Note on the
Revision of the Madagascar PSIA Multi-Market Model
to incorporate the FMG Depreciation

David Stifel (Lafayette College)

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This note is a follow up to a previous poverty and social impact analysis (PSIA) of the distributional impact of changing rice price tariffs in Madagascar (Stifel and Randrianarisoa, 2004). The purpose of this note is to reassess the results of this study in light of the recent large depreciation of the Franc Malagache (FMG) against all major currencies between April and July, 2004. We do this first by highlighting the basic findings of the this follow up, and then by examining the simulations in more detail. The detailed description of the model as it appears in Stifel and Randrianarisoa (2004) can be found in Appendix 1, while a listing of all the equations appears in Appendix 2.

<u>Basic Findings</u>:

Effects of Rice Tariff Reduction Prior to Depreciation

In their pre-depreciation study, Stifel and Randrianarisoa (2004) find that despite the simulated fall in rice prices due to a 20 percent decrease in the rice tariff, rural poverty falls slightly as prices of other non-traded goods fall by even more. Real incomes in rural areas rise in their simulation by a small percentage, which follows from rice producers being both buyers and sellers of rice. The reduction in the price of rice benefits the buyer and hurts the seller. With the two wrapped up into one outcome, the balance in this simulation leans marginally toward the buyers. The urban poor, however, are adversely affected with their real incomes falling by just under half a percent. Overall, national poverty falls by 0.2 percent.

Effects of Depreciation

A simulated 50 percent depreciation of the FMG translates into a 50 percent increase in the prices of all tradables, which then pull up prices of all other goods. Thus, even though nominal incomes all rise by at least 25 percent, a higher rate of inflation results in real incomes falling for all household groups except the urban poor. While urban poverty is predicted to fall by 6 percent, rural poverty rises by almost 10 percent, leaving national poverty 7.6 percent higher.

Effects of Rice Tariff Reduction After the Depreciation

When we couple the 50 percent depreciation of the FMG with a 20 percent reduction in the tariff on rice imports, we find similar yet dampened results to those of the depreciation alone. For example, real incomes of rural households and of urban non-poor households fall, but by slightly smaller amounts than those induced by the depreciation alone. As the tariff reduction has beneficial effects on rural incomes, rural poverty rises by 9.6 percent instead of 9.8 percent due to the depreciation. Similarly, national poverty increases by 7.4 percent instead of 7.6.

An additional simulation of an entire elimination of the 15 percent tariff on rice imports was conducted along with the 50 percent depreciation. In this scenario, national poverty rises by only 6.4 percent as real incomes of rural households and the urban non-poor fall by 20 percent less than they do in the case of the depreciation alone. The idea of this simulation is to illustrate that in the presence of already large increases in prices of all tradable goods, the complete removal of rice tariffs is not an unthinkable policy option. In fact, the result of the rice price increasing by a third due to the simultaneous depreciation of the FMG and the removal of the tariff means that the protection previously provided by the tariff is now swamped by the high FMG price of imported rice. If the FMG stabilizes at its current value against all major currencies, farmers will receive more protection from rice imports without the tariff than they did prior to the depreciation with the tariff.

We caution that this multi-market model was developed to analyze the distributional effects of external shocks on the agricultural sector in particular. Further, as with all such models, the shocks are meant to be marginal to the extent that structural and behavioral parameters remain unchanged. The 50 percent depreciation of the Malagasy currency stretches this model thin in two regards. First, the depreciation affects the prices of all tradable goods including non-food items. This would certainly affect non-agricultural incomes in a manner not captured by this model because these nominal non-agricultural incomes are exogenous. Second, the effect of the large changes in relative prices is very likely to be a transformation of the structure of the economy (i.e. structural parameters will change) as well as modifications by both consumers and producers in their responses to marginal price changes (i.e. behavioral parameters will change). Indeed, the simulated effects of the depreciation is limited to a 50 percent weakening of the FMG relative to the US dollar instead of the observed 62 percent because of model instability. As the model was calibrated to the pre-depreciation structure of the economy, it was unable to solve for a unique solution when a 62-percent depreciation of the FMG was introduced. We conclude then that while this revision of the model is informative in terms of the directions of changes in prices, incomes, output and consumption, the reader should be cautious when interpreting the levels of these changes. Once the 2004 household survey (Enquete auprés des Menages, EPM) is conducted and the data become available, we recommend that the parameters for this model be updated to account for the new structure of the economy.

Table 1: Effects of Changes in Rice Tariffs On Production and Consumption in Madagascar

Percentage Change

	Baseline	20% drop in tariff	50% depr.	Tariff drop & depr.	Tariff elim. & depr.
Production (Total Domestic Supply)					
Rice	**1,474.4**	-0.1	-12.6	-12.7	-13.2
Course Grains	**285.7**	-0.4	-4.0	-4.4	-6.1
Roots & Tubers	**3,022.2**	0.2	-0.8	-0.6	0.3
Cash Crops	**353.1**	0.4	-3.5	-3.2	-1.7
Livestock	**68.4**	-0.2	2.4	2.1	1.1
Other Food	**362.1**	-0.1	1.1	1.0	0.4
Non-Food	**151.9**	0.0	22.5	22.5	22.5
Consumption					
Rice	**1,686.9**	0.4	-1.4	-1.0	0.6
Course Grains	**269.9**	-0.4	-4.3	-4.7	-6.4
Roots & Tubers	**2,686.4**	0.2	-0.9	-0.7	0.3
Cash Crops	**19.7**	-0.5	-10.2	-10.7	-12.9
Livestock	**68.4**	-0.2	2.4	2.1	1.1
Other Food	**342.0**	-0.1	1.2	1.0	0.5
Non-Food	**592.5**	-2.0	-12.1	-14.0	-20.9
Input Demand					
Fertilizer	**5.5**	-1.4	28.1	26.3	19.1
Traction	**58.0**	0.0	0.0	0.0	0.0
Net Imports					
Rice	**212.6**	3.8	76.3	79.9	96.1
Cash Crops	**-333.4**	0.4	-3.1	-2.7	-1.0
Non-Food	**440.6**	-2.7	-24.1	-26.5	-35.8
Fertilizer	**5.5**	-1.4	28.1	26.3	19.1
Government Import Revenues					
Rice	**80.1**	-5.1	164.5	146.8	68.1
Non-Food	**204.4**	-2.7	13.9	10.2	-3.7
Fertilizer	**0.8**	-1.4	92.1	89.5	78.7
Land Shares					
Rice	**0.5**	0.0	-0.8	-0.8	-0.8
Course Grains	**0.1**	-0.2	0.2	0.0	-1.0
Roots & Tubers	**0.2**	0.3	-3.1	-2.8	-1.8
Cash Crops	**0.1**	0.3	-3.8	-3.5	-2.2
Other Food	**0.1**	0.0	1.1	1.1	0.9
Total	**1.0**	0.1	-1.5	-1.4	-1.1

