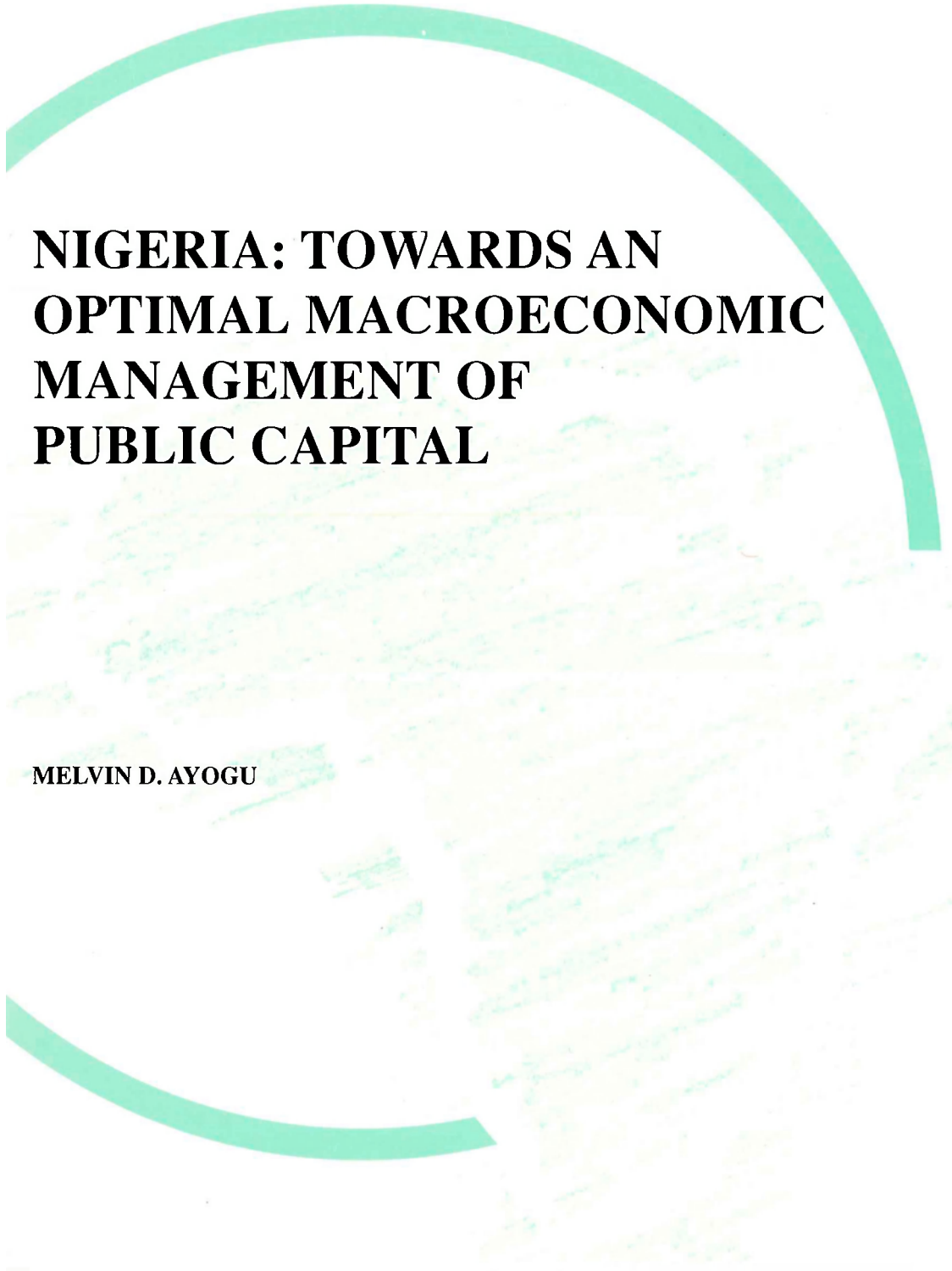


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**NIGERIA: TOWARDS AN
OPTIMAL MACROECONOMIC
MANAGEMENT OF
PUBLIC CAPITAL**

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AFRICAN ECONOMIC RESEARCH CONSORTIUM

CONSORTIUM POUR LA RECHERCHE ECONOMIQUE EN AFRIQUE

**Nigeria: Towards an optimal
macroeconomic management
of public capital**

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Abstract

This paper develops a framework for making decisions on the type of infrastructure to build and where to build. The basic intuition is that by deriving the marginal physical products of installed infrastructure, we can prioritize infrastructure investment of the same type *among* regions, and of different types *within* a region.

The methodology is to estimate a panel of regional production functions that allows the intercepts to capture individual differences ("the fixed effects") but uses interactive dummies to capture the effect of individual differences on marginal productivity. This framework could be a useful tool for the management of public capital in an economy subject to fiscal federalism, particularly where the interaction of interest group struggles and the politics of centre-state grants may involve difficult trade-offs.

1. Introduction

This study develops a method for prioritizing additional infrastructure investment by ranking the marginal product of existing facilities. Such a contribution to the literature on the formal analysis of infrastructure investment may be useful in public finance. In particular, we focus on two aspects of the multifarious decision process of allocating infrastructure investment in a fiscal federalism—the simultaneous decision of what to build and where to build. Our principal interest in initiating this line of research is to further analyse the extent to which political power affects decisions on geographic allocation of infrastructure expenditures. This is an issue that can only assume more importance with increasing democracy and decentralization.

