A GAME THEORETIC MODEL OF AGRICULTURAL AND FOOD PRICE POLICIES IN SENEGAL

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ABSTRACT

A game theoretic model of the political economy of agricultural and food price policies in Senegal is proposed. A cooperative bargaining game is used to describe and estimate the relative bargaining strength of three representative players: the farmers producing groundnuts and millet and consuming fertilizer; urban dwellers consuming imported rice and wheat; and a small set of governmental institutions intervening in these markets. Farmers are shown to have about twice as much bargaining power as urban consumers or the governmental agencies involved in the game. The bargaining power structure is influenced by changes in exogenous variables such as the world price of commodities, exchange rate and population. The bargaining power of farmers is positively influenced by increases in the world price of rice and groundnuts; urban consumers' strength is weakened by the same exogenous changes. The opposite results are obtained for increases in the foreign exchange rate and population.

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The political economy of price policies in tropical Africa has been studied at length by Bates and Lofchie. The determination of agricultural and food price policies through the political economic process is a central theme in their work.

Bates argues that many governments (e.g., Ghana and Senegal) compromise with different social groups to gain their legitimacy, and this is reflected in the price policy formation. Policies are chosen according to the relative political strength of social groups, given resource constraints and policy objectives of the government. Policy decisions involve urban consumers, farmers, and bureaucratic institutions (e.g., marketing board and stabilizing funds) which have conflicting interests.

In many cases hybrid policies are adopted, which create economic inefficiencies and undermine economic growth. Tariffs on imported staple food for urban dwellers are moderate or negative. Producer prices for traded agricultural commodities are set below their world level, and input prices are generally subsidized. Marketing boards receive institutional monopoly and monopsony power for the markets mentioned above.

These policies are nevertheless coherent when put into a larger political economic framework. Price policies are necessary to generate surplus administratively, which is a necessary condition for the reproduction of governments and their large administrations. But these governments will not use their monopoly/monopsony power fully since retaliation by socioeconomic groups can ruin the rent generating mechanism. Farmers can respond by changing their output and crop patterns, smuggling, and defaulting on debt loan payments as potential threats against low producer prices; urban consumers can retaliate against high food prices by undermining the government legitimacy (votes, political unrest, rioting, and going on strike). Hence, market interventions which are essential to the survival of the government reflect the relative political strength of the different economic groups affected by the policies. Bates' thesis is informally game theoretic, but no quantification nor modeling are offered to test the theory.

The purpose of this research is to propose a game theoretic model of price policy formation that will be applied to the political economy of agricultural and food price policies in Senegal. The game

involves three representative players: the farmers producing groundnuts and millet (main crops of Senegal); urban dwellers consuming imported rice and wheat products; and a small set of institutions intervening in the fertilizer, groundnuts, rice, and wheat markets. The model is based on cooperative game theory (Harsanyi, 1977). It departs from the traditional Nash game (Nash) by incorporating reference points[1] (Thomson). The introduction of reference points allows us to make less restrictive assumptions on the behavior of the players than the Nash game does (see section 2).

We bring a second modification to the traditional model by letting the bargaining power of the players vary with exogenous shocks influencing the game (e.g., changes in world prices and exchange rate). As the economic environment changes, so do the welfare possibilities and the bargaining power of the three players.

The first order conditions for the existence of a solution to the game are used to derive and estimate econometrically the relative bargaining power coefficients of the three players and the impact of exogenous shocks on the bargaining power structure. The results show a relatively stable power structure where farmers have about twice as much bargaining strength as the urban consumers or the governmental agencies involved in the policies. These bargaining coefficients can be seen as the weights the social planner puts on the different objectives (maximizing the welfare of different pressure groups). The results also indicate that the bargaining power of farmers is positively influenced by increases in the world price of their cash crop and of imported cereals while the bargaining strength of urban consumers is negatively related to these prices.