	Baseline	20% drop in tariff	50% depr.	Tariff drop & depr.	Tariff elim. & depr.
Household Demand					
Rice					
Harvest					
Urban Nonpoor	**104.8**	0.6	0.5	1.1	3.9
Urban Poor	**45.5**	0.3	3.3	3.6	5.2
Rural Nonpoor	**351.6**	0.5	-3.0	-2.5	-0.4
Rural Poor	**409.0**	0.2	-1.1	-0.9	0.1
Lean					
Urban Nonpoor	**89.2**	0.6	0.5	1.1	3.9
Urban Poor	**38.8**	0.3	3.3	3.6	5.2
Rural Nonpoor	**299.5**	0.5	-3.0	-2.5	-0.4
Rural Poor	**348.4**	0.2	-1.1	-0.9	0.1
Course Grains					
Harvest					
Urban Nonpoor	**10.1**	0.0	-2.8	-2.8	-2.9
Urban Poor	**8.4**	-0.5	-2.7	-3.1	-5.1
Rural Nonpoor	**46.8**	-0.3	-3.6	-3.8	-4.9
Rural Poor	**64.2**	-0.6	-5.2	-5.8	-8.2
Lean					
Urban Nonpoor	**10.9**	0.0	-2.8	-2.8	-2.9
Urban Poor	**9.1**	-0.5	-2.7	-3.1	-5.1
Rural Nonpoor	**50.7**	-0.3	-3.6	-3.8	-4.9
Rural Poor	**69.6**	-0.6	-5.2	-5.8	-8.2
Roots & Tubers					
Harvest					
Urban Nonpoor	**72.0**	0.6	0.1	0.7	3.1
Urban Poor	**85.9**	0.3	-1.3	-1.1	0.2
Rural Nonpoor	**342.2**	0.4	1.0	1.4	3.0
Rural Poor	**762.6**	0.1	-1.8	-1.7	-1.2
Lean					
Urban Nonpoor	**81.2**	0.6	0.1	0.7	3.1
Urban Poor	**96.8**	0.3	-1.3	-1.1	0.2
Rural Nonpoor	**385.9**	0.4	1.0	1.4	3.0
Rural Poor	**859.9**	0.1	-1.8	-1.7	-1.2

	Baseline	20% drop in tariff	50% depr.	Tariff drop & depr.	Tariff elim. & depr.
Household Demand (cont.)					
Cash Crops					
Urban Nonpoor	**0.7**	-0.4	-3.0	-3.4	-4.9
Urban Poor	**3.0**	-0.7	4.6	3.9	1.3
Rural Nonpoor	**14.6**	-0.5	-14.1	-14.6	-16.7
Rural Poor	**1.3**	-0.8	-3.8	-4.6	-7.4
Livestock					
Urban Nonpoor	**16.3**	-0.1	4.4	4.3	3.8
Urban Poor	**6.9**	-0.5	17.4	16.9	15.0
Rural Nonpoor	**20.1**	0.1	-6.7	-6.8	-7.1
Rural Poor	**25.0**	-0.5	4.3	3.8	2.1
Other Foods					
Urban Nonpoor	**117.7**	0.0	2.6	2.6	2.4
Urban Poor	**35.6**	-0.4	11.8	11.5	10.0
Rural Nonpoor	**94.1**	0.0	-5.8	-5.9	-6.1
Rural Poor	**94.7**	-0.3	2.3	2.0	0.8
Non-Food Products					
Urban Nonpoor	**216.3**	-1.3	-5.9	-7.2	-12.4
Urban Poor	**72.3**	-2.1	17.9	15.6	7.0
Rural Nonpoor	**151.1**	-1.8	-37.8	-39.3	-44.6
Rural Poor	**152.8**	-3.1	-9.8	-12.5	-22.6
Fertilizer					
Urban Nonpoor	**0.6**	-1.4	28.1	26.3	19.1
Urban Poor	**0.6**	-1.4	28.1	26.3	19.1
Rural Nonpoor	**2.2**	-1.4	28.1	26.3	19.1
Rural Poor	**2.2**	-1.4	28.1	26.3	19.1
Traction					
Urban Nonpoor	**21.8**	0.0	0.0	0.0	0.0
Urban Poor	**21.2**	0.0	0.0	0.0	0.0
Rural Nonpoor	**93.2**	0.0	0.0	0.0	0.0
Rural Poor	**44.4**	0.0	0.0	0.0	0.0

Source: Simulation Results

Table 2: Effects of Changes in Rice Tariffs On Prices and Incomes in Madagascar

Percentage Change

	Baseline	20% drop in tariff	50% depr.	Tariff drop & depr.	Tariff elim. & depr.
Urban Consumer Prices					
Harvest Period					
Rice	**2,173.0**	-2.2	50.0	46.7	33.3
Course Grains	**1,072.6**	-5.2	155.5	142.4	94.0
Roots & Tubers	**999.1**	-0.9	67.0	65.6	59.9
Lean Period					
Rice	**2,499.0**	-2.2	50.0	46.7	33.3
Course Grains	**1,179.8**	-5.2	155.5	142.4	94.0
Roots & Tubers	**1,049.1**	-0.9	67.0	65.6	59.9
Cash Crops	**3,031.4**	0.0	50.0	50.0	50.0
Livestock	**6,497.7**	-0.8	8.2	7.3	3.8
Other Food	**3,770.5**	-1.0	23.9	22.6	17.3
Non-Food	**1,954.8**	0.0	50.0	50.0	50.0
Fertilizer	**2,500.0**	0.0	50.0	50.0	50.0
Traction	**499.7**	-2.8	146.1	139.4	112.8
Urban Producer Prices					
Rice	**1,671.5**	-2.2	50.0	46.7	33.3
Course Grains	**825.1**	-5.2	155.5	142.4	94.0
Roots & Tubers	**768.6**	-0.9	67.0	65.6	59.9
Cash Crops	**2,331.9**	0.0	50.0	50.0	50.0
Livestock	**4,998.3**	-0.8	8.2	7.3	3.8
Other Food	**2,900.4**	-1.0	23.9	22.6	17.3
Non-Food	**1,503.7**	0.0	50.0	50.0	50.0