The proposition that public capital stock has significant positive effects on private sector output, productivity and capital formation is known as the public capital hypothesis. The premise is that the stock of public capital raises private sector output both directly and indirectly. “The direct effect because it provides intermediate services to private firms. The indirect effect from an assumption that public and private capital are complements in production” (Tatom, 1991: 3).¹

Past government investment activities in Nigeria (and elsewhere) have been criticized for being wasteful and highly inefficient (Krueger, 1990; Faruquee and Husain, 1994). Wasteful expenditure from this source raises concern because of the order of magnitude usually associated with infrastructure investment.² Such profligate spending adds significantly to fiscal deficits already under pressure from government’s budgetary spending, and from loss-making public enterprises. The macroeconomic implications are not hard to figure out—high inflation rates, heavy debt overhang, disincentive to financial savings and crowding out of private investment.³

The monetary–fiscal policy connection can be troubling when monetary policy is accommodative of government’s preferred spending patterns. Exchange rate policies are also critical factors in infrastructure investment as almost all materials and equipment are imported, while a significant portion of the funds are borrowed externally. For instance, since 1987, Nigeria’s external debt service ratio has averaged between 4 and 5% of GDP, and since 1958 the World Bank has approved 98 loans and credits for a total commitment of \$6.8 billion, the largest aggregate infrastructure lending to any single country in sub-Saharan Africa.

There is little disagreement that developing countries “need to get their macroeconomic policies right” in the sense of avoiding over-valued exchange rates and keeping their inflation and budget deficits low. But there is concern (World Bank, 1994: 171) that “there is little scope for cutting overall public spending in many countries, although the

composition of spending can and should be improved." Furthermore, while public capital may provide valuable services to private firms, close substitutes for these same services could also be available from private producers. If so, some types of public capital may crowd out private capital formation by lowering the value of acquiring new private capital. Reorienting spending priorities to shift resources to education and infrastructure would be both sound and feasible, but the task of "picking winners is likely to produce the same government failures and inefficiencies that hampered economic development in the past decades."⁴

Furthermore, the fact that the linkage between infrastructure and economic development clearly depends on the individual location in question means that prioritizing spending may not in general be a trivial task. Therefore, it is important to have a properly articulated policy on spending priorities—a policy that is based on a disaggregated study of the particular economy in view, particularly as not all worthwhile programmes can be implemented. Limits to public sector programming, implementation and managerial capacity, as well as budgetary constraints, imply that priorities must be set. The lack of clear priorities hinders achievement of desirable goals and intensifies the pressure to spend even more, thereby making it more difficult to rein in deficits and control inflation:

Adjustment alone will not put countries on a sustained, poverty-reducing growth path. That is the challenge of long-term development, which requires better economic policies and more investment in human capital, infrastructure, and institution-building along with better governance....
(World Bank, 1994a: 2)

2. Review of related literature

The connection between infrastructure and economic development is firmly rooted in the development literature. One of the early treatments was by Rosenstein-Rodan (1943), who analysed the demand side of capital formation and particularly identified one category of physical capital for special attention—the social overhead capital. According to him, not only was this class of capital characterized by nonconvexities (which he referred to as generalized external economies), but they constituted prerequisites to private sector investment. However, it was much later that Aschauer (1989a/b), in linking infrastructure to productivity slow down in the USA, econometrically attempted to establish the empirical connection implied in Rosenstein-Rodan (1943). Most of the research in this area has focused on the United States and other developed countries where the issues have been whether there ever was a shortage of infrastructure investment and how the fact (of the shortage) was established. Gramlich (1994) estimates that these issues have generated at least 40 econometric studies using various data and techniques.

The literature addresses issues of the definition of infrastructure capital from two basic perspectives. One broad definition is rooted in the economically sensible definition of large capital-intensive natural monopolies (although in some countries they are privately owned). The other, which is expedient in applied work, is based on a narrow definition of just the tangible stock owned by the public sector. The literature also notes that like other public goods, some benefits of infrastructure capital such as improved security, time saving, improved health and a cleaner environment are magnitudes that are difficult to measure and thus are not included in official measures of national output. “Hence it will also be difficult to relate infrastructure to [all of] its goals, or changes in them” (Gramlich, 1994: 1178).

Nonetheless, a strand of the literature estimates the impact of infrastructure on productivity by imposing the Cobb–Douglas functional form with the influence of public capital explicitly modelled. Examples are Aschauer (1989a, 1993), Holtz-Eakin (1992) and Fernald (1993), to name a few. Other authors such as Aaron (1990), Jorgenson (1991) and Tatom (1991) have expressed concern about estimates of rates of return on public capital coming out of previous studies. The critics contend that the numbers are overly optimistic and simply suspect. Yet other criticisms focus on the possible misspecification of the dynamics of the variable for public capital stock. They reason that many of the stocks of building do not have the implied short-term impact on the supply of aggregate output. This observation, they note, makes the high rates of return even more implausible.

Subsequently, these and other econometric problems have been addressed, some (Rubin, 1991) for example by mining various definitions of the appropriate stock of

capital.⁵ One particular definition—core infrastructure, meaning highways, water and sewerage systems, that is, a large component of state and local government stock—yields the highest output elasticity and so fails to resolve the puzzle. As a consequence, Gramlich (1994) recommends pooled time-series cross-section data across states (expenditure units) as a way of mitigating some of the econometric problems raised in the previous studies. This approach gives more plausible estimates of the implied rate of return on infrastructure investment. Munnell (1990), Eisner (1991), Eberts (1990) and Holtz-Eakin (1992) followed this approach. Munnell (1992) summarizes these findings.

There is little doubt that infrastructure generally supports economic activities. What is not obvious is the degree to which public infrastructure stimulates economic development in specific locations. Fox and Smith (1990) discuss the relationship between public infrastructure policy and economic development, and conclude that infrastructure cannot be expected to stimulate the economies of all communities, but most communities can benefit from exploring new ways to deliver infrastructure services more efficiently. They argue that new infrastructure is less likely to boost economic development in lagging regions than in intermediate or congested regions because few other characteristics (development ingredients) are present to attract new economic activities. Some lagging regions actually face disinvestment because of inability to maintain existing facilities. Building infrastructure will probably not overcome an unskilled labour force, inadequate raw materials or long distance to markets.⁶

Easterly and Levine (1994) attempt to explain “Africa’s growth tragedy” by using a cross-sectional regression on a list of variables thought to explain growth. One of the variables that do not show up as significant is the measure for infrastructure investment. This is interesting in view of the many studies of Africa that cite the poor state of its infrastructure. Aschauer’s (1989a) influential paper claimed to have found large effects on US productivity growth. Canning and Fay (1993) report similar findings for a cross-country sample, although cross-sectional study by Khan and Reinhart (1993) failed to find significant growth effects. Canning and Fay used physical measures of infrastructure such as kilometres of roads and railways per worker, electricity-generating capacity per worker, and telephones per worker. Easterly and Levine (1994) find no significant effect of either roads, railways or electricity generation. This is hardly surprising, given the level of aggregation at which the study was conducted and the failure to account for the quality dimension of the existing infrastructure. To the extent allowed by the available data set for this study, we take account of the variation in quality across regions for the same infrastructure type.

