A Computable Household Model Approach to Policy Analysis: Structural Adjustment and the Peasantry in Morocco

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Abstract: This paper opens a new field in quantitative policy analysis by developing a methodology for the construction and simulation of computable non-separable household models. Non-separability originates in market failures and in a binding credit constraint, both of which transform the products and factors affected into non-tradeables. The methodology is applied to a simulation of the impact on Moroccan peasant households of the new pricing rules for cereals introduced by structural adjustment. The results show that the elasticity of supply of tradeables is hampered by the presence of nontradeable factors in the household; that small farmers are pushed on to the labour market as a strategy to relax a credit constraint; and that technological change should be directed at enhancing the productivity of non-tradeables to increase the elasticity of supply response of tradeables. Further, a rising price for cereals shifts the farm economy from animals to crops. Nevertheless, as the price of tradeable animal forage rises, child labour used for herding in the commons is substituted for this forage, and children's work load increases. The expected consequence is increased school absenteeism and more overgrazing in the commons, two historical curses of Moroccan underdevelopment.

Structural Adjustment and Moroccan Peasants

As in many other countries, structural adjustment in Morocco has led to the definition of new rules for price formation that bring the domestic prices of tradeables closer to international prices. With a long history of price discrimination against the cereals sector, these new rules have the potential significantly to raise the prices of hard and soft wheat, barley, and maize. Through multimarket and general equilibrium effects, these price changes also affect all other prices in the economy, including wages and the exchange rate. Because, in Morocco, smallholders in dryland areas are the main producers of cereals, and because it is among these households that the greatest incidence of absolute poverty is found, the new prices have the potential not only to induce import substitution in cereals if these producers are able to respond to price incentives but also to help reduce poverty among this segment of Moroccan society.

The smallholder economy is, however, highly heterogeneous as it relies on a complex portfolio of activities that include not only a variety of crops but also, very prominently, livestock and wage earnings. Smallholders are also important buyers of many of the commodities whose prices are rising. Further, their economy is characterized by numerous market failures (in particular for child labour, which is essential for the herding of animals in the commons) and by credit constraints that limit their adaptability to the new set of costs and incentives. As a result, it is not clear whether these households will benefit or not from the price adjustments or how different members of the household will be affected, women and children in particular.

This paper develops the methodology of computable non-separable household models so as to allow measurement and simulation of the complex implications on different types of households and different household members of price changes brought about by structural adjustment. It is applied to small and medium farm households in the Chaouia, a dryland area with extensive poverty.

Household Model with Market Failures and Credit Constraint

The household produces ($q \geq 0$) hard wheat, soft wheat, coarse grains, other crops (legumes, fruit, and vegetables), forage, milk, and meat. Nonagricultural sources of income include handicrafts and services and the sale of labour. Production factors ($q \leq 0$) used are machinery and fertilizers; coarse grains and forage; male, female, and child labour; and the depreciation of fixed factors. Products and factors are related through the production technology $G(q, Z)$, where Z is a vector of structural characteristics of the farm household and fixed factors (land, livestock, and capital). The household consumes ($c \geq 0$) hard wheat, soft wheat, coarse grains, other crops, milk, meat, nonagricultural goods and services, and leisure time (male, female, and child) and also saves.

The household has initial endowments ($T \geq 0$) in total time (male, female, and child) and receives net transfers S. Expenditure on machinery, fertilizers, forage, and hired labour has to be incurred ahead of harvest, and this requires financial liquidity at that time of year. For this, the household has access to credit in an exogenous amount K (including transfers received ahead of harvest) and to cash income from wage earnings if it is a net seller of labour. Since all farms have a surplus of coarse grains, they carry over stocks of these grains with the result that they do not enter the liquidity constraint. According to the net amount of these entries and outlays that occur before harvest, the credit constraint may or may not be binding.

The household may be a net seller or net buyer of any product and factor. It is a price taker ($\bar{p}$) for all products and factors for which markets exist (or more exactly for which the subjective equilibrium price falls outside a price band between risk equivalent sale and purchase prices). For milk and child labour, market failure (or a subjective equilibrium within the effective price band) implies that an internal equilibrium must obtain between the supply ($q+T$) and demand (c) of these nontradeable commodities.