	Baseline	20% drop in tariff	50% depr.	Tariff drop & depr.	Tariff elim. & depr.
Rural Consumer Prices					
Harvest Period					
Rice	**1,521.1**	-2.2	50.0	46.7	33.3
Course Grains	**815.2**	-5.2	155.5	142.4	94.0
Roots & Tubers	**799.3**	-0.9	67.0	65.6	59.9
Lean Period					
Rice	**2,573.9**	-2.2	50.0	46.7	33.3
Course Grains	**1,097.2**	-5.2	155.5	142.4	94.0
Roots & Tubers	**923.2**	-0.9	67.0	65.6	59.9
Cash Crops	**2,273.6**	0.0	50.0	50.0	50.0
Livestock	**4,548.4**	-0.8	8.2	7.3	3.8
Other Food	**3,016.4**	-1.0	23.9	22.6	17.3
Non-Food	**2,248.0**	0.0	50.0	50.0	50.0
Fertilizer	**2,875.0**	0.0	50.0	50.0	50.0
Traction	**574.6**	-2.8	146.1	139.4	112.8
Rural Producer Prices					
Rice	**1,170.1**	-2.2	50.0	46.7	33.3
Course Grains	**627.0**	-5.2	155.5	142.4	94.0
Roots & Tubers	**614.8**	-0.9	67.0	65.6	59.9
Cash Crops	**1,748.9**	0.0	50.0	50.0	50.0
Livestock	**3,498.8**	-0.8	8.2	7.3	3.8
Other Food	**2,320.3**	-1.0	23.9	22.6	17.3
Non-Food	**1,729.2**	0.0	50.0	50.0	50.0

	Baseline	20% drop in tariff	50% depr.	Tariff drop & depr.	Tariff elim. & depr.
Incomes					
Nominal Income					
Urban Nonpoor	**2,259.4**	-1.1	41.8	40.1	33.4
Urban Poor	**556.5**	-1.6	66.7	64.3	54.8
Rural Nonpoor	**1,899.2**	-0.7	25.3	24.2	19.7
Rural Poor	**455.8**	-1.3	43.2	41.3	34.1
Real Income					
Urban Nonpoor	**100.0**	0.0	-2.9	-2.7	-2.3
Urban Poor	**100.0**	-0.4	9.1	9.1	8.7
Rural Nonpoor	**100.0**	0.8	-20.4	-19.6	-16.3
Rural Poor	**100.0**	0.2	-10.4	-10.0	-8.5
Nominal Agricultural Income					
Urban Nonpoor	**226.0**	-1.3	29.1	27.3	20.4
Urban Poor	**83.4**	-3.8	162.3	156.9	136.3
Rural Nonpoor	**1,367.5**	-0.4	14.4	13.8	11.4
Rural Poor	**364.6**	-1.3	39.8	38.1	31.4
Real Agricultural Income					
Urban Nonpoor	**100.0**	-0.2	-11.6	-11.6	-11.8
Urban Poor	**100.0**	-2.6	71.7	70.6	65.9
Rural Nonpoor	**100.0**	1.1	-27.4	-26.3	-22.1
Rural Poor	**100.0**	0.2	-12.5	-12.0	-10.3
Caloric Intake					
Urban Nonpoor	**2,121.0**	0.4	1.1	1.4	2.9
Urban Poor	**996.1**	0.1	3.3	3.4	3.9
Rural Nonpoor	**3,380.1**	0.4	-2.5	-2.2	-0.8
Rural Poor	**1,436.9**	0.0	-1.4	-1.4	-1.1
Poverty (Headcount Ratio)					
Urban	**44.1**	0.0	-5.9	-5.9	-5.9
Rural	**77.1**	-0.3	9.8	9.6	8.4
National	**69.6**	-0.2	7.6	7.4	6.4

Source: Simulation Results

Discussion of Simulations:

Effects of Rice Tariff Reduction Prior to Depreciation

Despite the fact that rice is the major staple crop produced throughout most of Madagascar,[1] the country is a net importer of rice. This has been the case since 1970 when production stagnated and demand increased sharply in the presence of rapid population growth. Following a rather liberal policy toward agricultural commerce in the 1980s, the government introduced a 30 percent import tax in 1991 in response to concerns over the effect of low prices on producers. The level of this tax changed frequently throughout the 1990s, and now the current effective tariff is relatively high at 35 percent – a 15 percent import tax and a 20 percent value added tax applied to imports.

A 20 percent reduction in the tariff on rice imports was simulated by Stifel and Randrianarisoa (2004). This means that the effective tax on imports falls from 35 percent to 32 percent. We note, however, that since not all importers currently appear to pay the tariff, the simulations of the tariff changes may overestimate the effects of the policy changes. The following is Stifel and Randrianarisoa's description of the results:

The major outcomes of the simulated 20 percent reduction in rice import tariffs are (see Tables 1 and 2):

a. Rice prices drop by 2.2 percent, pulling down the prices of all non-traded commodities by 0.8 percent (livestock) to 5.2 percent (course grains).

b. Real incomes rise in rural areas (0.2 percent for poor households, and 0.8 percent for non poor), remain unchanged for the urban rich, and fall by 0.4 percent for the urban poor. National poverty falls by 0.2 percent as the rural headcount ratio falls 0.2 percent.

c. Demand for rice and roots and tubers increase by 0.4 percent and 0.2 percent, respectively, while demand for all other consumption commodities decline. The net effect of the changes in consumption of food items is a 0.4 percent increase in calorie consumption by the non poor, a 0.1 increase for the urban poor, and no change for the rural poor.

d. Rice imports rise by 3.8 as production falls (0.1 percent) and consumption rises (0.4 percent). But because the tariff rate is reduced, government import revenues from rice fall by 5 percent. As demand and consequently imports of non-food products and fertilizer fall, so do tariff revenues. Overall, government import revenues decline 3.4 percent.

e. Total land use increases by 0.1 percent as farmers shift out of course-grain production into roots and tubers and cash crops.

[1] In parts of southern Toliara province, cassava is a primary staple crop (Paternostro et al., 2000, Dostie et al., 2002).

The immediate effect of the tariff reduction from 15 to 12 percent (total tax decline from 35 to 32 percent) is a 2.2 percent fall in rice prices across the board – both consumer and producer prices. This, however, translates to only a negligible fall in rice production because falling prices[2] of other staple crops make substitution to these crops less attractive. Indeed, prices of course grains fall by over 5 percent, resulting in a 0.4 percent fall in production in this sector.

With prices of traded goods fixed by world prices, the relative producer prices of cash crops to other crops rise by 2.3 percent, making this a relatively attractive crop. But since substitution possibilities from staple to cash crops are limited, especially in the one-year time frame of the model, the share of land allocated to cash crops only increases by 0.3 percent, and production increases by 0.4 percent.

These limited production substitution possibilities and declining producer prices translate into a fall in nominal agricultural incomes and total nominal incomes of over 1 percent (note that non-food producer prices do not change, and consequently production and any revenues from this sector are unchanged). These declining incomes also have effects on demand for consumer goods in addition to price changes.

