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Agricultural Technology, Risk, and Gender: A CGE Analysis of Mozambique

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Summary. — Interactions between agricultural technology improvements, risk-reducing behavior, and gender roles in agricultural production in Mozambique are examined. The analysis employs a computable general equilibrium (CGE) model that explicitly incorporates key features of the economy. These include: detailed accounting of marketing margins, home consumption, risk, and gender roles in agricultural production. Our results show that agricultural technology improvements benefit both male and female occupants of rural households. Due to economic interactions, agricultural technology improvements are particularly compelling when combined with marketing system improvements. Moreover, technological change in cassava appears to be a particularly strong lever for increasing female and overall household welfare, especially when risk is considered. © 2000 Elsevier Science Ltd. All rights reserved.

1. INTRODUCTION

The growing mass of microeconomic evidence supporting the key role, which women play in the development process, has led to calls for much greater consideration of gender issues in economic policy-making. A special issue of *World Development* (Vol. 23, No. 11, 1995) was devoted to gender and macroeconomics. The articles in this issue provide, among other things, frameworks for introducing gender into macroeconomic models (Darity, 1995; Elson, 1995; Palmer, 1995; Walters, 1995). In addition, due to the relatively recent nature of the research, suggestions for future work are also provided. For example, Çağatay, Elson and Grown (1995) state in the introductory article:

> Much remains to be done, particularly in developing more complex and insightful gender-aware models. Several further projects suggest themselves: the introduction of gender into computable general equilibrium models of the sort that have been used to investigate income distribution and structural adjustment (1995, p. 1833).

In this article, a computable general equilibrium (CGE) model is employed to analyze the interactions between agricultural technology improvement, risk, and gender roles in agricultural production in Mozambique. These interactions are important. The population of Mozambique is predominantly rural and overwhelmingly poor. Analysis of data from the 1996–97 marketing year (a good production year) revealed that 64% of the rural population had insufficient calories available to meet the caloric requirements of household members (MPF/UEM/IFPRI, 1998). As detailed in the next section, women figure prominently in agricultural activities (as well as in domestic tasks); cassava is an important food crop; rural households are heavily dependent on agriculture for income; and climate induced variability in agricultural production can be large (Rojas & Amade, 1997). Furthermore, gender asymmetries within households are distinct. The CGE model employed here contains significant

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agricultural sector detail and a number of other unique features which are needed to capture the basic structural characteristics of the Mozambican economy.

The remainder of this paper is organized as follows. Section 2 summarizes gender roles in rural households and the agricultural sector. Section 3 presents the CGE model with a focus on special features. Section 4 presents model simulations and results. A final section concludes and provides suggestions for future research.

2. A GENERAL EQUILIBRIUM PERSPECTIVE ON GENDER AND AGRICULTURE IN MOZAMBIQUE

In moving from a microeconomic, household approach to a macroeconomic, general equilibrium approach, some detail is necessarily suppressed. As usual, there are numerous pitfalls for the generalizer. The results and conclusions from our analyses, explained in Sections 4 and 5, are driven primarily by a few features relating to gender roles and the characteristics of the agricultural sector in Mozambique. These features are discussed in this section.

First, rural women are busy people. Studies undertaken by de Sousa (1997) and Adam and Coimbra (1996) considered time allocation by rural women and men. These studies found that rural women and men allocate roughly equal amounts of time to crop production, women allocate more time to fetching water, and men allocate more time to livestock production. Overall, women's time allocated to these three activities alone exceeded men's time. While both men and women allocate time to other activities, the list of additional tasks for women is long and daunting. It includes: food processing, cooking, cleaning, other housekeeping, collection of firewood, and childcare. In review of the evidence, Naeraa-Nicolajsen (1998) concludes that rural women in Mozambique work long hours and have far less leisure time than rural men. [1]

Second, as alluded to in the preceding paragraph, gender roles in household activities exist. Women bear almost all of the burden of domestic tasks, including the daily provision of meals, and women are responsible for ensuring food security at the household level (Naeraa-Nicolajsen, 1998). Similarly, a reasonably coherent story of sex roles in agricultural production emerges from recent research. Clearing land and rearing livestock are primarily male activities (DNDR, 1992; Liberman, 1989; MAP/MSU, 1997; ZADP, 1997). Women tend to be heavily involved in the production of food crops (including maize and cassava in particular) while production responsibility for cash crops tends to be more equally divided between men and women (Waterhouse, 1997; Liberman, 1989; Pitcher, 1996).

Third, agriculture is the critical income source for the large majority of rural households. In a study of 2,176 farm households in Nampula province for the 1995–96 cropping year, Benfica (1998) finds that agriculture accounted for 88% of household income (with a valuation given to home-consumed production and remittances excluded). As indicated above, women are strongly involved in agricultural production. According to Benfica, home consumed staple foods, the production of which involves women most deeply, represented 53% of total household income. A national survey conducted in 1996–97 gives similar results on the importance of agriculture to rural households. Analysis of these data finds only a small proportion of the rural population engaged in activities outside of agriculture (Datt, Simler, Mukherjee & Dava, 1999, p. 29).

Fourth, cassava is an important crop in terms of total production and has distinct risk reducing attributes. Critically for gender related issues, available data indicate that women provide the large majority of labor input into cassava production. According to Early Warning System data, the area allocated to cassava, 1.0 million ha in 1996–97, is second only to maize, 1.2 million ha in 1996–97. Fresh cassava yields on a per hectare basis exceed maize yields by a factor of approximately six. As a result, fresh cassava production substantially exceeds maize production (Early Warning System, 1998). Despite the large supply, fresh cassava prices are relatively firm (SIMA, 1998). Large marketing margins create a very significant wedge between the price of fresh cassava to the consumer and the price at the farmgate. In the 1995 social accounting matrix on which the CGE analysis in subsequent sections is based, the farmgate price of cassava is less than 25% of the consumer marketed price. Even after accounting for the large marketing margins, however, cassava is the most important crop in Mozambique in value terms.

According to national accounts data, the value of cassava production at producer prices exceeded the value of maize production (the other major crop) by 42% and 33% in 1995 and 1996, respectively (NIS, 1998).

The hardiness of cassava is a particularly attractive factor. Adverse climate conditions, defined as a climate outcome producing a greater than 25% decline in maize yields relative to the most likely of five climate scenarios, are estimated to occur 18%, 30%, and 63% of the time in the North, Center, and South of Mozambique respectively (Rojas & Amade, 1997). With rural income almost totally dependent on agriculture *and* insufficient to cover the full caloric needs of most of the rural population even following a good harvest, drought and disease tolerance are attractive properties. In addition, cassava is well adapted to soils with low fertility (Cock, 1985), and it can support drought periods of up to eight months making it relatively tolerant of seasonal drought (Osiru, Porto & Ekayanake, 1995). Furthermore, relative to most other crops, cassava is less demanding in terms of the timing of labor inputs; and, according to the International Center for Tropical Agriculture, it exhibits "an unrivaled ability to recover from pests and diseases" (CIAT, 1999). Cassava is also a relatively convenient food source. Cassava root stores easily as it is essentially left in the ground until needed (Bay, 1998). During the growing season, cassava leaves serve as an additional food source. In sum, the above properties make cassava attractive as a risk reducing crop. Cock refers to cassava as a "famine reserve crop" (1985, p. 20).

