business²². We use the magnitude of this return to pin down the capital input K_* .

The following tables summarize the parameter values used in our study. The first set of tables (1a - b) contain the parameters that are fixed prior to computing an equilibrium. Table 2 contains the parameters that are set by “trial and error”; that is, repeatedly using the equilibrium of the model with different parameter values to compute model-generated outcomes and then choose parameters so that model outcomes target empirical counterparts to those outcomes.

²¹They measure the share of fracking boom revenues at the state level in the U.S. that stays in the local economy. We base our target on this measure.

²²See https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/roe.html.

Table 1a. Pre-Determined Parameters

Parameter	Value
Urban Share of Population	0.33
Rural Share of Population	0.6463
Large Farm Population	0.0237
Govt. Service Consumption to GDP	0.06
Price Elasticity of Food Imports	2.5
Baseline Public Infrastructure Stock to GDP	0.5
Agricultural Productivity Elasticity wrt. Infrastructure	0.1758
Services Productivity Elasticity wrt. Infrastructure	0.3126
Manufacturing Productivity Elasticity wrt. Infrastructure	0.2271
Education Investment Rate of Return	0.3436
TFP of Agriculture	1.00
Price of Manufactures	1.00
World Real Interest Rate	0.016

Table 1b. Pre-Determined Tax Parameters

Tax	Statutory Rate	Tax Gap
Agriculture VAT	0.18	0.582
Manufacture VAT	0.18	0.582
Food CIT	0.25	0.531
Export CIT	0.25	0.531
Manufacture CIT	0.32	0.531
Labor PIT	0.25	0.531
Food Imports	0.25	0.531

Parameter	Value
CES Curvature in Util. of Food	1.0556
Weight of Log Utility of Services	0.8856
Weight of LogUtility of Manufactures	0.2570
Discount Factor	0.92
Idiosyncratic Shock Variance Rural	0.2666
Idiosyncratic Shock Variance Urban	0.1736
Idiosyncratic Shock Persistence (Rural and Urban)	0.93
TFP of Informal Services	0.5786
TFP of Manufacturing	1.4142
TFP of Export Commodities	0.6558
TFP of Government Services	0.4398
Capital Share of Government Servives	0.350
TFP of Mining	0.5573
Poverty Line	0.6444
World Price of Food	0.6965
GDP	2.527

The parameters that are calibrated by “trial and error” are set by matching model generated outcomes to data-based targets. Table 3 shows the list of targets and compares the model generated outcome with its data-based target. The fit to all targets is very good and sufficient to conduct our policy analysis with confidence that the model can mimic important aspects of the Guinean economy.

We provide some additional moments that were not actively targeted, in order to check the specification and calibration of the model with non-targeted outcomes. Table 4 below shows the model generated outcomes that we can compare to the data, given its availability for Guinea.

According to our definition of equilibrium, markets have to clear in our baseline equilibrium. Table 5 presents the value of the market clearing prices for each market as well as the approximation error in achieving a zero of the excess demand function.

3.10 Laffer Curve

A key ingredient of our study is the relationship between tax policy in the mining sector and revenue. Figure 1 illustrates the Laffer curve that holds in our model, given the calibration of the mining sector described above. The figure illustrates the great sensitivity of the shape of

Table 3. Model Outcomes and their Data-Based Targets

	Data(Target)	Model
Ratio of Food Expenditure Shares:		
Bottom 20 percent vs. Average	1.05	1.0446
Expenditure Share in Services	0.42	0.4227
Expenditure Share in Manufactures	0.12	0.1227
Gini Coefficient	0.5	0.571
Wealth Share of Top 10 percent	0.9	0.543
Investment to GDP Ratio	0.1	0.1093
Private Services Output to GDP Ratio	0.27	0.3078
Manufacturing Output to GDP Ratio	0.22	0.2109
Commodity Exports to GDP Ratio	0.008	0.0087
Government Services to GDP Ratio	0.1	0.1011
Government Wage Bill to GDP Ratio	0.0657	0.0657
Mining Output to GDP Ratio	0.15	0.1508
Poverty Rate	0.43	0.4299
Food Imports to GDP Ratio	0.13	0.1283

Table 4. Basic Allocation Statistics

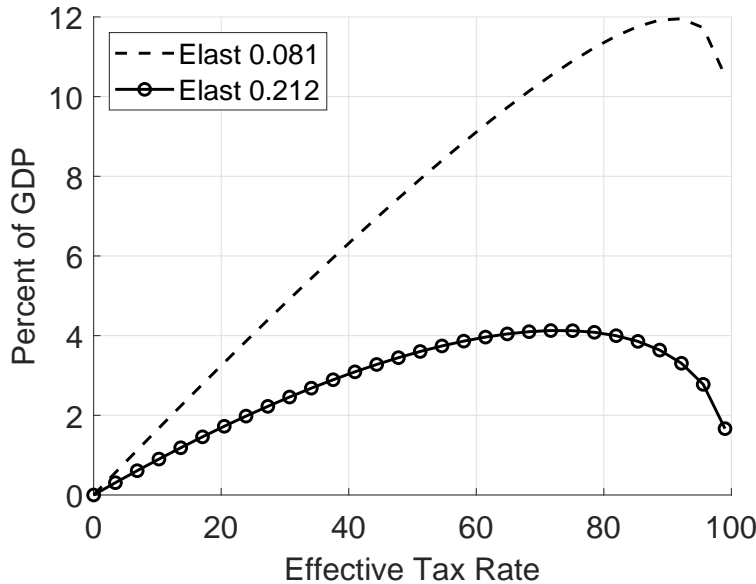
Tax Revenue to GDP	0.1243
Share of Time in Formal Work Rural Area	0.0047
Share of Time in Formal Work Rural Area	0.1271
Mean Income Ratio Rural vs. Urban	0.2002
Poverty Depth Indicator	0.3618

the Laffer curve to the price elasticity of supply keeping all the remaining calibration targets constant. When we employ the overall elasticity from Caldara et al.(2016), the top of the Laffer curve is reached at an effective taxation rate of nearly 90 percent. When we use their top estimate of 0.212, we obtain a top of the Laffer curve at an effective tax rate slightly above 70 percent.

Table 5. Equilibrium Conditions and Prices

	Price	Excess Demand
P_s	4.1709	0.000
P_a	0.6059	0.000
w_u	4.3120	0.000
w_r	0.3477	0.000

Figure 1. Mining Laffer Curve Implied by Calibration



Note: this Laffer Curve is traced in partial equilibrium. This implies that the rural wage and the value of GDP are fixed at their initial level.

While the credibility of our tax reform rests both in the empirical estimates of the elasticity. We also rely on previous project-level studies by IMF staff that indicate small reforms can produce additional revenues of up to 1 percent of GDP (see Mogues, 2021).