The household maximizes a utility function, $U(c, z)$, where z denotes exogenous household characteristics, with respect to production and consumption decisions subject to a cash constraint, a credit constraint, a technology constraint, and equilibrium conditions for tradeables and non-tradeables. Goods are decomposed into three subsets: tradeables that are not subject to a credit constraint, TNC; tradeables subject to a credit constraint, TC (jointly, these two subsets of tradeables are also indexed as T); and non-tradeables, NT.

The household's problem is thus to:

$$\underset{c,\, q}{Max} U(c, z)$$

subject to:

$$\sum_{i \in T} P_i(q_i + T_i - c_i) + S \geq 0 \qquad \text{(cash constraint)}$$

$$\sum_{i \in TC} P_i(q_i + T_i - c_i) + K \geq 0 \qquad \text{(credit constraint)}$$

$$G(q, Z) = 0 \qquad \text{(production technology)}$$

(1a) $p_i = \bar{p}_i, \; i \in T$ (exogenous market price for tradeables)

(1b) $q_i + T_i = c_i, \; i \in NT$ (equilibrium for non-tradeables)

The Lagrangean length scale associated with the constrained maximization problem is written as:

$$L = U(c, z) + \lambda\left[\sum_{i \in T} \bar{P}_i(q_i + T_i - c_i) + S\right] + \eta\left[\sum_{i \in TC} \bar{P}_i(q_i + T_i - c_i) + K\right] + \phi G(q, Z) + \sum_{i \in NT} \theta_i(q_i + T_i - c_i)$$

The three types of goods can be treated symmetrically in the first-order conditions by defining endogenous decision prices as follows:

$$P_i^* = \bar{P}_i, \; i \in TNC$$

$$P_i^* = \bar{P}_i(1+\lambda_c), \quad \lambda_c = \eta/\lambda, \quad i \in TC$$

$$P_i^* = \bar{P}_i\,\theta_i/\lambda, \quad i \in NT$$

In the reduced form, production decisions are represented by a system of supply and factor demand functions in the endogenous decision prices p^* that derive from maximizing a generalized profit function Π for all tradeables and non-tradeables:

$$\text{(2a)} \quad \Pi^* = \sum P_i^* q_i$$

$$\text{(2b)} \quad q = q(P_i^*, Z)$$

Consumption decisions in terms of the p^* prices are represented by:

$$\text{(2c)} \quad c = c(p^*, Y^*)$$

subject to the credit-extended full income constraint:

$$\text{(2d)} \quad Y^* = \sum_i P_i^* c_i = \Pi^* + \sum_i P_i^* T_i + S + \lambda_c K$$

The Kuhn-Tucker condition on the credit constraint can be written using a slack variable K_{net} in the credit constraint as:

$$\text{(2e)} \quad K_{net}\lambda_c = 0, \; K_{net} = K + \sum_{i \in TC} \bar{P}_i(q_i+T_i-c_i) \geq 0, \; \lambda_c \geq 0$$

In these equations, either the credit constraint is effective, in which case $K_{net} = 0$ and $\lambda_c > 0$ or it is ineffective, in which case $K_{net} \geq 0$ and $\lambda_c = 0$.

The household model with non-tradeables and credit-constrained tradeables thus contains three sets of prices: decision prices, prices of tradeables, and prices of non-tradeables. Decision prices p^* affect how production and consumption decisions are taken to accommodate the credit constraint. The endogenous markup λ_c on the price of the credit-constrained tradeables serves to raise the decision price of the credit-constrained tradeable products and factors with a positive marketed surplus (in particular, labour on the small farms). Even though these goods are transacted at the market price $\bar{p}$, their supply increases and their use by the household falls, since $p^* > \bar{p}$, reflecting the fact that higher exports of these goods and factors help ease the credit constraint. Similarly, the endogenous markup λ_c raises the decision price of the credit-constrained tradeables of which the household is a net buyer, such as forage on all farms and labour on the medium farms, inducing it to produce for import substitution and to use less in production. Even though the transaction occurs at the market price $\bar{p} < p^*$, imports of these goods and factors are reduced to accommodate the credit constraint.

