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POPULATION DENSITY, CAPITAL INVESTMENT AND AGRICULTURE: THE FRANC ZONE

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In a previous paper a model of an administratively centralized colonial economy was used to examine export growth within an enviroment of abundant land resources.[1] Particular interest was focused on how public expenditures are allocated within the empire and their vital role in stimulating development by improving the terms of trade facing individual farmers through the construction, for example, of transportation infrastructure. Of equal interest was the effect of population density, first on the allocation of public expenditure, and second on the agricultural methods employed at the end of the "vent for surplus" period of growth.[2] On the one hand, it was suggested that in the absence of a reorganization of the rural economy and improvement in farming techniques, high rates of population growth, also induced by government expenditures, exert strong pressures for decreasing the degree of commercialization and returning to subsistence production, a phenomenon which has been dubbed" agricultural involution".[3] On the other hand, it was asserted that population growth might have beneficial effects on the agricultural sector owing to the decreased costs per capita of internal transportation and communications.

It is the purpose of this paper to test empirically some of the propositions advanced earlier using cross-section data from 25 countries, departments, and territories of the Franc Zone for the years 1949 and 1960. These observations include French Guiana and a number of small islands in the West Indies and Indian and Pacific Oceans, colonized at various times from the seventeenth through the nineteenth centuries and having a political status today as French departments or territories, and 18 countries in Africa, which came under colonial rule in the latter half of the nineteenth century and achieved independence about 1960. They present a particularly useful sample because of their great range of population density and accessibility to world markets.[4] The degree of centralization in allocating public resources within the French colonial empire was great, moreover, especially after World War II.

In the next section of the paper the principal hypotheses to be tested are formalized within the contect of a simple aggregate model. The empirical results of these tests are presented in the following section, after which some econometric problems are discussed. The final section draws some conclusions.

I. The Theoretical Model

It is assumed in this model that colonial rule is established over a population which has been producing entirely for subsistence needs but has land and time available to produce cash crops if there were a demand for these products at the level of the farm. What prevents the world market from effectively reaching these farmers, however, is the lack of law and order in the countryside, the absence of low cost transportation facilities, and no knowledge of the potentiality of the environment for profitable production for export. The colonial government provides these missing ingredients by its establishment of political and military rule, its construction of a transportation and communications infrastructure, and its investment in agricultural research and extension.[4a]

Due to the lack of past experience, however, the government is at first unsure of the potentialities of various regions. Furthermore, its initially perceived goal is that of establishing some minimum level of government administration throughout the empire in order to ensure military security.[5] This is apt to be accomplished first along the coast, where communications with the metropole are good, and then progressively further into the interior with the advancement of railways and other means of transportation.

Once this minimum government expenditure is made, private commercial interests follow in an effort to stimulate trade.[6] With these come the necessary working capital, commercial skills, and imported incentive goods which were previously absent. The extension of these trading operations to each village, however, continues to depend on the government's construction of feeder roads, introduction of profitable crops, and other expenditures.

After a period of time, the colonial government begins to reassess the basis of its resource allocation. For one thing, these resources are apt to be quite limited owing to the reluctance of parliament in the mother country to pour public funds into a venture for which a socially profitable return is not easily envisioned. For another, experience is being gained in the various colonies, and some are proving to be more profitable than others. Starved for funds, the colonial regime must fall back on its main source of revenue--foreign trade. In the absence of the ability to manipulate the tariff rate to its own advantage, this means increasing exports, the foreign exchange from which is used to purchase imports. The expansion of exports has the further advantage of being virtually synonomous with the development of the colonies' endowment of natural resources.[7]

More formally, assume that the stock of cumulated past government expenditures in any territory i at a relatively early stage of colonization is determined by

$$(1) \qquad G_i = G(D_i, N_i, N_i/A_i, G_E)$$

where D_i is the distance of the territory from the coast, N_i is the population and A_i the land area of the territory, and G_E is the total stock of past expenditures throughout the empire.[8] G_i is assumed to vary inversely with D_i because limitations on the availability of public resources and the time required to construct transportation routes into the interior imply, at this early stage of colonization, that coastal territories benefit first. G_i is also inversely related to population density because greater government expenditures must be allocated to more sparsely populated areas in order to supply the same per capita level of administration.[9] The other two independent variables, N_i and G_E, vary directly with G_i.

Past government expenditures determine current exports[9a] by influencing the terms of trade facing the farmers in the ith territory, where these are given by

$$(2) \qquad P_i = P(D_i, N_i/A_i, G_i/N_i, P_W).$$

P_i is assumed, here, to vary inversely with D_i and directly with each of the other independent variables, including the world price ratio P_w. For reasons analogous to those outlined above, given the ratio G_i/N_i, P_i is positively related to N_i/A_i since each dollar of government expenditure is more effective the higher is the population density.

The terms of trade in each territory, in turn, influence the supply of exports X_i from that territory by

(3) $$X_i = X(P_i, N_i/A_i, N_i, M_i)$$

where M_i is a variable denoting the natural environment. The partial derivative of exports with respect to population density is negative in this case to account for the effect of diminishing returns where less land is available to a given population. Since G_i is the integral of past government expenditures, it is exogenous to the system in any current year. Exports X_i may then be expressed solely in terms of the exogenous variables by substituting equation (2) into equation (3).

Alternatively, it may not be exports alone which are influenced by these variables but all of agricultural production. This is likely to be true, for example, if exported products are also consumed at home. It is especially important to consider the impact of population density on total agricultural production since exports may merely replace domestic consumption with no increase in overall production and, consequently, no effects of diminishing returns, a possibility which will be examined empirically in the next section of the paper.

As the export potential of each territory is revealed, and as the level of colonial administration rises towards the minimum necessary for military security, the government's expenditures may be shifted increasingly towards those areas which promise greater export growth. If the only objective, in fact, was to maximize exports, public resources in any given time period would be allocated so as to equalize all dX_i/dG_i, where

$$\frac{dX_i}{dG_i} = \frac{\partial X_i}{\partial P_i}\frac{\partial P_i}{\partial G_i}. \quad (4)$$

This formulation poses some interesting questions. Given that $\partial P_i/\partial(N_i/A_i)$, $\partial X_i/\partial P_i > 0$ and $\partial X_i/\partial(N_i/A_i) < 0$, what is the net effect of a change in population density on exports? In other words, at what point, if any, is the effect of diminishing returns in agriculture likely to outweight the benefits of lower transportation and communications costs associated with higher population densities? In addition, does the allocation of public capital at any given time reflect parimarily the objective of establishing a minimum level of colonial administration? Or does a more purely economic goal, such a maximizing exports, seem to have been more important in its allocation? To what extent does the allocation of private capital tend to correspond to that of past public expenditures?