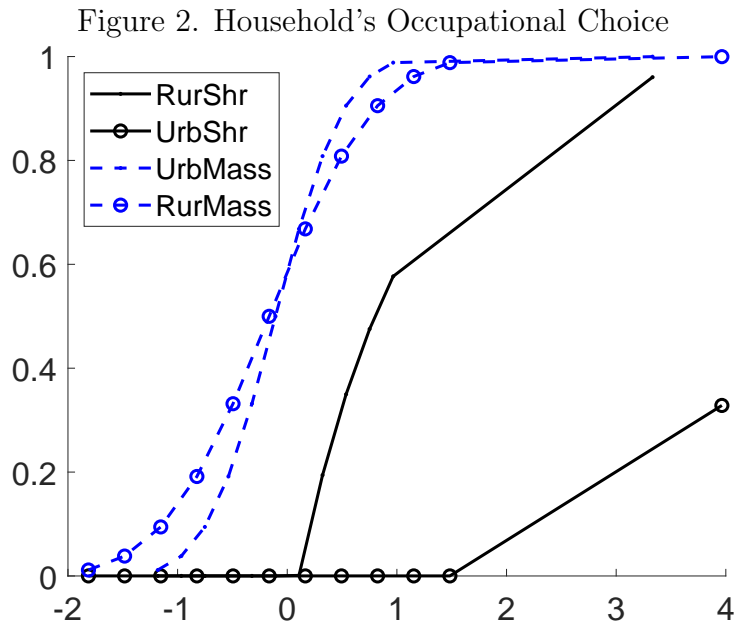
Jumping ahead, when we pushed the limits of our model in general equilibrium, the maximum revenue from our mining sector model comes at an effective tax rate between 64.4 and 74.4 percent. At these rates the size of the mining sector has declined from 15 percent of GDP to roughly 9 percent.

This effect shrinks our steady-state measure of output by between 5 and 6 percent. This fall comes from the mining sector, as the rest of the economy is not impacted significantly. Sectoral indicators and inequality indicators remain basically unchanged except for a mild increase in informality in the rural sector, accompanied by a mild drop in the price of food (2 percent for the largest tax increase).

Our baseline reform (i.e. setting the rate at 34.4) achieves roughly half of the maximum revenue potential at 2.6 percent of GDP. This, as we will revisit in the results section, implies a drop in steady-state output of less than 2 percent.

3.11 Functioning of the Calibrated Economy

The aggregate balance between formal and informal work is controlled by the ratio of informal goods prices and the wage rate. In the rural sector, households decide whether to work informally in agriculture, formally for large agroindustrial units, or for the mining sector. Households with abundant skills exhaust the possibilities of independent informal production and devote more time to market work. This mechanism is established by Proposition 1, Section 1.2. This follows from the assumption of decreasing returns to scale to the labor input in the informal production. The solid lines in Figure 2 show the formal market participation of rural and urban households. In the rural area, the relative scarcity of capital leads to lower wages and higher informality. Only households with the highest innate ability work in formal enterprises. In the urban areas, households with lower skill levels find it profitable to also participate in the formal labor market, due to the higher wages, relative to the price of informal services. The dotted lines show the cumulative share of households in the distribution of skills. The crossing of the cumulative distributions shows that skill distribution in the urban area has thinner tails than the distribution of the urban area. This also leads to higher inequality in the rural area.



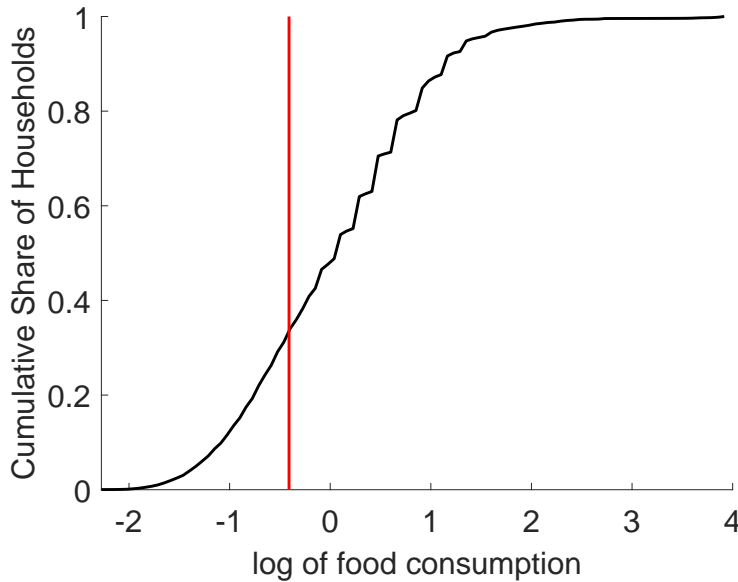
The heterogeneity in the savings rate is related to the skill distribution and ultimately results in heterogeneity of consumption expenditures. The heterogeneity in skills, which leads to

endogenous heterogeneity in occupational choice across households, also leads to heterogeneity in saving rates. In incomplete markets models, households choose to save to smooth their consumption over time. They also save for precautionary motives; that is, saving for periods of low productivity, when household income may be disrupted. For this reason, the savings rate can be increasing in the household’s budget.

Figure 3 shows the distribution of food consumption and the calibrated model poverty line. The distribution of food consumption mirrors the distribution of overall expenditures but is less sensitive to changes in the relative prices of consumption goods (food, services and manufacturing). We thus measure poverty in the model using food consumption rather than overall expenditure.

The equilibrium price of food sustains the balance between the domestic agricultural sector and imported food supply. The presence of a strong imported food supply, calibrated to match national accounts data, helps taper fluctuations in food prices and food scarcity.

Figure 3. Distribution of Food Consumption and Poverty Line



Because of the higher formalization rate in urban areas and its more favorable skill distribution, consumption is higher, across the distribution, in the urban area. The ratio of average consumption in the rural area relative to the urban area is 0.2 as indicated in Table 4. This difference in the skill distribution is also present at the bottom of the distribution of consumption. Due to this difference, the vast majority of poor households in the model come from the rural area, where the depth of poverty is also higher than in the urban area.

Demand of food, services and manufactured goods is regulated by households preferences over saving and consumption and their preferences across consumption goods. In the aggregate,

saving is regulated by the discount factor β and the interest rate, r , which we assume to be fixed. The savings can be channeled to the national productive enterprises (manufacturing, farmtrepneurship and government services), government loans, and foreign assets.

Households with low consumption expenditures devote a larger share of their income to food consumption. For this reason, an increase in the disposable income of poor households, such as the one that would be generated by social transfers, would lead to an increase in the demand of food, relative to the demand of other goods.