The model thus consists of production decisions (2a) and (2b), consumption decisions (2c) and (2d), a credit constraint (2e), and equilibrium conditions (1a) and (1b). Because of the existence of both a credit constraint that transforms the prices of credit-constrained tradeables into endogenous prices and of endogenous non-tradeables prices, production and consumption decisions are not separable. This system of equations consequently needs to be solved simultaneously. Since this is analytically intractable, a computable version of this model is set up by specifying a generalized Leontief for the profit function and a translog for the indirect utility function.

To determine the values of the parameters of these two functions, we start from "best guess" elasticities for the medium farms derived, on the production side, from the multi-market model for Morocco developed by Aloui, Dethier, and Houmy (1989) and on the demand side from Laraki (1989). These elasticities are then calibrated to satisfy the constraints imposed by the chosen functional forms. An algorithm is used that minimizes the sum of the squares of the discrepancies between this initial set of elasticities and a set of new elasticities that satisfy all these constraints, keeping untouched the diagonal values in which the greatest confidence can be placed. For the small farms, these elasticities are scaled to correspond to their levels of fixed factors.

Simulation Results

The new pricing rules for cereals introduced by the agricultural structural adjustment programme (ASAP), together with the secondary effects they induce in other prices and wages—predicted for the medium run using a CGE for Morocco adapted from Mateus (1988) and the multi-market model developed by Aloui, Dethier, and Houmy (1989)—result in the following percentage changes in prices: hard wheat, 17.8; soft wheat, 14.4; coarse grains, 27.8; fruit and vegetables, 8.7; forage, 24; milk, 8.3; meat, 12.8; manufactured goods, 6.1; machinery and fertilizers, 1.5; other consumption goods, 5; and agricultural wages, 6.7. Since the changes are very large, the possibility arises of a credit constraint on the ability to respond to price incentives; consequently, the effects of ASAP when this constraint is alternatively present and relaxed are simulated.

As the base-run data in Table 1 show, a key distinguishing feature between small and medium farms is that the former are net buyers of soft wheat and coarse grains while the latter are net sellers. Both have a marketed surplus of meat, but it is a much more important source of income for the small than for the medium farms. Finally, the small farms are net sellers of male and female labour while the medium are net buyers.

The effects of ASAP reported in Table 1 are clearly different between small and medium farms, with the medium farmers deriving significant welfare gains, while the gains are much more modest for the small farmers as they are caught, on the consumption side, by rising prices of food, of which they are important buyers. Rising cereal prices distort the farm economy towards crops and away from livestock. In this response, the medium farms are more constrained by credit needs, as the shadow price of credit rises by 2.9 percent on these farms as opposed to 0.4 percent on the small ones. This is due to the fact that the small farms are engaged on the labour market as important net sellers and consequently find in wage incomes an important source of credit. While all labour income is not available at the time when credit is needed, it nevertheless provides important liquidity. The effect of the credit constraint on the medium farmers is sharply to reduce their ability to hire labour and to buy machinery and fertilizers. As a result, even though cereal prices rise, the hiring of female labour and the use of machinery and fertilizers fall to accommodate the hiring of more male labour. Relaxing this constraint, by contrast, allows them to hire more labour and use purchased inputs, significantly increasing their aggregate elasticity of supply response.

The credit constraint prevents households on small farms from reducing the sale of labour in spite of rising farm prices and the incentive to substitute imports. This is because the labour market is their source of access to credit. When this constraint is relaxed, the sale of labour falls sharply (–4.7 percent for men and –59.1 percent for women) and the elasticity of supply response increases. Eliminating the credit market failure thus increases the elasticity of supply response of the traded goods that make use of credit in production.

The paradoxical result of ASAP is that, in spite of shifting the farm economy from livestock to crops, resulting in a falling production of milk and meat, rising forage prices induce a substitution in meat production from the use of forage to the use of grazing in the commons and hence intensified need for child labour. As a result, the use of children in production increases, their shadow price rises sharply, and their leisure time falls. Market failure for child labour and access to commons reduce the negative effect of ASAP on the livestock economy. The long-run consequence is increased school absenteeism and increased overgrazing in the commons, two of the curses of Moroccan underdevelopment.