To answer these questions it is necessary to specify the previous relationships more precisely. Assume that equation (2) and (3), for example, take the form

(5) $$P = \lambda_0 e^{\lambda_D D} (N/A)^{\lambda_{N/A}} (G/N)^{\lambda_{G/N}} P_w^{\lambda_{P_w}} \quad \text{and}$$

(6) $$X = \gamma_0 P^{\gamma_P} (N/A)^{\gamma_{N/A}} N^{\gamma_N} M^{\gamma_M},$$

where the subscript i has been dropped to simplify the notation. The variable X may now be expressed as

(7) $$X = \gamma_0' e^{\gamma_P \lambda_D D} (N/A)^{\gamma_P \lambda_{N/A} + \gamma_{N/A}} (G/N)^{\gamma_P \lambda_{G/N}} N^{\gamma_N} M^{\gamma_M},$$

where γ_0' is a constant term which includes the identical prices faced in the world market by all territories. It is expected that the signs of the exponents of G/N and N are positive and that of the coefficient of D is negative. The sign of the exponent of N/A may be either positive or negative depending on whether $\gamma_P \lambda_{N/A} \gtrless \gamma_{N/A}$.

The hypothesis of equation (1) may now be formulated more precisely as

(8) $$G = \delta_0 e^{\delta_D D} (N/A)^{\delta_{N/A}} N^{\delta_N},$$

where the constant term δ_0 includes the variable G_E, the same for all territories. It is expected that the signs of δ_D and $\delta_{N/A}$ are negative and that of δ_N is positive. To test the alternative hypothesis that dX/dG is equated in each territory, we take that derivative from equation (7), assume it is equal to some constant η in each territory, and solve for G to obtain

(9) $$G = \frac{\gamma_0'}{\eta} \; e^{\frac{\gamma_P \lambda_D D}{1 - \gamma_P \lambda_{G/N}}} \; (N/S)^{\frac{\gamma_P \lambda_{N/A} + \gamma_{N/A}}{1 - \gamma_P \lambda_{G/N}}} \; N^{\frac{\gamma_N - \gamma_P \lambda_{G/N}}{1 - \gamma_P \lambda_{G/N}}} \; M^{\frac{\gamma_M}{1 - \gamma_P \lambda_{G/N}}}$$

For equation (9) to be satisfied, it is not only necessary that the sole objective of the colonial government be to equate dX/dG everywhere, but also that this has been its objective for a sufficiently long period of time so the stock of government expenditures reflects this goal. One can envision a contrary situation, for example, in which resources are allocated entirely to territories of high potential, but public funds are in such short supply that the value of dX/dG in these territories remains well above that of the regions of lower potential.

The hypotheses formulated in equation (8) and (9) may also be extended to the distribution of private investment by assuming some fixed relationship between cumulated public expenditures and private capital. This will be done in the next section.

II. Empirical Evidence from the Franc Zone

Using single-equation, least-squares regression analysis for a cross section of 25 observation from the Franc Zone, the following equations were estimated:

(10) $$\lg X = \lg a_0 + a_D D + a_N \lg N + a_{K/N} \lg \frac{K}{N} + a_A \lg A + u_X$$

(11) $$\lg Y = \lg b_0 + b_D D + b_N \lg N + b_{K/N} \lg \frac{K}{N} + b_A \lg A + u_Y$$

(12) $$\lg K = \lg c_0 + c_D D + c_N \lg N + c_A \lg A + u_K$$

In these equations K represents both the public and private stock of capital, Y is total agricultural production, and u_X, u_Y, and u_K are stochastic variables assumed to be normally distributed about a mean of zero. All equations were estimated for 1960, but because of data limitations only equations (11) and (12) were estimated for 1949 as well. Populations density was not included as a separate variable because of the multicollinearity that would have introduced, but it's coefficients in equations (7), (8), and (9) are easily derived from the regression results.

The possibility of bias resulting from the omission of an important variable, the effect of climate and soil conditions (M), will be discussed in more detail later. One way of avoiding the worst effects of this bias, however, is to omit any observation for which these conditions are extreme. Since there are five countries, Algeria, Mali, Mauritania, Niger, and Chad, in which are found large parts of the Sahara Desert, these countries were omitted from a subset of regression equations.

Data on population, land area, three indicators of the capital stock, and the real value of agricultural production were obtained from estimates of these variables constructed by a research group headed by Boris Maldant at the Institut d'Etudes de Développement Economique et Social in Paris.[10] Estimates of the real value of exports were constructed from separate sources.[11] Two separate measures, to be discussed later, were employed for the variable D.

Population estimates are total and not just those living in rural areas. Nevertheless, the majority of the population in most of the countries of the Franc Zone is rural and participates at least part-time in agriculture. Land area, too, is total and not restricted to land which is cultivable or devoted to agriculture. In many of the countries considered here fallow periods, sometimes of very long duration, are employed in agriculture, and it is very difficult to obtain accurate estimates of the area of land actually devoted to farming. Furthermore, many of the interesting effects of land on exports or production are due to spacial separation which is independent of the cultivability of land. There are, however, possibilities of bias, which will be discussed later, arising from these particular measures of population and land area.

Three separate indicators of the capital stock were used, each of which is only partial, but all of which are strongly correlated with one another.[12] The first of these K_1 includes road mileage, health facilities, and the number of heavy motor vehicles, each weighted by its cost or price assumed to be constant throughout the Zone. The advantage of using this indicator is that the data upon which it is based are relatively sound. The second indicator K_2 includes K_1 plus some other items of capital which are more difficult to estimate. These are the number of head of livestock, the capital invested in various tree crops, and the number of pupil-school years invested in the population, each again weighted by a constant set of costs and prices. Finally, the third indicator of the capital stock K_3 is the constant franc value of foreign public investment, primarily French, accumulated from 1946 to 1960.

Because of the difficulty of obtaining data on this investment prior to World War II, K_3 was calculated for 1960 only, whereas the other indicators are available for both 1949 and 1960. Total foreign public investment during these fifteen years was much more important than in previous years, so the failure to include investment made prior to 1946 is not so important by 1960. Thus the first two indicators include private as well as public capital whereas the last is confined to public expenditures.