Polenske (1994) summarizes the state of both the theoretical and empirical literature on public infrastructure and productivity. She finds that competent researchers have reached opposite conclusions on the relationship between regional economic performance and infrastructure expenditure and views this as convincing evidence that more work is needed on the topic. A review of the empirical research reveals that the productivity effects of public capital vary from negative to positive and from small to large with causality working in either direction. Polenske (1994: 476) observes:

Theory currently provides little guidance regarding possible outcomes, but there are three critical issues which mainly concern analysts in industrial economies although applicable to developing countries as well: (1) The development of clearly stated theoretical expectations concerning the economic impact of public investment ... that will lead to the design and testing of improved models for gauging the productivity of public investment. (2) The improvement of data used in empirical research, particularly regarding infrastructure lives, depreciation, and the role of maintenance ... in the growth of net capital stock. (3) The changing institutional arrangement that affects public investment, especially in view of the current emphasis on privatization.

On the last item, Polenske cites Lee and Anas (1992), who propose several policies for responding to Nigeria's current infrastructure deficiencies, including regulatory reforms, private sector participation, and alternative pricing to account for capacity limitations and congestion.

3. Methodology and empirical estimates

Profile of data and outline of methodology

The basic quantitative methodology for estimating the marginal efficiency of core infrastructure is based on Ratner (1983). That model is the first to explicitly add public capital to the production function to test whether the marginal product of public capital is positive (with respect to private production). The model assumes that the business sector production function can be approximated with a Cobb–Douglas functional form:

$$Q_t = Ah_t^\alpha K_t^\beta g_t^\delta e^{(rt + v_t)} \quad (1)$$

where A is a scale parameter, h_t measures business sector hours, k_t measures the flow of services from K_t , the inflation-adjusted stock of private capital at the end of the previous year, g_t measures the flow of services from G_t , the public capital stock at the end of the previous year, r is the rate of disembodied technical change, t is a time trend, and v_t is the error term. The utilization rate for the flow of private capital services is assumed to be measured by the index of manufacturing capacity utilization, c_t . The utilization rate for the flow of infrastructure services is assumed to be measured by a quality index, θ , which has changed little during the period analysed. Therefore, g_t equals θG_t , and k_t is $c_t K_t$.

The production function allows returns to scale that are either decreasing, constant or increasing. Also, Equation 1 can be log-transformed to:

$$\ln\left(\frac{Q}{cK}\right)_t = \ln A + \alpha \ln\left(\frac{h}{cK}\right)_t + \delta \ln\left(\frac{\theta G}{c_t K_t}\right) + rt + v_t \quad (2)$$

Some economic meanings can be given to the exponents α , β and δ . Each exponent indicates the relative share of that input in the total product, while the sum of the exponents measures the return to scale. In Equation 2, these exponents are interpreted as (partial) elasticities of output with respect to a unit of that input. The goal is to estimate the values of these exponents.

The variables for core infrastructure are: (1) kilometres of “motorable” roads, (2) percentage population with access to potable water through either stand pipe or house connection, (3) electric power consumed as (an admittedly unsatisfactory) proxy for

power infrastructure, and (4) number of telephone main lines.⁷ A detailed description of the data set is in the Annex.

Empirical methodology

We use a model that captures the relationship between regional economic performance and installed infrastructure, while allowing for characteristic differences among the states. We also seek an efficient method of estimation and an inference procedure that together allow us to analyse our results. We begin with a general representation of the panel data:

$$y_{it} = \alpha_i + \sum_{j=1}^K \beta_{ij} \chi_{ijt} + e_{it} \quad (3)$$

where $I=1,2,\dots,N$ denotes a cross sectional unit (a state), and $t=1,2,\dots,T$ denotes a given period. Thus y_{it} is the value of the dependent variable (output) for state i at period t , and χ_{ijt} is the value of the j th non-stochastic explanatory variable for state i at period t . The random error term e_{it} is assumed to have a mean of zero, and a constant variance. The α_i 's and β_{ij} 's are unknown response coefficients to be modelled.

As there may be correlation between the error terms in each of the sets of equations, it is plausible that these errors are rooted in some common unmeasurable or omitted factors, and so should be expected to exhibit some (contemporaneous) correlation. In addition, it is assumed that with contemporaneous correlation,

$$E(e_{it} e_{jh}) = \begin{cases} \sigma_{ij}, \forall t = h \\ 0, \forall t \neq h \end{cases} \quad (4)$$

Thus we have as the contemporaneous variance-covariance matrix of the joint disturbance vector,

$$\Sigma = \begin{pmatrix} \sigma_{11} & \sigma_{12} & \dots & \sigma_{1N} \\ \sigma_{21} & \sigma_{22} & \dots & \sigma_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{N1} & \sigma_{N2} & \dots & \sigma_{NN} \end{pmatrix}$$

The parameters of interest are the estimates of the state-specific marginal physical products of the core infrastructure. For various reasons, these estimates of marginal products can vary across some states. Sources of variation that easily come to mind are differences in the quality of governance, in the initial stock of human capital, in the dominant cultural influence in each state, in the level of economic development, and in other historical developments such as location factors (climate and natural resources).