Rice consumption increases by 0.4 percent following the fall in rice prices as the substitution effect outweighs the effect of falling nominal incomes. Non-poor households witness the largest gains with rice consumption rising by more than 0.5 percent, whereas rice consumption among the poor rises by no more than 0.3 percent. Consumption of roots and tubers also increases as the effect of declining prices and incomes have the same positive effect on demand for inferior goods. Again, consumption among the non-poor increases by a larger percentage than among the poor.

Since prices of traded goods such as cash crops and non-food products are unchanged, they become more expensive relative to non-traded goods, the prices of which all fall. The combination of lower nominal incomes and higher relative prices translates into reduced demand for cash crops and non food. Consumption of livestock and other food also falls, largely driven by the declines in nominal incomes.

The decline in the prices of non-traded goods translates into 0.8 percent and a 0.2 percent rise in real incomes of the rural non poor and poor, respectively. As a result, rural poverty falls by 0.3 percent. However, calories consumed by the rural poor do not increase because the increase in calorie consumption from increased rice and cassava consumption is offset by the drop in consumption of course grains, cash crops, livestock and other foods. The substantially larger increase in rice consumption by the rural non poor means that caloric consumption for this group rises by 0.4 percent. Conversely,

[2] For those who are critical of the realism of falling prices given downward rigidities of prices, it is best to think of these price changes as relative declines. This model abstracts from inflation, holding it constant at zero. By allowing for general price inflation, declining prices observed in the simulations can be conceptualized as rising at rates slower than the overall rise.

although the real incomes of the urban poor fall by 0.4 percent, their caloric intake rises marginally by 0.1 percent.

Given the marginal decline in rice production and the increase in consumption, rice imports rise by 3.8 percent. Tariff revenues from rice imports fall, however, as the increase in the volume is insufficient to cover the loss from the lower tariff. Overall, tariff revenues fall by 3.4 percent as imports of (i) fertilizer fall 1.4 percent because rice and course-grain production drops following the decline in producer prices and (ii) non-food fall because lower nominal incomes and higher relative prices diminish demand.

Effects of a 50 Percent Depreciation of the FMG

The major outcomes of the simulated 50 percent depreciation of the FMG relative to the US dollar are (see Tables 1 and 2):

a. Rice prices and the prices of all other traded goods (cash crops, non-food and fertilizer) rise by 50 percent, pulling up the prices of all non-traded commodities. These price rises range from by 8.2 percent (livestock) to 155 percent (course grains).

b. Real incomes fall in rural areas (10.4 percent for poor households, and 20.4 percent for non poor), fall for the urban rich (2.9 percent), and rise by 9.1 percent for the urban poor. National poverty rises by 7.6 percent as the rural headcount ratio rises 9.8 percent.

c. Demand for rice, course grains, roots and tubers, and cash crops fall by 1.4, 4.3, 0.9 and 10.2, respectively, while demand for all other consumption commodities increases. The net effect of the changes in consumption of food items is a decrease in rural calorie consumption, and an increase in calorie consumption in urban areas.

d. Despite the higher price of rice and the fall in demand (1.4 percent), rice imports rise by 76 percent as production falls (12.6 percent). Net imports of cash crops and non-food fall as the domestic prices of these commodities rise. But since fertilizer is an input, the demand for which depends not only on the price of fertilizer, but also on agricultural output prices, demand for fertilizer increases.

e. Total land use decreases by 1.5 percent as farmers shift out of agriculture into non-farm enterprises.

The immediate effect of the depreciation is a 50 percent increase in the prices of all traded goods. This leads to a fall in demand for traded consumption goods (rice, cash crops, and non food). As producers substitute out of producing non-traded goods into traded goods (especially non-food items), the prices of non-traded goods increase. Indeed, the prices of course grains and roots and tubers rise by more than 50 percent (155 percent and 67 percent, respectively), which in turn leads farmers to allocate 0.8 percent less land to rice production. Consequently the domestic supply of rice falls by 12.6 percent.

Despite higher producer prices (155 percent) and more land allocated to it, output falls for maize (coarse grains) as yields decline due to fewer costlier inputs being used. Having said this, overall use of imported agricultural inputs (fertilizer) increases some 28 percent. This follows despite the fact that the price of fertilizer increases by 50 percent, because rising agricultural output prices increase the value marginal product of fertilizer more than the increase in fertilizer prices.

Depreciation-induced inflation translates into lower real incomes for rural poor, rural non-poor and urban non-poor households (10.4 percent, 20.4 percent, and 2.9 percent, respectively) even though nominal incomes rise for each of these household groups. Urban poor households, however, experience a 9.1 percent increase in real income which stems primarily from a 71 percent increase in their real agricultural income. The result is that urban poverty is simulated to fall by 6 percent while rural poverty rises by almost 10 percent, and national poverty rises by 7.6 percent.

The fall in real rural incomes translates into lower calorie consumption among both the poor and the non-poor there (1.4 percent and 2.5 percent, respectively). Calorie consumption among urban households rises as rice and livestock consumption increase for both the poor and the non-poor.

Effects of a 50 Percent Depreciation of the FMG Coupled with Rice Tariff Reduction

The simulated effect of both the depreciation of the currency and a reduction in the tariff on rice imports is simply a combination of the previous two simulations. As such, we list the major outcomes without repeating the description of the underlying mechanisms. Further, we illustrate an extreme case in which the 15 percent rice tariff is completely eliminated (both a 20 percent reduction and the complete elimination appear in Tables 1 and 2):

a. Rice prices and the prices of all other traded goods (cash crops, non-food and fertilizer) rise 33 percent, pulling up the prices of all non-traded commodities. These price increases are lower than with the depreciation alone and now range from by 3.8 percent (livestock) to 94 percent (course grains).

b. Real incomes fall in rural areas (8.5 percent for poor households, and 16.3 percent for non poor), fall for the urban rich (2.3 percent), and rise by 8.7 percent for the urban poor. National poverty rises by 6.4 percent as the rural headcount ratio rises 8.4 percent. Note that these magnitudes are all smaller than with the depreciation alone.

c. Demand for rice and roots and tubers actually rise (0.6 percent and 0.3 percent, respectively) as the tariff elimination effect offsets the depreciation effect. Demand for course grains and cash crops still fall but by greater amounts (6.4 percent and 12.9 percent, respectively) as the both the tariff elimination and the depreciation have similar effects. The net effect of the changes in consumption of food items is a decrease in rural calorie consumption, and an increase in calorie consumption in urban areas.

d. Despite the higher price of rice, production falls further by 13.2 percent. Coupled with an increase in demand, rice imports rise by 96 percent. Net imports of cash crops fall by less than with the depreciation alone (1.0 percent versus 3.1 percent) and net imports of non-food falls further as the domestic prices of these commodities rise both in absolute magnitude and relative to rice prices. But since fertilizer is an input, the demand for which depends not only on the price of fertilizer, but also on agricultural output prices, demand for fertilizer increases by 19.1 percent.

e. Total land use decreases by 1.1 percent as farmers shift out of agriculture into non-farm enterprises.