Estimates for agricultural production and exports include virtually all the products of farming, livestock raising, and fishing. The quantities for each country are valued in terms of the average prices received in 1956 by the largest producer of each product within the Franc Zone. Generally prices are valued either f.O.b. at the customs station or, in the case of internally consumed products, at the domestic market. Where prices are not available, unit values are used. Since most of the products are relatively homogeneous, these should not differ much from actual prices.

Two separate methods were employed to examine the influence of distance to the sea. The first consists of measuring the distance D to the nearest sea coast from the center of the smallest circle which completely encloses each territory, an approximation to its geographical center. This measure probably overestimates average long-haul distances since it does not take into account differences in the density of population, capital, and agricultual production within the territory, which are likely to be higher closer to the coast. The second measure consists of two dummy variables.

The first D_1 is equal to unity if the observation is an island and otherwise equals zero; the second D_2 equals unity if the observation is a coastal country and otherwise zero. It is expected that the coefficient of D_1 is greater than that of D_2 since, for the same land area, the average distance to the sea of each point on an island is shorter than of each point in a coastal territory.

Various estimates of the export function, equation (10), are shown in Table 1. Where the sample size is 25, all observations were included; where it is 20, the regressions were run omitting the Sahara Desert countries. Standard errors of the regression coefficients are given in parentheses, and the coefficient of determination is shown in the last column.

Using a two-tailed t-test, the coefficients of N, A and K/N are significantly different from zero at the .05 level of confidence in each case, a_N and $a_{K/N}$ in the positive and a_A in the negative direction. The algebraic sum of the coefficients a_N and a_A, which is the coefficient of population size given its density, does not differ significantly from but is always greater than unity, indicating the possibility of size economies, albeit over a range confined to relatively small populations. The influence of the indicators of distance is never significantly different from zero, the standard errors being quite large.[13] This may be because long-haul transportation costs are not very important relative to other factors once the basic transportation infrastructure is laid down and because of the fairly close association which exists between these indicators and the capital stock making it difficult to distinguish any separate influence of the distance variable. Finally,

Table 1

COEFFICIENT ESTIMATES OF EQUATION (10)

No.	Year	Sample Size	lgN	lgA	lg(K_1/N)	lg(K_2/N)	lg(K_3/N)	D_1	D_2	D	R^2
			Independent Variables								
1.	1960	25	1.851	-0.600	1.005						.833
			(0.205)	(0.104)	(0.331)						
2.	1960	25	1.766	-0.487		1.038		0.095*	0.141*		.862
			(0.199)	(0.158)		(0.361)		(0.935)	(0.516)		
3.	1960	25	1.841	-0.571		1.206				0.912*	.868
			(0.171)	(00.119)		(0.300)				(0.859)	
4.	1960	25	1.787	-0.494		1.077					.861
			(0.164)	(0.095)		(0.275)					
5.	1960	25	1.773	-0.571			0.715				.837
			(0.184)	(0.102)			(0.225)				
6.	1960	20	1.811	-0.613	1.024						.813
			(0.265)	(0.130)	(0.426)						
7.	1960	20	1.740	-0.524		1.063		0.251*	0.467*		.853
			(0.227)	(0.174)		(0.409)		(1.053)	(0.709)		
8.	1960	20	1.775	-0.528		1.151				0.443*	.848
			(0.218)	(0.140)		(0.379)				(1.394)	
9.	1960	20	1.756	-0.504		1.104					.847
			(0.203)	(0.114)		(0.340)					
10.	1960	20	1.820	-0.622			0.835				.828
			(0.243)	(0.125)			(0.303)				

Notes: All equations are linear in logarithms and were estimated using the least squares regression technique. The standard errors of the coefficients are in parentheses. An asterisk indicates that the regression coefficient does not differ significanty from zero at the .05 level of confidence using a two-tailed t-test.

the omission of the Sahara Desert countries from the sample increases the standard errors of the regression coefficients somewhat but generally has little effect on the coefficients themselves. Where there is a fairly important change in the regression coefficients, as in regression (10) compared with regression (5), the direction of change is such as to increase a_N and decrease a_S.

These results strongly confirm the hypothesis of the greater importance of the positive over the negative effects of higher population densities on exports. Furthermore, the influence of private as well as of public capital on the expansion of exports is important, though the two are also highly correlated with each other. The parameters estimated in Table 1, moreover, appear to be stable over the entire range of observations. An examination of the residuals of several of the regressions plotted against population density revealed no discernable trend or evidence of a fit which is non-linear in logarithms. Furthermore, when the data are entered in order of increasing population density, the Durbin-Watson coefficients are such that the hypothesis of positive serial correlation is definitely not supported.

The relationship between these independent variables and total agricultural production is shown in Table 2. The coefficients of determination for these regressions are considerably greater than for those of the export function previously examined, though all are highly significant. Furthermore, the absolute size of the regression coefficients of N, K/N, and A are much lower for the total production function than for the export function. Nevertheless, the negative coefficient of A remains significant

Table 2

COEFFICIENT ESTIMATES OF EQUATION (10)

No.	Year	Sample Size	Independent Variables lgN	lgA	$lg(K_1/N)$	$lg(K_2/N)$	$lg(K_3/N)$	D_1	D_2	D	R^2
11.	1949	25	1.203	-0.215	0.236*						.958
			(0.079)	(0.042)	(0.123)						
12.	1949	25	1.192	-0.164		0.260		0.192*	0.051*		.966
			(0.073)	(0.062)		(0.117)		(0.345)	(0.186)		
13.	1949	25	1.211	-0.203		0.305				0.141*	.966
			(0.067)	(0.049)		(0.104)				(0.334)	
14.	1949	25	1.205	-0.191		0.291		1			.965
			(0.064)	(0.038)		(0.097)					
15.	1960	25	1.089	-0.179	0.218*						.956
			(0.077)	(0.039)	(0.124)						
16.	1960	25	1.088	-0.171		0.271*		-0.105*	-0.004		.960
			(0.078)	(0.062)		(0.141)		(0.366)	(0.202)		
17.	1960	25	1.094	-0.173		0.284				0.208*	.961
			(0.068)	(0.048)		(0.120)				(0.343)	
18.	1960	25	1.082	-0.155		0.254					.960
			(0.064)	(0.037)		(0.108)					
19.	1960	25	1.061	-0.173			0.134*				.954
			(0.071)	(0.039)			(0.087)				
20.	1949	20	1.207	-0.250	0.211*						.961
			(0.091)	(0.050)	(0.139)						
21.	1949	20	1.205	-0.222		0.252					.966
			(0.072)	(0.045)		(0.109)					
22.	1960	20	1.122	-0.199	0.278*						.950
			(0.103)	(0.051)	(0.166)						
23.	1960	20	1.112	-0.169		0.313					.956
			(0.082)	(0.046)		(0.138)					
24.	1960	20	1.107	-0.198			0.198*				.950
			(0.099)	(0.051)			(0.124)				