We believe that if states did not differ and all other things were held equal, then the purely technical role of each infrastructure facility in augmenting output—measured as the marginal rate of product transformation—would be the same across all regions. However, the past experiences of Nigerians from the civil war in the 1960s and its aftermath, condition decisions on private investment and occupational mobility. The more “Asunken” is the nature of an investment, the less mobile across regions is private capital flow into such an investment. Similarly, the more idiosyncratic is an occupation, the less mobile across regions is labour *ex ante*. We expect these facts of resource flow to also influence the degree of diversity of private capital—the immobility of factors should prevent marginal products from completely equalizing. These enumerated diversities across political regions are modelled by allowing the response coefficients to differ in the panel.

The question that then arises is whether the fixed differences across regions are correlated with the infrastructure variables. The answer is, yes. Using Lagos as an example, we can relate the level of access to potable water, the density of the network of roads and the density of the network of telephones in that metropolis to its preeminent position in the political and commercial history of Nigeria. For a long time, it was the seat of the federal government and later also doubled as the seat of a state government. It is still the commercial nerve centre of the nation. Most, if not all, the policy makers involved in earlier decisions to install infrastructure facilities lived and worked in the Lagos metropolis. Regions that have attained a higher level of urbanization are associated with higher levels of infrastructure stock. For instance, pit latrines are now banned in most urban areas. Therefore states with higher levels of urbanization demand more access to piped water, although the quality of water so delivered is not necessarily better.

Using quality of governance as another example, we point to the former Western Region of Nigeria, which is endowed with a relatively better quality infrastructure. This can easily be partially attributed to the foresight of the late Chief Obafemi Awolowo, who was very much development oriented in his approach to governance.⁸ The Western Region boasts a string of firsts in infrastructure-related variables—the first stadium in Nigeria (Liberty Stadium), the first-to-be the most populous modern city in Nigeria (Ibadan), the first university, as well as the first teaching hospital in Nigeria (University of Ibadan), the first broadcasting station in Nigeria, and home of an important road transportation nexus (Ibadan) from Lagos to the Eastern and Northern regions. The implication of having these fixed differences correlate with the infrastructure variables is that it requires an empirical modelling that treats the correlation more explicitly. Such a treatment can be handled conveniently within a dummy variable model.

The following model is based on the production function specified in Equation 2. It allows the estimates of the intercepts to capture individual differences (fixed effects), but uses interactive dummies to capture the effect of the individual differences on marginal productivity. By this, we aim to uncover variations across regions of the marginal product of infrastructure, as well as to rank infrastructures within the same region. For a given political region $i(=1, \dots, N)$, within a period $t(=1, \dots, T)$ where for convenience the time subscripts are suppressed, we have:

$$y_i = \alpha_1 + \sum_{i=2}^N (\alpha_i - \alpha_1) D_i + \sum_{j=1}^K \beta_{1j} \theta_j \chi_{1j} + \sum_{i=2}^N \sum_{j=1}^K (\beta_{ij} - \beta_{1j}) D \chi_i + \omega L_i + r t + e_i \quad (5)$$

where

$$D_i (i = 2, \dots, N) = \begin{cases} 1 & \text{for an observation in state } i \text{ else,} \\ 0 & \end{cases}$$

$$D \chi_i (i = 2, \dots, N) = \begin{cases} \theta_j \chi_{ij} (j = 1, \dots, K) & \text{for an observation in state } i \text{ else,} \\ 0 & \end{cases}$$

θ_j is the quality index for variable j , and L_{it} (cKt) is the labour–capital ratio for state i . The measure for h is the economically active labour force. θ_{it} is the rate of employment in state i in year t . Therefore $\theta_{it} h$ is the quantity of labour input in region i in a given period. The choice of the reference state ($i = 1$) is arbitrary. Equation 5 corresponds to a regression of y on D, x, Dx and a constant term. Here, the constant term measures the scale parameter; and for the reference state, it incorporates the individual effect as well. D is the individual effect for all the other states (i.e., $\forall i \neq 1$) and x is the set of infrastructure variables; and Dx , the “interactive dummy”, captures the impact of the individual effect on an infrastructure. All the necessary transformations of the variables to conform to the functional form specified in Equation 2 are made, with output $y \equiv \ln(cK)t$ and the infrastructure variables summarized by $\ln(\cdot)$.

We gain efficiency by jointly considering all the equations (pooling the cross-section) to use the contemporaneous correlation across equations. An efficient method of estimation is the method of generalized least squares (GLS), particularly the Seemingly Unrelated Regression procedure (see Zellner, 1962, 1963). This version of the GLS obtains single equation estimates of the parameters of the model, and uses these to form a consistent estimate of the residual covariance matrix of the structure specified in Equation 4. We assert and test three different hypotheses. The first is a test for regional differences in the production functions. The second and third hypotheses prioritize infrastructure across regions and within regions, respectively.

The first null hypothesis of identical production function (conversely uniform output elasticity) may be parameterized as

$$H_0: R\bar{\beta} = 0$$

with

$$R = \begin{pmatrix} i_1 & i_2 & 0 & 0 \dots 0 \\ 0 & i_2 & -i_3 & 0 \dots 0 \\ 0 & 0 & i_3 & -i_4 \dots 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 \dots -i_N \end{pmatrix}$$

as an $(N - 1) \times N$ matrix containing $K \times K$ identity submatrixes. $\beta = (\beta_1, \beta_2, \dots, \beta_N)'$ is an $N \times 1$ matrix whose elements are the vector of estimated slope coefficients, and 0 is a null matrix. The linear restrictions may be summarized as,

$$\beta_{1j} = \beta_{2j} = \dots = \beta_{Nj} \quad \forall j = 1, \dots, K$$

Our test is the likelihood ratio (LR) test, which compares constrained and unconstrained estimates. The LR test can be implemented by obtaining the value of the logarithm of the likelihood evaluated at the estimated parameters. If we define LR_{ur} as the value of the likelihood function for the maximum of the unconstrained model and LR_r as the value when the constraints are imposed, then the likelihood ratio statistic is

$$\Lambda = 2(LR_{ur} - LR_r)$$

The LR statistic Λ is distributed asymptotically as a $\chi^2(\rho)$ where \bar{n} is the degrees of freedom equal to the number of constraints.⁹ The difference between the constrained and the unconstrained models is that the interactive dummies (Dxs) are excluded in the constrained model. Therefore, we have two sets of regressions: one that allows for separate intercepts and a common slope, and one that allows for both the intercepts and slopes to differ across regions.