4 Development Policy

4.1 Human Capital Formation

We analyze an educational reform that consists of providing every student with a given level of expenditure for a given number of years. We first analyze the per-student, per-year return to education. At a given level of wages per unit of effective labor w_0 we define the return to an annual expenditure e as the change in earnings divided by the expenditure.

$$1 + \theta \equiv \frac{w_0 \bar{z}_1(e) - w_0 \bar{z}(0)}{e}.$$

This definition is consistent with causal elasticities obtained from linear regressions. Solving for z_1 we obtain the relationship between individual one-year investments and skill

$$z_1 = z_0 + \frac{1 + \theta}{w_0} e.$$

We follow Garcia, Heckman and Laef (2016) and specify a baseline lifetime rate return of expenditures of $\theta = 0.13$. This rate of return has been calculated for the best targeted resources using best practice interventions in the U.S. assuming constant wages. For small intervention programs, higher rates of return have been found for Guinea Bassu (Fazzio et al. 2020), while Psacharopoulos and Patrinos (2018) has found rates of return of approximately 9.3 percent for each additional year of schooling in developing countries (see their Table 2).

Now we consider a multi year investment in a single student. Abstracting from compounding and assuming a constant return rate per year of investment we obtain

$$z_1 = z_0 + t \frac{(1 + \theta)}{w_0} e.$$

Where e is the annual investment θ is the per-year return over t years for a single student.

The total cost of the policy in each region, assuming that the size of an age cohort is S , would be given by $E = Ste$. In simple terms, S is the number of students in each grade, t is the number of grades that each student will receive the policy for, and e is the expenditure per student per grade.

To allocate the expenditure between the rural and urban areas we take into account that wages are different across location. We would like to have an equal skill impact per student per grade so we set $e_{rural}/w_{rural} = e_{urban}/w_{urban}$. After combining this condition, the cost of the policy and the population sizes in each region, we determine that the per-student expenditure for the rural and urban areas, given an aggregate education expenditure E per year, are given by:

$$e_{rural} = \frac{w_r E}{St(w_u \mu_u + w_r \mu_r)}$$

$$e_{urban} = \frac{w_u E}{St(w_u \mu_u + w_r \mu_r)}$$

Empirically, the share of population between 0 and 14 years in Guinea has fluctuated between 0.4 and 0.47 since 1960, according to the WB WDI. This implies that the size of an age cohort is approximately $47/15 = 3.13$ percent of the population. To focus on early and primary education we consider ages 0 to 9 and therefore set $t = 10$. This finalizes the parameterization of our policy framework.

Figure 4. Impact of Human Capital Policy on Labor Productivity

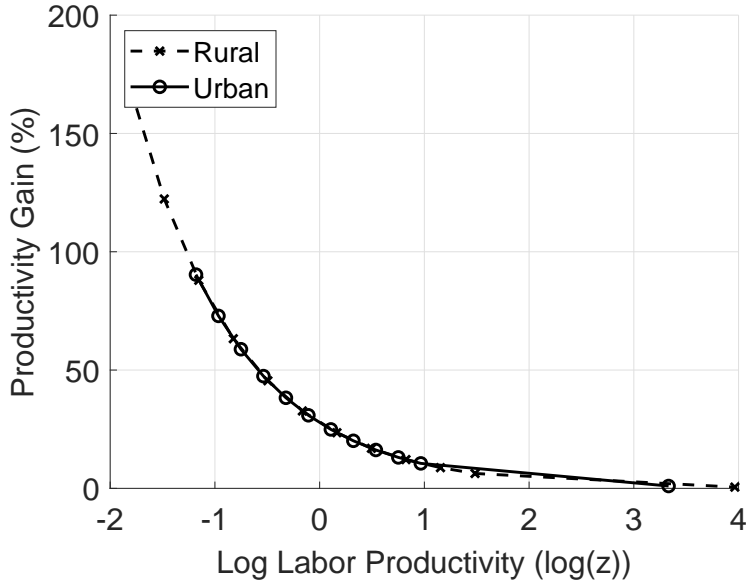


Figure 4, above, shows the impact of the policy on the skills of households by the initial level of skill. Because the reform has the same return for all households, regardless of their initial skill, it can have a much larger proportional impact on low skilled households. This reflects the

power of educational reform to improve the bottom of the income distribution.

When we push the model to its limits by gradually increasing the investment in education and recalculating the equilibrium we obtain the long-run reaction of the economy to increasing levels of skill and a larger effective labor supply.

In Figure 5a, below, the investment in education is increased in steps from zero to 2 percent of GDP. Across these sequence of reforms, the government's long run surplus is reduced while GDP growth increases. At 2 percent investment the surplus is 0.52 percent of GDP, down from an initial level of 2.57 percent of GDP. In terms of growth, we assume the total impact of the reform is spread over 30 years and calculate that annual educational investments of 0.5 percent of GDP can generate 0.41 percent annual growth over 30 years. Each additional 0.5 percent of GDP invested in education initially boosts the annual growth rate by roughly 40 basis points, while subsequent increases in education investment have smaller and smaller effects.

Figure 5b shows that for inequality, increasing investment in education to 2 percent of GDP can reduce the poverty rate to even 11 percent in the long run while the Gini drops from 0.55 to 0.47. The reform does not have a large impact over the rural-urban income gap, which remains near its initial level.

In figure 5c, below, the effect of increasing education investments on formalization is mixed. In the urban area formalization increases while formalization falls in the rural area. In the urban area, the public service sector and the manufacturing sector are able to absorb additional labor as wages fall and government enterprise capital rises (with GDP). In the rural area, an increased demand for food that is not matched by increases in the productivity of formal food producers leads to a higher food prices, larger informality and larger informal food production.

Figure 5. Exploring the Impact of Education Policy

a. Macro Impact

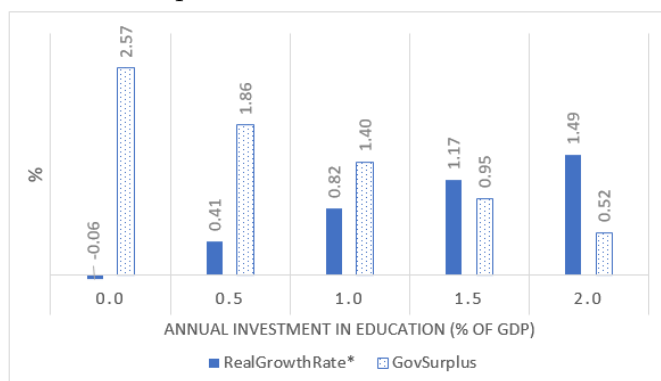
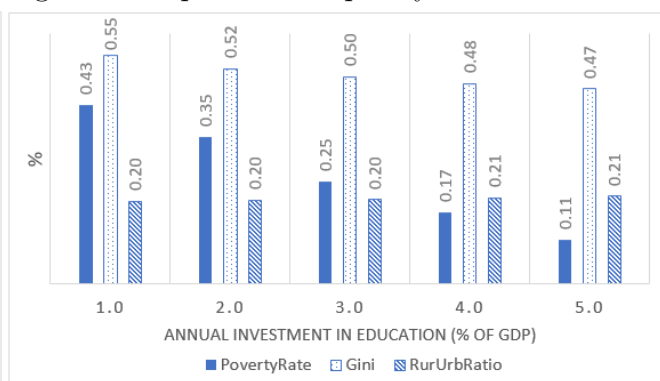
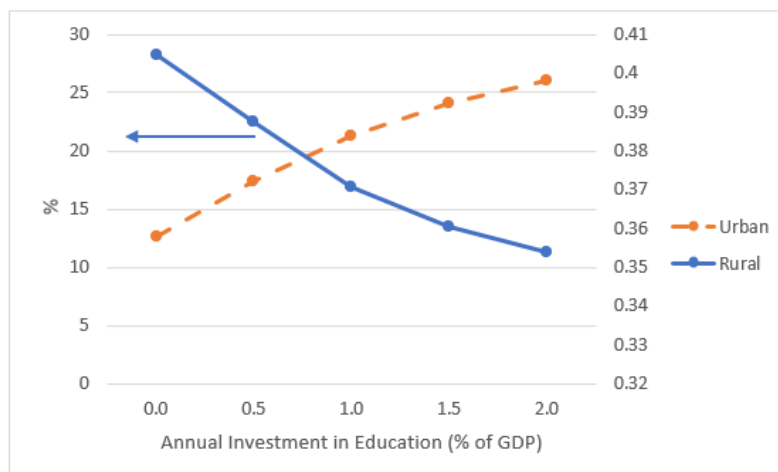