Notes: See Table 1.

at the .05 level in every case. The capital coefficient, on the other hand, is not significant in regressions (19), (20), (22) and (24), and is significant only at the .10 level in regressions (11), (15), and (16). The coefficient of the most complete capital indicator K_2 is significant at the .05 level or greater, however, in each case where it is introduced without the variables D_1 and D_2 or D with which it is partially correlated. As in the instance of the export function the coefficients of these distance indicators are all insignificant with large standard errors, and the sum of the coefficients b_N and b_S does not usually differ significantly from unity. Similarly, none of the coefficients are greatly affected by omitting the Saharan countries from the sample, the only influence being such as to strengthen the results previously stated.

The effects of population density and of capital on total agricultural production are thus considerably less important than in the case of exports. Partly this may be because of the dampening influence of production which is consumed on the farm without the need for commercial transactions or the transportation of crops and is therefore insulated from the factors affecting exports. More likely, in view of the higher R^2s and lower standard errors obtained when total agricultural production is the dependent variable, population density and capital accumulation affect not only production for export but also production for sale to domestic markets and for home use as well, with the last tending to be displaced as the degree of commercialization increases. Nevertheless, it is clear from our empircial results that the net effect of greater population density on the value of total agricultural production is positive. Although capital appears to contribute much more to exports than to total production, its net influence would also appear to be positive.

Using approximate values of the coefficients of regression (14), for example, this relationship may be expressed in a form similar to that of equation (7),

$$(13) \qquad Y = b_0 \left(\frac{N}{A}\right)^{.2} \left(\frac{K}{N}\right)^{.3} N.$$

Alternatively, equation (13) could be expressed as an aggregate production function

$$(14) \qquad Y = b_0 N^{.9} K^{.3} A^{-.2},$$

the marginal product of land being negative. This formulation clearly highlights the necessity of considering land not only as a factor of production but also as space which imposes a cost in any aggregate relationship.

Aside from having a relatively low standard error, the negative coefficient of land area remains quite stable over time and regardless of the sample used or particular variables introduced. An examination of the residuals, furthermore, revealed no discernible correlation with population density, indicating the stability of the coefficients throughout the entire range of observations.

Finally, the results of the capital function regressions are shown in Table 3. The variable N differs significantly from both zero and unity in every case. The coefficient of land, on the other hand, though always positive

Table 3

COEFFICIENT ESTIMATES OF EQUATION (12)

No.	Year	Sample Size	Dependent Variable	Constant Term	lgN	lgA	D_1	D_2	D	R^2
25.	1949	25	lgK_1	3.851	0.547	0.219	1.225	0.676		.836
				(1.133)	(0.095)	(0.096)	(0.491)	(0.279)		
26.	1949	25	lgK_1	5.434	0.570	0.152*			-1.060*	.807
				(0.716)	(0.099)	(0.086)			(0.562)	
27.	1949	25	lgK_2	4.464	0.623	0.164*	1.461	0.634*		.780
				(1.319)	(0.110)	(0.112)	(0.572)	(0.325)		
28.	1949	25	lgK_2	6.603	0.644	0.053*			-1.013*	.736
				(0.844)	(0.117)	(0.101)			(0.662)	
29.	1960	25	lgK_1	4.365	0.534	0.216	1.264	0.642		.851
				(1.031)	(0.084)	(0.087)	(0.448)	(0.255)		
30.	1960	25	lgK_1	6.115	0.559	0.129*			-0.946*	.813
				(0.679)	(0.091)	(0.080)			(0.531)	
31.	1960	25	lgK_2	5.111	0.615	0.146*	1.499	0.773		.838
				(1.087)	(0.088)	(0.092)	(0.472)	(0.269)		
32.	1960	25	lgK_2	7.153	0.645	0.048*			-1.162*	.787
				(0.732)	(0.098)	(0.086)			(0.572)	
33.	1960	25	lgK_3	4.306	0.432	0.220*	1.629	1.335		.760
				(1.326)	(0.108)	(0.112)	(0.576)	(0.328)		
34.	1960	25	lgK_3	5.851	0.482	0.196*			-1.913	.672
				(0.911)	(0.122)	(0.107)			(0.711)	
35.	1949	20	lgK_1	4.301	0.539	0.194*	1.042*	0.553*		.808
				(1.362)	(0.110)	(0.114)	(0.624)	(0.449(		
36.	1949	20	lgK_1	5.544	0.535	0.165*			-1.388*	.803
				(0.779)	(0.107)	(0.094)			(0.868)	
37.	1949	20	lgK_2	5.002	0.622	0.111*	1.391*	0.691*		.748
				(1.561)	(0.126)	(0.131)	(0.716)	(0.514)		
38.	1949	20	lgK_2	6.708	0.617	0.067*			-1.851*	.740
				(0.897)	(0.124)	(0.109)			(1.000)	

Table 3 continued:

No.	Year	Sample Size	Dependent Variable	Constant Term	lgN	lgA	D_1	D_2	D	R^2
39.	1960	20	lgK_1	4.975 (1.165)	0.516 (0.092)	0.198* (0.097)	0.913* (0.532)	0.329* (0.385)		.839
40.	1960	20	lgK_1	6.352 (0.702)	0.514 (0.094)	0.133* (0.084)			-0.904* (0.777)	.820
41.	1960	20	lgK_2	5.689 (1.269)	0.602 (0.100)	0.116* (0.106)	1.262* (0.580)	0.607* (0.420)		.813
42.	1960	20	lgK_2	7.370 (0.765)	0.599 (0.103)	0.058* (0.091)			-1.420* (0.847)	.791
43.	1960	20	lgK_3	5.043 (1.469)	0.397 (0.116)	0.190* (0.123)	1.351* (0.672)	1.153 (0.486)		.727
44.	1960	20	lgK_3	6.108 (0.869)	0.391 (0.117)	0.230 (0.104)			-2.084 (0.962)	.707

Note: See Table 1.

is not always significantly so. It is usually somewhat higher when the dummy variables D_1 and D_2 are included rather than the distance indicator D. The coefficients of the dummy variables are also larger in relation to their standard errors than is that of D, though the latter is often significant, at least at the .10 level, and its sign is negative as expected. As predicted, too, the coefficient D_1 is always larger than that of D_2. The latter coefficient is not generally significant when the Saharan countries are removed from the sample, probably because only two inland countries then remain with which to distinguish the effects of being a coastal or an inland country.