The null of Hypothesis 2 asserts that for the same type of infrastructure, marginal products across regions are equal. The test is parameterized as:

$$H_0: R(b' \beta) = 0$$

and tested with the Wald test of exclusionary restrictions. R is as previously defined, and $b' \beta = (b_1 \beta_1, b_2 \beta_2, \dots, b_N \beta_N)'$ is an $N \times 1$ column matrix whose elements are the vector of the derived marginal products of the set of infrastructures from the N regions. b is the output-input ratio (Q/G), and β is the regression estimate of the output elasticity. Specifically, the test analyses that the 18 pairs of linear restrictions

$$b_{1j} \beta_{1j} = b_{2j} \beta_{2j}, b_{1j} \beta_{2j} = b_{2j} \beta_{1j}, b_{3j} \beta_{3j} = b_{4j} \beta_{4j}, b_{3j} \beta_{4j} = b_{4j} \beta_{3j}, \dots, b_{N-1j} \beta_{N-1j} = b_{Nj} \beta_{Nj}$$

hold jointly for j ranging from 1 to 4, which corresponds to water, power, telecommunications and highways in the 19 states. A Wald test statistic for testing H_0 is given by

$$\Omega_j (j = 1, \dots, 4) \equiv \frac{(b_{ij}\beta_{ij} - b_{i+1j}\beta_{i+1j})^2}{[b_{ij}^2 \text{var}(\beta_{ij}) + b_{i+1j}^2 \text{var}(\beta_{i+1j}) - 2b_{ij}b_{i+1j} \text{cov}(\beta_{ij}, \beta_{i+1j})]}$$

where $b_{ij}\beta_{ij}$ ($i = 1, K, 18$) is the GLS estimator of $b_{ij}\beta_{ij}$, while $\text{var}(\cdot)$ and $\text{cov}(\cdot)$ are the estimates of variance and covariance of β_{ij} , respectively. Under the null hypothesis, Ω_j is distributed $\chi_{(18)}^2$ asymptotically.

The test of Hypothesis 3 examines the equality of the marginal products of the infrastructure within a state. The null hypothesis asserts,

$$b_{il}\beta_{il} = b_{ik}\beta_{ik}; i = 1, \dots, 19, k = 2, \dots, 4,$$

and can be tested with the same Wald test specified above. The appropriate test statistic is

$$\Omega_i (i = 1, \dots, 19) \equiv \frac{(b_{il}\beta_{il} - b_{ik}\beta_{ik})^2}{[b_{il}^2 \text{var}(\beta_{il}) + b_{ik}^2 \text{var}(\beta_{ik}) - 2b_{il}b_{ik} \text{cov}(\beta_{il}, \beta_{ik})]}$$

where $b_{il}\beta_{il}$ and $b_{ik}\beta_{ik}$ ($k = 2, \dots, 4$) are, respectively, the GLS estimators of $b_{il}\beta_{il}$, and while $\text{var}(\cdot)$ and $\text{cov}(\cdot)$ are the estimates of variance and covariance of β_{ik} , respectively. Under the null hypothesis of equality of the marginal products, Ω_i is distributed $\chi_{(3)}^2$ asymptotically. The results of these tests are reported below.

Empirical estimates

The estimation uses panel data on the 19 states of the Federation. Our data cover 1985 to 1995. We can only go as far back as 1985 because of data constraints. And although more states were created subsequently from the 19 states, we nonetheless merged the observations from the spin-off states into their corresponding parent states to form a geographically consistent data set.

The hypothesis of an identical production function is clearly rejected. Therefore, we cannot impose an aggregate production as the proper specification for analysing productivity in this economy. Our dummy variable model, which allows diversities among regions, and also allows these diversities to influence public capital, appears to fit the data fairly well, with an adjusted R-squared of 0.83. Table 1 reports the results for the first hypothesis.

Table 1: Regression parameters and Hypothesis 1 test results

	Unrestricted regression	Restricted regression
Standard error of regression	0.499020	0.534317
R-squared	0.908	0.827
Adjusted R-squared	0.829	0.805
Number of observations	209	209
Test statistic	p-value	
$\chi^2_{(72)}$	132.3230	0.00002

Notes: Hypothesis 1 tests for equality of output elasticities across the states. The restricted regression is:

$$y_i = \alpha_1 + \sum_{j=1}^K \beta_{1j} \theta_j x_{1j} + wL_i + rt + e_i,$$

and the unrestricted is:

$$y_i = \alpha_1 + \sum_{i=2}^N (\alpha_i - \alpha_1) D_i + \sum_{j=1}^K \beta_{1j} \theta_j x_{1j} + \sum_{i=2}^N$$

Estimates of the output elasticities, their associated standard errors and the elasticities of production are listed in tables 2, 3 and 4, respectively. The marginal physical products for each of the infrastructures across the 19 states are listed in Table 5. We know that production functions can exhibit constant returns to scale at some points in input space and increasing or decreasing returns to scale at other points. A local measure of returns to scale, defined at a point in input space, is the elasticity of production—the sum of all the elasticities of output with respect to the various inputs at that point. According to Table 4, returns to scale vary from decreasing to constant to increasing. We view these estimates as highly imprecise, however, presumably due to estimating so many parameters with a relatively limited amount of poor quality data. As is typical of infrastructure stock variables, the time series display very little variation. Most of the variation would have come from adjustments for depreciation that should affect the net capital stock. Unfortunately, this information is not routinely kept even though its availability would be a big step towards better measures of infrastructure stock, as has been pointed out in the literature. The low variation across time can induce high standard errors in the parameter estimates.