Figure b. Impact on Inequality



*Percent growth assuming 30 year horizon.

c. Impact on Formalization



Our multisector model thus shows that standard intuitions about the relationship between educational investments and the return to education can be different in multisector models. Paradoxically, in our model the additional educational investment decreases the average return to education in the urban area while it increases the return to education in the rural area. The return to education in the informal sector depends on the price of agriculture and the price of services while the return to education in the formal sector depends on wages. In equilibrium, movements in relative prices of goods across sectors can offset the movements in wages that one would expect in one-sector models from an increase in the total supply of labor.

4.2 Social protection via cash transfers

This policy consists of increasing g , a transfer that is independent of income and enters the budget sets of the households and the farmtrepreneurs directly as formalized above.

4.3 Inclusive Infrastructure Investments

We assume that sectoral infrastructure investments per unit of output can have a positive on sectoral output. We conduct a panel data estimation to obtain empirically relevant estimates of the relationship between investments and productivity.

4.3.1 The Impact of Infrastructure on Sectoral Output

Following the empirical and theoretical literature - which notes that infrastructure consists of a vector of four distinct stocks of capital that represent railroads, roads, communications and energy - we denote the vector of infrastructure capital per person as: $E = [E_1, E_2, E_3, E_4]$. The stocks of infrastructure capital affect the vector of productivities:

$$A = [A_a, A_m, A_s]$$

according to a function $A(E) = R_+^4 \rightarrow R_+^3$. Specifically, for each sector we use the elasticities estimated as follows:

$$A_j = E_1^{d_{1j}} E_2^{d_{2j}} E_3^{d_{3j}} E_4^{d_{4j}}.$$

Functions of this kind have been estimated in the empirical literature using panel data and time series data. The vector A contains the productivity of the different productive centers of the economy: services (s), informal agriculture (a), farming (f), commodity export ($*$) and manufactured goods (m). The accumulation of infrastructure stocks is as follows:

$$E' = (1 - \delta^E) \times E + I_E$$

is the law of motion for infrastructure capital, where E' is next period's vector of infrastructure stocks. Investment is characterized by a private and a government component:

$$I = I + (1 - \lambda) \times I_g$$

where g denotes the vector of government investments in infrastructure and λ is a parameter vector measuring the wastefulness in public infrastructure investment (note that \times denotes element-by-element multiplication). In a steady state, the stock of each infrastructure compo-

ment is given by ($E_n = I_n/\delta$). Furthermore, assuming equal prices of 1 for all components of infrastructure, we can easily prove using a Lagrangian optimization that the optimal amount of investment on infrastructure n for sector: j is

$$I_n = I_j \times \frac{d_{nj}}{\sum_n d_{nj}},$$

where I_j is the ammount of investment exogenously devoted to sector j . This result provides us with the relationship between productivity in a sector and the ammount of total investment in infrastructure:

$$A_j = \left(\frac{I_j}{\sum_n d_{nj}} \right)^{\sum_n d_{nj}} \sum_n (d_{nj})^{d_{nj}}.$$

4.3.2 Data

We combine sectoral real GDP and population data from the World Bank's World Development Indicators (WDI) with indexes of infrastructure stocks from the Canning (2008) database. Our base sample consists of an unbalanced panel with 158 low, middle and high income countries. The periodicity of the data is annual and the sample covers years 1950 to 2008. Table 6 presents basic sample statistics and variable counts. The list of countries is presented in Appendix 2.

4.3.3 Empirical Specification

In order to measure the impact of infrastructure on growth we follow the academic literature that focuses on the long run and short run elasticities of output to elasticity. In particular Shioji (2001) utilizes a convergence equation that holds in many versions of the one sector growth model and state-level data from the United States and Japan, assuming that TFP depends positively on public capital per capita. This convergence equation says that convergence speed toward the steady state is proportional to the distance of GDP per worker from its steady-state level. Shioji (2001) derives this equation from a theoretical one-sector growth model which includes an adjustment cost of investment. In that model, the stock of public capital impacts the steady state level of income per capita, thus increasing the convergence speed (growth rate) compared to regions at similar distance from the steady state but lower stocks of public capital. Shioji (2001) recognizes the difference between short and long run elasticities and accounts for (i) the short-run endogeneity of public capital with respect to output, and (ii) the sluggish adjustment of productivity to increased public capital. Our analysis employs the same technique, but applies it separately to each sector of the economy. Our empirical model rests on two assumptions, which we can verify using numerical simulations of our quantitative model. See Appendix 2 for the formal derivations.

4.3.4 Estimation

Shioji (2001) employs panel data estimators, including Pooled OLS and Pooled OLS with country fixed effects, Arellano and Bond’s (1991) estimation technique (referred to as “Difference GMM” in Blundell and Bond’s (1998)) estimation technique (known as “GMM” in levels), and Kiviet’s (1995) estimation technique (known as the “LSDV-C”) to estimate the convergence equation.²³ The results in Shioji (2001) favor GMM(Diff) as the most stable across all estimations, so we employ this estimator. See Shioji (2001) Table 3 and the explanations in Shioji’s Section 6. We now rearrange and take a first difference of our specification elaborated in Appendix 2 to obtain

$$\Delta y_{jit} = (b_{1j} + 1)\Delta y_{ijt-1} + \sum_{s=1}^3 b_{2j}^{(s)} \Delta \log E_{i,t-1}^{(s)} + \Delta u_{ijt}.$$

The differenced error term is correlated with the lagged dependent variable that multiplies b_{1j} , so GMM estimation of the b ’s is recommended utilizing orthogonality conditions between the disturbance Δu_{ijt} and any elements of the vector of lagged log output per worker $(\Delta y_{ijt-2}, \Delta y_{ijt-3}, \Delta y_{ijt-4}, \dots, \Delta y_{ij0})$. The idea is to add lags (moment conditions) until the observed error term distribution satisfies the assumption of no serial correlation. We construct the sectoral GDP combining the real GDP in PPP dollars of 2010 with the sectoral shares of value added and divide by total population. The right hand side variables are constructed by taking the stock variable from Canning et al. (2008) dividing by total population from the WDI and taking logarithms. Our specification is similar to Shioji’s (2001) and also to Calderon and Servén’s (2004), but our approach differs in that it applies the methodology separately to each sector of the economy. Our sample includes 158 countries. The characteristics of the panel are described in Table 6.