Labor availability is the primary constraint to cassava production. [2] Detailed information on labor input into cassava in Mozambique is not readily available. Cock reviews crosscountry evidence and concludes that "per hectare, cassava requires more labor than most other starchy staples" (1985, p. 56). More recent crop budgets from Côte d'Ivoire show that hand weeding constitutes the single largest labor input in smallholder cassava production. In these budgets, smallholder cassava requires approximately 80 labor days per year (Haly, 1990). This accords roughly with the 78 labor days per year required for maize in Mozambique estimated by Moll (1993). Weeding is a particularly heavy input for cassava due to the length of the production cycle. The production cycle for cassava varieties grown in Mozambique takes nine to 12 months (Bay, 1998). In short, area planted, production, price, and available crop budget information for cassava point to very substantial aggregate labor input to this crop. Finally, cassava's status as a food crop and the importance of weeding labor requirements imply a substantial role for female labor in cassava production. It is a crop for which women rather than men have responsibility.

3. A CGE MODEL FOR MOZAMBIQUE

The model employed for the present analysis is in many ways standard. [3] The Mozambique model, however, exhibits a number of important departures from traditional neoclassical CGE models. These departures, plus a brief description of other model characteristics, are in focus in this section. Nevertheless, the model employed for this analysis still omits much, so important omissions are discussed at the end of this section. The full set of model equations is available in Appendix A.

(a) *Marketing margins*

Margins between the price paid at the source of supply, such as the farm gate, and the price paid by the final consumer are often very large (e.g., cassava as mentioned above). High marketing costs reflect: [4] large distances between production and consumption centers, poor infrastructure, high costs of capital which result in high costs of holding inventories, and high risks associated with trading activities combined with limited opportunities for diversification. They are particularly large in primary agriculture and primary agriculture processing. In the 1995 social accounting matrix (Arndt, Cruz, Jensen, Robinson & Tarp, 1998), these two sectors account for 70% of total spending on marketing margins. In the model, marketing margins are carefully accounted for. In addition, marketing margin rates vary depending upon whether the product is produced and sold domestically, exported, or imported.

Operationally, the marketing margins enter the price linkage equations. For example, consider the link between marketed and home consumed commodity prices shown in Eqn. (1).

$$PDC_i = PDCH_i + MRD_i \cdot PQA_{imr}. \tag{1}$$

The market price of a domestically produced commodity i, PDC_i, is equal to the domestic home consumption price of good i, $PDCH_i$, plus the number of units of marketing services required to market commodity i, MRD_i, multiplied by the price of marketing services, PQA_{imr}. The same premise applies to exported and imported commodities. These marketing services create a wedge between border and domestic prices for imports, factory gate, and border prices for exports, and factory gate and domestic prices for commodities which are produced and consumed locally.

The commerce activity, which provides marketing services, is capital intensive. This reflects the capital intensity of the transport, inventory, and trading activities that it is designed to represent. [5] Due to the capital intensity of the commerce sector, returns to capital have a strong impact on marketing services prices. In addition, generalized capital scarcity within the economy constrains the growth of marketed production, particularly agricultural production. Even though agricultural production activities are very labor intensive, the capital required to market the products limits expansion of marketed agricultural production.

(b) *Home consumption*

The presence of high marketing margins implies a significant wedge between the factory/farm gate sales price and the purchase price for consumption of a given commodity. Rather than sell at a low price and purchase at a high price, households, particularly rural agricultural households, can opt to consume at least some of what they produce. In this manner, marketing margins are avoided.

Home and marketed consumption of all commodities is captured in a linear expenditure system (LES) formulation. Home and marketed commodities are treated as separate commodities in the system. So, for example, home-consumed maize differs from marketed maize. In this formulation, supernumerary income, defined as household income less savings, taxes, and the cost of minimum consumption levels of both home and marketed commodities, is allocated across commodities via share parameters. Elasticities of substitution between home and marketed commodities are determined by minimum consumption parameters. If these minimum consumption parameters are set to zero, the LES formulation collapses to a Cobb–Douglas utility function with elasticities of substitution equal to one. [6]

The parameters of the utility function (estimation described in Arndt, Robinson & Tarp, 1999a), set the quantity of home consumption to be relatively insensitive to changes in price through relatively high values on the minimum consumption parameters, especially for rural households. This implies that marketed production of agricultural commodities will tend to be more variable than total production volume as rural households will sell more surplus in good years and retain a greater share of harvest to meet family needs in poor years.

While large marketing margins and high shares of home consumption are common features of African economies, this is the first CGE model, of which the authors are aware, of an African economy that simultaneously captures these features.

(c) *Male and female agricultural labor*

Agricultural labor is divided into male and female categories. The percentages of total labor allocated to the female categories for each crop are presented in Table 1. As emphasized above, cassava production is female dominated. These percentages reflect the available data on gender roles in agricultural production summarized in the previous section, interviews with knowledgeable individuals in Mozambique, and the judgement of the authors. The division of labor presented in Table 1 implies that 63% of agricultural labor is undertaken by women. This accords reasonably well with the 60% figure calculated by Pehrsson (1993). Even though time allocation studies show roughly equal time working in agricultural production for women and men, these are reasonable figures since there are more working age women in rural areas than working age men. Due to the war and male migration for off-farm work, slightly more than one rural household in five is female headed (Datt *et al.*, 1999). In addition, due primarily to the war, females

Table 1. *Female labor share by agricultural activity*

	Female (%)
Grains	69
Cassava	80
Other basic food crops	70
Raw cashew	60
Raw cotton	50
Other export crops	20
Livestock	10
Forestry	50

represented 53% of the population in 1997 as opposed to 51% in 1981, the year just prior to the onset of hostilities (NIS, 1999). The effects of the war on the gender structure of the population are certain to be strongest in the working age cohort.

(d) *Risk aversion*

Low incomes, rudimentary technology, heavy dependence on agriculture, and a variable climate generate a strong need for risk reduction strategies among rural households. Gender inequality may also make women in rural households more risk averse than men. [7] In more recent household models, men and women are therefore treated as separate agents with different, often competing, interests and, potentially, an unequal power structure. Under these conditions women may not be sure to have access to an adequate share of family cash income. Different attitudes to risk are likely, especially when women are responsible for food security at the household level as in the case of Mozambique.

As mentioned above, cassava is drought tolerant, resistant to disease, relatively flexible with respect to timing of labor inputs, and easy to store. Due to these attractive risk-reducing properties and the control which women exert over cassava, we assume, in some of the simulations in the next section, that cassava plays an explicit role in risk reduction. Specifically, we assume that a safety first strategy is pursued. Under this strategy, households aim to produce a certain (exogenous) amount of cassava for risk reduction purposes only. Once the resources necessary to produce the minimum amount of cassava have been allocated, the household allocates resources to other agricultural and nonagricultural activities in accordance with relative prices.