Table 2: Estimates of the response coefficients and the implied output elasticities of water and power

States	Estimate of water	Standard error	Output elasticity	Estimate of power	Standard error	Output elasticity
Anambra	0.88	1.0558	0.88	-0.47	1.1681	-0.47
Bauchi	-0.97	1.5244	-0.08	0.01	1.8850	-0.47
Bendel	-2.98	7.5324	-2.10	1.02	1.7108	0.54
Benue	0.01	1.7357	0.90	0.16	1.5969	-0.32
Borno	-3.90	2.1889	-3.01	-1.56	1.3568	-2.04
Cross River	-0.85	2.2431	0.03	0.14	1.4373	-0.34
Gongola	-0.53	1.6719	0.35	0.76	1.7805	0.28
Imo	-5.02	2.3462	-4.13	-0.65	1.5453	-1.12
Kaduna	-0.33	1.8437	0.56	-0.24	3.4865	-0.71
Kano	-1.44	1.7007	-0.56	2.20	1.8623	1.72
Kwara	-0.06	2.8650	0.82	0.35	1.2823	-0.13
Lagos	-0.47	1.7982	0.41	0.43	2.2068	-0.04
Niger	-0.90	1.8666	-0.01	0.11	1.3224	-0.37
Ogun	-1.18	3.0174	-0.30	0.36	2.2168	-0.11
Ondo	-0.92	1.4026	-0.04	0.75	1.4799	0.27
Oyo	-12.58	2.4410	-11.70	-0.45	1.2905	-0.93
Plateau	-0.98	1.5130	-0.09	0.77	1.3957	0.29
Rivers	-2.58	1.2414	-1.69	1.54	1.5387	1.07
Sokoto	0.12	4.6820	1.01	0.60	1.6714	0.12

Notes: The tabulated estimates for water, $(\beta_{11} - \beta_{11})$'s, and power, $(\beta_{22} - \beta_{22})$'s, are deviations from the reference state. So, to recover the output elasticity for water, β_{21} , we add β_{11} and $(\beta_{21} - \beta_{11})$.

Table 3: Estimates of the response coefficients and the implied output elasticities of telecom and highways

States	Estimate of telecom	Standard error	Output elasticity	Estimate of highways	Standard error	Output elasticity
Anambra	-0.55	1.1231	-0.55	0.32	0.6011	0.32
Bauchi	0.56	1.1781	0.13	1.44	2.5573	1.76
Bendel	0.25	4.0198	-0.30	-1.27	1.3447	-0.96
Benue	3.96	4.0378	3.41	-1.16	2.2792	-0.84
Borno	-2.40	2.1107	-2.95	6.34	1.9018	6.65
Cross River	0.00	5.3691	-0.55	0.44	0.9061	0.76
Gongola	0.98	5.0018	0.42	1.99	6.1605	2.31
Imo	-5.06	3.2905	-5.61	-0.34	1.0012	-0.07
Kaduna	0.78	1.8851	0.25	-0.15	0.7443	0.16
Kano	0.78	1.3123	0.25	-0.64	0.9102	-0.32
Kwara	0.84	1.7427	0.29	-1.29	6.4011	-0.97
Lagos	-0.53	2.1323	-1.08	-0.23	1.1737	0.08
Niger	0.19	2.7377	-0.36	2.37	2.7523	2.69
Ogun	0.03	2.6248	-0.53	0.29	1.4758	0.60
Ondo	0.91	2.3796	0.35	0.00	1.0850	0.31
Oyo	9.70	2.5167	9.15	0.14	1.1480	0.46
Plateau	-0.16	4.5295	-0.71	-0.13	4.2088	0.19
Rivers	-8.39	3.0681	-8.94	0.13	3.0633	0.45
Sokoto	1.55	3.3880	1.00	0.03	1.1447	0.35
Labour-capital ratio	1.09	0.1291				
Tech progress	-0.035	0.0491				

Notes: The tabulated estimates for telecom, $(\beta_{13} - \beta_{13})$'s, and highways, $(\beta_{14} - \beta_{14})$'s, are deviations from the reference state. So, to recover the output elasticity for telecom, β_{23} , we add β_{13} to $(\beta_{23} - \beta_{13})$.

Table 4: Returns to scale parameter (elasticities of production)

State	Value	State	Value
Anambra	1.3	Kano	2.2
Bauchi	2.3	Kwara	1.2
Bendel	-1.8	Lagos	0.3
Benue	4.3	Niger	3.0
Borno	-0.2	Ogun	0.8
Cross River	1.0	Ondo	2.0
Gongola	4.5	Oyo	-1.9
Imo	-9.9	Plateau	0.8
Kaduna	1.4	Rivers	-8.0
Sokoto	3.6		

Table 5: Derived marginal products

States	Water	Power	Telecom	Highway
Anambra	1.2970	-0.00071	-0.0000	0.0004
Bauchi	-2.1293	-0.0006	0.0003	0.0029
Bendel	-4.1054	0.0010	-0.0000	-0.0012
Benue	1.2987	0.0003	0.0018	-0.0009
Borno	-4.2290	-0.0161	-0.0011	0.0033
Cross River	-1.2245	0.0006	-0.0000	0.0017
Gongola	0.0219	0.0130	0.0011	0.0026
Imo	-7.0684	-0.0035	-0.0009	-0.0003
Kaduna	1.0689	-0.0009	0.0000	0.0003
Kano	-0.8720	0.0043	0.0001	-0.0007
Kwara	1.2543	-0.0001	0.0001	-0.0002
Lagos	1.2324	-0.0007	-0.0000	0.0003
Niger	1.1628	-0.0006	-0.0000	0.0006
Ogun	0.6038	-0.0002	-0.0000	0.0007
Ondo	1.0217	0.0001	0.0000	0.0004
Oyo	-8.2489	-0.0013	0.0005	0.0005
Plateau	1.0387	-0.0000	-0.0000	0.0003
Rivers	-18.8534	0.0172	-0.0124	0.0010
Sokoto	1.5434	0.0047	0.0008	0.0005

The marginal products can be interpreted in terms of the need to optimize—operate within the economic region of production (where the marginal products of the inputs are positive). In the circumstance, a negative marginal product of infrastructure components does not mean a scaling back of the facilities, which often are inadequate or malfunctioning. We interpret the marginal products as signalling the direction of optimal adjustment of inputs. Consider, for example, the oil rich coastal region of Rivers State. The ordering of facilities suggests that it could use more power and highways to improve overall productivity. Similarly, the arid northern regions of Sokoto State could use more water supply and power to augment productivity.

