May 26, Tues, 1 ll
Brown Bag mtg – SA-18 Rm 520 12-1:00 pm

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A MODEL OF THE EFFECT OF A FERTILIZER SUBSIDY ON INCOME DISTRIBUTION AND EFFICIENCY IN MALAWI[1]

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Abstract

This paper develops a 32 equation model which describes the effects of changing the subsidy on smallholder fertilizer on prices, production and real incomes in Malawi. In the process, it shows how to develop and analyze a simple, linearized, highly aggregated, policy-oriented, computable general equilibrium model. We find that the smallholder sector benefits from the subsidy, while those in the estate sector and in the industrial sector lose; within the smallholder sector large landholders benefit while landless workers incur slight losses.

A. Introduction

In this paper we present a 32 equation model which describes the effects of changing the subsidy on smallholder fertilizer on prices, production, and incomes in Malawi. The model is a simple one that focusses only on the most important interactions. This reflects the view that in model building the best strategy is to

[1] An earlier version of this paper was contained in a report which was written for USAID in Malawi in May 1987. The authors are grateful to Ohad Bauernfreund, Tobias S. Chinkhwangwa, Christina Gladwin, Tom Loo, Sudhir Shetty and Peter Wyeth for helpful comments.

start by building the simplest model that will do the job,[2] so that all concerned can understand what assumptions are being built into the model, and hence why it generates the conclusions that it does. Only after basic agreement is achieved on how the economy works, and what questions are important does it make sense to extend the modeling effort.

This model is a tool designed to help understand the effect of the fertilizer subsidy on the Malawian economy. Like any other model its results must be understood as being the product of the assumptions built into it. Some of these are no more than educated guesses about parameter values, and others are likely to be controversial, reflecting as they do the world view of the modelers. Having said this, we proceed to study the construction of the model, the results it generates and the conclusions which follow. Then we discuss how changing assumptions would have affected the results.

B. An Overview of the Model and An Introduction To The Philosophy of Building Simple Computable General Equilibrium Models

The model consists of the linear equations generated by differentiating a non-linear economic model. Specifically, we developed a 32 equation system to describe the Malawian economy,

[2] On the "tension between theoretical simplification and empirical realism" in model building see the section on "Analytic, Stylized, and Applied Models" in Robinson (forthcoming). Robinson would characterize the model presented here as a "stylized numerical model."

and differentiated it, in order to have a set of 32 linear equations in 32 endogenous variables. These are the changes in the Malawian economy that are responses to the changes in the 2 exogenous variables. The most important exogenous variable is the change in the fertilizer subsidy. We assumed that the subsidy was financed by an increase in the value added tax. Consequently, we were curious to know the marginal welfare cost of an increase in the value added tax, so we included an autonomous shift in the need for real government revenues as a second exogenous variable. We specified both the endogenous and exogenous variables as proportional changes, so that all variables are dimensionless, which makes the results of the simulations easier to interpret.

There is, incidently, a distinction between a linearized model of this sort and the old-fashioned linear models that assume fixed proportions in production and consumption and use linear programming to solve. Our linearized model does not assume fixed proportions and is solved by simple matrix inversion and matrix multiplication using the "Lotus 123" program on a personal computer. One goal of this exercise is to demonstrate that modeling efforts using this technique need not require a great deal of work and can provide useful insights into the policy making process. Thus, we regard this simplicity as an important virtue.[3]

[3] In fact after we had decided on the basic structure of the model, it took one of us less than two days to develop the precise equations, calibrate the model for an initial set of runs

The model, which is illustrated schematically in Figure 1, contains 3 sectors. The smallholder sector uses labor, fertilizer and a fixed amount of land to produce agricultural output. The estate sector uses labor and a fixed amount of land to produce agricultural output which is identical to the output of the smallholder sector.[4] The third sector encompasses all other economic activity, which we label the industrial sector, and it is assumed to use a fixed capital stock in combination with labor and imports to produce industrial output.

In all sectors we assume constant returns to scale and that factor proportions used depend on relative prices. We assume that all actors in the model are perfect competitors in product and factor markets. Labor is assumed to be perfectly mobile between the smallholder sector and the estate sector, working for whomever pays it the best wages. This implies that landholders will choose the mix of working their own land and the land of

and to debug the results, even though neither of us had used the Lotus 123 program before. For discussion of the construction of more sophisticated linearized models see Dixon, Parmenter, Sutton and Vincent (1982). A catalogue of documents on linearized modeling as applied to Australia is available free of charge from The Impact Project Information Officer, Mr. Mike Kenderes, Industries Assistance Commission, P.O. Box 80, Belconnen, ACT 2616, Australia. Of particular interest is software, recently developed by the project, called GEMPAC, which facilitates linearized modeling. This is available from Dr. Ken Pearson, Impact Research Centre, The University of Melbourne, 153 Barry Street, Carlton, Victoria 3053, Australia.

[4] For our purposes it did not seem worthwhile to disaggregate the products produced by the two agricultural sectors. We argue that by suitably reallocating the factors of production from one agricultural commodity to another, the agricultural sectors can transform one commodity into another at roughly constant rates.