The safety first risk-aversion strategy is implemented by adding an endogenous variable, $RISK_j$, that serves as a risk premium. The variable $RISK_j$ enters the factor demand Eqn. (2) and factor income Eqn. (3):

$$FDSC_{jf} = \frac{RISK_j \cdot QA_j \cdot PV_j \cdot \alpha_{jf}}{WF_f \cdot WFDIST_{jf}}, \tag{2}$$

$$YFCTR_f = \sum_i WF_f \cdot FDSC_{jf} \cdot \left(\frac{WFDIST_{jf}}{RISK_j} \right), \tag{3}$$

where $FDSC_{jf}$ represents use of factor f in activity j. QA_j is output of activity j, PV_j the value-added price of activity j, α_{jf} the cost share of factor f in production of the value-added aggregate for activity j, WF_f the price (wage or rental rate) of factor f, $YFCTR_f$ total income for factor f, and $WFDIST_{jf}$ a scaling factor that allows factor returns to differ by sector (when capital is fixed in one sector for example).

As shown in Eqn. (2), a value greater than one for the variable $RISK_j$ implies that more factors are allocated to the production of activity j than pure profit maximization would dictate. Activity j might be cassava, whose risk-reducing properties cause farmers to allocate extra resources to cassava production. This risk based allocation of resources to activity j comes at a cost in terms of factor income. In the factor income Eqn. (3), returns to factors allocated to the activity j are reduced by the risk premium factor represented by the variable $RISK_j$. In the risk scenarios, the risk premium on cassava production is complementary to cassava production. That is, as long as the value for the variable $RISK_{cassava}$ is greater than one, cassava production ($QA_{cassava}$) is fixed at base levels while the risk premium is endogenous. If, as in some of the experiments, the value for $RISK_{cassava}$ is driven to one (e.g., the risk premium is eliminated), cassava production is then permitted to increase.

(e) *Other features plus parameter estimation and model validation*

Besides male and female agricultural labor, a third category of labor, nonagricultural labor, is also included. The simulation results presented below are based on a formulation with separate labor pools fixed in agriculture or nonagriculture. [8] As mentioned above, remaining elements of the model are standard. Capital is mobile across sectors (excepting capital associated with mining and fishing activities). Production technology is Cobb-Douglas in value added. [9] This value-added aggregate combines with intermediate products in a Leontief fashion. The model contains a rural and an urban household. The model is closed by fixing the value of foreign currency inflows and allowing the exchange rate to adjust endogenously. This closure is the most logical due to the importance of aid flows.

Base data for the model are derived from the 1995 social accounting matrix (SAM) for

Mozambique (Arndt *et al.*, 1998). The SAM contains detailed primary agriculture, primary agriculture processing, and marketing cost accounts. Simulations are conducted on a slightly aggregated SAM containing 10 primary product activities, three primary agriculture processing activities, five industrial activities, and 10 service activities. Excepting the commerce activity, to which there is no corresponding commodity, activities and commodities correspond one to one.

A novel maximum entropy approach was employed to validate the model and to estimate behavioral parameters (Arndt *et al.*, 1999a). Briefly, the full CGE model was backcasted to follow the historical record for the period 1996–92 (five observations). Import (CES) and export (CET) parameters, LES preference parameters, and technical change parameters were chosen which permitted the model to best reproduce the historical record conditional on a set of prior distributions for these parameters. Measures of goodness of fit indicated that the model is capable of reproducing many of the salient aspects of recent economic history in Mozambique, reported in Arndt, Jensen and Tarp (1999b).

In order to reduce computational burden, a fairly aggregate version of the model was employed in the estimation/validation procedure. In parameterizing the more disaggregate model employed here, the parameter value estimated for an aggregate is assigned to all of its components. For example, the Armington import elasticity estimated for the aggregate food crops was assigned to all components of that aggregate. Therefore, commodities such as grains and other basic food crops, which were components of the aggregate food crops, are assumed to have the same Armington import elasticity in the simulations conducted here.

(f) *Important omissions*

While capturing many salient features of the Mozambican economy, the model used in this paper also misses much. Perhaps most importantly, production within the household and other intrahousehold resource allocation issues are ignored. For example, traditional processing of cassava is a time-consuming, within-household task undertaken almost exclusively by women. Since formal studies of time allocation to cassava processing have not been undertaken in Mozambique, a precise estimate of time allocation to cassava processing is not available. Time allocation studies have however been undertaken in other African countries. For example, Adekanye (1985) finds significant time allocated by rural women in Nigeria to the processing of cassava into *gari*, a local staple. Improved treatment of gender and resource allocation issues as well as production activities within the household are therefore critical topics for future research and data-generation work.

4. SIMULATIONS AND RESULTS

In order to examine the interactions between agricultural technology improvements, risk reducing behavior in cassava production, and gender roles in agricultural production, a series of four experiments were conducted. They are:

—A 30% Hicks-neutral increase in agricultural productivity in all agricultural commodities excepting cassava.

—A 30% Hicks-neutral increase in agricultural productivity in all agricultural commodities.

—A 15% decline in marketing margins for all commodities.

—Experiments two and three combined.

Each of these experiments was conducted under the alternative assumption of the presence or absence of risk-reducing behavior in cassava production. Thus, results from a total of eight simulations are presented.

The simulations were designed to reflect plausible shocks to the economy over the medium term. Agricultural technology in Mozambique is highly rudimentary. At the same time, agricultural potential is high. Given the divergence between performance and potential, a 30% technology increase is reasonable to conservative. In the family sector (which dominates agricultural production), the most promising new technologies come in the form of improved seed and better farming practices, especially higher planting densities. In addition, agricultural chemical use is practically zero at the moment. Use of agricultural chemicals offers promise for increased production in high potential regions served by operational marketing networks (Bay, 1998). A Hicks-neutral technological improvement is a reasonable representation of the first two improvements, which are the more likely advances to come about in the near term.

Regarding marketing margins, the 15% shock introduced in the simulations reflects the effects of the war, which ended only in 1992. The war devastated rural infrastructure in particular (Arndt *et al.*, 1999b). Substantial efforts have been undertaken to improve infrastructure and provide market information. These investments, combined with a general growth in the sophistication of marketing sector participants, should lead to approximately a 15% increase in the efficiency of the marketing system relative to the level observed in 1995.

We turn now to analysis of these eight simulations. Non-gender-related aspects are considered first and subsequently we discuss gender specific results.