Table 6. Characteristics of the Dataset

	Initial Year	End Year	Observations
mean	1974.66	1999.86	23.97
median	1973	1999	24
min	1960	1989	7
max	1996	2002	43

Most of our coefficients have the correct sign and given our inclusive sample, the precision is surprisingly good.

²³Depending on country (the United States or Japan), Shioji (2001) considers either four or five types of infrastructure capital. For example, his definition of the infrastructure vector for Japan includes public housing sewage, garbage disposal, water, city parks, roads, airports and industrial water.

Table 7 indicates that the Arellano-Bond test for autocorrelation of the errors reject serial autocorrelation at the 1% confidence level for all of specifications. The sample includes all countries in the intersection of the Canning (2008) dataset and the WDI that had at least 10 annual observations for all of the variables in the regression. The standard errors are computed using the heteroskedasticity and autocorrelation robust standard errors. The estimates are computed using one step GMM.

Table 7. Coefficients from Arellano-Bond Estimate of the Convergence Equations

	Aggregate	Agriculture	Manufacturing	Services
Rail	0.0280	0.0753	-0.173	0.00711
Road	0.0271	0.0652	0.165*	0.115***
Telephones	0.0341**	-0.0476	0.0838	0.0765*
Energy	0.0175	0.0499	0.165**	0.0285
N	1811	1421	1290	1286
r^2				

p -values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

For consistency with the theory, we now restrict the coefficients to be positive. We do so in the simplest way possible, which is by omitting the variables that display a negative coefficient from the estimations. Clearly, the negative signs could be caused by multicollinearity issues, but examining the correlation structure of the regressors reveal that the correlation between the differenced regressors is not large.²⁴

We now proceed with the restricted estimation, summarized in Table 8.

²⁴The cross correlations of the regressors (in first differences) are as follows: $\text{corr}(\text{Railroad}, \text{Roads}) = 0.0130$, $\text{corr}(\text{Railroad}, \text{Telephones}) = -0.0004$, $\text{corr}(\text{Railroad}, \text{Energy}) = -0.0025$, $\text{corr}(\text{Roads}, \text{Telephones}) = 0.0589$, $\text{corr}(\text{Roads}, \text{Energy}) = 0.1227$, $\text{corr}(\text{Telephones}, \text{Energy}) = 0.0715$.

Table 8. Restricted Coefficients from Arellano-Bond Estimate of the Convergence Equations

	Agriculture	Manufacturing	Services
Rail	0.106* (0.021)		0.00711 (0.881)
Road	0.0428 (0.248)	0.152** (0.003)	0.115*** (0.001)
Telephone		0.104** (0.008)	0.0765* (0.018)
Energy	0.0270 (0.353)	0.0566 (0.219)	0.0285 (0.259)
N	1533	2385	1286
r^2			

p -values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The signs of the remaining coefficients are stable and their significance is enhanced by the two restrictions imposed on negative coefficients from Table 7. The measurements from this regression will allow us to control the differential effect of each type of infrastructure across the sectors of the economy in our model. We need to adequately capture the differential impact of infrastructure across sectors in order to credibly model the quantitative response of inequality to a particular infrastructure policy.

Combining our estimates and the derivations for investment, we obtain the equations relating investments to productivity for each of the sectors:

$$A_{agro} = 3.49(I_{agro})^{0.1758}$$

$$A_{manu} = 3.44(I_{manu})^{0.3126}$$

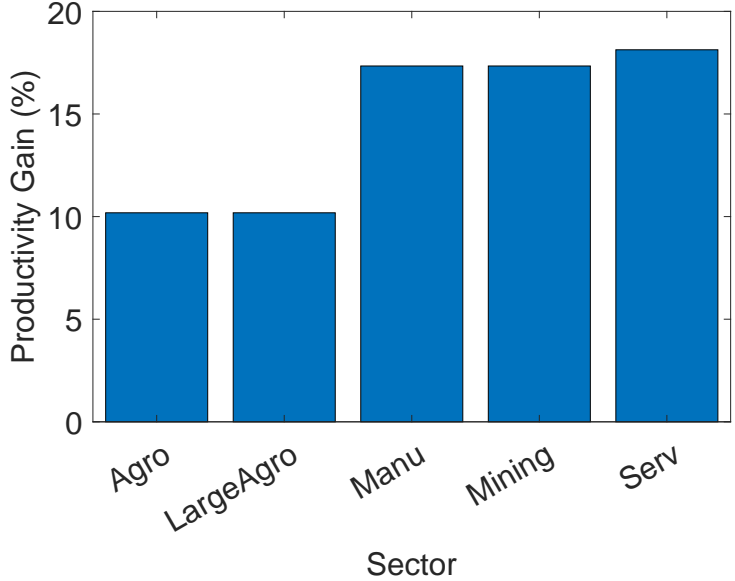
$$A_{service} = 4.86(I_{service})^{0.2271}$$

Our running assumption is that all measured stocks of infrastructure are represented by manufactured goods in the data. This implies that their prices are equal to the price of manufactured goods and that we can aggregate them as a single stock. We have also used the optimal combination of different types of infrastructure derived above. Finally, we assume that the initial value of infrastructure capital to GDP is equal to 49.9 percent, which is the value in data from Guinea from the IMF Investment and Capital Stock Dataset (2019) averaged for the period 2015 to 2017. The total investment is therefore:

$$I = E\delta = 0.499 \times 0.025 = 0.0125$$

We assume that the investment in each of the sectors is proportional to its share of output from the described in Section 2, so that $(I_{agro}, I_{serv}, I_{manu}) = 0.0125 \times (0.23, 0.39, 0.37)$. Note that our last value for the sectoral shares corresponds to the sum of the output shares of mining (15 percent) and manufacturing (22 percent).

Figure 6. Impact of Infrastructure on Sectoral Productivity



The sectoral impact of the infrastructure policy is depicted in the Figure 6. We observe that our estimates imply that an annual investment of 1 percent of GDP in infrastructure sustains a productivity increase between 10 and 20 percent across the productive sectors of our economy.