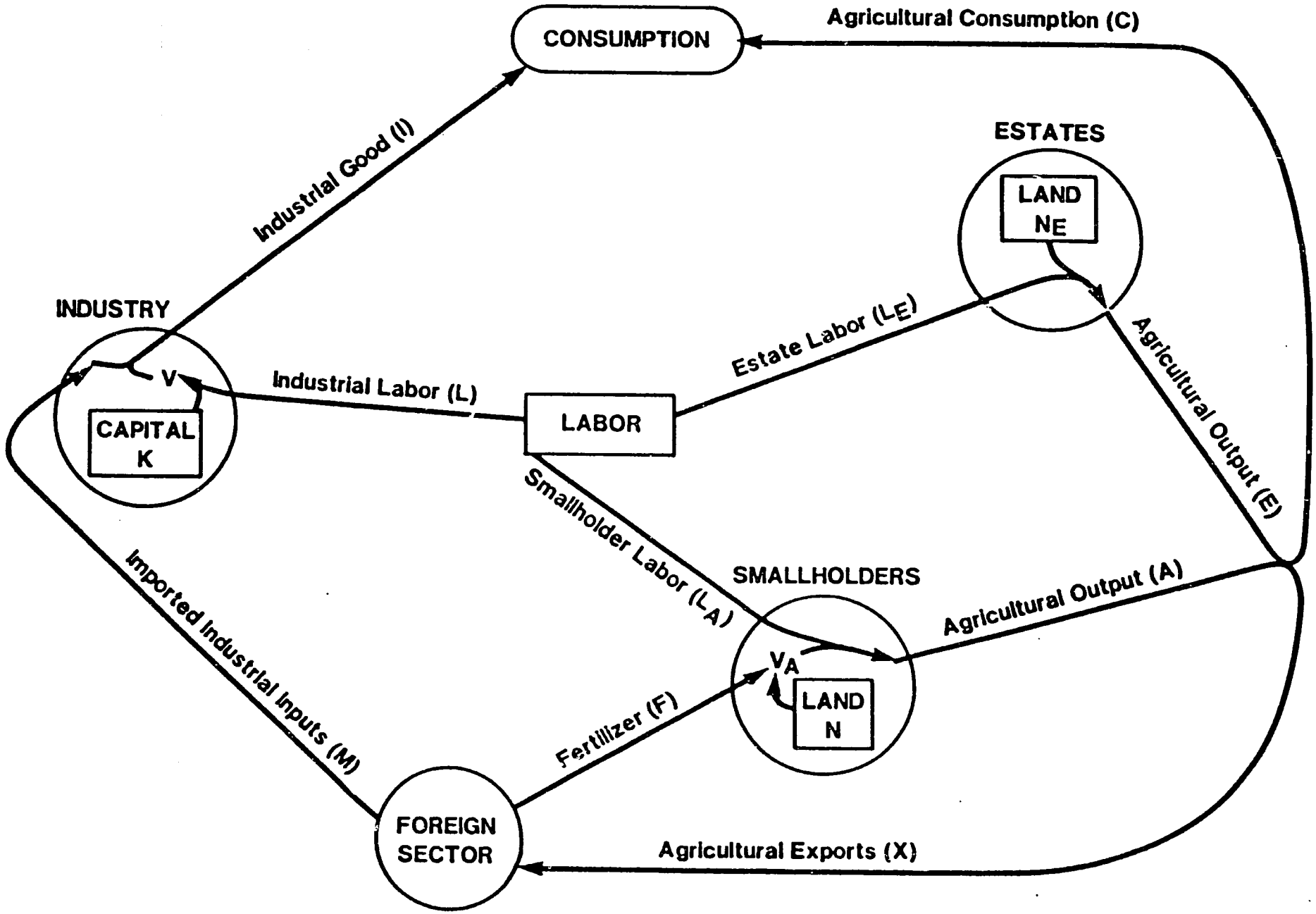

Figure 1. A Schematic View of the Malawian Economy

others which yields the highest income. Thus the wage rate in the two sectors will be driven to equality. However, labor is assumed to be imperfectly mobile between agriculture and industry, moving between these sectors only in response to changes in relative wages.[5]

There is no explicit taxation of the domestic sale of agricultural commodities. Also, there is no explicit or implicit taxing of agricultural commodities sold abroad by either the estate or smallholder sectors except for tobacco, the production of which is allocated by fixed quota, and any implicit tax imposed by Admarc's inefficiency.[6] Moreover, some private traders in agricultural commodities are being licensed to compete with Admarc in 1987. If properly implemented, this should force

[5] We assume that labor is homogeneous when defined in efficiency units. This along with the assumption that factors are paid their marginal products implies that a plant manager with a wage 40 times that of a laborer can do the same job that the 40 laborers do. This assumption is, of course, unrealistic, but it is a reasonable starting point. However, it is not as bad as it initially appears. One is not really assuming that it is possible to turn all farmers into plant managers. But one gets the same results as if it were, if it is possible to turn some farmers into grocery clerks, some grocery clerks into school teachers, some school teachers into salesmen, and some salesmen into plant managers, so long as the value of their marginal product in their initial activities and the activities which they move into are equal to their initial wages. In these circumstances, our mathematical modeling of the labor market will be legitimate.

[6] Our model assumes policies have been implemented which assure that the prices charged by Admarc (Malawi's agricultural marketing board) reflect the marginal cost of processing, sales and transport. If one assumes that Admarc's trading margins exceed its marginal costs of performing these activities, then there is an implicit tax on this set of Admarc's activities.

Admarc to lower any implicit taxes that exist. For all of these reasons, we assume that all agricultural commodities with variable production is sold free of tax or subsidy.

World market prices for all commodities are assumed to be fixed. This is because there is a perfectly flat foreign demand curve for Malawi's non-tobacco agricultural exports in the rest of the world, the export of tobacco is fixed, and the supply of Malawi's imports from the rest of the world is perfectly elastic. In our model, these imports are fertilizer and goods which are used in manufacturing.

We assume that a combination of variations in the money stock and flexible wages and prices serve to keep Malawi in balance -of-trade equilibrium, so that Malawi's exports of agricultural products just pay for its imports of fertilizer and intermediate inputs for industry.[7] These assumptions were designed to describe the Malawian economy as it might look several years from now. However, the answers the model would have provided if we had assumed that donor aid is maintained at current levels, so that the trade balance remains at its current level, would not have altered the results materially.

We ignore saving and investment in Malawi, assuming that all incomes are spent on consumption. Also, industrial and

[7] Instead of flexible wages and prices the reader can assume appropriate exchange-rate adjustment along with a fixed industrial money wage. Under this assumption all of the multipliers for changes in output, employment, real wages, real rentals and real incomes are unchanged, while changes in nominal variables are given in our tables when the change in the money wage in industry, calculated in the table is subtracted from them.

agricultural output are assumed to be consumed in the same proportions by everybody, with these proportions depending only on the relative price of the two commodities.

We assume that the foreign exchange shortage has already been solved in the sense that the exchange rate has already been adjusted so that the demand for foreign exchange has come to equal the supply without rationing. We make this assumption because we believe that such a situation reflects the goals of the Government of Malawi, and that the current foreign exchange rationing is a response to what is perceived as temporary adverse conditions.