Table 2 shows the impact of the alternative scenarios on cassava production, price, and the risk premium. In the no-risk scenarios, the risk variable has a value of one reflecting no-risk premium. In the risk scenarios, the risk variable is endogenous with a starting value of 1.3 reflecting a premium of 0.3. [10] In these scenarios, the premium will vary depending upon the shock. If the shock causes the opportunity cost of attaining the safety-first level of cassava production to increase, the risk premium will increase. If, on the other hand, the shock reduces the opportunity cost of attaining the safety first level of cassava production, the risk variable will decrease toward its lower bound value of one, reflecting a risk premium of zero. Once the risk variable attains a value of one, cassava production is permitted to increase above the safety first level. [11]

Not surprisingly, there are considerable differences in production and price movements for cassava between the risk and no risk scenarios. For example, in experiment one where productivity increases for all crops excepting cassava, the no-risk scenario predicts a small increase in cassava production. This comes about to satisfy increased cassava demand due to higher income. There are no exports or imports of cassava; so domestic supply equals domestic demand in equilibrium. In contrast, in the risk scenario, production of cassava remains at the minimum safety-first level while the risk premium declines. In the risk scenario for experiment two (productivity increases for all agricultural activities), the risk premium disappears and cassava production increases 9.4% over the safety first level. This compares to a 25.2% increase in cassava production for the no risk scenario. Due to the muted production response, cassava price movements in the risk scenario are far less pronounced as well.

When marketing margins are reduced (experiment three), cassava production is projected to decline very slightly in the no-risk scenario. [12] This occurs even though marketing margins on cassava production are very high relative to other crops. The small share of cassava marketed in total production supplies the explanation. Only about 8% of cassava production is marketed. When marketing margins are reduced, demand for marketed cassava increases. This increase is more than compensated for, however, by a decline in home consumption of cassava. The resulting decline in cassava production frees resources, which in the present model are allocated to production of more market oriented crops. The results from experiment four, the combined experiment, are roughly additive from the two preceding experiments.

Some additional comments on technical change in cassava merit mention. Cassava is widely regarded as a neglected crop in agricultural research (Cock, 1985; CIAT, 1999). One reason for this neglect is the low share of

Table 2. *Cassava production, price, and risk premium*

		Base run	Percentage deviation from base values			
			Exp. 1	Exp. 2	Exp. 3	Exp. 4
No risk	Production	10.3	3.5	25.2	−0.7	23.4
	Price	1	2.2	−20.3	10.3	−9.9
	Risk premium	1.00	0	0	0	0
Risk	Production	10.3	0	9.4	0.0	7.7
	Price	1	7.4	−4.0	9.2	8.9
	Risk premium[a]	1.30	−30	−100	6.7	−100

[a] Calculated using the formula (new – base)/(base – 1).

production of cassava that is marketed. For Mozambique, the logic of neglecting cassava research due to a low marketed share is dubious. Caloric intake for most of the rural population is insufficient. As a result, increases in home consumption of cassava (a 27% increase is predicted in the no-risk scenario) are a good thing. But since cassava is a risk-reducing crop, an improvement in cassava technology is also likely to reduce the risk premium or insurance cost associated with cassava production. As shown in the risk scenario, the level of cassava production remains relatively constant after technological change in cassava. It is the risk premium that declines. With the technological improvement, the resources necessary to meet the safety first requirement are reduced. For example, considering experiment 2, the increase in grain production is 51% in the risk scenario compared with 44% in the no risk scenario. The differential reflects resources allocated to grain production rather than to cassava production. The effect is similar, though less pronounced, for most other agricultural activities.

At this point, it is also worth considering the omission of female labor time allocated to cassava processing. In the more realistic risk scenario this omission is not critical. If cassava production levels change relatively little, total time allocation to cassava processing remains unaffected. Overall, results are likely to be very similar. In the no-risk scenario, on the other hand, explicit treatment of cassava processing would quite likely influence some of the results. In particular, the increase in cassava production induced by technical advance would almost surely be attenuated as the demands on female labor time for processing would preclude a large expansion of cassava production. The net effect on female labor time allocated to cassava and cassava processing combined is an empirical question.

Table 3 shows real gross domestic product (GDP) and nominal absorption for the eight experiments. In CGE models, only relative prices matter. To establish a reference point, one price, known as the numeraire, is fixed. We choose the consumer price index as the model numeraire. As a result, nominal absorption (or absorption as read directly from model output) is effectively deflated by the consumer price index and is an appropriate welfare indicator. In a macroeconomic perspective, the difference in welfare between the risk and no-risk scenarios is very small. Two items, however, do emerge from the table. First, due to the importance of cassava as a crop, technology gains in cassava production provide substantial gains to the economy. Welfare increases by an additional 1.5% from experiment one to experiment two. Second, note that simultaneous improvements in agricultural technology and marketing efficiency interact. The welfare gains in experiment four exceed the sum of welfare gains from experiments two and three by 1.2% and 1.1% in the no-risk and risk scenarios, respectively. In other words, these synergy effects account for about 9% of the total welfare gain in experiment four under both the no-risk and risk scenarios.

Table 4 shows agricultural terms of trade. This measure is simply a ratio of price indices for the agricultural and nonagricultural sectors. An increase in this measure indicates that agricultural prices are rising relative to nonagricultural prices. A variety of price indices (consumer, producer, export, etc.) may be used. The terms of trade measure shown in Table 4 is the relative price of value added in the agricultural and nonagricultural sectors. As is standard following an agricultural productivity

Table 3. *Macroeconomic indicators*

		10^{11} Mt[a] Base run	Percentage deviation from base values			
			Exp. 1	Exp. 2	Exp. 3	Exp. 4
No risk	Real GDP	172.1	5.1	6.8	5.0	12.2
	Nominal absorption	223.3	5.3	6.8	4.9	12.9
Risk	Real GDP	172.1	5.2	6.7	5.0	12.2
	Nominal absorption	223.3	5.2	6.7	4.9	12.7

[a] The metical (Mt) is the local currency. The exchange rate was 8,890 Mt/US$ in 1995.

Table 4. *Agricultural terms of trade (value added)*

	Base run	Percentage deviation from base values			
		Exp. 1	Exp. 2	Exp. 3	Exp. 4
No risk	100.0	−21.9	−29.4	7.1	−22.4
Risk	100.0	−21.4	−27.9	7.0	−20.5

Table 5. *Equivalent variation*

		Base run	Percentage of base consumption			
			Exp. 1	Exp. 2	Exp. 3	Exp. 4
No risk	Urban	0.0	4.7	5.2	4.6	10.4
	Rural	0.0	8.7	12.3	4.6	18.2
	Total	0.0	6.6	8.5	4.6	14.1
Risk	Urban	0.0	4.9	5.8	4.6	11.1
	Rural	0.0	8.5	11.5	4.7	17.4
	Total	0.0	6.6	8.5	4.6	14.1

shock, agricultural terms of trade decline indicating transmission of some of the benefits of the productivity increase to the rest of the economy through lower agricultural prices. Other terms of trade measures show roughly similar declines. For the productivity shocks, the value-added terms of trade declines are smaller in the risk scenarios. This is due primarily to the firmness of cassava prices in the risk scenario compared with the no-risk scenario (see Table 2).

Table 5 presents household welfare, as measured by equivalent variation, for urban and rural households.[13] A total welfare measure is also provided. Despite the terms of trade decline, rural households benefit substantially from agricultural technology improvements. Gains from marketing efficiency improvements are shared roughly equally between the urban and the rural household. As with nominal absorption, interaction effects between agricultural technology improvements and increases in efficiency in the marketing system lead to greater than additive benefits to both rural and urban households in the combined experiment (experiment 4).