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Appendix 1: Description of the Model (from Stifel and Randrianarisoa, 2003)

The multi-market model used in this analysis extends Lundberg and Rich's (2002) generic model designed to facilitate analysis of agricultural policy reform issues in Africa. The purpose of this extension is to adjust the generic model to more accurately reflect the conditions in Madagascar, as well as to take advantage of recent household survey data to estimate supply response elasticities. Further, unlike the computable general equilibrium (CGE) model of Dorosh et al (2003), this multi-market model concentrates on the production relationships in the agricultural sector, and adds a seasonal component in a manner different from Dostie, et al's (2000) multi-market model.

We begin with a description of the product and household categories, before elaborating on the structure and the equations that make up the model.

2.1 Product Categories

The product categories are broadly broken down into (a) food items, (b) non-food consumption items, and (c) agricultural inputs. More specifically, the food items include:

1. Rice (RICE): As in many Asian economies, rice is the dominant crop in Madagascar. As such, it is given its own category in the model.

2. Course grains (CGRAIN): This group is comprised primarily of maize, sorghum and millet which are treated as non-tradables in this model. These commodities are an important source of livestock feed, and will frequently be referred to as "maize" given its dominance within this category.

3. Roots and tubers (ROOTTUB): Also an important source of livestock feed, roots and tubers such as cassava, sweet potatoes, and potatoes are used as food products of the poor and are non-tradables. In addition, cassava is the primary starchy staple consumed in southern Madagascar.

4. Cash crops (CASHCRP): Such crops as vanilla, coffee and cloves are produced primarily for export.

5. Livestock (LIVESTK): This is an aggregation of the various non-tradable meat products in Madagascar (e.g. cattle, pigs and poultry), but is primarily made up of cattle.

6. Other food products (OTHFOOD): This remaining food category captures a basket of miscellaneous non-tradable food crops and processed food products.

Non-food consumption items are aggregated into one product category since the emphasis of this model is the agricultural sector:

7. Non-agricultural production (NONFOOD): Such tradable products as manufactures, industrial products, oil, and forest products are included.

Two agricultural inputs are modeled explicitly:

8. Fertilizer (FERT): Given the potentially high returns and the extremely low levels of fertilizer use in Madagascar (Stifel, Minten and Dorosh, 2003), this imported input is the subject of policy considerations.

9. Animal and mechanical traction (TRACT): This non-tradable input is an aggregation of the use of cattle and tractors for plowing and other uses of traction.

The four other obvious agricultural inputs are land, labor, water and seed. Land is included as a variable input, but is not incorporated into the model as a traded commodity given the weakness of markets for land. Labor is not considered as a variable input in the multi-market model because it is better studied through the use of a CGE model. As such it is assumed to be supplied inelastically and allocated in fixed proportions to each of the production activities. Although water input is not entirely beyond the control of farming households – through development of irrigation systems – we assume it to be exogenous in the model since determining shadow prices is not possible given the lack of sufficient data. Finally, seed inputs are modeled as fixed proportion of output. These relationships are clarified below in the detailed discussion of the model.

2.2 Households

Production and consumption patterns are distinguished among four broad types of household groups: urban non-poor (URBRICH), urban poor (URBPOOR), rural non-poor (RURRICH), and rural poor (RURPOOR). Each of the household groups is assumed to be involved in all of the production activities, though to differing degrees. As such, these are representative agent households that may not correspond to any particular household within their groups, but rather embody the average activities of all the households in the group.

2.3 Structure of the Model

There are six blocks of equations in this multi-market model: prices, supply, input demand, consumption, income, and equilibrium conditions. (a) The price block defines the relationship between producer prices (*PP*) and consumer prices (*PC*) in the domestic economy based on the degree of transactions costs. For tradable goods, domestic prices are related to world prices, while prices of non-traded goods are determined by supply and demand conditions. (b) The supply block represents the domestic production of food crops, livestock, and non-agricultural production. (c) The input demand block describes the household demands for agricultural inputs. (d) The consumption block shows household demand for food and nonfood consumption items. (e) The income block describes household income as the sum of income derived from agricultural production and exogenous nonagricultural income. (f) Finally, the equilibrium condition block contains equations equating domestic supply and net import to demand for each of the ten product categories.

Seasonality is incorporated into the model on the demand side for three “seasonal” consumption commodities – rice, maize and roots and tubers. This is done by allowing consumer prices to differ during the harvest (April - September) and the lean period (October - March) by the cost of storage for these products, as well as by seasonally variant urban-rural marketing margins. Production decisions for the seasonal products, however, are made based on prices received at the time of harvest. This is justified by conceptualizing the lean-period premium as storage costs (a leakage) which are not captured by the producers.[3]

2.3.1 Price Block

The price block is comprised of 111 equations that reflect the relationships between producer prices, consumer prices, international prices and transactions costs – including seasonal storage costs. These equations also reflect the laissez-faire approach of the government to transactions in the domestic economy. As Randrianarisoa and Minten (2001) describe:

> The current situation in agricultural markets can be described as one in which private traders have been given free reign to set prices and [to] move agricultural products around the country, and in which there is little state intervention.

In the presence of transactions costs due to distribution and transportation costs, producer prices for each household group (h) are lower than the harvest ($t = 1$) market or consumer prices. The band between these prices is determined exogenously by commodity-specific (c) domestic marketing margins ($MARG_c$). Changes in the domestic marketing margins can proxy for changes in transportation costs that arise from improvements in infrastructure. The first 36 equations (9 x 4) in this block thus describe the relationship between producer and consumer prices for each commodity (c):

$$PP_{c,h} = \frac{PC_{c,h,1}}{1 + MARG_c} \qquad (1\text{-}36)$$

[3] This differs from Dostie et al’s (2000) approach in which they solve sequentially for each season with six seasons linked by the previous season prices and levels. Their approach is appropriate in the context of their objective to study the seasonality of food consumption. Given the objective of this paper to analyze the second round income effects of agricultural policies, however, we prefer a more limited seasonal model that solves simultaneously. The rationale for this is that farmers make their major input decisions at the time of planting based on their ex ante expectations of producer prices that they receive for their crop at the time of harvest, as well as on current input prices. Since these prices – output and input – are realized during different seasons, we are more comfortable modeling production in a simultaneous model. (Note that this multi-market model exercise assumes that household consumption and production decisions are separable; Singh, Squire and Strauss, 1986). In the rice sector, Bockel (2002) finds a certain degree of producer price stability in the 1980s and 1990s, and more variation among consumer prices.