We ignore any import tariffs, since a major study of tax reform for Malawi is currently being undertaken, and we believe that the study should recommend integration of the current import duties on imports with the current surtax regime, so that final consumer goods would pay a tax on the value that is created in the Malawian economy plus that embodied in intermediate inputs from abroad. The bulk of tax revenue in Malawi is raised by the tax on companies, the surtax on non-agricultural production, import duties, the surtax on imports, and personal income taxes collected from those in non-agricultural employment. For all these reasons we have modeled all tax revenue as arising from a proportional tax on the output of the industrial sector. Therefore, we assume only two government interventions in the Malawian economy: a fertilizer subsidy, and a tax on industrial production for domestic consumption. The latter is, in effect, a

uniform tax on labor, capital and imported inputs used in non-agricultural production.

We assume that the labor market adjusts to leave employment unchanged. This can be justified either if wages are flexible, or we suppose that the government adjusts the money supply and the exchange rate to make the demand for labor just equal to the quantity employed at the initial industrial money wage (see footnote 7).

All the data used come from the Ministry of Agriculture, the 1986 edition of the Financial and Economic Review of the Reserve Bank of Malawi, the September 1986 edition of the Monthly Statistical Bulletin and the Urban Household Expenditure Survey 1979/80 both of the National Statistical Office. The adjustments we made to the data are discussed in Appendix 2. The data are rudimentary. In particular, we had no input-output table.

To summarize, we have postulated a full-employment model, where labor moves between agriculture and industry in response to changes in the wage differential, the trade balance is kept in equilibrium and changes in the value added tax on the industrial sector are used to keep the budget in balance, and in particular to pay for any fertilizer subsidy. The model, data and "Lotus" spreadsheet are presented in the appendices. We now turn to the results of the simulations and an intuitive description of the mechanisms that generate them.[8]

[8] A methodological note on model building seems appropriate in order to specify what we believe the role of simple model building like this to be. Our model is not intended to be

C. The Simulation Results

Table 1 indicates the percentage increase in the variables of the model in response to the imposition of a 10% fertilizer subsidy, starting from an initial zero subsidy position. It should be remembered that the money stock is assumed to be automatically adjusted to maintain balance of trade equilibrium. Further, the government budget is balanced by assuming a change in the surtax on industrial production which balances the losses in real government revenues due to the increase in the subsidy.

Table 1. Policy Multipliers From the Model, Showing The Impact of a 10% Subsidy on Fertilizer Starting From a Base of Zero

definitive. Rather, it is designed to make some plausible guesses about the effects, and in particular the costs and benefits, of a changed fertilizer subsidy. Moreover, we believe that even a simple exercise like this one contributes real value to the debate, because every participant in the discussion over the fertilizer subsidy issue has an implicit model in mind, and these implicit models rarely have all of their assumptions spelled out or even figured out, and typically these conceptual models are much simpler than the one employed here. Also, at times these models are not even hypotheses about the linkages within the economy. Rather, they are simply hunches about the ultimate effects of a change in policy, lacking any well-articulated mechanism specified about how disturbances to the economy bring about these results. Thus, the sort of model developed here introduces more clarity into the conceptualization of the issues and generates some rough guesses about the sizes of the effects of a change in the fertilizer subsidy under one set of assumptions about how the economy behaves. Participants in the debate should then use these results to make more educated guesses than would otherwise have been possible about how the economy responds under alternative economic assumptions. This, we believe should be a common use of CGE model building in the policy process.

The change in

Consumer price of the industrial good.....+.79%
Producer price of the industrial good.....+.20%
Output of the industrial good.....-.23%
Imports of the intermediate input.....-.18%
The industrial wage.....+.39%
Industrial employment.....-.36%
Rental rate on industrial capital.....+.04%
Smallholder output.....+1.50%
Fertilizer imports for the smallholder sector.....+10.00%
Smallholder sector employment.....+.92%
Wage in the smallholder sector.....+.57%
Rental rate on smallholder land.....+2.00%
Net output of the estate sector[9].....-1.34%
Employment in the estate sector.....-1.91%
Rental rate on estate land.....-1.34%
Consumption of the agricultural good.....+.56%
Agricultural exports.....+1.45%
Aggregate real income or economic welfare[10].....-.053%
The surtax rate[11].....+.41%
Consumer price index.....+.61%
Real industrial wage.....-.22%
Real agricultural wage.....-.04%
Real rental rate on industrial capital.....-.58%
Real rental rate on smallholder land.....+1.38%
Real rental rate on estate land.....-1.95%
Real income of capital and labor initially in the industrial sector.....-.33%
Real income of land and labor initially in the smallholder sector.....+.39%
Real income of land and labor initially in the estate sector.....-.61%
The marginal efficiency cost of using a higher fertilizer subsidy to create increased employment in agriculture, defined as the incremental real income lost to the economy divided by the wages paid to the incremental agricultural worker as a result of an incremental increase in the fertilizer subsidy.....+57%
The marginal efficiency cost of using a higher fertilizer subsidy to create increased agricultural consumption of

[9] This is defined as the percentage change in the value of crops produced net of the value of fertilizer used by the estate sector, where values are calculated at world prices. Thus, it is the percentage change in foreign exchange earned by the estate sector.

[10] This is the standard measure of economic efficiency.

[11] This is defined as $dT/[1-T] * 100\%$ where T is the surtax rate on industrial output, expressed as a proportion of industrial sales at prices to consumers.

agricultural goods, defined as the incremental real income lost to the economy divided by the incremental increase in the value of agricultural consumption.....+43%

The marginal welfare cost of raising tax revenue in the model, defined as the ratio of the decrease in real income divided by the increase in real tax revenue due to an incremental increase in the industrial value added tax..+9.63%

The marginal efficiency cost of using a higher fertilizer subsidy to create increased real income for those initially in the smallholder sector.....+34%

Table 1 tells how a 10% increase in the fertilizer subsidy starting from zero affects the economy. The increased fertilizer subsidy makes smallholder agriculture more profitable, drawing labor into it from both the estates and industry, resulting in declines in both employment and output in those two sectors. The increased fertilizer subsidy results in increased fertilizer imports, which, combined with increased employment in the smallholder sector, results in increased smallholder output. Agricultural exports and agricultural consumption increase as a consequence. Wage rates throughout the economy are pushed up by the increased demand for labor in the smallholder sector. This, in combination with agricultural prices that are fixed by the world price, causes land rents in the estate sector to decline markedly. The increased labor and fertilizer used in the smallholder sector raises the marginal product of land there and consequently increases smallholder land rents. The higher tax on industry required to finance the fertilizer subsidy increases the wedge between the consumer and producer prices of the industrial good. Part of the wage hike in industry is passed on as a higher price for the industrial good, with rents to capital remaining virtually unchanged.