The concept of endogenization of market interventions is not new. The revealed preference approach (Rausser and Freebairn) explicitly acknowledges the existence and influence of pressure groups in the policy decision-making process. The government maximizes a weighted objective function, sometimes called the criterion function, reflecting the welfare of the different groups and reveals its preferences throughs the weights it attributes to the different objectives. The revealed preference approach has an ad hoc flavor because it does not provide a formal structure of the political economy

1 A reference point is a n-tuple (for a n-person game) of payoffs to which players find it natural to compare any proposed compromise. The Nash conflict point and Raiffa ideal point are two examples of reference point.

on which the government objective function is based (Zusman). Game theory remedies that shortcoming since it offers a formal model of the bargaining process among social groups that leads to the criterion function. The weighted objective function of the revealed preference model is a corollary of the cooperative bargaining game solution (Harsanyi, 1963). In this case the weights express the bargaining power of the different players.

The structure of the paper is as follows. First, the Senegalese context is introduced; the different markets and policies affecting them are described to motivate the game theoretic approach. Then, the cooperative bargaining model is presented; in the same section we explain briefly the modeling of the Senegalese case into the game theoretic framework. The empirical results of the econometric estimation of the game follow the model section. Tentative conclusions are last. An extended version of the present paper is available upon request.

1. Trade and Price Policies in Senegal

This section attempts to summarize the major policies that have consistently affected the agricultural production of groundnuts and millet, the demand for fertilizer, and the urban consumption of wheat and rice for the period 1960 to 1980. That period corresponds to the stability and continuity in the administrative institutions and type of policies of the Senegalese government. Groundnuts and millet are principally grown in the groundnut basin which is the major agricultural region of the country. Groundnuts are the major agricultural source of foreign exchange of Senegal. Millet is the principal staple crop in the groundnut basin. Rice and wheat products are the major staple food commodities for urban consumers. The five markets are introduced next.

1.1. The Groundnuts Market

Since the early 1960's, farmers have been organized into cooperatives. Theoretically the cooperative has been defined as a multiple function structure (production, marketing, credit, and education) that would improve the farmer's wellbeing. In practice, the cooperatives have become the instrument to modernize groundnuts production and marketing. The cooperatives are unionized and are represented in several important state agencies involved in groundnuts marketing. After independence in 1960, small, private groundnuts traders were progressively replaced by a national marketing board, which has had

total monopsony power on groundnuts production since 1964. In 1980, the dissolution of the marketing board was imposed by France as a condition to providing more financial assistance to Senegal. The farmers sold their production to the marketing board through the cooperative.

Since 1962, official prices have been announced to the farmers before the beginning of the planting season by the marketing board. The prices are decided by the Comite des Grands Produits, which is an interministerial government committee where cooperatives are present. The political influence of religious leaders (marabouts) is also an important element in the decision-making process of price policy. The political stability in rural areas relies on the hegemony of moslem leaders who are important groundnuts producers. This puts a lower bound on the groundnuts producer price. These producer prices have been respected most of the time by the marketing board. The producer price has been stabilized at a price below world price but systematically higher than the level corresponding to full monopsony power.

1.2. The Millet Market

Millet is produced by the same farmers producing groundnuts. Millet and groundnut productions compete for the same land and labor for which markets do not exist or are very thin. The millet market is essentially a private market. The marketing board was marginally involved in millet marketing (small purchases and loans for the bridging period during the rainy season). Millet is essentially a non-traded staple crop consumed in the countryside. Nevertheless, millet production and consumption decisions are influenced by groundnuts and fertilizer related policies. The market quantity and price of millet are endogenously determined once the fertilizer and groundnuts prices are known.