For non-tradable commodities, these prices adjust endogenously to equate supply and demand as described later in the discussion of the equilibrium conditions. For tradable goods, however, prices are determined exogenously by fixed world prices, with net imports (imports less exports) clearing the domestic market (i.e. filling the gap between domestic demand and supply at the fixed prices). We first describe the relationship between world and border prices, and then clarify the distinction between border prices and consumer prices.

For exportable products (*ix*), the border price (*PX*) is linked to the world price (*PW*) by the exchange rate (*er*), export tariffs (*te*), and transactions costs – marketing margin – from the rest of the world to the border of Madagascar (*RMARG*). Given that cash crops are the sole exportable product category in this model, one equation is introduced:

$$PX_{ix} = \frac{\overline{PW_{ix}} * er}{(1 + RMARG_{ix}) * (1 + te_{ix})} \tag{37}$$

The prevailing producer price of exportables in the domestic market, however, is not equal to the border price since there also exist transactions costs that result in a marketing margin between the border and the domestic market. The domestic producer price of cash crops must then be adjusted downward to account for this margin (*IMARG*). Using the relationship between consumer prices and producer prices described in equations 1 through 10, we thus get the following relationship between domestic consumer price and the border export price for cash crops:

$$PC_{ix,urbrich,1} = PX_{ix} * \left(\frac{1 + MARG_{ix}}{1 + IMARG_{ix}} \right) \qquad (38)^{4}$$

Note that since consumer prices are defined for each household group for each season, the price described here is for urban non-poor households during the harvest ($t = 1$). The relationship between this price and the remaining consumer prices of exportables is described below.

The border prices of the three importable products (*im*) – food grains, non-agricultural products, and fertilizer – are similarly linked to the world price by the exchange rate, import tariffs (*tm*)[5], and the international marketing margin:

[4] An intuitive interpretation of this equation is based on understanding that the producer price is determine by the border price, and that the consumer price responds to adjustments in the producer price. For example, an decrease in the market-to-border marketing margin (*IMARG*) means that producers receive a higher price for exports even if the border price is unchanged, and consequently the domestic consumer price must also rise. While a fall in the domestic marketing margin (*MARG*) does not affect the producer price, it does reduce the band between the producer and consumer prices. Thus the consumer price falls.
[5] These tariffs – and value added taxes (VAT) – are not uniformly enforced (World Bank, 2003), in fact Bockel (2002) suggests that realistically only half of all import transactions are actually taxed.

$$PM_{im} = \overline{PW_{im}} * er * (1 + RMARG_{im}) * (1 + tm_{im}) \quad (39\text{-}41)$$

Consumer prices for the three importable items (*mc*) – rice, fertilizer and non-agricultural products – are related to the border price by the commodity specific border-to-market marketing margin and by potential import subsidies (*isub*):

$$PC_{im,urbrich,1} = PM_{im} * (1 + IMARG_{im})(1 - isub_{im}) \quad (42\text{-}44)$$

Prices that consumers face during the lean period (t = 2) for all nine commodities are marked up above the harvest (t = 1) prices by commodity-specific storage costs (*STCOST*):

$$PC_{c,urbrich,2} = PC_{c,urbrich,1}(1 + STCOST_c) \quad (45\text{-}53)$$

Since these seasonal storage costs are applicable only to rice, maize and roots and tubers, they are set to zero for the remaining six commodities – i.e. prices are invariant over seasons for these "annual" commodities.

Rural consumer prices differ from urban consumer prices by an internal marketing margin (*INTMARG*) that reflects transportation and marketing costs that can differ by commodity and season (18 equations).

$$PC_{c,rurrich,t} = PC_{c,urbrich,t} * (1 + INTMARG_{c,t}) \quad (54\text{-}71)$$

This internal margin is negative for products that are primarily exported from rural to urban areas (rice, maize, roots and tubers, cash crops, other food), and is positive for those goods flowing from urban to rural areas (non food, fertilizers). The combination of seasonal storage costs and internal marketing margins that vary by season, permit us to calibrate the model consistently with the stylized fact that seasonal price variation is greater in more remote rural areas (Minten and Randrianarison, 2003).

All of the consumer prices above have been defined for non-poor households. We assume that poor and non-poor households within any given milieu face the same prices. Thus there is one urban price for each commodity during each season (18 equations),

$$PC_{c,urbpoor,t} = PC_{c,urbrich,t} \quad (72\text{-}89)$$

and one rural price (18 equations),

$$PC_{c,rurpoor,t} = PC_{c,rurrich,t} \; . \qquad (90\text{-}107)^6$$

Finally, price indices for each household group are included to reflecting changes in prices weighted by their shares of consumption:

$$PINDEX_h = \sum_i \sum_t \left(pcwt_{i,h,t} * \frac{PC_{i,h,t}}{PC0_{i,h,t}} \right) \qquad (108\text{-}111)$$

2.3.2 Supply Block

There are 75 equations in this block that describe production of agricultural crops, livestock, and nonfood products by each of the four household types (*h*). This specification allows for simulations such as improvements in agricultural productivity and increased input use to have differential effects on households.

Household supply of the five food crops (*f*) – fine grains, course grains, roots and tubers, cash crops, and other food products – is determined by (a) the total quantity of land available to each household, (b) the share of that land allocated to the specific crops, and (c) the associated yield for the crops. We begin with an initial total amount of land under cultivation ($area_0$). For the most part, land can be reallocated by each household group among the food crops in order to maximize profits. Thus the share of land owned by household group *h* allocated to the cultivation of food crop *f* ($SH_{h,f}$) is determined by the prices of all food crops (*ff*), giving us 20 equations (4 x 5):

$$\log(SH_{h,f}) = \alpha^s_{h,f} + \sum_{ff} \beta^s_{h,f,ff} \log(PP_{ff,h}) \qquad (112\text{-}131)$$

We do not restrict the sum of the shares to one (i.e. not $\sum_h \sum_f SH_{h,f} = 1$), thus land inputs are endogenously determined even though land is not explicitly traded. If the shares add up to more than one following a simulation, then extensification is practiced.[7] As is discussed later in Appendix I, the substitution and expansion elasticities are nonetheless quite small reflecting the difficulties inherent in switching crops and in bringing new productive land into production.

The 20 equations for the yields of food crops *f* for household groups *h* ($YLD_{h,f}$) are also represented in log-linear form as a function of output prices and input (*in*) prices (proxying for conditional input demand):

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[6] In one of the simulations, however, we allow these prices to differ – a fertilizer subsidy targeted to the poor.