The fixed price of the agricultural good combined with the raised price of the industrial good raises the consumer price index. This rise in the cpi overcompensates for the money wage increase in agriculture, so the agricultural real wage falls slightly, shrinking the real wage in industry.

The largest winners are landholders in the smallholder sector. This is not surprising, because the intersectoral mobility of labor prevents the agricultural wage from changing very much. The greatest losers are the landowners in the estate sector, for they are squeezed by having to pay higher wages while selling output at the exogenously determined world price, and having to pay higher prices for the industrial products they consume.

Expressing gains and losses on a sector by sector basis, factors initially employed in the smallholder sector gain on average by the subsidy, while the factors initially employed in the other two sectors lose.

The most important message to emerge from this analysis is that raising the tax on industry to pay for the agricultural subsidy imposes efficiency costs on the economy that must be paid by someone. Consequently, the benefits won by landholders in the smallholder sector are more than offset by the losses to other factors of production. Finally, because agricultural labor loses slightly from the policy while smallholders find the yield on their land rises means that the larger smallholders will benefit from the program at the expense of the smaller smallholders. This is not consistent with use of the policy to improve the income distribution.

The model has been used to calculate several cost benefit ratios that reflect the concerns of Malawian policy makers. As Table 1 indicates using a fertilizer subsidy to create agricultural jobs or to increase agricultural consumption has a welfare cost attached equal to roughly half of the value of jobs or agricultural consumption created thereby, while using it to increase real income of those initially employed in the smallholder sector imposes an efficiency burden on the economy of roughly one third of the increased real smallholder real income.

Finally, the efficiency cost estimates hinge on our calculation of the marginal welfare cost of tax collection. Our model yields an estimate for this figure of 9.6%. As we discuss

subsequently, this is less than corresponding estimates for the U.S. and it might be reasonable to assume a figure twice or three times as large, which would multiply the corresponding cost benefit ratios by the same proportion and make the fertilizer subsidy seem less desirable than we have calculated it to be.

D. Efficiency, The Marginal Welfare Cost of Tax Collection, Inadequate Fertilizer Application in the Smallholder Sector, and The Optimum Fertilizer Subsidy

With regard to efficiency, recall that the model was designed so that the only distortion initially afflicting the economy was the tax on industrial output. This is because the fertilizer subsidy was initially zero, and farmers were assumed to apply fertilizer until the value of its marginal product equaled its price. Since we assumed away any distortions in the agricultural sector , the entire loss in efficiency due to the fertilizer subsidy arises from the need to raise taxes on industrial output to pay for it. We calculate the efficiency loss to be only .022% of GNP as a result of raising the fertilizer subsidy by 10%. This is because the model calculates a marginal welfare cost of using a higher surtax in order to raise additional revenue equal to 9.6%. An estimate by Charles Stuart(1984) puts this ratio for the United States at 24.4%. The U.S. has a reasonably efficient tax system. Thus, it seems that the administrative and efficiency costs of raising tax revenue in Malawi should be at least as high unless the tax reform is

particularly successful.[12]

However, had we assumed that farmers apply a suboptimum amount of fertilizer, due to lack of knowledge or inadequate credit facilities, we would have concluded that there would be a net gain in efficiency from an increase in the fertilizer subsidy, so long as the value of the increased net output of the agricultural sector (i.e. the value of the extra output produced minus the value of the extra fertilizer used) exceeds the incremental value of the subsidy disbursed.[13] In fact, as the following footnote shows, a small subsidy to fertilizer will increase economic efficiency so long as the elasticity of demand for fertilizer multiplied by the proportion by which the value of the marginal product of fertilizer exceeds its price to farmers (due to lack of knowledge and inadequate credit facilities) is greater than the marginal welfare cost of collecting taxes to finance the subsidy. Thus, for example, if the efficiency cost of collecting additional tax revenue is 25% of the amount of tax revenue collected, and if farmers use fertilizer only up to the point where the value of its marginal product exceeds its price

[12] There are three reasons why our estimate was low. First, our model was highly aggregated and ignores the distortions which the tax system imposes on the allocation of resources between subsectors. Second, we ignored the fact that higher taxes induce the substitution of nonmarket for market activity, which is a major component of standard estimates of the marginal welfare cost of taxation. Third, we ignored certain complexities of any tax system which is likely to be developed, including the administrative cost of tax collection.

[13] In this analysis the employment in agriculture of all other intermediate inputs is assumed to be constant.

to them by 25%, and if the elasticity of demand for fertilizer is 1, on efficiency grounds the optimal subsidy is zero and we should be almost indifferent between a small subsidy and no subsidy at all.

For higher elasticities of demand, lower marginal welfare costs of tax collection, and higher margins between the value of the marginal product of fertilizer and its cost, a subsidy would be appropriate. Building further along these lines, it is easy to show that the optimal subsidy on efficiency grounds is given by

$$s = [D - (T/E)]/[1 + T]$$

where s is the subsidy rate expressed as a fraction of the price of fertilizer to farmers, D is the proportion by which the value of the marginal product of fertilizer exceeds its price to farmers, T is the marginal welfare cost of tax collection, and E is the elasticity of demand for fertilizer, defined to be non-negative.[14] Thus if D were 48.5%, the marginal welfare cost of

[14] This formula is derived as follows.

$$dNB = dB - dC$$

where dNB is the net benefit of a change in the subsidy, dB is the change in the benefit associated with more fertilizer use and dC is the welfare cost of increased tax collection needed to finance the increase. We measure the change in benefits as

$$dB = VMP * dF - PW * dF$$

where VMP is the value of the marginal product of fertilizer, PW is the world price of fertilizer and dF is the change in

tax collection were 35% and the elasticity of demand for fertilizer were 1, the optimum subsidy on fertilizer use would be 10%. If one accepts Christina Gladwin's estimate that the value of the marginal product of fertilizer in smallholder agriculture exceeds the price of fertilizer to farmers by a factor of 2, this formula would imply an optimum fertilizer subsidy of 177% of the price to farmers, which is equivalent to a subsidy of 64% of the world price. Finally, if one believes that the distortion in the use of fertilizer will be cured by improvements in the credit market, the optimum policy is a 26% tax on fertilizer use.