These results support the hypothesis that the allocation of capital within the Franc Zone was not determined primarily by the objective of maximizing exports, at least over any long period of time. The best measure of public expenditures most amenable to centralized decisions regarding its allocation is K_3, the sum of foreign public investment in each territory from 1946 to 1960. Taking the estimated value of the coefficients of equation (10) in which this is the measure of capital stock and substituting into equation (9), we find

$$(15) \qquad K_3 = \frac{\gamma_0'}{\eta} e^{1.7D_1} (N/A)^{1.7} N^{3.5}$$

The parameters of this relationship differ very markedly from those estimated directly, as, for example, those of regression (33) from Table 3,

(16) $$K_3 = c_0 e^{1.6D_1 + 1.3D_2} (\frac{N}{A})^{-.2} N^{.6}.$$

Although the coefficient of D_1 in equation (15) is similar to that of equation (16), it must be remembered that the coefficients of the distance variable estimated in the export function are not significantly different from zero, and consequently this similarity may be spurious.

The coefficients in Table 3 are consistent, however, with the hypothesis that public capital has been allocated in the basis of population and that the ordering of this allocation has been a function of the proximity of each territory to the sea. Since the coefficient of N, after allowing for the economies associated with higher population density, is in general significantly less than unity, there is also the presumption of economies of scale in the provision of some government services.[14]

The coefficients strongly indicate, too, the importance of geographical location in determing the allocation of capital. The islands benefitted from the first colonial government expenditures and have reaped advantages ever since. A comparison of any number of indicators of educational achievement, health, mortality, communication facilities, research, etc. shows the distinctly favorable position of these islands. Although benefitting from less accumulated public investment than the islands, the coastal countries were clearly in a better position than were their inland neighbors.

As expected the constant term for the regressions run on 1960 data are somewhat higher than those estimated for 1949. This reflects the increase in the size of the capital stock which occurred everywhere between those years.

Although there is generally no clear trend in the sizes of the other coefficients over time, if the Saharan countries are omitted, there appears to be some decrease in the absolute size of the coefficients of the dummy variables and of D from 1949 to 1960. This could indicate some diversion of capital resources away from areas previously favored toward those with less capital.

This conclusion is strengthened by comparing the coefficients of the constant term and of the dummy variables in regression (33) with those of regressions (29) and (31) or, omitting the Saharan countries, the coefficients of regression (43) with those of regressions (39) and (41). Although the constant term is usually lower for K_3 because that indicator is less complete than K_2, and also frequently K_1, the coefficients of the dummy variables, especially D_2, are always larger for K_3 than for both K_1 and K_2. These differences would be even greater if it were possible to exclude accumulated public foreign investment from the total capital stock so as to compare the coefficients of the function of that investment with those for domestic capital alone. Since the differences in the coefficients of D_2 are considerably greater than those of the coefficients of D_1, it would appear that France, realizing that her initial goals had largely been achieved in the islands, was attempting to focus mere of her efforts on the next area of development need, the coastal countries, but at the same time maintaining the level of investment in the territories of proven export capacity.

Possibilities of Bias

There are a number of econometric problems associated with the preceeding regressions, only the more important of which will be discussed here.[15] We are particularly interested in examining closely the possibility that the absolute values of the coefficients a_A and b_A are biased upward to an extent sufficient to nullify our conclusion concerning their negative sign. This might be true if the residuals of equations (10) and (11) were negatively correlated with A. because of errors in the measurement of the independent variables or because there are other independent variables which are correlated with A but omitted from the regressions.

The problem of errors in measurement can be examined by assuming that each measured variable is equal to the actual value of that variable multiplied by a term (1+ε), where ε is a factor of proportionality representing the magnitude of error. The size of the observed population $\hat{N}$, for example, is equal to $N(1+\varepsilon_N)$. Substituting for N, equation (10) may be written as

$$\text{(17)} \qquad \lg X = \lg a_0 + a_D D + a_N \lg \hat{N} + a_{K/N} \lg \frac{K}{\hat{N}} + a_A \lg A + u_X - (a_N - a_{K/N}) \lg(1+\varepsilon).$$

Assuming that the true variable N in equation (10) is the rural rather than the total population, what effect does this sources of bias have on the coefficient a_A? Since our theory and empirical results support the hypothesis that greater commercialization in agriculture is associated with higher population densities and if, as is reasonable, it is assumed that the degree of commercialization is positively related to the degree of urbanization, then ε_N is negatively correlated with A and, since $a_N - a_{K/N}$ is always positive and a_A is always negative, the absolute value of a_A is biased downwards. Similarly, the effects of errors in the measurement of K and of A can be analyzed, and, in each case, the direction of bias of the absolute value of the coefficients a_A and b_A is downward.

The variable D is measured with an admittedly large degree of error. The assumption that its effect may be indicated by two dummy variables D_1 and D_2 underestimates long-haul distances when countries are very large. On the other hand, the measurement of this variable by approximating the shortest distance from the geographical center of each country to the sea probably overestimates long-haul distances in large countries to the extent that populations and agricultural production tend to be concentrated in the areas closest to the sea. The inclusion of neither variable in the regression, however, has any appreciable effect on the coefficients a_A and b_A, which remain significantly negative in each case. Since these measures presumably bracket the true variable representing the effect of distance to the sea, the possibility of serious bias seem unlikely.

The source of bias which could prove most damaging to our conclusion conerning the negativity of the coefficients a_A and b_A results from the omission of climate and soil conditions from the regressions. If higher population densities and more capital investment are found where natural conditions are better for agricultural production, the coefficients of N and K/N will be biased upwards and that of A will be biased downwards algebraically.

There are a number of reasons to suppose, however, that densities of population and physical capital do not depend too greatly on natural conditions outside of areas where these conditions are extremely unfavorable for agriculture. Hance has examined in detail population densities in each country in Africa and has concluded that, though conditions of soil, climate and topography are important permissive factors in allowing high population densities to develop, historical circumstance, of which chance may be an important element, have frequently been more decisive in determining actual population densities.[16] This is particularly true of the French-speaking regions of Africa where population densities in many areas are unexplainably low. It would seem, therefore, that disease, warfare, pressures resulting from extended migrations, and the practice of birth control techniques during the pre-colonial period had a more important influence on population densities in various territories than did natural conditions.