[7] We recognize, however, that given the existing degree of agricultural extensification in Madagascar, further expansions are largely limited fragile or denuded soil. Thus the model does not fully capture the effects of extensification. Further, as is discussed in Appendix I, reallocation of land that takes place through extensification is assumed to take place at the margin. In other words, farmers are not likely to reallocate more productive lowland rice plots to, say, maize. Rather, less productive upland plots are the more likely candidate.

$$\log(YLD_{h,f}) = \alpha^{y}_{h,f} + \beta^{y}_{h,f,f}\log(PP_{f,h}) + \sum_{in}\gamma^{y}_{h,f,in}\log(PC_{in,h,2}) \qquad (132\text{-}151)$$

where the coefficients represent price elasticities. Total household supply to the market is then determined as the product of the initial area of cultivated land, the share of land devoted to the crop, and the yield. Further, it is adjusted for losses and use of the output for seed (*loss*), and for any related conversion factors (e.g. paddy to rice) (*conv*):

$$HSCR_{h,f} = area_0 * SH_{h,f} * YLD_{h,f} * \overline{(1-loss_f)} * \overline{conv_f}\ . \qquad (152\text{-}171)$$

Total supply of each of the five food crops is the sum of household supply:

$$SCR_f = \sum_h HSCR_{h,f} \qquad (172\text{-}176)$$

Household supply of livestock ($HSLV_h$) and non-agricultural production ($HSNF_h$) are represented as functions of own producer prices. And as with food crops, total market supply of livestock (*SLV*) and non-agricultural production (*SNF*) are equal to the sums of the varying household supplies:

$$\log(HSLV_h) = \alpha^{l}_{h} + \beta^{l}_{h,l,l}\log(PP_{l,h}) \qquad (177\text{-}180)$$

$$SLV = \sum_h SLV_h \qquad (181)$$

$$\log(HSNF_h) = \alpha^{nf}_{h} + \beta^{nf}_{h,nf,nf}\log(PP_{nf,h}) \qquad (182\text{-}185)$$

$$SNF = \sum_h HSNF_h \qquad (186)$$

2.3.3 Input Demand Block

Household group *h*'s demand for agricultural input *in* ($HDIN_{h,in}$) is a function of the price of the input and prices of the food crops for which the input are used. For the two inputs – fertilizer and traction – this results in 10 household demand equations:

$$\log(HDIN_{h,in}) = \alpha^{f}_{h} + \sum_f \beta^{f}_{h,f,in}\log(PP_{f,h}) + \gamma^{f}_{h,in}\log(PC_{in,h,2}) \qquad (187\text{-}194)$$

Total demand for the two inputs is simply the sum of the household demands:

$$DIN_{in} = \sum_h HDIN_h \qquad (195\text{-}196)$$

2.3.4 Consumption Block

Demand for each of the seven consumption items (*i*) – rice, maize, roots and tubers, cash crops, livestock, other food products, and non-food products – by the four household groups in each season (56 equations), $HC_{h,i,t}$, is modeled as an Almost Ideal Demand System (AIDS) (Deaton and Muelbauer, 1980):

$$\log(HC_{h,i,t}) = \alpha^{h}_{h,i,t} + \sum_{j} \beta^{h}_{h,i,j,t} \log(PC_{j,h,t}) + \gamma^{h}_{h,i,t} \log(YH_{h}) \qquad (197\text{-}252)$$

where YH_h is household income defined below. Note that these consumption levels only differ across seasons for rice, maize and roots and tubers – the "seasonal" commodities. Total demand for the seven consumption commodities is the sum of the household demands:

$$CONS_{i} = \sum_{h}\sum_{t} HC_{h,i,t} \qquad (253\text{-}259)$$

2.3.5 Income Block

Agricultural incomes in the four household groups ($YHAG_h$) are the sum of the values of crop and livestock production, less input costs:

$$YHAG_{h} = \sum_{f}(PP_{f,h} * SCR_{h,f}) + (PP_{l,h} * SLV_{h,f}) - \sum_{in}(PC_{in,h} * DIN_{h,in}) \qquad (260\text{-}263)$$

Total household incomes ($YHAG_h$) are the sum of agricultural incomes and exogenously determined non-agricultural income, with non-agricultural income adjusted by the price index:

$$YH_{h} = YHAG_{h} + \overline{YHNAG_{h}} * PINDEX \qquad (264\text{-}267)$$

2.3.6 Equilibrium Conditions

Equilibrium in the economy requires that each of the nine product markets clears. For each of the five food crops (*f*), this means that total quantity supplied (sum of domestic supply and net imports) is equal to the total quantity demanded (demand by households as well as animal feed):

$$SCR_{f} + M_{f} = CONS_{f} + \overline{FEED}_{f} \qquad (268\text{-}272)$$

Note that net imports are fixed at zero for the three non-tradable food crops – course grains, roots and tubers, and other foods.

Total supply livestock (*l*) and non-agricultural products (*nf*) are defined analogously to food crops (noting that livestock is a non-tradable), though domestic demand is limited to household demand:

$$SLV_l = CONS_l \tag{273}$$

$$SNF_{nf} + M_{nf} = CONS_{nf} \tag{274}$$

Supply of importable inputs – fertilizer – derive entirely from imports, while the supply of non-tradable inputs that are marketed[8] – traction – are exogenously determined by the current local supply.

$$M_{mn} = DIN_{mn} \tag{275}$$

$$\overline{SDIN_{dn}} = DIN_{dn} \tag{276}$$

Given that demand for draft power is not uniform throughout the year, instead occurring during peak periods characterized by supply bottlenecks, and that supply is slow to respond for various reasons including credit constraints, we opt to model the supply of traction as perfectly inelastic.[9]

In total, these 276 equations correspond to the 276 endogenous variables permitting the model to be solved. The original GAMS code using the NLP solver provided by Lundberg and Rich (2002), was adapted to solve this revised system of equations and to run the simulations described below.

Finally, once the systems of equation were solved, we used changes in the average real income levels of each household group to simulate the effects of the policy experiments on urban, rural and national poverty. This was done by scaling the household consumption aggregate levels in the 2001 nationally representative household survey data up or down by the percent change in the real income levels for the corresponding household groups. Poverty measures were then applied to these new distributions using the original poverty line[10] to derive the simulated effects on poverty. These were then compared to the baseline poverty levels that are consistent with the estimates of INSTAT (2002).

For information on calibration of this model, see Stifel and Randrianarisoa (2004)

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[8] As differentiated from land and seed, that are not marketed but do enter the model as inputs.

[9] While stocks of draft animals can and do accumulate, they are also frequently hit by negative shocks such as disease and family deaths requiring animal sacrifices (Freudenberger, 1998) thus dampening supply responses.