While total welfare gains are very similar between the risk and no-risk scenarios, the distribution of benefits between rural and urban households is somewhat different. Specifically, rural households gain less from agricultural technology improvement when risk is introduced into the model. The intuition behind this shift in gain between rural and urban households is as follows. Equivalent variation measures consumption of goods. In the no risk scenario, resource allocation is unfettered by risk considerations. An increase in cassava production technology increases cassava production. Since only 8% of this production is marketed in the base case, most of the increase in cassava production is home consumed. More than 90% of this home consumption occurs in rural households.[14] The increase in cassava consumption increases welfare, particularly rural household welfare. In the risk case, the increase in cassava technology impacts the risk premium rather than cassava production. Instead of increasing cassava production, resources are allocated to other crops, all of which tend to have a higher marketed share of production. While the share of marketed production is by no means fixed, it is a very important determinant of first-order impacts of the technology or marketing efficiency shock. In the risk scenario, the increase in production of crops other than cassava tends to push more goods into the marketing channels where urban consumers can access them. As a result, urban welfare tends to be higher and rural welfare lower in the risk scenario compared with the no-risk scenario.

Table 6. *Factor prices*

		Base run	Percentage deviation from base values			
			Exp. 1	Exp. 2	Exp. 3	Exp. 4
No risk	Male ag. labor	1.0	−1	−3	12.3	16.2
	Female ag. labor	1.0	2.3	0.3	10.9	14.2
	Non-ag. labor	1.0	6.6	8.9	4.9	14.4
	Capital	1.0	8.1	10.6	2.0	13.4
Risk	Male ag. labor	1.0	−0.2	−0.3	12.2	16.4
	Female ag. labor	1.0	2.8	1.9	10.8	16.2
	Non-ag. labor	1.0	6.5	8.6	4.9	14.0
	Capital	1.0	8.0	10.5	2.0	13.2

Factor returns represent a final welfare indicator. [15] These are presented in Table 6. The rural household in the CGE model represents an average rural household. This household owns some nonagricultural labor (family members working in the city or in rural industry) and some capital. But, as indicated in Section 2, a large number of rural households own only male and female agricultural labor. For these typically very poor households, returns to labor are probably a better welfare indicator than the equivalent variation measures presented in Table 5.

Let us first focus analysis on experiments one and two. A first noteworthy impact of the technology shocks is the effect on the return to capital, which increases dramatically. Part of the explanation lies in the choice of the consumer price index (CPI) as numeraire. Since food is such a large part of the household consumption basket, food price declines raise the price of nonagricultural goods, such as capital and nonagricultural labor, relative to the CPI. Marketing margins represent the second major push factor on returns to capital. The commerce sector, which supplies marketing services, is a large sector representing about 22% of total value added in the 1995 SAM. It is also capital intensive with capital accounting for 68% of factor cost. Since agriculture and processed food account for almost all of the sales of the commerce sector, technological change in agriculture substantially increases demand for marketing services from the commerce sector. This increase in demand is reinforced by a consumer preference structure that allocates greater shares of marginal income to marketed commodities. Expansion of the commerce sector (output increases by 5% and price by 9.8% in experiment two) has a strong impact on the return to capital.

The second important impact in experiments one and two concerns the returns to male and female agricultural labor. Wage rates to male agricultural labor decline slightly while female agricultural labor rates rise. This is a crop composition effect. By construction, male agricultural labor tends to be more highly involved in production of goods with a relatively high marketed share. The share weighted average proportion of production marketed is 40% for males and 29% for females. [16] Given the increase in the price of marketing services provided by the commerce sector, the relatively heavy involvement of males in marketed production tends to reduce male wages. In other words, male wages decline slightly to accommodate the increase in the price of marketing services. Since female labor is more concentrated in activities with relatively low marketed shares of production, the effect of increases in the price of marketing services is less strong and female wages tend to rise.

There are also important differences in impacts on female wages between the risk and no-risk scenarios in experiments one and two. The relative firmness of cassava prices, due to the presence of the risk premium, makes the difference. As pointed out above, in the risk scenario, the risk-reducing properties of cassava cause greater allocation of resources to cassava than ordinary profit maximization would dictate. This "overallocation" of resources comes at the cost of reduced returns to factors allocated to cassava production as represented by the risk premium (see Eqn. (3)). Since female labor represents by far the largest factor cost share in cassava production (nearly 80% since the contribution of capital in cassava production is negligible) and since the value of cassava production is large, the risk premium substantially dampens female wage rates in particular.[17] As the risk premium declines in response to the technology shocks (see Table 2), returns to female labor allocated to cassava production increase. This has the effect of supporting the overall female wage.

Finally, it is worth noting that the interaction effects between agricultural technology improvements and increases in marketing efficiency, captured in experiment four, are strong for agricultural wages, particularly male agricultural wages. In the risk scenario, the interaction effects add an additional 4.5% to the additive percentage wage increases from experiments two and three for male labor and 3.5% for female labor. In other words, interaction effects account for 27% and 22% of the agricultural labor wage gains in experiment four for males and females respectively. Interaction effects are not nearly as pronounced for the other factors of production. These large interaction effects in agricultural labor wage rates (male and female) are due to the relatively greater importance of marketing margins in the primary agriculture and primary agriculture processing sectors. The larger interaction effects for male labor compared with female labor are due to the relative concentration of male labor in agricultural activities where the marketed share is relatively high.

5. CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The results lead to the following conclusions.

—General agricultural technology improvements induce important welfare gains for the economy in general and rural households in particular.

—Regardless of whether risk is a factor in cassava production, technological improvements in cassava production have strong welfare effects.

—If, as is likely, risk reduction is a factor in cassava production, impacts of technological improvement in cassava are likely to be particularly positive to rural women. With improved cassava technology, women have the opportunity to allocate time to other activities, including more market-oriented crops. In addition, the factor returns penalty to risk reduction, which weighs particularly heavily on female agricultural labor due to its high level of involvement in cassava production, declines. As a result of this decline in the risk premium, female wage rates tend to improve with improved technology in cassava. Women would also have the possibility of reallocating time formerly devoted to cassava production to for example domestic tasks or leisure. This possibility is not, however, captured in the model. In this case, female wage gains for agricultural labor would tend to be even stronger following technological change in cassava due to an effective decline in the supply of female agricultural labor.

—Recent research points strongly to increased household welfare stemming from increased female cash income and time allocation to domestic tasks (Haddad, forthcoming). It can also be recalled that Elson (1989, p. 73) argues that a recognition of the crucial role of women cultivators in food production should lead to a greater focus on increasing their productivity in growing staple foods such as cassava. The analysis in this paper support this. Consequently, technical change in cassava appears to be a particularly strong lever for increasing rural household welfare.