This conclusion is supported by Maldant's attempts to compare soil and climate conditions in French-speaking Africa with the distribution of population density.[17] An examination of relevant maps, for instance, indicates little correlation between these variables outside of areas in which the lack of moisture makes agriculture virtually impossible. A more precise method of estimating the degree of association of soil and climate conditions with population density consisted of grouping 408 non-Saharan administrative districts in francophone Africa into six classes of soil quality.[18] The geometrically weighted average of the population densities in each class were then calculated using land areas as weights. The results are shown in Table 4. The differences between the means are relatively slight and not always in the expected direction, as in the case of the means of soil classes 1 and 2. This contrasts with the enormous

TABLE 4 GEOMETRIC MEAN OF POPULATION DENSITY BY SOIL CLASS (About 1960)

Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
6.03	3.09	4.36	4.79	4.90	13.19

Source: B. Maldant, "Facteurs Naturels, Densité de Population, et Production Agricole: les Phénomenes d'Economie d'Echelle dans les 28 Pays de la Zone Franc; Essai d'Analyse Statistique par Coupe Intemporelle," Revue Tiers--Monde, Vol. IX (April-June 1968), p. 429.

Notes: Population densities are given as numbers of persons per square kilometer.

dispersion of population densities across administrative districts, from 0.5 to 1,100.0 inhabitants per square kilometer. Even within each soil class the dispersion is large. The poorest soils represented by class 1 support population densities ranging up to 70.8 persons per square kilometer, while the densities on the two best classes of soil, 5 and 6, range from about 1 to 1,100.

A correlation ratio,

$$\eta^2 = 1 - \frac{((N/A)_i - (\overline{N}/A)_c)^2}{((N/A)_i - (\overline{N}/A))^2}, \tag{18}$$

was also calculated, where $(N/A)_i$ is the population density in district i, $(\overline{N/A})_c$ is the geometric mean of population densities in all districts of soil class c, and $\overline{N}/A$ is the geometric mean of population densities in all 408 districts. The value of η^2 was only 0.04. Because a number of districts have several soil classes, possibly biasing the result, these were eliminated and η^2 was found to equal 0.13 for 163 districts with homogeneous soil. Assuming this to be the correct magnitude of the correlation between soil conditions and population density, it is possible to estimate the maximum bias which this relation may impart to the coefficients a_A or b_A, given the simple correlation between X/A and N/A or between Y/A and N/A. As shown in the Appendix this bias is not sufficient to refute the conclusion that both a_A and b_A are significantly negative.

No attempt has been made to estimate separately the quantitative effect of climate on both agricultural production per unit of land area and population density, though it is partially taken into account in the soil classification. From the map examination by Maldant and from the results obtained by omitting the Saharan countries from the sample, however, it does not appear as if climate has a very important effect on population density. Nevertheless, it remains an important area for research to discover the costs which soil and climate place on the population density which can be supported within a given region.

Although a variety of historical factors may be more important than natural conditions in explaining population densities where traditional subsistence food crops are predominant, it seems likely that capital would be attracted to those areas in which the environment is particularly favorable for commercial agriculture, as indicated by equation (9). The historical experience of the Franc Zone and our empirical findings indicate, however, that many areas may not as yet have received a sufficient amount of investment to accurately indicate their economic potential. The lack of correlation between capital density and natural conditions is supported, too, by studies indicating the many areas in Africa in which natural conditions are favorable for commercial agriculture but in which little investment has yet been made, frequently because of the very low population densities.[19]

Another omitted variable might be the proportion in the population of Europeans, whose relative importance differs considerably, especially between the islands and mainland countries. If a large European population is associated with higher densities of population and capital and, at the same time, a higher level of technology, then the absolute values of a_A and b_A are biased upward. Since French influence has been enormous everywhere, however, it seems reasonable to suppose that all countries have had access to the same technology but that the degree of adoption of that technology has been a function of investment in human and physical infrastructure. Where this investment was substantial one would expect to find a relatively large number of Europeans during the colonial period involved both in the development of that infrastructure and in its exploitation. An examination of the population structure reveals, in fact, a close association between the amount of capital per person and the proportion of Europeans as well as those of mixed blood. It would seem, then, that during the period under consideration this proportion should be treated as an endogenous variable which has contributed to the means by which capital investment has helped to develop the agricultural sector.[20]

Finally, there are problems raised by the possibility of simultaneous relationships. In particular, the uneven development of commercial agriculture is likely to have stimulated interterritorial migrations. The most important instances of this are the either forced or voluntary importation of labor into the islands of the West Indies and Indian Ocean. Migration has also been extensive in Africa but probably is yet insufficient to dominate differences in indigenous population densities. Since the current population of immigrants is a function of past not current income differentials, there is no problem of simultaneous equation bias in the estimates of a_A and b_A. This problem could arise in the estimation of equation (12), however, if past migration has been influenced by the allocation of capital so that current population is some function of the current size of the capital stock. The result would be a positive correlation between the stochastic term in equation (12) and the variable N and a resulting upward bias of the coefficient c_N. What was surprising about our estimates of this coefficient, however, was that they are relatively low rather than high. Consequently, this source of bias would not seem to be a problem. Furthermore, the significance of the coefficients of D, D_1, and D_2, variables which are not well correlated with population, and the large differences already noted in population density which do not appear to be related to economic phenomena ensure the identification of equation (12).

Conclusion

The empirical results of this paper indicate that within the Franc Zone the positive effects of higher population densities on both exports and total agricultural production outweigh the negative effects across the entire range of observations. After examining the most important sources of bias, it is also possible to state that these are not likely to cause this conclusion to be refuted. In fact, our conclusion might be even further strengthened if the numerous biases in the direction of underestimating the absolute values of the true coefficients of land are greater than those causing these coefficients to be overestimated. Furthermore, the estimated values of the parameters of the export and production relations are quite stable over time and are little changed if the Saharan countries, with their extreme climate conditions, are omitted from the sample.

In addition it was found that capital is very important in the production and distribution of exports. The size of the capital stock in various countries appears, however, to be dominated by the early goal of effectively extending colonial government throughout the empire. Although private capital could flow freely within the Franc Zone, the high correlation between this and public expenditure indicates that the necessity of first providing a government infrastructure of transportation, education, health, research, etc. has effectively limited the amount of capital invested in those countries which have lagged behind in public investment, often for reasons of geographical location. The lack of capital, and thus exports, in these countries has, in turn, prevented the mobilization of domestic resources through local taxation. There is some evidence that France was attempting during the last years of the colonial period in Africa to increase the proportion of public investment in some of her previously neglected colonies. The chief benefactors, however, were the coastal rather than the inland countries, and the islands continued to receive the largest proportion of foreign aid in relation to their populations and land area.