1.3. The Fertilizer Market

From 1964 to 1980, a credit system allowed the members of agricultural cooperatives to buy fertilizer and equipment at subsidized prices. The Senegalese government hoped that the subsidized inputs would compensate for the negative impact of low groundnut producer price. The marketing board was in charge of the delivery of the inputs, which sometimes arrived late at the cooperative. At the start of the marketing season, the farmers were supposed to pay back the loans. The input credit system has had little success. Despite the subsidies, inputs have not been purchased . The variability in revenues

due to droughts made the farmers cautious and delays in the delivery had slowed the adoption of equipment. Some cooperatives have had very bad records for the payment of their debt. The government postponed repayments of the debts twice during the seventies because of the droughts. This was a disincentive to pay back the loans and made the credit system quite expensive for the Senegalese government. The credit system was abolished in 1980 with the dissolution of the marketing board.

1.4. The Imported Rice Market

Rice is the major imported cereal. It was introduced by France during the colonial period to induce the specialization of farmers in groundnuts production. Nowadays, rice is the staple food in urban areas. The imports are cheap broken from Burma and Thailand. An agency closely related to the marketing board (Caisse de perequation et de stabilization des prix) has had a monopoly for this market. The retail price is fixed by law. It has been set most of the time above the import cost, but the tariff has been moderate. The retail price has been subsidized when unexpected increases in world prices occurred. These increases in world prices have been passed on progressively to consumers.

1.5. The Wheat Market

Wheat is not produced in Senegal and is imported by two authorized millers (Sentenac and Moulins de Dakar). There is an annual quota for wheat import, but it has never been binding. Wheat is milled and transformed into bread which is consumed in urban areas. The market is entirely regulated by the government. The two millers have been subsidized to sell the flour below cost to bakers. This policy stopped in 1977. The price of bread is also fixed by law at a very low level.

2. The Model

We first introduce the bargaining game and then we describe the specific model for the Senegalese issue. A simple n-person cooperative bargaining game is assumed. Several solution concepts exist for that type of game. We use the class of solutions based on reference points (Thomson). Players might compare proposed payoff compromises not only to the conflict payoffs but also to other potential payoffs called reference points. Once the conflict point is known, the Nash solution is unique. This is not the case with the reference point solutions. For a given conflict point, many reference points are possible; hence, fewer solution candidates are excluded a priori from being the equilibrium one.

We allow the payoff set and its frontier to be shocked by making them depend explicitly on a vector of exogenous variables z. The objective is to see how the solution and the resulting power structure are altered by exogenous shocks (e.g., exchange rates and world prices).

The axiomatic underlying the game can be found in Thomson and Friedman. The axioms are analogous to Nash's but are defined with respect to the reference points instead of the conflict point. Under these axioms, the solution u^* maximizes the Nash product, modified to include the reference point g,

$$(1) \quad \prod_{i=1}^{n} [\, u_i - g(P,d)_i \,]$$

where $u = (u_1, u_2, \ldots, u_n)$ is an element of the payoff set P, and d is the conflict point. If P is compact and convex the following conditions are necessary and sufficient for defining the solution u^*:

$$(2) \quad H(u_1^*, u_2^*, \ldots, u_n^*, z) = 0,$$

$$(3) \quad a(z)_i \, [u_i^* - g(P,d)_i] = a(z)_j \, [u_j^* - g(P,d)_i] \quad , \text{for } all \; i, j,$$

where $a(z)_i$ is the derivative of H with respect to u_i evaluated at u^* or $a(z)_i = \partial H(u^*, z)/\partial u_i$. H is the frontier of the payoff set P. The $a(z)_i$'s represent the bargaining power coefficients of the n players. They are normalized such that they sum up to one. It can be shown that maximizing the Nash product is equivalent to maximizing the following weighted sum of utilities:

$$(4) \quad MAX\, [a(z)_1 \, u_1 + a(z)_2 \, u_2 + \cdots + a(z)_n \, u_n],$$

subject to u belonging to P.