—Technological change in agriculture and marketing system improvements interact with significant additional benefits accruing to both male and female occupants of rural households. These interaction effects are significant in both the risk and no risk scenarios.

The research presented here represents an attempt at incorporating gender into CGE models. Much remains to be done in responding adequately to this challenge. With reference to Mozambique, firming our understanding of the functioning of the agricultural sector, through continued data collection and analysis, is a clear priority. This would permit, for example, a richer specification of gender and risk issues. More information is also desirable to understand more fully the importance of household-level productive activities such as food processing. In addition, further household and regional disaggregation would permit, for example, the model to capture regional variation in gender roles in agricultural production. Finally, with reference to more general gender-related modeling issues, it would be highly relevant and challenging to examine intrahousehold production activities and resource allocation within a CGE model.

NOTES

1. The World Bank Mozambique Agricultural Sector Memorandum (1997) asserts that rural women work, on average, 14–16 h per day, though it is not clear where these figures were obtained.

2. Land is generally regarded as abundant though there is evidence of land shortages in certain regions (MAP/MSU, 1992).

3. Excellent descriptions of standard neoclassical CGE models are available in Dervis, de Melo and Robinson (1982) and Devarajan, Go, Lewis, Robinson and Sinko (1997).

4. The price gap may also reflect some degree of imperfect competition. In this paper, they are assumed to reflect real costs.

5. Legitimate concerns about capital intensity data for developing economies exist. Difficulties in tracking labor inputs in the informal sector can result in labor inputs being counted erroneously as returns to capital, which are typically calculated as a residual. Pains were taken in the development of the Mozambican national accounts and the subsequent social accounting matrix to avoid this pitfall. While the most visible element of the commerce sector, street hawking, is labor intensive, the capital intensity of transport, inventory, and trading activities, combined with high costs of capital, make the sector capital intensive.

6. Alternative formulations to the LES are certainly possible and might well be desirable. For example, one could specify a two-stage budget process where the shares of home and marketed consumption for each good are determined in the lower nest and consumption quantities of the composite are determined in the upper nest. Other alternatives also exist. This is an important area for future research.

7. Gender asymmetries have been shown to be important for intrahousehold resource allocation (Haddad, Hoddinott & Alderman, 1997), and Hoddinott and Haddad (1995) find that as women's share of cash income increases, the household budget share of food tends to increase and the household budget share on alcohol and tobacco tends to decline.

8. A version of the model permits migration between the male agricultural labor and the nonagricultural labor pools. Simulations with this specification lead to similar conclusions.

9. This implies an elasticity of substitution of one between male and female labor in agricultural production.

10. There are no data on the appropriate value for the risk premium. This level allows for elimination of the risk premium, and consequent increases in cassava production, in some scenarios.

11. The PATH solver automatically handles these complementary slackness conditions (Dirkse and Ferris, 1995).

12. This translates into a slight increase in the risk premium in the risk scenario as shown in Table 2.

13. Formally, equivalent variation shows the amount of money, at base prices and income levels, that would have to be given to (or taken from) the household in order to achieve the utility level attained by the household in the experiment. Table 5 shows this measure as a percentage of base income.

14. Urban households in Mozambique often maintain a field in the countryside where they produce goods for home consumption.

15. Robinson and Thierfelder (1999) point out that factor returns are not always valid as a welfare indicator, but in this case of technology shocks and marketing margin improvements, they are a valid indicator.

16. Marketing margins are slightly higher on average for goods produced by females. This would tend to increase the role of margins for females relative to males. This slight difference in average margins is not enough, however, to offset the effects of male tendency to produce for the market and female tendency to produce for home consumption.

17. Cassava accounts for 30% of female agricultural labor factor returns.

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APPENDIX A. CGE MODEL DEFINITIONS AND EQUATIONS

(a) *Indices*

j	Activities	
	Aliases of *j*: activ, activ1	
	Subsets of *j*:	
	iaga	Agricultural activities
	iagr	Risk constrained agricultural activities
	pactiv	Productive activities
	imr	Marketing activities
	iagn	Nonagricultural activities
i	Commodities	
	Aliases of *i*: comm, comm1	
	Subsets of *i*:	
	im	Imported commodities
	imn	Nonimported commodities
	ie	Exported commodities
	ien	Nonexported commodities
f	Factors of production	
	Subsets of *f*:	
	aglabo	Agricultural labor (the elements of this subset of *f* are female and male agricultural labor)
	naglabo	Nonagricultural labor
h	Households	

(b) *Parameters*

a(comm,activ)		Input–output coefficients
ac(comm)	a_i^C	Armington function shift parameter
ad(activ)	a_j^D	Production function shift parameter
af	a^f	CET labor function shift parameter
alpha(f,activ)	α_i	Factor share parameter—production function

at(comm)	a_i^T	CET export function shift parameter
betah(comm,hh)		LES marginal consumption level of home produced goods
betam(comm,hh)		LES marginal consumption level of marketed commodities
cpiwtsh(comm)		Price index weights for home consumed goods in consumer price index
cpiwtsm(comm)		Price index weights for marketed goods in consumer price index
delta(comm)		Armington function share parameter
esr0		Enterprise savings rate
eta(comm)		Export demand price elasticitity
etr0		Enterprise tax rate
exrb		Base exchange rate
gamma(comm)	γ_i	CET export function share parameter
gammah(comm,hh)		LES minimum consumption level of home produced goods
gammam(comm,hh)		LES minimum consumption level of marketed commodities
qd(activ)		Dummy variable for computing ad(activ)
gles(comm)		Government consumption share
imake(activ,comm)		Make row coefficients
makef(activ,comm)		Make FLOWS matrices
mrd(comm)		Domestic margin coefficient
mrdf(comm)		Value of margins on domestics
mre(comm)		Export margin coefficient
mref(comm)		Value of margins on imports
mrm(comm)		Import margin coefficient
mrmf(comm)		Value of margins on imports
pcb(comm)		Base final consumption commodity price
pdab(activ)		Base domestic price
pdcb(comm)		Base domestic marketed supply price
pdchb(comm)		Base domestic home consumed supply price
ppiwts(activ)		Price index weights for producer price index
pqab(activ)		Base composite activity price
pqqb(comm)		Base composite consumption price
pqxb(comm)		Base composite commodity price
pweb(comm)		Base export price
pwmb(comm)		Base import price
pvb(activ)		Base value added price
rhoc(comm)	ρ_i^C	Armington function exponent
rhof	ρ^f	CET labor function exponent
rhot(comm)	ρ_i^T	CET export function exponent
risklow(activ)		Lower bound on production for risk
rmd(comm)		Ratio of imports to domestic sales
sdistr(hh)		Distributed profit shares
sremit(hh)		Remittance shares
strans(hh)		Government transfer shares
SUPERNUM(hh)		Household supernumerary income
tau	τ	CET labor function share parameter
tcb(comm)		Base consumption tax rate
tc0(comm)		Consumption tax (+) or subsidy (−) rates
te(comm)		Export tax (+) or subsidy (−) rates
teb(comm)		Base export tax
tf(f)		Factor tax rates
th(hh)		Household tax rate
thmul0		Uniform household tax rate multiplier
tm(comm)		Tariff rates on imports
tmb(comm)		Base tariff rate
txb(activ)		Base indirect tax
tx0(activ)		Output tax rates
ymap(instp,f)		Factors to private institutions map