Although we have no evidence that the parameters estimated in our regressions vary across the range of population densities found within the Franc Zone, this may be misleading. Various writers have remarked, on the basis of casual evidence, that some of the more densely populated island are, in fact, overcrowded in relation to their natural resources--certainly if they continue to specialize in agriculture.[21] Furthermore, most of these islands benefit from supported prices in France for their most important exports, such as sugar and bananas. Since products in our empirical analysis are weighted in terms of prices within the Franc Zone rather than world prices, the effects of high population densities in this upper range may not be accurately shown. Certainly it is not expected that increasing returns to population density in agricultural production and distribution will continue indefinitely. Variations in these parameters, however, can only be determined by research using different data.

For this reason and others it is difficult to derive any direct implications for policy without further research. First of all, the association of higher population densities with greater production of cash crops does not have an unambiguous implication for welfare since there is also less leisure time in densely than in sparsely populated areas. Furthermore, the only truly exogenous variables of the model described in this paper are land area and geographical location, neither of which can be easily altered by government action.

Even if the government is able to affect population density, the result is not entirely clear. The advantages of higher population densities, for example, may be outweighed by disadvantages associated with rapid rates of its growth. A number of these such as higher dependency ratios, lower per capita growth rates of capital, higher rates of unemployment, and the need for more rapid changes in technique, especially in agriculture, are well known. Furthermore, unfavorable climate and soil conditions in some areas are likely to severely limit the population densities which can be sustained or the cash crops, if any, which can be grown without massive investments of capital. Finally, the advantages gained from higher population densities within the Franc Zone during the colonial period, to the extent that they depended on the free movement of private capital, skilled labor, and traded goods, may not be easily duplicated today given the political pressures for restrictions found in many less developed countries.

The results do, however, point to some possible benefits from higher population densities in rural areas which should not be ignored. Given the population pressures building up in the less developed countries it is important to investigate more thoroughly the conditions necessary to reap the advantages and dispell the disadvantages of these higher densities.

Appendix

Assume that agricultural exports are determined by population N, land area A, and natural conditions M according to the relation

$$X = \lambda_0 N^{\lambda_N} A^{\lambda_A} M^{\lambda_M} (1 + u_X). \tag{19}$$

If λ_N plus λ_A equals unity, equation (19) may be written

$$\frac{X}{A} = \lambda_0 \left(\frac{N}{A}\right)^{\lambda_N} M^{\lambda_M} (1 + u_X). \tag{20}$$

When the effect of N/A on X/A is estimated without including the variable M, the positive correlations existing between N/A and M on one hand and between X/A and M on the other result in an upward bias to the estimated value of the parameter λ_N. It is possible, however, to estimate the magnitude of this bias.

The regression coefficient of N/A is given by

$$b_{12.3} = \frac{r_{12} - r_{23}\, r_{13}}{1 - r_{23}^2} \;\frac{S_1}{S_2} \tag{21}$$

where the b represents the regression coefficient, r the simple correlation coefficient, and S the standard deviation of the variables 1,2, and 3 representing respectively X/A, N/A, and M. The coefficient of determination $R^2_{1.23}$ may also be expressed in terms of the simple correlation coefficients,

(22) $$R^2_{1.23} = \frac{r^2_{12} + r^2_{13} - 2\, r_{12}\, r_{13}\, r_{23}}{1 - r^2_{23}}$$

Finally, define the symbol Δ as $b_{12.3}$ minus its standard error times the t-ratio corresponding to any given number of degrees of freedom and probability level,

(23) $$\Delta = b_{12.3} - t\, S_{b_{12.3}} = b_{12.3} - t\, \frac{S_1}{S_2} \sqrt{\frac{1 - R^2_{1.32}}{(n-k)\ (1-r^2_{23})}}\ .$$

Solving equation (22) for r_{13} and substituting into equation (21), $b_{12.3}$ may be expressed as

(24) $$b_{12.3} = \frac{S_1}{S_2}\left(r_{12} \pm r_{23} \sqrt{\frac{R^2_{1.23} - r^2_{12}}{1 - r^2_{23}}}\right).$$

If there is no correlation between N/A and M, then r_{23} equals zero and the estimated value of the regression coefficient $b_{12.3}$, equal to $r_{12}\, \frac{S_1}{S_2}$, is unbiased. Otherwise the extent of the bias is indicated by the last term in parentheses.

Confining our attention to biases only in the upward direction, $b_{12.3}$ from equation (24) may be substituted into equation (23),

(25) $$\Delta = \frac{S_1}{S_2}\left(r_{12} - r_{23} \sqrt{\frac{R^2_{1.23} - r^2_{12}}{1 - r^2_{23}}} - t \sqrt{\frac{1 - R^2_{23}}{(n-k)\ (1-r^2_{23})}}\right).$$

The only variable on the right-hand side of equation (25) for which we have no estimate is $R^2_{1.23}$. Under the most unfavorable assumption, $R^2_{1.23}$ will be such as to minimize the value of Δ. Setting the partial derivative of Δ with respect to $R^2_{1.23}$ equal to zero, we can solve for $R^2_{1.23}$ to obtain

(26) $$R^2_{1.23} = \frac{r^2_{23} + r^2_{12}\frac{t}{n-k}}{r^2_{23} + \frac{t}{n-k}}$$

This expression may be substituted for $R^2_{1,23}$ in equation (25) and that equation simplified to yield

(27) $$\Delta = \frac{S_1}{S_2}\left(r_{12} - \sqrt{\frac{(r^2_{23}\ (n-k) + t^2)\ (1 - r^2_{12})}{(n-k)\ (1-r^2_{23})}}\right)$$

From Maldant, r_{23} is estimated to equal .36. The variables S_1, S_2, r_{12}, and n may be estimated from the data. Choosing a t-ratio corresponding to a probability of 95% that the true value of λ_N is greater than unity if the estimated value of Δ is greater than one, the following values of Δ were calculated:

TABLE 5 VALUES OF DELTA CALCULATED FOR VARIOUS INDEPENDENT VARIABLES

Sample Size 25			Sample Size 20		
Y/A (1949)	Y/A (1960)	X/A (1960)	Y/A (1949)	Y/A (1960)	X/A (1960)
1.0652	1.0240	1.1848	1.0693	0.9645	1.0892

Only in one instance, the estimation of $b_{12.3}$ for 1960 when Y/A is the dependent variable and the sample is confined to the non-Saharan countries, is the value of Δ less than unity. In that case it is because the number of degrees of freedom are relatively few rather than because the bias is greater, since the value of $b_{12.3}$ hardly differs from that obtained when the Saharan countries are included in the sample.