Table 1—Simulation of Household Behaviour: ASAP Responses*

Experiment	Base Run (in 1,000 dirham)		ASAP Credit Constraint		ASAP No Credit Constraint	
Farm size	Small	Medium	Small	Medium	Small	Medium
Utility (per 1,000 change)	26.28	42.98	9.8	35.4	10.3	37.9
Credit:						
Credit deficit			0.0	0.0	0.4	2.9
Shadow price			8.4	16.6	0.0	0.0
Consumption:						
Total consumption	12.25	23.47	1.8	9.8	−0. 1	5.4
Leisure/men	2.95	7.90	1.4	6.1	2.6	8.4
Leisure/women	1.60	5.61	−5.4	−9.7	10.3	14.4
Leisure/children	1.78	3.22	−0.9	−1.9	−0.9	−2.8
Savings	1.33	4.28	13.7	27.8	10.7	20.0
Production:						
Hard wheat	1.99	8.56	1.6	1.8	2.0	1.8
Soft wheat	0.42	6.73	2.1	−0.7	8.5	2.3
Coarse grains**	0.17	6.67	82.5	8.1	98.6	11.5
Forage**	−0.98	−1.83	−2.6	−8.3	−1.5	−3.3
Total crops	3.24	24.54	4.4	1.8	6.5	3.8
Total livestock	9.31	15.67	−1.0	−4.1	−1.0	−1.8
Machinery and fertilizer:	−0.90	−8.44	3.1	−2.0	7.1	4.0
Labour/men	−3.55	−6.60	−0.5	−5.0	1.0	2.2
Labour/women	−2.53	−2.55	0.1	−0.4	0.7	5.5
Labour/children	−1.76	−1.91	0.9	3.1	0.9	4.7
Shadow prices:						
Labour children	1.06	1.02	12.7	17.1	11.2	13.2
Wage labour:						
Men	2.36	−1.66	−1.0	9.1	−4.7	48.7
Women	0.31	−1.74	27.5	−31.8	−59.1	54.4
Marketed surplus:						
Hard wheat	1.14	6.17	3.6	−0.5	4.9	1.4
Soft wheat	−1.00	5.01	2.7	−1.2	− 2.1	0.5
Meat	6.85	10.05	−1.4	−11.2	−0.6	−4.4

*Results in percentage changes over base run unless otherwise indicated.
**Net of intermediate use.

The price adjustments brought about by ASAP, which are typical of the effects of foreign sector crises on agriculture, thus have a highly positive welfare effect for medium farmers who have important marketed surpluses, particularly if the ASAP is accompanied by credit availability that allows them to incur the higher cash expenditures necessary to hire labour and purchase modern inputs. For small farmers, rising prices are a mixed blessing as they are important buyers of cereals for consumption and feed. And relaxation of the credit constraint only brings small relief as they can, in any case, use the labour market as a source of cash at a small efficiency cost. As such, the effects of ASAP are regressive on the distribution of income on agriculture. In all types of farms, the effects on the welfare of children, and thus indirectly on literacy and the environment, are negative unless the productivity of forage production is enhanced, suggesting as well complementary types of interventions to the price effects of ASAP if these negative consequences are to be avoided.

Conclusion

This paper opens up the field of computable non-separable household (CNH) modelling as a micro-level instrument of policy analysis. This can be thought of by analogy with the computable general equilibrium (Johansen, 1964; and Adelman and Robinson, 1978), the multi-market (Quizon and Binswanger, 1986; and Braverman and Hammer, 1986), and the integrated multi-market CGE (Sadoulet and de Janvry, 1990) approaches, which offer macro-level and sectoral instruments of policy analysis that are now widely used. Indeed, the household and macro-sectoral modelling approaches have much in common, from use of the concepts of tradeables and non-tradeables to use of the same computational algorithms. A clear advantage of the CNH approach is that survey data are available for the whole model as opposed to the CGE and multi-market situations, making estimation of the model possible, clearly the next step in developing this approach. Another part of the next step is to add behaviour towards risk, which must be introduced in the computable form of the model at the level of the indirect utility function.