Hypotheses 2 and 3 use these derived marginal physical products as the basis for ranking infrastructure facilities *across* regions, and *within* a region. Therefore, combining the two hypotheses forms the basis for prioritizing infrastructure investment. The test results are reported in tables 6 and 7.

Table 6: Hypothesis 2 test results

Infrastructure	p-value	$\chi^2_{(18)}$
Water	0.00260	39.2925
Power	0.79180	12.9961
Telecom	0.00250	39.4213
Highways	0.50656	17.2415

Note: Hypothesis 2 tests for equality of marginal products across regions for the same type of infrastructure.

Table 7: Hypothesis 3 test results

State	p-value	$\chi^2_{(8)}$
Anambra	0.7616	1.1640
Bauchi	0.7284	1.3027
Bendel	0.4412	2.6941
Benue	0.7467	1.2261
Borno	0.0430	8.1498
Cross River	0.9836	0.1609
Gongola	0.9643	0.2768
Imo	0.1421	5.4428
Kaduna	0.9773	0.2021
Kano	0.6051	1.8454
Kwara	0.9659	0.2678
Lagos	0.9854	0.1491
Niger	0.9130	0.5266
Ogun	0.9629	0.2848
Ondo	0.8664	0.7288
Oyo	0.0000	27.3128
Plateau	0.8155	0.9410
Rivers	0.0354	8.5802
Sokoto	0.9651	0.2729

Note: Hypothesis 3 tests for equality of marginal products within a region.

As indicated by the findings in Table 6, we can rank water and telecommunication facilities across the regions, but not power and highways. Also, from Table 7, we infer that there is no significant variation in the marginal product of the infrastructures within 16 of the 19 states. The three exceptions—Borno, Oyo and Rivers—are each characterized by a negative marginal product of water relative to the other infrastructure facilities. We suspect data measurement and/or reporting errors to be at work here, but since our source is the published cluster indicator surveys, there is very little we can do to improve the existing data set.

Taken together, the results in tables 5, 6 and 7 suggest that productivity can be improved by optimally reallocating investment expenditure. These hypothetically optimal allocations can be derived using the parameters in Table 4 to equate across the regions the marginal products of the infrastructure facilities (through a joint maximization programme).

4. Conclusions

This study uses state-level data on Nigeria to contribute to the literature on the connection between regional economic performance and infrastructure investment. At one level, our findings add to the body of accumulated evidence suggesting a correlation between output and the availability of certain kinds of infrastructure. At another level, it suggests that infrastructure can differ in the degree to which it stimulates economic activities in specific locations. We have also learned that there can be a great deal of variation in the specifics of each empirical study, which calls for more caution in comparing results across studies.

For instance, Gramlich (1994) reminds us that in a comparison of a whole list of variables suggested to influence output across 119 countries, most of the alleged variables do not pass tests of statistical robustness. One variable that “definitely does not pass their robustness test, indeed never gets significantly positive coefficients, is the government capital stock”. Similarly for the study by Easterly and Levine (1994), which attempted to explain “Africa’s growth tragedy”. So, combined with experiences from the present study, what lessons should be learned. First, that cross-country comparisons of infrastructure and productivity studies are tricky unless variables are comparable and, second, that reported results that speak to the effect of public capital should take pains to define what represents public capital and how it is measured.

This call for caution is underscored herein, where although variables are comparable across regions, results are still statistically not robust. For instance, when we estimate an aggregate production function, we find almost all the variables, including labour and technical change, to be individually significant at the 1% level. Telecommunications is the only exception.¹⁰ Also, consistent with past studies, current estimates of the elasticities of output varied from negative (water, telecom and technical change) to positive (highways, power and labour). However, when the same data set is re-estimated, controlling for regional differences only but still imposing a common slope, we discover that at the 1% level, only power and labour are individually significant. In our working model—which allows differential slopes and intercepts—we observed that some of the infrastructure variables were individually significant in some of the regions. Nonetheless, the only consistent pattern to the whole result is the joint significance of infrastructure variables, which seems to rest any doubts as to the importance of public capital to economic activities in Nigeria.

As stated in the beginning, this study does not specifically examine distributional politics or its effect on infrastructure, but it does provide the ingredient for such an analysis. Ultimately, the need to rank investment across regions and within a region

depends on the structure of decision making within a federation, as well as on the nature of the distributive politics. Nonetheless, in lobbying for infrastructure investments it would be useful for regions to get their priorities right so as to make efficient trade-offs at the margin. Studies such as this can serve as a springboard for the analysis.

The finding that marginal productivity does not vary across regions suggests a logical extension of this study, since it is not obvious that this result is a pure happenstance, or an outcome of a deliberate policy of balanced investment. The principle of balanced investment is rooted in the fiscal federalism that came with the ascendancy of the central government during the 1970s, following the OPEC-oil boom.¹² It was during this period that many key elements of accommodation were introduced, including the proportional allocation of federal resources. Whether the country has in fact kept faith with these “key elements of accommodation” makes for an interesting research agenda—one that focuses on the political economy of infrastructure investments.

For each category of infrastructure, the present study has consistently estimated the parameters of the regional production functions needed to generate the first-best allocation across the regions. These optimal allocations can be compared with the actual distributions to secure a measure of economic distortion. The economic distortion is then used as a benchmark of the role of political influence. Going forward, we hope that a better understanding of distributive politics can help us design efficient policies on public expenditure.