Footnotes

[1] J. Dirck Stryker, "Vent for Surplus Growth in a Colonial Economy: A Tentative Model," Center Discussion Paper No. 153 (Economic Growth Center, Yale University, August 1972).

[2] The "vent for surplus" concept was first applied to the experience of a number of less developed countries by Hla Myint, "The 'Classical Theory' of International Trade and the Less Developed Countries," Economic Journal, Vol. 68 (June 1958).

[3] Clifford Geertz, Agricultural Involution; the Process of Ecological Change in Indonesia (Berkeley: University of California Press, 1963).

[4] Population densities range from .87 persons per square mile in French Guiana to 640 persons in Martinique. On some of the islands there is no point more than a few miles from the sea, whereas the interior countries of Africa are hundreds of miles from the nearest port. As will be seen, these geographical differences are an important variable affecting the allocation of public expenditures.

[4a] The extensive range of government activities which helped to develop colonial exports has been emphasized by Thomas Birnberg and Stephen Resnick, "A Model of the Trade and Government Sectors in Colonial Economies," Center Paper No. 130 (Economic Growth Center, Yale University, November 1971). My paper has been heavily influenced in many ways not, always easily acknowledged, by the research of these authors.

[5] The primacy of this object for the French colonial government in Africa in the first years of this century is indicated by the placement of

Footnote 5 continued:

railway lines in such á way as to gain access as quickly as possible to the interior rather than to develop the economic potential of the coastal regions. See, for example, the discussion of this decision in the Ivory Coast found in F. J. Amon d'Aby, La Côte d'Ivoire dans la Cité Africaine (Paris: Editions Larose, 1951).

[6]In actuality, private traders frequently preceded colonial governments but generally confined their activities to areas near the coast as long as movement into the interior was hazardous.

[7]The evolution of this objective of expanding exports as rapidly as possible given severe constraints on financial resources, though presented in a rather stylized fashion here, is more fully explored and documented for the French colonial empire in my forthcoming book on the economy of the Ivory Coast.

[8]The use of the stock of cumulated total government expenditures as the relevant variable is due to Birnberg and Rèsnick, op. cit., p. 11.

[9]On the importance of gains associated with population density in the use of social overhead capital and government services, especially where these densities are relatively low, see E. Van de Walle, "The Rèlationship between Population Change and Economic Development in Tropical Africa," in J. C. Caldwell and C. Okonjo (eds.), The Population of Tropical Africa (New York: Columbia University Press, 1968) and B. Maldant, et. al., "Facteurs Naturels, Densité de Population, et Production Agricole," Revue Tiers-Monde, Vol. 9 (April-June, 1968). William A. Hance, Population, Migration, and Urbanization in Africa (New York: Columbia University Press, 1970), p. 132, even cites evidence of the efforts of colonial governments in numerous territories to "...agglomerate dispersed groups and to require scattered peoples to align themselves along routeways in order to permit more effective control...and to assist in the introduction of education and other social services."

[9a]The specification of the supply function of exports to include past government expenditures is a major feature of the model formulated and estimated by Birnberg and Resnick, op. cit.

[10]Maldant, op. cit. These data, only a summary description of which is presented here, are discussed at greater length in Maldant.

[11]Comité Monetaire de la Zone Franc, La Zone Franc en 1962 (Paris: Secrétariat du Comité Monétaire de la Zone France, n.d.) and United Nations, Statistical Office, Yearbook of International Trade Statistics (New York: United Nations, 1962).

[12]The correlation coefficients between pairs of these indicators all lie between .942 and .983.

[13]Since the results of introducing these indicators into the regressions were substantially the same regardless of the measure of capital used, only the runs which included K_2 as the capital variable are included in Table 1.

[14]These results may be compared with those obtained by. E. J. Taaffe, R. L. Morrill, and P. R. Gould, "Transport Expansion in Underdeveloped Countries: A Comparative Analysis," The Geographical Review, Vol. 53 (1963). Using cross-section analyses of data by district in Ghana and Nigeria for about 1950, they estimated the following equations:

Footnote 14 continued:

Ghana: $\lg Y = 0.171 + 0.628X_1 + 0.414X_2$, $R^2 = .75$

Nigeria: $\lg Y = -0.448 + 0.446X_1 + 0.482X_2$, $R^2 = .81$.

where Y is highway mileage, X_1 is population, and X_2 is land area. With the exception of the larger size of the land area coefficient these results are very similar to our own. Even the relative magnitude of the constant terms is consistent with the coefficients of our dummy variables if allowance is made for the relatively long distance from northern Nigeria to the sea. The larger coefficient of the land area variable may be due to their limiting of the dependent variable to road mileage, not subject to the same economies of scale as are some other government services.

[15] A more complete discussion of these problems and their implications for our principal conclusions is found in J. Dirck Stryker, "Analyse Econométrique: Facteurs Naturels, Densité de Population, et Production Agricole dans les Pays de la Zone Franc--Une Etude Critique," Revue Tiers-Monde, forthcoming.

[16] Hance, op. cit., Chap. 2.

[17] Maldant, op. cit., pp. 423-36.

[18] The 278 catagories of soil type established by the Commission de Coopération Technique en Afrique were used as indicators of a number of dimensions of the quality of soil for agriculture. The characteristics of the soil in any given area then determined the class into which that area was placed. Although this procedure is somewhat arbitrary, it is unlikely that a more refined technique is warrented given the state of existing knowledge concerning African soils and their usefulness for agriculture.

[19]Hance, op. cit. and Food and Agricultural Organization of the United Nations, Crop Ecologic Survey in West Africa (Rome: FAO, 1966).

[20]Although there were not sufficient data to introduce the proportion of Europeans as an independent variable, some of the regressions were run on two subsets of the sample: those countries with more than and those with less than a 5% European population. There were no significant differences in the values of the coefficients between the subsets, a_A and b_A remaining always significantly less than zero.

[21]Hance, op. cit., has made this observation, for example, with respect to Réunion.