E. An Efficient Tax Package for Financing The Fertilizer Subsidy

fertilizer usage. We measure the change in costs as

$$dC = T * dS$$

where dS is the change in the value of the subsidy disbursed. Since

$$dS = -F * dP + [PW - P] * dF$$

where P is the price of fertilizer to farmers, we can combine these 4 equations to solve for dNB. The optimum fertilizer subsidy is that which equates the derivative of NB with respect to the fertilizer subsidy to zero. Defining the elasticity of demand for fertilizer as $E= -[dF/F]/[dP/P]$ (so that it is positive, defining D as $[VMP - P]/P$ and defining s as $[PW - P]/P$, we get the formula given in the text.

Incidently, all of our analysis both in this footnote and in the model itself has ignored the problem of the leakage of subsidized fertilizer to the estate sector. Taking this into consideration would reduce the optimum subsidy. Also, we have aggregated all agricultural output, which ignores crop-specific differences in yield responses to fertilizer application. Thus we have failed to recognize the fact that the fertilizer subsidy distorts the mix of agricultural output. In the neighborhood of a zero subsidy, this causes no problem, but in calculating the optimum fertilizer subsidy this should be reckoned with.

We have argued that the figure we have used for the marginal welfare cost of revenue collection is a reasonable one. But the marginal welfare cost of tax collection will vary from tax to tax. A tax on pollution has a negative welfare cost of tax collection, so long as higher taxes mean more revenue. Similarly, to replace the current system of administrative allocation of foreign exchange with an auction system would yield revenue and at the same time would allocate foreign exchange to its most highly valued use while liberating the foreign exchange allocators to do other tasks. Thus the marginal welfare cost of collecting taxes in this way is negative. Similarly, allocating tobacco quotas by auction, or equivalently, setting the price of tobacco to farmers low enough to induce them to grow and export the appropriate amount without recourse to quotas would enhance efficiency and simultaneously raise revenue. It enhances efficiency from Malawi's standpoint, because it prevents the flooding of the foreign market and keeps the world price up just as the current system does, but additionally it would assure that those farmers with a comparative advantage in tobacco growing end up growing it. Thus here is yet another tax with a negative welfare cost of tax collection attached. This discussion implies that the fertilizer subsidy would be more attractive if it could be granted as part of a package which increases the efficiency of tax collection.

Since the fertilizer subsidy benefits agriculture, it might

be possible to use it as justification for the imposition of an increased tobacco export tax or for the auctioning of tobacco growing quotas. Such a proposal has appeal from a political economy standpoint as well. If the subsidy is financed by a tax on industry, then one sector would advocate the taxation of another one, and the subsidy will emerge if and only if agriculture is more politically powerful than industry is. However, if agriculture is taxed to finance an agricultural subsidy, the costs and benefits of the subsidy would be located within the same sector and to some extent within the same economic units. This seems to us to be equitable and to be more likely to yield an appropriate result without conflict between ministries. Moreover, confining the tax and subsidy to a smaller number of concerned individuals, many of which are likely to gain on the one hand and lose on the other, will give the individuals involved a better incentive to become well informed. This implies that the policy which increases net social welfare is more likely to be enacted. Of course some asymmetries in costs and benefits will still exist to the extent that tobacco growers who have initial allocations of tobacco quotas will bear the cost while users and potential users of fertilizer in the smallholder sector will reap the benefits.[15]

[15] Sudhir Shetty has noted that we ignore pan-territorial pricing of both fertilizer and agricultural crops. He suggests that a fertilizer subsidy tied to transport costs (e.g., as a given proportion of fertilizer prices inclusive of transport costs) might be a reasonable alternative to pan-territorial pricing if regional equity is an objective.

F. Conclusion

We have established that the smallholder fertilizer subsidy, when financed by a tax on industry, benefits the smallholder sector at the expense of the rest of the economy. Obviously, the benefits of the subsidy to smallholder agriculture do not come without costs elsewhere, and these costs should be fully reckoned with in any debate over the issue. The precise gainers and losers will often be hard to identify, but broadly speaking, the further away from the smallholder sector an individual is and the closer he or she is to a sector which is taxed to pay for the subsidy, the more likely he or she is to lose from the subsidy.

In our computer modeling we assumed that farmers use the amount of fertilizer which maximizes their expected profits at a discount rate which approximates the social cost of capital to the economy, so there was no need for the fertilizer subsidy. If, on the other hand, smallholders use a suboptimum amount of fertilizer due to lack of knowledge or inadequate credit facilities, as the formula for the optimum fertilizer subsidy developed above indicates, a case can be made on efficiency grounds for a smallholder fertilizer subsidy, although it is second best to education or the development of a more effective

credit market. However, if the resource costs of correcting the imperfections in knowledge or credit exceed the inefficiencies of collecting revenue and disbursing it via a fertilizer subsidy, a subsidy may be the best policy. Ideally, a whole arsenal of policy weapons should be used to correct the distortions in the smallholder sector up to the point where marginal benefits equal marginal costs, but as this exercise emphasizes, using every weapon entails some cost.

Appendix 1: Specification of the Model

The model consists of the following equations. We start with equation 2 and number them successively through 33 in order to maintain the correspondence with the "Lotus" spreadsheet presented in Appendix 3. Each equation is presented followed by the definition of its variables, presentation of relevant parameter values and discussion of the its underlying logic.

We postulate a uniform value added tax on industrial output which is levied on the value added by primary factors of production as well as intermediate inputs, all of which are assumed to be imported. Thus, the value added tax is effectively a sales tax, the initial value of which we take to be 30%, because a tax of roughly that rate will be required to balance the budget. Thus we have $[1-t]p_c = p$, where p_c and p are, respectively, the consumer and producer prices of the industrial good. In differential form this gives us:

(2) $$\hat{p}_c - (\widehat{1-t}) = \hat{p}$$

where a hat, "^" , denotes a proportional change in the hatted variable.