First-order conditions in the strategy space can be equivalently derived. Define s_k the k^{th} strategy available to the players, then the necessary conditions for the existence of a solution are

$$(5) \quad \sum_{i=1}^{n} a(z)_i \; \partial u_i / \partial s_k = 0, \quad \text{for } all \; k.$$

By convexity of the set P, the second-order conditions are satisfied.

Now we turn to the Senegalese modeling problem. It is assumed that three players are playing the bargaining game. They are the farmers of the groundnut basin, growing groundnuts and millet; the urban dwellers consuming rice and wheat products; and the few government agencies determining the food and price policies and hereafter referred to the marketing board. The marketing board sells fertil-

izer to farmers, rice and wheat to urban consumers, and buys groundnuts from the farmers. It has a monopoly on imported rice and wheat, and on fertilizer, and a monopsony on groundnuts purchases.

Urban consumers and farmers are utility maximizers, and the negative of the compensating variation[2] derived from their utility function will be used as their money metric utility function. The marketing board maximizes the net tax revenues from the sales of rice, wheat and fertilizer and from the purchases of groundnuts. Its payoff function will be the change in tax revenues from the current level to a given reference level.

2.1. The Farmers

The indirect utility function of the representative farmer is

(6) $U_1 = U[p_m, p_{-m}, m(p_g, p_m, p_f, z_1)_1 - C_1]_1$

where p_m, p_{-m}, p_g, and p_f are the price of millet, the price vector for consumption goods other than millet, the producer price of groundnuts, and the producer price of fertilizer. The restricted profit function m_1 minus the cost of implementing conflict strategies C_1 constitutes the net income of the farmer. The vector of exogenous variables restricting is z_1. the profit function which is well behaved. By Hotelling's lemma, the supplies of groundnuts and millet q_g^s, q_m^s and the demand for fertilizer q_f^d are derived; Roy's identity gives the demand for millet of the farmer, q_m^d. At the market level, millet supply and demand have to be equal since millet is a nontraded commodity. Each farmer takes prices as given but changes in the groundnut and fertilizer prices affect the equilibrium price of millet through market mechanisms.

The negative of the compensating variation is

(7) $CV_1 = -[e(p_m, p^o_{-m}, u^o_1)_1 - e(p^o_m, p^o_{-m}, u^o_1)_1 - m(p_g, p_m, p_f, z_1)_1 + m(p^o_g, p^o_m, p^o_f, z_1)^o_1]$

where m_1 and p_m refer to the current period, and m^o_1, and p^o_m are their counterparts in the starting period. The expenditure function of the farmer is e_1.

We derive the market equivalents of these individual supplies, demands, and compensation function by summing them up over the rural population. At the market level, the millet market clears; changes in

2 The compensating variation gives the dollar amount necessary to keep constant the utility u of a consumer when prices and income move from p^o, m^o to p, m or $cv = e(p, u^o) - e(p^o, u^o) - m + m^o$, where p, m are the price vector, and income of the consumer at the current period, and e is the expenditure function.

the millet market equilibrium due to changes in fertilizer on groundnut prices are obtained through total differentiation of the equilibrium condition in the millet market.

2.2. The urban consumers

A typical urban consumer has an indirect utility function U_2,

(8) $U_2 = U(p_r, p_w, p_{[-r,-w]}, m_2 - C_2)_2$

with $p_r, p_w, p_{[-r,-w]}$ being the prices of rice, wheat products, and other goods. The income of the urban consumer is equal to the wage income m_2 assumed exogenous minus the cost of applying conflict strategies C_2 (e.g., cost of rioting or striking).

Roy's identity yields the cereal demands q_r^d and q_w^d. The negative of the compensating variation is

(9) $CV_2 = -\,[e_2(p_r, p_w, p^o_{[-r,-w]}, U_2^o) - e_2(p_r^o, p_w^o, p^o_{[-r,-w]}, U_2^o) - m_2 + m_2^o]$

with the superscript o corresponding to the reference period and e_2 being the expenditure function of the urban consumer. The individual demands and welfare measure are aggregated over the urban population.