5 Results

We begin with our baseline scenario, where the effective tax rate on the mining sector is 14.4 percent. This tax rate is a combination of a 30 percent statutory corporate tax and a tax gap of 53.1 percent from Table 1(b) above. Our four development policies consist of the five following policy scenarios:

1. Close the tax gap (CloseGap), raising the effective rate on mining from 14.4 to 34.4 percent.
2. In addition to the policy in (1), increase education investment to 0.5 percent of GDP, annually (Edu).
3. In addition to the policy in (1), increase investment in infrastructure to 1 percent of GDP, annually (Infra).

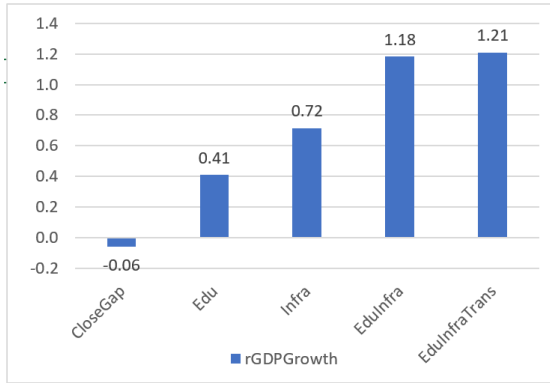
4. Combine policies (2) and (3) (InfraEdu).
5. In addition to the policy in (4) rebate any additional revenue (as compared to (1)) in equal lump sum transfers to all households.

Figures 7 and 8 show the impact of our development policies on the economy relative to the baseline scenario. Figure 7(a) shows the long run impact on GDP. We observe that the largest impact on GDP comes from policy (5), which is the combination of education, infrastructure and transfers. The transfers have the power to increase the return to education in rural areas, as this increases formalization and therefore the productivity of the agricultural sector via an increased demand for food by poor households that receive the transfers. In Figure 7(a), we also observe that the infrastructure and education policy (InfraEdu) have comparable power when it comes to boosting GDP in the long run.

When education and infrastructure are applied simultaneously (EduInfra), the increase in growth is 1.18 percentage points, which is more than the sum of improvements attained by each policy separately. Education and Infrastructure policies are thus complementary.

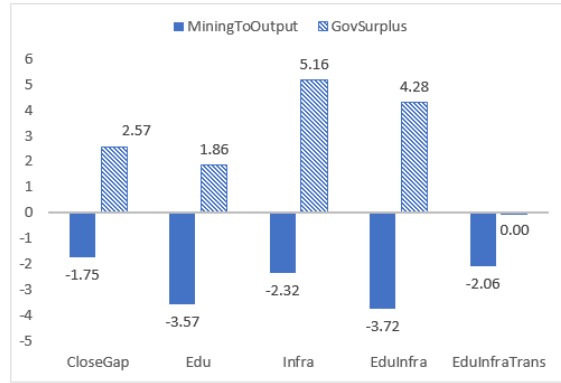
Figure 7. Main Results, Output and Revenue

a) Impact on GDP



Addl. annual growth assuming a 30 year uniform transition.

b) Impact on Revenue by Source (%)



Change with respect to baseline in percentage points.

In terms of tax revenue, all of the policy scenarios produce additional government surplus, with the highest surplus coming from policies (3) and (4). Note that policy 4 involves infrastructure and education simultaneously. Although all policies finance themselves, the complementarity between the increased labor supply from more education and the increased productivity from more infrastructure give the largest benefits as the surplus is comparable to the case of only infrastructure (Infra) while the growth and inequality indicators are also enhanced, as we describe below.

In Figure 7b, when infrastructure and education are combined there is a surge in government surplus of 4.28 percentage points coming mainly from an increase in urban formality, which increases from 13 to 30 percent of the urban labor force. The rise in surplus pays for the reforms because the surplus becomes larger than the baseline. If the additional revenue is rebated as a lump sum transfer, approximately 4.28 percent of GDP thus can be rebated. This implies a fall in poverty rate to 25 percent, which can be observed in Figure 8 (EduInfraTrans case).

The MiningToGDP variable, shows the reaction of mining revenue as a share of GDP with respect to the baseline scenario. We observe that all policies generate reductions in mining activity as a share of GDP. This follows from an equilibrium version of the Laffer Curve described in section 2.10. Note that the equilibrium Laffer curve is more curved than the partial equilibrium one depicted in section 2.10. Revenue as a share of equilibrium GDP (rather than as a share of baseline GDP) has a larger curvature and therefore peaks earlier because revenues follow a hump shape, and, at the same time, GDP is increasing in the denominator.

Figure 8. Main Results, Poverty and Inequality

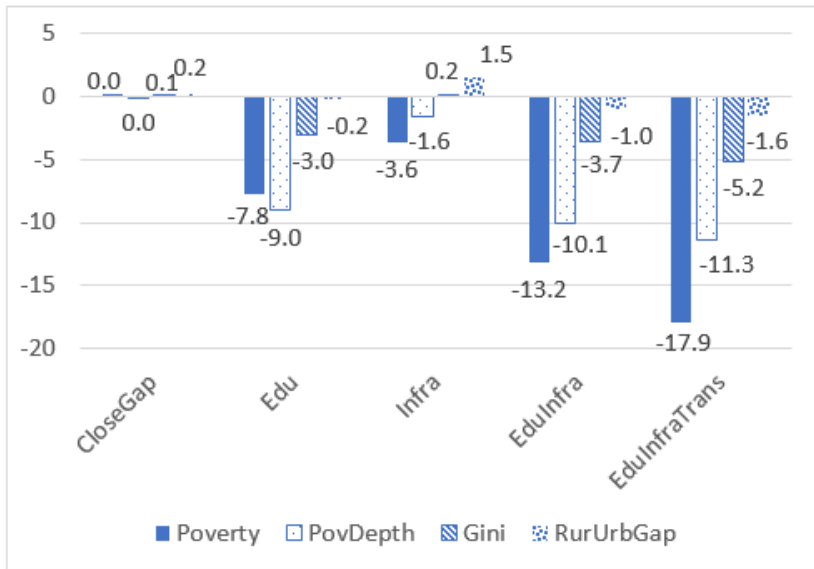


Figure 8 shows the impact of our policies on poverty and inequality. We observe that the highest reductions in poverty rate come from policies (4) and (5), which combine infrastructure and education investments. The impact of the transfers on poverty is substantial: the decline in poverty rates is 17.9 percentage points with transfers (policy 5) and only 13.2 without the transfers (Policy 4).