(3) $$\hat{I} = \theta_M \hat{M} + [1 - \theta_M]\hat{V}$$

where I is industrial output, θ_M is the share of industrial

output paid for imports of intermediate inputs, M is the level of imports (all of which are assumed to be intermediate inputs used in industry), and V is the "value added aggregate in industry" which is a fictitious good produced by capital and labor. This equation follows from the assumption that I is a variable proportions, constant-returns-to-scale function of M and V.[16] The same logic applies to equations 5,9,11 and 15.[17]

$$(4) \qquad \hat{p} = [1 - \theta_M]\hat{p}_V$$

where p_V is the price of industrial value added. This equation follows from the assumption that M and V are combined with constant returns to scale to produce industrial output and that the price of imports is fixed by the fixed world prices of all traded goods and the maintenance of free trade at a fixed exchange rate. Similar logic underlies equations 6,10,12 and 16.[18]

$$(5) \qquad \hat{V} = \theta_L\hat{L}$$

[16]The mathematics of all of the equations in this appendix are explained in the chapter supplements of Caves and Jones (1985) and in Tower (1984, Chapter 2).

[17]The idea is that with constant returns to scale and variable proportions in production, the proportional change in the output quantity will equal the sum of the share-weighted proportional changes in the input quantities.

[18]The idea is that with constant returns to scale, the proportional change in the output price will equal the sum of the share-weighted proportional changes in the input prices.

where L is labor employed in industry and θ_L is the share of wages in the price of industrial value added. This equation reflects the assumption that the capital stock is specific to industry and is fixed in size, combined with the fact that V is a constant returns to scale and variable proportions function of labor and capital inputs.

$$(6) \qquad \hat{p}_V = \theta_L \hat{w} + [1 - \theta_L]\hat{r}$$

where w is the industrial wage and r is the rental rate on industrial capital.

$$(7) \qquad \hat{M} - \hat{V} = \sigma \hat{p}_V$$

where σ is the elasticity of substitution between M and V in the production of I, which we assume to equal .25. Equation (7) follows from the definition of σ along with the fixity of the price of M.[19]

$$(8) \qquad \hat{L} = \sigma_V[\hat{r} - \hat{w}]$$

where σ_V is the elasticity of substitution between L and capital in the production of industrial value added, which we assume to

[19]The idea behind equations 7, 13, 14, 17 and 20 is that the elasticity of substitution between inputs is defined as the ratio of the proportional increase in the ratio in which they are employed to the proportional decrease in their relative price, combined with the simple calculus relationship that $[x/y] = x - y$.

equal 1.

$$(9) \qquad \hat{A} = \theta_{LA}\hat{L}_A + \theta_{VA}\hat{V}_A$$

where A is agricultural output of the smallholder sector, L_A is labor employed in the smallholder sector, θ_{LA} is the share of wages in smallholder output, V_A is the value added aggregate in smallholder agriculture which is a function of land and fertilizer input, and θ_{VA} is the share of payments for the value added aggregate in the value of smallholder output.[20]

$$(10) \qquad 0 = \theta_{LA}\hat{w}_A + \theta_{VA}\hat{p}_{VA}$$

where w_A is the agricultural wage which prevails in both the estate and smallholder sectors, and p_{VA} is the price of smallholder value added. This reflects the assumption that the price of agricultural output is fixed by constant world prices and a fixed exchange rate.

$$(11) \qquad \hat{V}_A = \theta_F\hat{F}$$

where F is imports of fertilizer, all of which is used in the smallholder sector and θ_F is the share of fertilizer in the production of smallholder value added. This equation reflects

[20]We modeled the smallholder sector in this way because a study the Australian fertilizer subsidy by the Australian Industries Assistance Commission argued that fertilizer is a closer substitute for land than for labor.

the fixed supply of smallholder land.

$$(12) \qquad \hat{p}_{VA} = \theta_F \hat{p}_F + [1 - \theta_F]\hat{n}$$

where p_F is the exogenously determined domestic price of fertilizer, which is equal to the fixed world price minus the subsidy on it, and n is the rental rate on smallholder land.

$$(13) \qquad \hat{L}_A - \hat{V}_A = \sigma_A[\hat{p}_{VA} - \hat{w}_A]$$

where σ_A is the elasticity of substitution between labor and smallholder value added in the production of smallholder output, which we assume to equal 1.

$$(14) \qquad \hat{F} = \sigma_F[\hat{n} - \hat{p}_F]$$

where σ_F is the elasticity of substitution between fertilizer and land in the production of smallholder value added aggregate.

We specified smallholder output to be a function of labor and a value added aggregate with the latter being a function of land and fertilizer, because fertilizer is generally understood to be a better substitute for land than for labor. We assumed a value for σ_F of 1.25 in order to yield an own-price elasticity of demand for fertilizer of 1 (as table 1 indicates) as this was the best estimate which we obtained from our econometric work, not presented here.

The fertilizer subsidy program in Malawi applies only to

smallholder agriculture. Since that was our focus, and we wished to keep the dimensionality of the model small, we ignored fertilizer input in the estate sector. Thus the estate sector was assumed to produce the same agricultural output using labor and land which was specific to the estate sector. Alternatively, we can think of E as the output of agricultural commodities net of fertilizer input in the estate sector, where one unit of net output is measured as that amount which trades for one unit of foreign currency on world markets.

$$(15) \qquad \hat{E} = \theta_{LE}\hat{L}_E$$

where E is the output in the estate sector, θ_{LE} is the share of labor in estate sector output, and L_E is labor employed in the estate sector.

$$(16) \qquad 0 = \theta_{LE}\hat{w}_A + [1 - \theta_{LE}]\hat{n}_E$$

where n_E is the rental rate of land in the estate sector. Like equation (10) the left hand side is zero, because the price of agricultural output is frozen by the constant exchange rate combined with the fixed world price of agricultural commodities.

$$(17) \qquad \hat{L}_E = \sigma_E[\hat{n}_E - \hat{w}_A]$$

where σ_E is the elasticity of substitution between the two factors in the estate sector, which we took to equal 1.