2.3. The Marketing Board

The marketing board is the third player in the game. Its strategies are the price policy variables p_g, p_f, p_r, p_w. The marketing board maximizes the tax revenues coming from the groundnuts, fertilizer, rice, and wheat markets. This assumption is not very restrictive because it does not specify how the surplus generated through taxes is allocated (e.g., investment and maintenance of bureaucracy). The marketing board can both extract or transfer surplus under this assumption depending on the power structure among players. More explicitly, the tax revenue function TR is

(10) $TR = (wp_g - p_g)\, q_g^s + (p_f - wp_f)\, q_f^d + (p_w - wp_w)\, q_w^d + (p_r - wp_r)\, q_r^d - B_1 - B_2$

where wp_g, wp_r, wp_w are the world prices of groundnuts, rice, and wheat, and wp_f is the ex-factory price of fertilizer. B_1 and B_2 represent the cost to the marketing board to be in conflict with the farmers (B_1) and the urban dwellers (B_2). The payoff function of the marketing board CV_3 is the change in tax revenues when prices move from $(p_g^o, p_f^o, p_r^o, p_w^o)$ to their current level (p_g, p_f, p_r, p_w) or

(11) $CV_3 = TR(p_g, p_f, p_r, p_w) - TR(p_g^o, p_f^o, p_r^o, p_w^o)$.

The necessary and sufficient conditions for the existence of a solution are applied to the Senegalese case. The strategies of the marketing board are the four price policies p_g, p_f, p_r, p_w. The farmers and the urban dwellers have political strategies which are not observed but which have a determining influence on the behavior of the marketing board. Recall that farmers can smuggle their cash crop, default on loans, and withdraw their political support to the existing political system. Urban consumers can riot, go on strike, or shirk.

3. The Results

The estimation is carried in two steps. First, functional forms of the different supply and demand functions are chosen and estimated. With these estimates, we generate measures of CV_1, CV_2, CV_3, and their derivatives with respect to the price policies. Then, the game itself is estimated.

Time series for the period 1960 to 1980 constitute the data set. A two stage least squares estimation technique is used. We do not report the first step of the estimation given the space constraint. The following specification was chosen for the estimation of the game, including the exogenous variables into the bargaining coefficients:

$$(12)\quad CV_3 = (a_{23} + a_{231}\ wp_g)\ CV_2 + b_{23},$$

$$(13)\quad CV_1 = (a_{31} + a_{311}\ wp_r + a_{312}\ \pi + a_{313}\ pop)\ CV_3 + b_{31},$$

$$(14)\quad \frac{\partial CV_3}{\partial p_r} = -\ (a_{23} + a_{231}\ wp_g)\ \frac{\partial CV_2}{\partial p_r},$$

$$(15)\quad \frac{\partial CV_3}{\partial p_w} = -\ (a_{23} + a_{231}\ wp_g)\ \frac{\partial CV_2}{\partial p_w},$$

$$(16)\quad \frac{dCV_1}{dp_g} = -\ (a_{31} + a_{311}\ wp_r + a_{312}\ \pi + a_{313}\ pop)\ \frac{dCV_3}{dp_g}, \text{ and}$$

$$(17)\quad \frac{dCV_1}{dp_f} = -(a_{31} + a_{311}\ wp_r + a_{312}\ \pi + a_{313}\ pop)\ \frac{dCV_3}{dp_f}$$

where π is the exchange rate and *pop* is total population in Senegal. Equations (12) and (13) are the first order conditions for the maximization of the modified Nash product (1). Equations (14) to (17) express the maximization of the criterion function (5). Attempts to include the other exogenous variables of the model into the the coefficients $(a_i/a_j)\ (z)$ failed. The linear specification of the $(a_i/a_j)\ (z)$ functions is obviously an approximation. The bargaining coefficients $a(z)_i$ are recovered by using the econometric estimates a_{ij} and a_{ijk}, and normalized to sum up to one (i.e., $a_1 + a_2 + a_3 = 1$). The