Education is more effective in reducing poverty and the Gini coefficient than infrastructure. In Figure 8 half percent in education spending has twice the effect on the poverty rate than one percentage point in infrastructure (compare policies 2 and 3). The outcome is similar with the

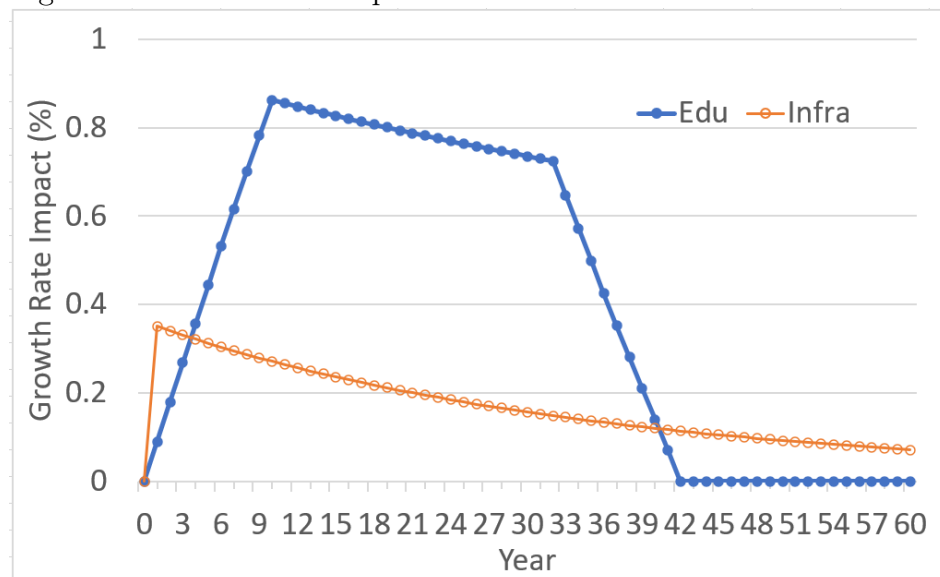
poverty depth, which is the average percent distance of the consumption of poor households with respect to the poverty line. In the case of the Gini coefficient, infrastructure actually increases the Gini coefficient as the upper end of the consumption distribution is enhanced, while Education has the power to reduce the Gini by lifting the lower end of the distribution. The additional fiscal surplus created by the combined power of infrastructure and education depends on many factors. First, the efficiency, effectiveness and inclusiveness of the infrastructure investments is key. These investments must favor the mining companies as well as the rest of the economy, in particular the urban economy and the informal economy. Also, there are no leakages of funds in our assumptions.

Finally the availability of additional surplus also depends on the efficiency of the transfers. We assume that the transfers are delivered in equal sums to all of the population. However, a more efficient targeting scheme would improve the outcomes. The next subsection discusses the timing of the impact of the reforms.

5.1 Essential Dynamics

The transitional dynamics of an equilibrium economy consist of the driving processes and the endogenous and equilibrium reaction of the economy. The two driving processes in our economy are the expansion of labor supply through the accumulation of skills that follow our educational reform and the increase of productivity that comes from the accumulation of infrastructure capital. The calculations presented in Figure 9 are performed by calculating the stock of educated workers and the stocks of infrastructure over time. These stocks increase because of the annual investments that we have imposed in our analysis.

Figure 9. Growth Rate Impact over Time



Our calculations imply that reforms to education have a quicker turnaround than those in infrastructure, due to the gradual accumulation of infrastructure as compared to the universal, albeit limited, educational reform. The impact on the annual growth rate, considering our particular policy analysis, is larger for education, but decays sooner.

Uncovering the nature of the transition for inequality variables is beyond the scope of our calculations (because it would require the computation of equilibrium over time, adding substantial complexity). We can nonetheless clearly anticipate that the transition for our inequality indicators would be monotonic (i.e. free of zigzagging) and gradual. Although we have no theoretical guarantees of this conclusion, existing numerical experiments have resulted in gradual and monotonic transitions for very similar models (see Mendes-Tavares et al. (2021)).

Conclusions

The results of our analysis show that mining revenues, if properly collected and invested, could have transformative impacts in Guinea. In particular, we find that policy reforms that combine spending on education with infrastructure investment and social transfers have the most balanced impact on GDP, public revenue, poverty, and other measures of inequality.

First, education and infrastructure are complementary in generating additional economic activity. The combined policy is more powerful in terms of real GDP than the sum of the policies applied separately to the model.

Second, along the poverty reduction and inequality relief, infrastructure-only policies of the magnitude we study do not produce substantial improvements, but can be highly effective when combined with education policy.

Third, the self financing nature of the policies allows the distribution of any extra revenue as a social transfer. In our experiment we assume a flat transfer (not targeted) that can be delivered without leakage. This transfers are highly effective in providing further reductions in poverty and inequality and well-designed targeted transfers, if available, could be even better.

These findings suggest that policymakers must consider the tradeoffs in investing resources generated by mining revenues only into “hard” infrastructure (i.e. roads) vs. combining investments in hard infrastructure with other social infrastructure that builds the country’s human capital, which could have a larger long-term impacts on growth, revenue, poverty and inequality.

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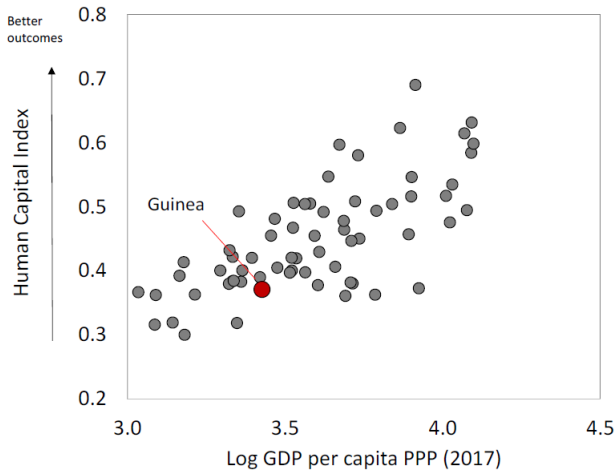
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Appendix 1

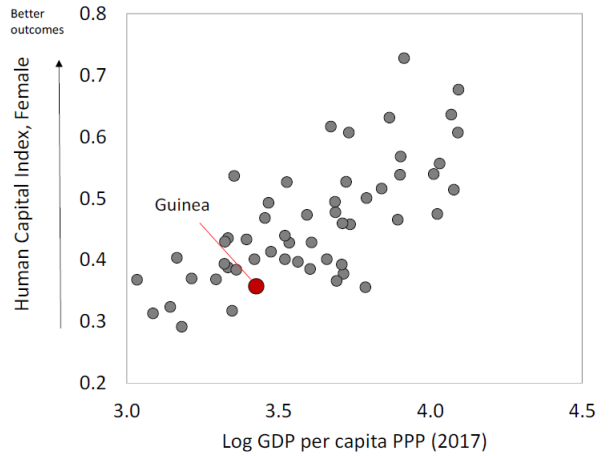
According to the World Bank's Human Capital Index - which captures dimensions of national health and education outcomes - Guinea consistently ranks among the 12 countries with the greatest human capital challenges worldwide (Figure A1.a). Guinea also ranks the seventh lowest worldwide in human capital outcomes for women (Figure A1.b).