(c) *Variables*

(i) *Prices*

EXR	Exchange rate (Mt per world $)
PC(comm)	Consumption price of composite goods
PDC(comm)	Domestic marketed commodity goods price
PDCH(comm)	Domestic home commodity goods price
PE(comm)	Price of exports
PINDEX	Producer prices or GDP index
PM(comm)	Price of imports
PQA(activ)	Average production composite activity price
PQQ(comm)	Price of composite consumption good
PQX(comm)	Average production composite commodity price
PV(activ)	Value-added price
RISK(activ)	Risk premium complementarity

(ii) *Production*

DC(comm)	Domestic commodity marketed consumption
DCH(comm)	Domestic commodity home consumption
E(comm)	Exports
M(comm)	Imports
QQ(comm)	Composite goods demand
QX(comm)	Domestic composite commodities output
QA(activ)	Domestic composite activities output

(iii) *Factors*

FDSC(f,activ)	Factor demand by sector
FS(f)	Factor supply
FSLAB	Aggregate labor supply
WF(f)	Average factor price
WFDIST(f,activ)	Factor price sectoral proportionality ratios
WFLAB	Aggregate average labor force
YFCTR(f)	Factor income

(iv) *Income and expenditure*

CAPINV	Real private investment
CAPINV	Total private investment
CDH(comm,hh)	Final demand for home produced commodities
CDM(comm,hh)	Final demand for marketed commodities
CI(comm)	Final demand for private productive investment
CONTAX	Consumption tax revenue
DISTR	Distributed profits
ENTSAV	Enterprise savings
ENTTAX	Enterprise tax
ESR	Enterprise savings rate
ETR	Enterprise tax rate
EXPTAX	Export subsidy payments
FACTAX	Factor tax revenue
FAIDGIN	Aid in government organization budget
FAIDNGO	Aid in non government organization budget
FSAV	Net foreign savings
GD(comm)	Final demand for government consumption
GDTOT	Total volume of government recurrent consumption
GI(comm)	Final demand for government productive investment
GININV	Total government investment
GINREV	Government investment account revenue
GINSAV	Government investment account savings
GOVTH	Government transfers to households
GOVTE	Government transfers to enterprises
GRESAV	Recurrent government account savings
GREREV	Government recurrent account revenue
HHSAV	Total household savings
HHTAX	Household tax revenue
ID(comm)	Final demand for productive investment
INDTAX	Indirect tax revenue

INT(comm)	Intermediates uses
INVEST	Nominal private investment
MPS(hh)	Marginal propensity to save by household type
NGOD(comm)	Final demand for non government organization consumption
NGOREV	Non government organization account revenue
REMIT	Remittances
SAVING	Total nominal private savings
SAVING	Total savings
TARIFF	Tariff revenue
THMUL	Uniform household tax rate multiplier
WALRAS1	Slack variable for savings investment
YE	Enterprise income
YH(hh)	Household income
Yinstp(instp)	Private institutional income

(v) *GDP and other derived variables*

ABSORB	Absorption in market prices
GDPVA	Value-added in market prices GDP
GOVRABS	Government recurrent to absorption ratio
GOVIABS	Government investment to absorption ratio
INVGDP	Investment to GDP ratio
RGDP	Real GDP

(vi) *Taxes*

TC(comm)	Consumption tax rate
TX(activ)	Output tax rate

(vii) *Other variables*

FOODAID(comm)	Food aid in form of composite commodity
TRADM(activ)	Demand for import commerce service by trade

(d) *Equations*

(i) *Prices*

D1 $$PM_{im} = pwm_{im} \cdot (1 + tm_{im}) \cdot EXR + MRM_{im} \cdot \sum_{imr} PQA_{imr}$$ Import prices

D2 $$PE_{ie} = pwe_{ie} \cdot (1 - te_{ie}) \cdot EXR - MRE_{ie} \cdot \sum_{imr} PQA_{imr}$$ Export prices

D3 $$PDC_i = PDCH_i + MRD_i \cdot \sum_{imr} PQA_{imr}$$ Marketed commodity prices

D4 $$PQQ_i = \frac{PDC_i \cdot DC_i + PM_i \cdot M_i}{QQ_i}$$ Composite commodity prices

D5 $$PQX_i = \frac{PDCH_i \cdot (DC_i + DCH_i) + PE_i \cdot E_i}{QX_i}$$ Producer commodity prices

D6 $$PC_i = PQQ_i \cdot (1 + tc_i)$$ Consumer prices

D7 $$PQA_{pactiv} = \sum_i imake_{pactiv,i} \cdot PQX_i$$ Producer activity prices

D8 $$PV_j = PQA_j \cdot (1 - tx_j) - \sum_i PC_i \cdot a_{ij}$$ Value-added prices net of output taxes

D9 $$WFLAB \cdot FSLAB = \sum_{lab} FS_{lab} \cdot WF_{lab}$$ Composite wage

D10 $$PINDEX = \sum_i cpiwts_i \cdot \left(\frac{PC_i}{pindex0}\right)$$ Consumer price index

(ii) *Quantities*

D11	$QA_j = a_j^D \cdot \prod_f FDSC_{j,f}^{\alpha_{j,f}}$	Cobb–Douglas production function
D12	$FDSC_{jf} = \dfrac{RISK_j \cdot QA_j \cdot PV_j \cdot \alpha_{jf}}{WF_f \cdot WFDIST_{jf}}$	Demand function for primary factors (profit maximization)
D13	$INT_i = \sum_j a_{ji} \cdot QA_j$	Total intermediate use
D14	$QA_{imr} = \sum_{im} M_{im} \cdot MRM_{im} + \sum_{ie} E_{ie} \cdot MRE_{ie} + \sum_i DC_i \cdot MRD_i$	Commodity/marketing services relationship
D15	$QX_i = \sum_{pactiv} imake_{pactiv,i} \cdot QA_{pactiv}$	Commodity/activity relationship
D16	$FSLAB = a^f \cdot \left[\tau FS_{aglabo}^{\rho^f} + (1-\tau) FS_{naglabo}^{\rho^f}\right]^{1/\rho^f}$	Composite labor—suppressed in this analysis
D17	$FS_{aglab} = FS_{naglab} \cdot \left(\dfrac{WF_{naglab}}{WF_{aglab}}\right) \cdot \left(\dfrac{\tau}{1-\tau}\right)^{\left(1/(1-\rho^f)\right)}$	Agricultural labor supply—suppressed in this analysis
D18	$QX_{ie} = a_{ie}^T \cdot \left[\gamma_{ie} E_{ie}^{\rho_{ie}^T} + (1-\gamma_{ie})(DC_{ie} + DCH_{ie})^{\rho_{ie}^T}\right]^{\frac{1}{\rho_{ie}^T}}$	Gross domestic output as a composite good for *ie* ∈ i
D19	$QX_{ien} = DC_{ien} + DCH_{ien}$	Gross domestic output for *ien* ∈ i
D20	$E_{ie} = (DC_{ie} + DCH_{ie}) \cdot \left(\dfrac{PDCH_{ie} \cdot \gamma_{ie}}{PE_{ie} \cdot (1-\gamma_{ie})}\right)^{\left(1/(1-\rho_i^T)\right)}$	Export supply
D21	$QQ_{im} = a_{im}^C \cdot \left[\delta_{im} M_{im}^{\rho_{im}^C} + (1-\delta_{im}) DC_{im}^{\rho_{im}^C}\right]^{1/\rho_{im}^C}$	Total supply of composite good—Armington function for *im* ∈ i
D22	$QQ_{imn} = DC_{imn}$	Total supply for *imn* ∈ i
D23	$M_{im} = DC_{im} \cdot \left(\dfrac{PDC_{im} \cdot \delta_{im}}{PM_{im}(1\delta_{im})}\right)^{1/(1+\rho_{im}^C)}$	F.O.C for cost minimization for composite good for *im* ∈ i