All agricultural output is either consumed or exported. Thus, $dC + dX = dA + dE$ which we can rewrite as

$$(18) \qquad C\hat{C} + X\hat{X} = A\hat{A} + E\hat{E}$$

where C is domestic agricultural consumption and X is agricultural exports.

Exports pay for imports of intermediate inputs into industry as well as imported fertilizer for the smallholder sector. Thus, $dX = dF + dM$ which can be rewritten as

$$(19) \qquad X\hat{X} = F\hat{F} + M\hat{M}.$$

$$(20) \qquad \hat{I} - \hat{C} = -e\hat{p}_C$$

where e is the elasticity of substitution between the two goods in domestic consumption, which we assume to be 1. This equation implies that all consumers have identical and homothetic preferences.

Labor is assumed to be perpetually fully employed, so $dL + dL_A + dL_E = 0$, which can be rewritten as

$$(21) \qquad L\hat{L} + L_A\hat{L}_A + L_E\hat{L}_E = 0.$$

$$(22) \qquad \hat{L} = \iota[\hat{w} - \hat{w}_A]$$

where ι is a positive constant, which we assume equals 2. This

reflects the assumption that labor moves between the agricultural and industrial sectors in response to changes in the wage differential between the two sectors, and that the elasticity of supply of labor to the industrial sector is 2.

(23) $$\widehat{cpi} = \Phi_I \hat{p}_c$$

where cpi is the consumer price index and Φ_I is the share of consumption expenditure which falls on the industrial good. This equation reflects the fact that the proportional change in the consumer price index is equal to the sum of the changes in the consumer prices of the various goods consumed weighted by the shares of consumption expenditure on each. This equation takes the simple form it does because the agricultural price is constant.

(24) $$\hat{w}_{real} = \hat{w} - \widehat{cpi}$$

which states that the proportional change in the real wage equals the proportional change in the money wage minus the proportional change in the consumer price index.

Equations (25) through (28) follow analogously:

(25) $$\hat{w}_{A_{real}} = \hat{w}_A - \widehat{cpi}$$

(26) $$\hat{r}_{real} = \hat{r} - \widehat{cpi}$$

(27) $\hat{n}_{real} = \hat{n} - c\hat{p}i$

(28) $\hat{n}_{E_{real}} = \hat{n}_E - c\hat{p}i$

where the left hand side variables are, respectively, the proportional changes in the real agricultural wage, the real rental on capital, the real rental on smallholder land, and the real rental on estate land.

(29) $\hat{y} = \Phi_I\hat{I} + [1 - \Phi_I]\hat{C}$

where y is the level of the economy's real income or welfare, and (29) follows from the definition of the change in real income as $dy = p_C dI + p_A dC$ where p_A is the price of the agricultural commodity.

The government adjusts tax rates to maintain constant real tax collections net of disbursement of the fertilizer subsidy. This adjustment is captured in:

(30) $\hat{R} - c\hat{p}i = d\{tp_C I + [p_F - 1]F\}/\{tp_C I + [p_F - 1]F\} - c\hat{p}i = \alpha$

where R is nominal tax revenue net of the fertilizer subsidy disbursement and α is an exogenous shift variable that takes on a value of .01 to represent a 1% increase in government revenue collections which is transferred back to residents. Incorporating α into the model enables us to calculate the marginal welfare cost of tax collection.

The proportional changes in real incomes of the factors initially employed in the three sectors are given by

$$\hat{y}_{I_{real}} = \theta_L \hat{w}_{real} + [1 - \theta_L]\hat{r}_{real} \tag{31}$$

$$\hat{y}_{A_{real}} = \beta_L \hat{w}_{A_{real}} + \beta_N \hat{n}_{real} \tag{32}$$

and

$$\hat{y}_{E_{real}} = \theta_{LE} \hat{w}_{A_{real}} + [1 - \theta_{LE}]\hat{r}_{real} \tag{33}$$

where the β's represent the shares of labor and land in smallholder incomes.

These equations are portrayed in the "Lotus" spreadsheet in appendix 3. As is indicated there, we assumed for each sector that the ratio of payments for labor services to payments for the fixed factor is .7, which corresponds roughly to production functions estimated for many industries in many countries.

Appendix 2: Data

The data sources are indicated in the text. We felt that the figures presented there underreported the true role of agriculture in the economy, and we have adjusted for this in the figures we have used. Our figures should be interpreted as reasonable guesses for what the Malawian national accounts will be after the tax reform proposals are put into effect in several years. Our data are admittedly weak. One of the purposes of the paper is to indicate the sort of analysis which could be accomplished if a more adequate social accounting matrix were available.

All national accounts figures are presented as percents of gross domestic product at factor cost.

Agricultural GDP* = 50.

where a "*" denotes "at factor cost."

Industrial (i.e. non-agricultural GDP* = 50.

Exports* = 25.

Imports* = 21.

Smallholder GDP* = (50)(256.2/321) = 40.

Estate sector GDP* = 10.

Imports of fertilizer*, all of which is used by smallholders = 4.

Industrial output* = 21 + 50 = 71.

Industrial output at market prices = 71/.7 = 101.43

Value added tax rate on industrial output expressed as a proportion of industrial output at market prices = 30%.

Labor's earnings in industry = .7×50 = 35.

Capital's earnings in industry = .3×50 = 15.

Labor's earnings in the smallholder sector = .7×40 = 28.

Capital's earnings in the smallholder sector = .3×40 = 12.

Labor's earnings in the estate sector = .7×10 - 7.

Land's earnings in the estate sector = .3×10 = 3.

Agricultural consumption = 4 + 50 - 25 = 29.

Share of consumption expenditure which is on the industrial good = Φ_I = 101.43/(101.43 + 29) = .778.

θ_M = 21/71 = .296.

θ_{LA} = 28/44 = .6364.

θ_F = 4/(4 + 12) = .25.