Figure A1. Human Capital Index

a) Human Capital Index



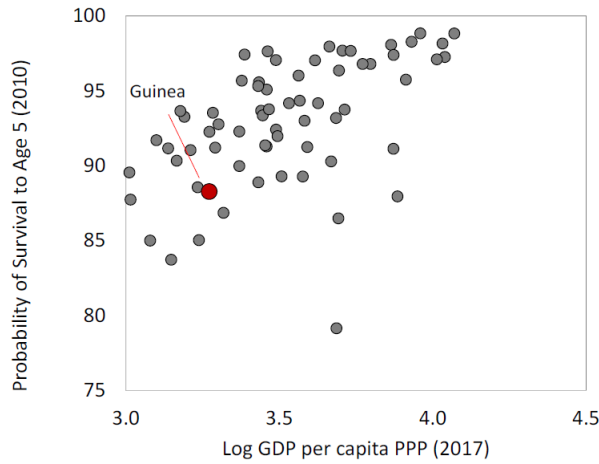
b) Human Capital Index, Female



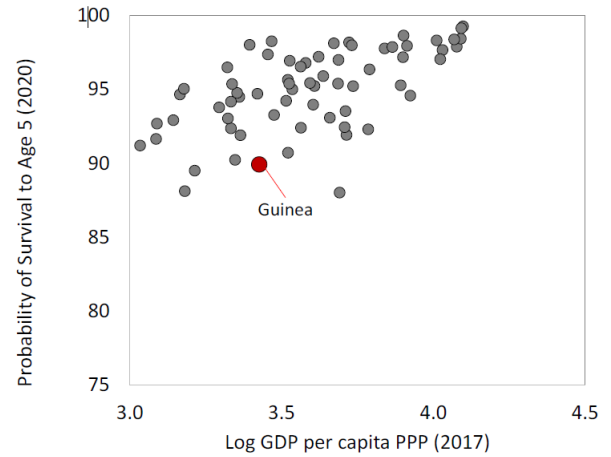
Weak health indicators contribute to Guinea's low human capital. Ten in 100 children will die before his or her fifth birthday, the fifth lowest child survival rate worldwide. Relative to other low and lower-middle income countries, Guinea has not significantly increased the rate of child survival from 2010 to 2020 (Figure A2).

Figure A2. Probability of Survival to Age 5

a) 2010



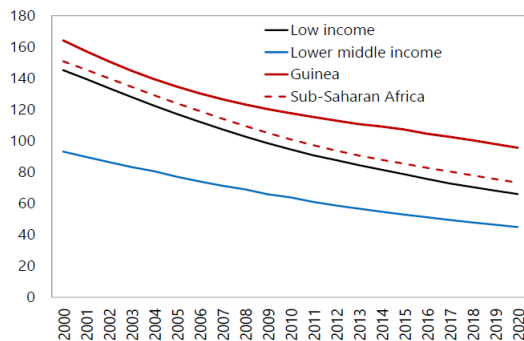
b) 2020



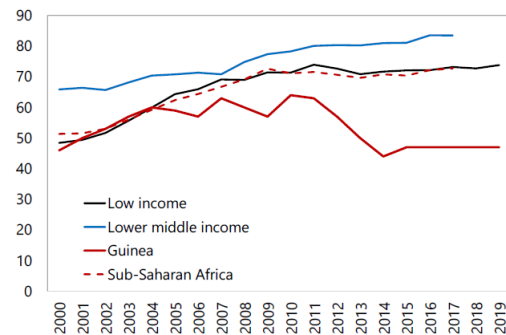
Guinea’s high under-five mortality rate outpaces the averages for Sub-Saharan Africa and low-income countries (Figure A3.a). The 2014-2016 Ebola outbreak led to a permanent decline in certain child immunization rates, which likely worsened during the COVID-19 pandemic (Figure A3.b).

Figure A3. Health Outcomes

a) Mortality Rate, under-5 (per 1,000 live births)



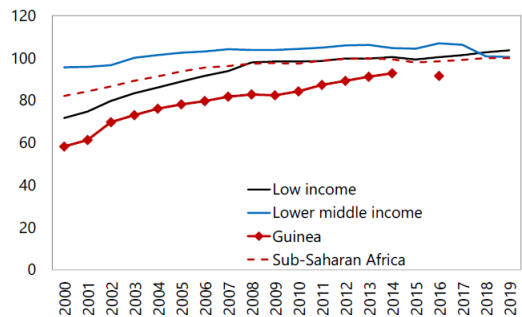
b) Immunization, DPT (pct. of children 12-23 mos)



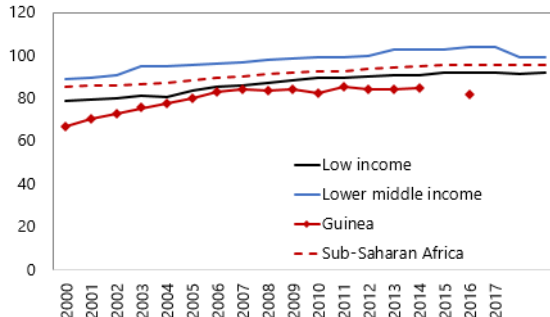
Education outcomes also contribute to Guinea’s low levels of human capital. Children complete an average of 7 years of education, but the suboptimal quality of education results in learning outcomes in line with receiving only 4.6 years of high-quality education. Although Guinea has made progress in increasing primary school enrollment since 2000, this progress has flattened since 2016 and worsened across gender dimensions (Figures A4.a and A4.b).

Figure A4. Primary School Enrollment

a) Percent of Gross



b) Percent of Gross, Gender Parity Index



Appendix 2

We derive our empirical formulation for the Multi-sector version of the Shioji (2001) estimation below. Denote variable x for country i and sector j by x_{ij} and the production function for sector j

$$Y_{jt} = B_j A_j(E_t) K_t^\alpha L_t^{1-\alpha}$$

with $A_j(E_t) = E_{1t}^{d_{1j}} E_{2t}^{d_{2j}} E_{3t}^{d_{3j}}$, we now make two assumptions.

Assumption 1. Near a steady state, for each sector j and all countries i , the log of output per unit of labor converges to each steady state at some fixed rate γ_j

$$\Delta y_{ijt} = -\gamma_j (y_{ijt} - y_{jt}^*).$$

Assumption 2. The steady state level of output for sector j in country i is an increasing function of the vector of infrastructure stocks and a country and sector specific constant \bar{y}_{ij} , so that

$$y_{ijt}^* = \bar{y}_{ij} + \Phi_j' \log E_{i,t-1}.$$

Where $\Phi_j = \frac{1}{1-a} [d_{j1}, \dots, d_{j4}]$. Combining Assumptions 1 and 2 and allowing for an .i.i.d random disturbance u_{ijt} , we can obtain the empirical specification

$$\Delta y_{jit} = b_{0ij} + b_{1j} y_{ijt-1} + \sum_{i=1}^4 b_{2j}^{(i)} \log E_{i,t-1}^{(i)} + u_{ijt}.$$

Where $b_{2j}^{(i)}$ is an estimator of $d_{ij}/(1-a)$ from the production function above.



PUBLICATIONS