(iii) *Income*

D24	$YFCTR_f = \sum_i WF_f \cdot FDSC_{jf} \cdot \left(\dfrac{WFDIST_{jf}}{RISK_j}\right)$	Factor income
D25	$Yinstp_{instp} = \sum_f ymap_{instp,f} \cdot YFCTR_f$	Private institutional income
D26	$YE = Yinstp_{enterp} + GOVTE$	Enterprise income
D27	$YE = DISTR + ENTTAX + ENTSAV$	Enterprise expenditure

D28	$YH_{hh} = Yinstp_{hh} + sdistr_{hh} \cdot DISTR + sremit_{hh} \cdot REMIT \cdot EXR + strans_{hh} \cdot GOVTH$	Household income
D29	$INDTAX = \sum_{activ} tx_{activ} \cdot PQA_{activ} \cdot QA_{activ}$	Indirect taxes on domestic production
D30	$EXPTAX = \sum_{ie} te_{ie} \cdot E_{ie} \cdot pwe_{ie} \cdot EXR$	Export subsidy payments
D31	$TARIFF = \sum_{im} tm_{im} \cdot M_{im} \cdot pwm_{im} \cdot EXR$	Tariff revenue
D32	$CONTAX = \sum_{comm} tc_{comm} \cdot PQQ_{comm} \cdot QQ_{comm}$	Consumption taxes
D33	$FACTAX = \sum_{f} tf_{f} \cdot YFCTR_{f}$	Factor tax
D34	$ENTTAX = ETR \cdot YE$	Enterprise tax
D35	$HHTAX = \sum_{hh} th_{hh} \cdot YH_{hh} \cdot THMUL$	Total household tax collected by govt.
D36	$ENTSAV = ESR \cdot (YE - ENTTAX)$	Enterprise savings
D37	$HHSAV = \sum_{hh} MPS_{hh} \cdot YH_{hh} \cdot (1 - th_{hh} \cdot THMUL)$	Household savings
D38	$GREREV = INDTAX + EXPTAX + TARIFF + CONTAX + FACTAX + ENTTAX + HHTAX$	Government recurrent account revenue
D39	$GINREV = FAIDGIN \cdot EXR$	Government investment account revenue
D40	$NGOREV = FAIDNGO \cdot EXR$	Nongovernment organization account revenue
D41	$SAVING = HHSAV + ENTSAV + GRESAV + GINSAV + FSAV \cdot EXR$	Total savings

(iv) *Expenditure* (Eqns. D42 and D43 form a single LES and as such could be written out as one equation only. They are separated here for modeling convenience.)

D42 Private consumption for marketed commodities

$$PC_{comm} \cdot CDM_{comm,hh} = PC_{comm} \cdot gammam_{comm,hh} + betam_{comm,hh} \cdot \Bigg((1 - MPS_{hh} \cdot YH_{hh}) \cdot (1 - th_{hh} \cdot THMUL) - \sum_{comm1} PC_{comm1} \cdot gammam_{comm1,hh} - \sum_{comml} PDCH_{comml} \cdot gammah_{comm1,hh} \Bigg)$$

D43	$PDCH_{comm} \cdot CDH_{comm,hh} = PDCH_{comm} \cdot gammah_{comm,hh} + betah_{comm,hh} \cdot \Big((1. - MPS_{hh}) \cdot YH_{hh} \cdot (1 - th_{hh} \cdot THMUL) - \sum_{comm1} PC_{comm1} \cdot gammam_{comm1,hh} - \sum_{comm} 1PDCH_{comm}1 \cdot gammah_{comm1,hh}\Big)$	Private consumption behavior for home consumption
D44	$GD_{comm} \cdot PC_{comm} = gles_{comm} \cdot \left(GDTOT. + \left(\frac{gdtot_0}{gininv_0 + gdtot_0}\right) \cdot \sum_{comm1} PC_{comm1} \cdot FOODAID_{comm1}\right)$	Government consumption
D45	$GREREV = GDTOT + GOVTE + GOVTH + GRESAV$	Government recurrent budget constraint
D46	$GI_{comm} \cdot PC_{comm} = gishr_{comm} \cdot \left(GININV + \left(\frac{gininv_0}{gininv_0 + gdtot_0}\right) \cdot \sum_{comm1} (PC_{comm1} \cdot FOODAID_{comm}1)\right)$	Real government investment
D47	$GINREV = GININV + GINSAV$	Government investment budget constraint
D48	$NGOD_{comm} \cdot PC_{comm} = ngoshr_{comm} \cdot NGOREV$	Nongovernment organization consumption
D49	$CI_{comm} \cdot PC_{comm} = cishr_{comm} \cdot CAPINV$	Real private investment
D50	$ID_{comm} = CI_{comm} + GI_{comm}$	Investment by sector of origin
D51	$INVEST = \sum_{comm} PC_{comm} \cdot CI_{comm}$	Total private investment at market prices
(v) *Market clearing*		
D52	$QQ_{comm} + FOODAID_{comm} = INT_{comm} + \sum_{hh} CDM_{comm,hh} + GD_{comm} + NGOD_{comm} + ID_{comm}$	Commodities market equilibrium
D53	$DCH_{comm} = \sum_{hh} CDH_{comm,hh}$	Home consumption equilibrium
D54	$\sum_{activ} FDSC_{f,activ} = FS_f$	Factor market equilibrium
D55	$\sum_{im} pwm_{im} \cdot M_{im} = \sum_{ie} pwe_{ie} \cdot E_{ie} + FSAV + FAIDGIN + FAIDNGO + REMIT$	Current account balance
D56	$SAVING = INVEST + WALRAS1$	Savings-investment equilibrium
D57	$QA_{imr} \geqslant risklow_{imr}$	Risk related minimum production

In the present analysis FS_f is fixed for nonagricultural labor as well as for the two elements of agricultural labor (i.e., female and male agricultural labor).