The usefulness in policy terms of these models lies in the systematic lack of comparable data over time that would allow separation *ex post* of the impact of policy instruments. For this reason, recourse is made to simulation of policy impacts in such models, either to retrace historical effects in duly-calibrated models or to explore alternative policy scenarios. As exemplified here, CNH models allow the exploration of the effects of adjustment programmes at the household level, an important policy question of the moment, in a considerable degree of detail that could not be achieved with available historical data.

Results Based on Structural Features of the Model

The elasticity of supply response of tradeables is reduced by the presence of non-tradeables among products that either are consumed or factors of production. The lower the levels of substitution between these goods and tradeable alternatives and the larger the shares of these goods in production or consumption, the lower the elasticity of supply response of tradeables. To increase the elasticity of supply response of tradeables, technological change needs to be directed at the non-tradeable products and factors to ease the constraint that their production or availability imposes on the production of tradeables.

Accommodating a credit constraint imposes an endogenous markup on credit dependent tradeables. This distorts the household's allocation of resources towards import substitution and greater exports of the credit-constrained products and factors. Small farmers were thus seen to remain heavily on the labour market, in spite of rising cereals prices, because wages give them a way of escaping the credit constraint at a relatively low efficiency cost. Such low-cost escape is not available to the medium farmers. Their elasticity of supply response and their ability to benefit from the higher prices offered by ASAP depend on relaxation of this credit constraint, confirming the fundamental importance of credit components in ASAP loans.

For the small farmers, vigorous programmes of rural development must be put into place to allow them to become net sellers of the commodities whose prices have increased. The productivity of their land must consequently be raised, and the new ASAP pricing rules should be seen as an historic opportunity to mount a massive complementary programme of rural development.

Results Based on Particular Elasticity Values

While ASAP displaces the farm economy from livestock to crops, pressures on the use of children for herding and overgrazing in the commons will not be relaxed if the price of forage increases with that of cereals due to competition in production. Avoiding this secondary effect thus requires focusing on the technology of forage production to lower its production costs. While the price adjustment occurs in cereals, technological change is needed in the forage-livestock economy. Also, infrastructure investments and institutional arrangements need to be sought that can reduce and ultimately eliminate the need for child labour in animal production. These include the enclosure of fields and innovations in contracts for herding that achieve economies of scale (and thus raise the productivity of labour in herding, making it a remunerative activity for adults) while avoiding the problems of moral hazards that maintain this ancestral practice of child use as economically rational.

Structural adjustment and the new pricing rules for cereals, by eliminating an historical bias in agricultural price formation, have the potential to benefit the peasantry in dryland areas of Morocco, the poorest segment of society, but only if accompanied by these complementary structural and policy interventions.

Note

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Discussion Opening—*Teruaki Nanseki* (National Agricultural Research Centre, Japan)

The paper makes several methodological contributions to the growing body of research on quantitative agricultural policy analysis. It presents computable non-separable household (CNH) models that are useful in micro-level analysis of the effects of alternative policy scenarios. CNH models allow the complex implications on different types of household and different household members of price changes caused by structural adjustment to be measured. Based on the application, the paper concludes that CNH models permit exploration of the effects of adjustment programmes at the household level in a considerable degree of detail that could not be achieved with available historical data. I am convinced that a combination of CNH and CGE models opens a new field in policy analysis. Furthermore, the simulation results and conclusion are generally understandable.

Several methodological questions also arise, however, since few explanations on the applied model are given in the paper. For example, no overview of the applied model, including equations and lists of variables is given (I understand this might be partly due to space limitations). It is nearly impossible to give a complete picture of the model and the results in the limited space and time. Nevertheless, since the main purpose of the paper is to develop a micro-level instrument of policy analysis, more clarification on the methodology would be useful to improve understanding of the approach.