parameter estimates are shown in table 1 with the bargaining power coefficients implied by the parameters. At the sample mean, the bargaining coefficients estimates are $a_1 = .583$, $a_2 = .179$, $a_3 = .238$, respectively for the farmer, urban consumer, and the marketing board. The bigger magnitude of a_1 can be explained as follows: farmers have their conflict point closer to their optimum payoff (u_1^*) than urban consumers and the marketing board. In case of conflict farmers have their subsistence crop as an alternative; conversely, the marketing board and urban consumers do not have such an alternative. They would be much worse off if there is a disagreement; their conflict points are further away from the optimum solution. The relatively bigger size of the rural population compared to the urban one explains also the relative strength of the farmers.

The derivatives of the coefficients a_i with respect to the four exogenous variables are calculated at the mean with the regression estimates of table 1 and are reported in table 2. As mentioned in the introduction, the bargaining power of the farmers is positively related to the world price of groundnuts and rice. The opposite is true for the urban consumers. The marketing board's strength is increased by a higher world price of groundnuts and decreased by a higher world price of rice. Population influences positively the bargaining position of the urban consumer and the marketing board but has a negative impact on the strength of the farmers. The exchange rate has a similar impact on the power structure as does the population variable.

4. Tentative Conclusions

We have attempted to model and quantify the political economy of agricultural price and food policies in Senegal. A cooperative bargaining game approach was used to describe and estimate the relative strength of three representative players: the farmer, the urban consumer and a marketing board. Farmers were shown to have about twice as much bargaining strength as the urban consumers or the governmental agencies involved in the game. We allowed for variable bargaining power coefficients and identified four variables that had a strong impact on the bargaining structure between the three players; they were the world price of two key commodities in the model (groundnuts and rice), the exchange rate, and the population size. Our model does not capture the urban bias of policies described by Bates. Asymmetric bargaining games could be considered to investigate this issue.

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TABLE 1. GAME PARAMETERS ESTIMATION

PARAMETER	ESTIMATE	APPROX. STD ERROR	'T' RATIO	APPROX. PROB>|T|
A312	0.01253	.00242248	5.17	0.0001
A314	1.72E-07	7.52E-08	2.29	0.0336
A311	-2.03E-05	2.77E-06	-7.33	0.0001
A31	-2.83484	0.79710	-3.56	0.0021
A23	1.67003	0.31913	5.23	0.0001
A232	-2.09E-05	6.98E-06	-2.99	0.0072
B31	-36.36516	12.78002	-2.85	0.0103
B23	-55.05971	14.29159	-3.85	0.0011

VARIABLE	N	MEAN	STANDARD DEVIATION
A1	21	0.58285149	0.14827008
A2	21	0.17933913	0.07362055
A3	21	0.23780938	0.08215406

TABLE 2. DERIVATIVES OF THE BARGAINING COEFFICIENTS WITH RESPECT TO WORLD PRICES PG PR EXCHANGE RATE PI AND POPULATION POP

VARIABLE	N	MEAN	STANDARD DEVIATION
DA1DPG	21	0.00065049	0.00017461
DA1DPR	21	0.00289010	0.00112743
DA1DPOP	21	-0.00000010	0.00000005
DA1DPI	21	-0.00562395	0.00239593
DA2DPG	21	-0.00097848	0.00034786
DA2DPR	21	-0.00114709	0.00048247
DA2DPOP	21	0.00000004	0.00000002
DA2DPI	21	0.00289828	0.00175148
DA3DPG	21	0.00032799	0.00019827
DA3DPR	21	-0.00174301	0.00090426
DA3DPOP	21	0.00000006	0.00000003
DA3DPI	21	0.00388216	0.00159703