Finally, we acknowledge that the reliability of the kind of analysis done in this paper can only improve with the reduction in the severity of obstacles to the accumulation of data, as well as with the improvement in the measurement and consistency of data on infrastructure. The trend towards privatization and commercialization of public enterprises (in developing countries) is already a step in this direction.

Notes

1. q-substitutability and q-complementarity refer to the effect of the quantity of one resource on the marginal product of another. Economic theory does not dictate whether private and public capital are complements or substitutes.
2. World Bank (1994c) estimates that infrastructure investments will account for between one-quarter and one-third of all fixed investments in developing countries, amounting to about \$700–\$750 billion a year. By the estimates, infrastructure investments in the 1990s are projected at \$200 billion annually, while current international aid for infrastructure is about \$15 billion a year. In Nigeria, the oil boom has financed about \$175 billion of investment so far, (source on Nigeria: World Bank, 1995b).
3. Nigeria's finance minister expressed concern over the high internal debt overhang and the use to which the funds were put: "Perhaps, the most painful aspect of our predicament in this area is that much of the expenditures that gave rise to the deficit were on projects and programmes that were either incapable of yielding any dividend howsoever defined or are so badly mismanaged that their upkeep or revival is in itself an additional drain on the public purse" (Offoaro, 1996: 2).
4. Borensztein (1994), quoted in *IMF Survey* No. 24(3), 6 February, 1995, p. 48.
5. Econometric problems such as causality issues, simultaneity bias, specification errors, non-stationarity, and common trends.
6. Botswana is an example. The Governor of the Bank of Botswana notes that "a good social and physical infrastructure—one of the best in Africa" simply has not produced the trickle-down effect on the scale or at the speed which the planners anticipated" (Address to 1995 BOCCIM Annual General Meeting, 21 June 1995).
7. A telephone main line connects the subscriber's equipment to the switched network and has a dedicated port at the exchange. The correct indicators for power infrastructure are the capacity to import energy (transmission infrastructure) and the spannage (distribution infrastructure). The relevant data sets comprising specifications and capacities include total circuit length of high tension transmission lines in kilometres, total injection substation capacity in megavolts amps (MVA), total circuit

length of low tension transmission lines in kilometres, total installed distribution capacity in MVA (composed of capacities of distribution transformers and distribution substations). Regrettably, such proper data sets were unavailable.

Some research, including the World Bank's *World Development Report 1994*, have used installed capacity of electricity generating plants as a proxy for power. However, we prefer power consumed as an indicator of the measurement of the contribution of electricity to productive activities. The reason is that considerable amounts of generated power are lost in the transmission and distribution process (system losses).

8. Chief Awolowo was one of Nigeria's premier nationalists. He was the first leader of the opposition group in the first republic, and the first premier of the Western Region. He was later jailed for treason, was released and became minister of finance during the period of the Nigerian civil war. Chief Awolowo was several times a presidential candidate, but is remembered most for his foresight and dedication to the cause of economic development in the Western Region. In the history of free primary education in Nigeria, he outdistanced everybody with his early introduction of free primary education in the west.
9. This test is always non-negative since the likelihood of the unconstrained model is necessarily higher than that of the constrained model.
10. The contribution of telecommunications infrastructure is hardly surprising, considering the quality of telecommunications services as discussed in the section on data profile. Additionally, we suspect that in the aggregate, it could be highly intercorrelated with highways.
11. Oil royalties and revenue from crude oil sales accrue to the Federal Government.

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Annex: Data sources

1. The figures for the various state gross domestic products (SGDP), and the state consumer price indexes are from the Federal Office of Statistics, Lagos (FOS), and Job (1997). Real SGDP is derived by deflating the nominal SGDP by the consumer price index for that state.
2. Data on capacity utilization are from the annual reports of the Central Bank of Nigeria for the various years. The capacity utilization figures for 1990 and 1993 are revised figures as reported in the Central Bank of Nigeria annual reports for the years 1991 and 1994, respectively.
3. Information on labour force uses the 1991 population census as the base data to derive the state labour force for the period 1985–1995. Both the data on the economically active population and the growth rate of the population were used to derive the population figures for the non-census years, namely 1985–1990 and 1992–1995. The 1991 report by the Nigerian Population Commission is that the Commission does not believe in the 1963 census. Therefore, the figures from the 1963 census were not part of the growth rate of 2.89% used in the projection for the non-census years. The growth rate was derived from the census of 1952/53 and that of 1991. As used by FOS, an employed person is said to be economically active, i.e., “all persons of either sex which furnish the supply of labour available for the production of goods and services”. Source of data for economically active population is *Census, National Summary, National Population Commission Census 1991*. Source of the state-level data on the unemployment rate is FOS.
4. Gross private sector capital formation is in millions of naira. Source is FOS. The method used to derive the reported figures modifies that used in aggregating the state gross domestic product. The numbers for the state-level gross domestic investment are components of the state domestic product and thus were derived from the tables of SGDP. To arrive at the capital stock, we used the average investment over the 11-year period as the base capital stock and then cumulated the investment. Nigeria does not report capital stock as part of the national accounts statistics. It reports only gross total (public and private) investment.
5. Power (electricity) consumed is measured in gigawatt hours (million kilowatt hours). Data source is FOS (National Income Accounts Office), Lagos.

6. Access to safe water is measured in percentages of the population of the respective states. The estimates are based on FOS surveys for about 6 years out of the 11 years reported. Additional source for water is, "Federal Republic of Nigeria, Multiple Cluster Indicator Survey: March 1995," in *UNICEF at 50: 1946–1996*. Lagos: Federal Office of Statistics and UNICEF (1996).
7. The source of telecommunications data is NITEL Plc Abuja, and NITEL Plc, Public Relations Office, Gerard Street, Ikoyi, Lagos. The data sets for 1990 and 1992 were decomposed from the zonal sales (lines installed) data for 1990–1992. The criterion is the 1992 distribution of sales returns from the states. The ratio for each state is the weight used in apportioning the total zonal sales to the constituent states.

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