Appendix 3: The "Lotus" Spreadsheet

The "Lotus" spreadsheet that solves the model presented in Appendix 1 is presented in Table 2. Rows 2 through 33 correspond to the equations with the same numbers. Columns B through AG indicate the coefficients of the endogenous variables in the equation system, while the two columns labeled pf and revenue correspond to the two exogenous variables. Denoting the matrix of coefficients for the endogenous variables by Ω_1, the matrix of endogenous coefficients by Ω_2, and the column vectors of changes in the endogenous and exogenous variables by N and X

respectively, our model is described by $\Omega_1 * N = \Omega_2 * X$.[21] To solve the model we multiply through by the inverse of Ω_1 to yield $N = \Omega_3 * X$, where $\Omega_3 = \Omega_1^{-1} * \Omega_2$ is the matrix of policy multipliers, with the i,j^{th} element showing the impact of a unit change in the jth exogenous variable on the ith endogenous variable. This matrix is shown over the subtitle "policy multipliers for the realistic case" for the policy parameters presented in appendix 1. The same matrix is presented in the last two columns for the case of fixed proportions in smallholder agriculture and in consumption. This latter case was one whose qualitative results are intuitively derivable, so the calculation was performed as a check that our model correctly portrayed the economic mechanisms we wished to portray. Solving a model for special cases in this way is an essential part of debugging the full blown CGE model in any modeling exercise.

The parameter values used in the "realistic" case are sho;wn in the lower left hand side with the corresponding parameter values used in the fixed proportions case presented in the same rows but further to the right.

Note that the simulation performed was for a fertilizer price increase, so all of the signs were reversed when constructing the table. Also, in constructing the table, the decimal was moved one place to the right.

[21]This is the implementation of the ideas discussed on p. 35 of Tower (1984).

eqn.#	PI	P	I	M	V	W	L	PV	R	A	F	VA	PVA	LA	WA	H	E	LE	NE	C	X	Y	TAX	CPI	W*	WA*	R*	N*	NE*	YI*	YA*	YE*	PF	RVHU	PF	RVHU	PF	RVHU
2	1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.4	0	0	0	0	0	0	0	0	0	0	0	-0.07	0.33	PC	-0.051	0.39
3	0	0	-1	0.29	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.02	-0.1	P	0	0.00
4	0	-1	0	0	0	0	0	0.70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.022	-0.0	I	0	0.00
5	0	0	0	0	-1	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.017	-0.1	M	0	0.00
6	0	0	0	0	0	0.7	0	-1	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.025	-0.0	V	0	0.00
7	0	0	0	-1	1	0	0	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.03	-0.1	W	0	0.00
8	0	0	0	0	0	-1	-1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.035	-0.1	L	0	0.00
9	0	0	0	0	0	0	0	0	0	-1	0	0.36	0	0.63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.02	-0.1	PV	0	0.00
10	0	0	0	0	0	0	0	0	0	0	0	0	0.36	0	0.63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.00	-0.2	R	0	0.00
11	0	0	0	0	0	0	0	0	0	0	0.25	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.14	0.05	A	0	0.00
12	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0.75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.2	0	-1.00	-0.1	F	0	0.00
13	0	0	0	0	0	0	0	0	0	0	0	1	1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.25	-0.0	VA	0	0.00
14	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.2	0	0.100	0.09	PVA	1E-17	0.00
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.09	0.10	LA	0	0.00
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.05	-0.0	WA	0	0.00
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.19	0.12	N	-0.333	0.00
18	0	0	0	0	0	0	0	0	0	44	0	0	0	0	0	0	10	0	0	-29	-25	0	0	0	0	0	0	0	0	0	0	0	0	0	0.133	0.12	E	0	0.00
19	0	0	0	21	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	-25	0	0	0	0	0	0	0	0	0	0	0	0	0	0.191	0.17	LE	0	0.00
20	-1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.133	0.12	NE	0	0.00
21	0	0	0	0	0	0	35	0	0	0	0	0	0	28	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.05	0.23	C	0	0.00
22	0	0	0	0	0	2	-1	0	0	0	0	0	0	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.14	-0.1	X	0	0.00
23	0.77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0.005	-0.0	Y	0	0.00
24	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	0	0	0	0	0	0	-0.04	0.30	TAX	-0.036	0.27
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-1	0	-1	0	0	0	0	0	0	0	0	-0.06	0.25	CPI	-0.039	0.30
26	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	-1	0	0	0	0	0	0	0	0.021	-0.3	W*	0.0399	-0.30
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	-1	0	0	0	-1	0	0	0	0	0	0	0.003	-0.3	WA*	0.0399	-0.30
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	-1	0	0	0	0	-1	0	0	0	0	0	0.057	-0.4	R*	0.0399	-0.30
29	0	0	0.77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	-0.13	-0.1	N*	-0.293	-0.30
30	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.33	-1	0	0	0	0	0	0	0	0	-0.1	1	0.195	-0.1	NE*	0.0399	-0.30
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0.3	0	0	-1	0	0	0	0	0.032	-0.4	YI*	0.0399	-0.30
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0.3	0	0	-1	0	0	0	-0.03	-0.2	YA*	-0.060	-0.30
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0.3	0	0	-1	0	0	0.061	-0.2	YE*	0.0399	-0.30
34	PC	P	I	M	V	W	L	PV	R	A	F	VA	PVA	LA	WA	H	E	LE	NE	C	X	Y	TAX	CPI	W*	WA*	R*	N*	NE*	YI*	YA*	YE*	PF	RVHU	PF	RVHU	PF	RVHU
35	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AI	AJ	AK AL	AM	AN	AO	AP

36 0.25 sigma — 0.25 This matrix (2,PC) through 33,YE*) is defined as omega 1 in appendix 3, i.e. the [omega 2] Matrix of exogenous variables' coeff'nts — policy multipliers for the realistic case ([omega 1 inverse] *[omega 2]) — policy multipliers for fixed proportions in smallholder agriculture and in consumption

37 1 sigmaV — 1 matrix of endogenous variables' coefficients

38 1 sigmaA — 0 In the row and coluan lables *'s denote real variables.

39 1.25 sigmaF — 0

40 1 sigmaE — 1

41 1 consumption elasticity of substitution — 0

42 2 supply elasticity of labor to industry — 0

43 Col.B figures are used to derive multipliers in columns AL & AM.

44 Col.M figures are used to derive multipliers in columns AO & AP.

Figure 2. The "Lotus" Spreadsheet

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