[10] This is slightly different from Stifel and Thorbecke (2003) and Decaluwe et al. (1999), in which hypothesized nominal income distributions and poverty lines are scaled (in the former, shifted in the latter). Note that the household consumption aggregates are scaled by the change in real incomes, thus producing an estimate of the new real incomes. Further note that scaling the consumption aggregates is intra-group inequality neutral.

Appendix 2: Model Equations

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*-------------------------------*
           SETS
*-------------------------------*

     T     seasons        / HARVEST, SOUDURE /

     C     commodities    / RICE              1  local rice
                            CGRAIN            2  coarse grains eg maize sorghum millet
                            ROOTTUB           3  roots and tubers
                            CASHCRP           4  exportable cash crop
                            LIVESTK           5  livestock
                            OTHFOOD           6  other food
                            NONFOOD           7  nonfood products
                            FERT              8  fertilizer
                            TRACT             9 traction eg tractors zebu etc /

        I(C)   all commodities less inputs
                          / RICE, CGRAIN,  ROOTTUB, CASHCRP,
                            LIVESTK, OTHFOOD, NONFOOD          /

        F(I)   food products less livestock
                          / RICE, CGRAIN,  ROOTTUB, CASHCRP,
                                     OTHFOOD                   /

        L(I)   livestock  / LIVESTK /

        NF(I)  nonfood products
                          / NONFOOD /

        IN(C)  inputs                / FERT, TRACT /

        CS(F)   seasonal commodities
                          / RICE, CGRAIN,  ROOTTUB /

        CY(C)   annual commodities
                          / CASHCRP, LIVESTK, OTHFOOD,
                            NONFOOD, FERT, TRACT  /

        IA(I)  food products only
                          / RICE,  CGRAIN,  ROOTTUB, CASHCRP,
                            LIVESTK, OTHFOOD                   /

        IM(C)  importable products
                          / RICE, NONFOOD, FERT /

        IX(C)  exportable products
                          / CASHCRP /

        MN(IN) importable inputs     / FERT /

        DN(IN) non importable inputs / TRACT /

        H      households /   URBRICH
                              URBPOOR
                              RURRICH
                              RURPOOR  /

       UH(H)   urban hh   / URBRICH, URBPOOR  /
       RH(H)   rural hh   / RURRICH, RURPOOR /
```

2.3.1 Price Block

$$PP_{c,h} = \frac{PC_{c,h,1}}{1 + MARG_c} \qquad (1\text{-}36)$$

$$PX_{ix} = \frac{\overline{PW_{ix}} * er}{(1 + RMARG_{ix})} \qquad (37)$$

$$PC_{ix,urbrich,1} = PX_{ix} * \left(\frac{1 + MARG_{ix}}{1 + IMARG_{ix}} \right) \qquad (38)$$

$$PM_{im} = \overline{PW_{im}} * er * (1 + RMARG_{im}) * (1 + tm_{im}) \qquad (39\text{-}41)$$

$$PC_{im,urbrich,1} = PM_{im} * (1 + IMARG_{im})(1 - isub_{im}) \qquad (42\text{-}44)$$

$$PC_{c,urbrich,2} = PC_{c,urbrich,1}(1 + STCOST_c) \qquad (45\text{-}53)$$

$$PC_{c,rurrich,t} = PC_{c,urbrich,t} * (1 + INTMARG_{c,t}) \qquad (54\text{-}71)$$

$$PC_{c,urbpoor,t} = PC_{c,urbrich,t} \qquad (72\text{-}89)$$

$$PC_{c,rurpoor,t} = PC_{c,rurrich,t} \, . \qquad (90\text{-}107)$$

$$PINDEX_h = \sum_i \sum_t \left(pcwt_{i,h,t} * \frac{PC_{i,h,t}}{PC0_{i,h,t}} \right) \qquad (108\text{-}111)$$

2.3.2 Supply Block

$$\log(SH_{h,f}) = \alpha^{s}_{h,f} + \sum_{ff} \beta^{s}_{h,f,ff} \log(PP_{ff,h}) \quad (112\text{-}131)$$

$$\log(YLD_{h,f}) = \alpha^{y}_{h,f} + \beta^{y}_{h,f,f} \log(PP_{f,h}) + \sum_{in} \gamma^{y}_{h,f,in} \log(PC_{in,h,2}) \quad (132\text{-}151)$$

$$HSCR_{h,f} = area_0 * SH_{h,f} * YLD_{h,f} * \overline{(1 - loss_f)} * \overline{conv_f}\ . \quad (152\text{-}171)$$

$$SCR_f = \sum_h HSCR_{h,f} \quad (172\text{-}176)$$

$$\log(HSLV_h) = \alpha^{l}_{h} + \beta^{l}_{h,l,l} \log(PP_{l,h}) \quad (177\text{-}180)$$

$$SLV = \sum_h SLV_h \quad (181)$$

$$\log(HSNF_h) = \alpha^{nf}_{h} + \beta^{nf}_{h,nf,nf} \log(PP_{nf,h}) \quad (182\text{-}185)$$

$$SNF = \sum_h HSNF_h \quad (186)$$

2.3.3 Input Demand Block

$$\log(HDIN_{h,in}) = \alpha^{f}_{h} + \sum_f \beta^{f}_{h,f,in} \log(PP_{f,h}) + \gamma^{f}_{h,in} \log(PC_{in,h,2}) \quad (187\text{-}194)$$

$$DIN_{in} = \sum_h HDIN_h \quad (195\text{-}196)$$

2.3.4 Consumption Block

$$\log(HC_{h,i,t}) = \alpha^{h}_{h,i,t} + \sum_{j} \beta^{h}_{h,i,j,t} \log(PC_{j,h,t}) + \gamma^{h}_{h,i,t} \log(YH_{h}) \qquad (197\text{-}252)$$

$$CONS_{i} = \sum_{h} \sum_{t} HC_{h,i,t} \qquad (253\text{-}259)$$

2.3.5 Income Block

$$YHAG_{h} = \sum_{f} (PP_{f,h} * SCR_{h,f}) + (PP_{l,h} * SLV_{h,f}) - \sum_{in} (PC_{in,h} * DIN_{h,in}) \qquad (260\text{-}263)$$

$$YH_{h} = YHAG_{h} + \overline{YHNAG_{h}} * PINDEX \qquad (264\text{-}267)$$

2.3.6 Equilibrium Conditions

$$SCR_{f} + M_{f} = CONS_{f} + \overline{FEED}_{f} \qquad (268\text{-}272)$$

$$SLV_{l} = CONS_{l} \qquad (273)$$

$$SNF_{nf} + M_{nf} = CONS_{nf} \qquad (274)$$

$$M_{mn} = DIN_{mn} \qquad (275)$$

$$\overline{SDIN}_{dn} = DIN_{dn} \qquad (276)$$