What is the assumption on substitution among male, female, and children labour in both the technological constraint and the utility function? What is the main difference between "best guess" or initial elasticities and the calibrated elasticities used in the simulation? How are the results of the base run under actual conditions similar to the actual household survey data in terms of values of the related variables of both production and consumption? How robust is the solution of the CNH model in the face of changes in the values of the parameters?

The attitude to risk of farmers and households plays an important role in agricultural analysis. The paper also states that part of the next step is to add behaviour towards risk. The question therefore arises of why attitude to risk is ignored in the present model and whether its results are still reliable.

[Other discussion of this paper and the authors' reply appear on the following page.]

General Discussion—*W.L. Nieuwoudt, Rapporteur* (University of Natal)

In relation to Tyler and Akinboade's paper, the view was expressed that CES and Cobb-Douglas production functions may not be appropriate for the economy studied, and the author was asked if the simulations were tested for Leontief technology. The perfectly elastic supply of labour scenario was not considered realistic, given that rural unemployment rates are low (about 1 percent). Another participant commented that, during the 1980s, a significant share (25–30 percent) of Kenya's officially recorded coffee exports originated in neighbouring states, with consumer good flows in the opposite direction; how could this phenomenon be incorporated in this model? Another participant questioned whether a positive sloping supply curve for labour could be incorporated in the model and to what extent the substitution of labour for other inputs allowed for in the model predetermines results. The authors were also asked if the model was consistent, given that the Cobb-Douglas production function cannot deal with optimization.

Tyler replied that the model was intended to be indicative of the likely general response of the Kenyan economy to certain important policy changes. For actual use in advising policy makers, a closer specification of the model would be required (e.g., including disaggregation of the agricultural sector and incorporation of the monetary side of the economy). The conclusion that results depend crucially on the specification of the labour markets has wider implications for CGE models in other LDCs. The use of a Cobb-Douglas production function for agriculture was based on empirical analysis of Kenya by other authors. It allows capital-labour substitution if relative prices change, and this occurred in some simulations.

In relation to the Amponsah and Hushak paper, the confidence that can be placed in the results, given the number of non-significant variables and the evidence of serial correlation was questioned. If about 25–30 percent of Kenya's coffee exports are derived from Uganda and Tanzania and the performance of the stronger economy is affected by changes in the domestic terms of trade in neighbouring states, how can this be incorporated in the model and what is the reliability of the data base? The authors were also asked about the choice criteria and characteristics of the three groups of farmers.

In reply, Amponsah stated that the objective of the study was macro-oriented and thus it does not consider the other social indicators. One of the bases for structural adjustment is to correct structural imbalances that impede the growth of the most productive sectors through the external terms of trade between exports and imports. The key argument is to improve supply response in agriculture (especially in exports) to generate needed foreign exchange. As far as the agricultural sector is concerned, a microeconomic approach could provide more in-depth information. The agricultural sector plays a weak role in both countries. Due to Kenya's arable land constraint, the country has had to depend more on tourism and other ancillary industries for foreign exchange. In the case of Cameroon, since discovery of petroleum in 1978, its agricultural exports have been stagnant.

The comment was made on the de Janvry *et al.* paper that it should be viewed as illustrative of an interesting technique and not as a reflection of what the actual experience might be, since the referenced elasticities have not been estimated and also the wheat price is now and has been for years higher than the world price and not lower as suggested in the paper. The extent to which the treatment of labour predetermines the outcome was questioned; does the model assume a fixed labour-machinery technology as is often the case in models of this nature (operations research) or can the model select a different labour-machinery technology if labour becomes more scarce? What is the derived demand for labour as incorporated in the model?

Sadoulet, in reply, indicated that labour substitutes in some areas but not in others. No labour-machinery substitution was specifically incorporated. Risk was not incorporated due to the difficulty of including risk, as price also appears in the consumption function.

Participants in the discussion included D. Belshaw (University of East Anglia), S. Hosomi (Institute of Developing Economies, Japan), H. Mahran (University of Gezira), S. Maruta (Ibaraki University), L. Nieuwoudt (University of Natal), C. Short (MPND, Kenya), and W. Tyner (Purdue University).