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AGRICULTURAL INPUT SUBSIDIES IN MALAWI: GOOD, BAD OR HARD TO TELL?

Edward F. Buffie and Manoj Atolia

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I. INTRODUCTION

Agricultural input subsidies have been a source of controversy in Malawi for over forty years. The government of Malawi (GOM) started providing smallholders with subsidized fertilizer and maize seed at independence in 1964. Under this policy, the country achieved self-sufficiency in maize but made only limited progress in reducing rural poverty. The subsidies were phased out in the eighties as part of World Bank and IMF structural adjustment programs that sought to reduce price distortions and promote diversification of the rural economy. Elimination of the subsidies was quickly followed, however, by a food crisis and record maize imports. The aftermath was a prolonged period of confusion, disputes with and among donors, and erratic, ad hoc policy interventions. Input subsidies reappeared in the Drought Recovery Input Program of 1992/93, were suspended in 1994, restarted on a smaller scale in the Supplementary Input Program in 1995, and then suspended again in 1996/97. When maize production plunged despite good rainfall, the government launched the Starter Pack program to distribute free fertilizer and hybrid seed to 2.8 million households in 1998-2000. Maize production recovered, increasing 50%, but donors objected that the program starved the government of resources for badly needed investments in social and physical infrastructure, undermined private input delivery, and encouraged overdependence on maize. This led to yet another period of bizarre start-stop policies. Since 2003, three new programs have been introduced and the number of rural households receiving subsidized inputs has cycled widely from 1-2.8 million. The current Agricultural Input Support Program (AISP) is the most ambitious and expensive to date. In 2006/7 it distributed 179,000 metric tons of subsidized fertilizer and seed – three times as much as the Extended TIP program of 2003/4 – at a cost of 2.2% of GDP (2% after deducting donors' contribution). The program was associated with a dramatic increase in maize production that earned President Bingu Wa Mutharika the United Nations Global Creative Leadership Award and the first Food, Agriculture and Natural Resources Policy Network Food Security Policy Leadership Award (Minde et al., 2008).

President Mutharika's awards notwithstanding, there is still considerable disagreement between donors and the GOM about the efficacy of input subsidies and the right strategy for combating rural poverty. The government contends that AISP compensates for incomplete markets that prevent smallholders from investing in highly profitable Green Revolution inputs. Only three percent of smallholders have access to credit for purchase of agricultural inputs (Dorward et al., 2008), and marketing and distribution networks have yet to reach many rural areas. Consequently, before the introduction of AISP, sixty percent of smallholders did not purchase any fertilizer even though correct application of the input packs greatly increases maize yields. On this view, public provision of cheap fertilizer and hybrid seed does not distort the allocation of resources; rather it improves efficiency and enhances food security for the poor.

Critics acknowledge some of these points but argue that three decades of experience shows that the benefits of input subsidies are too small to pull poor smallholders out of poverty. In part this reflects administrative inefficiency: a large fraction of subsidies miss the target group and end up displacing commercial purchases on medium- and large-scale farms. The more general problem, however, is that the growth potential of maize is inherently limited (Rubey, 2003; Dorward et al., 2004). AISP and its predecessors have kept Malawi mired in a "maize poverty trap." In the long run, both economic development and the poor would be better served if the money spent on input subsidies were used instead to finance investment in infrastructure projects that promote growth in the more dynamic sectors of the economy, principally manufacturing and cash-crop agriculture. The poorest smallholders already rely on off-farm activities for 40-60% of their income. Opening a pathway out of poverty thus requires "livelihood diversification" and the creation of more and better-paying jobs outside of agriculture (Dorward and Kydd, 2003).

Our objective in this paper is to move past the dialogue of the deaf. To bring more clarity to the policy debate, we develop a dynamic general equilibrium model in which agricultural input subsidies can be directly compared with alternative anti-poverty strategies. The model features a full array of imports (intermediates, consumer goods, and capital goods), transport and distribution costs, sector-specific capital, public investment in physical infrastructure, production for own-consumption, and separate small and large-scale agricultural sectors. It is also firmly grounded in optimizing behavior. The general equilibrium dynamics for the economy emerge from the intersection of market-clearing conditions with the government budget constraint and the perfect foresight solutions to private agents' optimization problems.

We investigate the impact of a large AISP-type increase in input subsidies on GDP, food security, and real income of the poor. Not surprisingly, the grades on the report card depend on how the subsidies are financed, on the return on public investments that compete for scarce government funds, and on the size of the productivity gains smallholders reap from increased application of fertilizer + seed packs. In the case where lump-sum taxes increase to pay for the subsidies, all poor groups gain but private investment contracts and the long-run increase in GDP is not positive and significant unless the shadow price of fertilizer is five times as large as the market price. The results are distinctly less favorable when input subsidies crowd out infrastructure investment. Smallholders who derive most of their income from farming enjoy permanent, large gains, but positive effects on real output and income of unskilled labor are limited to the short/medium run; across steady states, GDP decreases 2-12% and the real unskilled wage falls 1-11%. An argument can still be made for input subsidies on the grounds that the gains for the poor may be large for 15+ years on the transition path. This requires, however, extremely large productivity gains from additional fertilizer use (a shadow price five times the market price) *and* relatively low returns (10% or less) on investment in infrastructure.

The rest of the paper is organized into six sections. In Sections 2-4 we discuss the model and how it was calibrated to the data for Malawi. Following this, Sections 5 and 6 examine the effects of input subsidies financed either by lump-sum taxes or by cuts in infrastructure investment. The final section revisits the policy debate, drawing on the results to evaluate the conflicting views of donors and the GOM.

2. THE MODEL

Table 1 collects the equations of the model and defines notation. Since our objective is to develop a tool for policy analysis, a certain amount of detail and complexity is unavoidable. Below we discuss the components of the model *seriatim*.

2.1 Sectoral Structure and Technology

There are five sectors: foodstuffs, export crops + other highly tradable agricultural goods, food processing, other manufacturing, and services. Manufactures and export crops (sectors b, x, and i) are pure traded goods, while services are entirely nontraded. Foodstuffs (maize, pulses + nuts, and root crops) fall into a gray area where trade is significant (especially in maize) but the price is set in the domestic market, with an Armington elasticity governing the degree of substitution between domestic output and imports. The assumption of imperfect tradability is motivated by the fact that internal maize prices fluctuate much more than world prices.

Private inputs consist of capital, skilled labor, unskilled labor, land, and imported intermediates. Per IFPRI's Social Accounting Matrix for 2004 (Thurlow et al., 2008), agriculture does not employ skilled labor and smallholders do not utilize capital. (See the discussion in Section 3. Smallholder capital does not carry enough weight in production to significantly affect the results.) All sectors incur transport costs and the food-processing industry buys raw materials from primary agriculture. Entrepreneurial talent, or some type of skilled labor with highly specialized, sector-specific human capital, is also an input in manufacturing. Inclusion of this variable safeguards against "unstable" supply responses in the model. Without it, relative price changes sometimes cause one of the two manufacturing sectors to shut down on the path to the new steady state.[1]

The input-output coefficients are fixed at k_j (j = a, b, x, i) for transportation services and at c for raw materials purchased by the food-processing sector. Elsewhere in the production functions, input groups are modeled as CES functions. In equation (1c), for example, the labor input L is a CES function of skilled and unskilled labor; at the next level up, labor, capital, and imported intermediates combine in another CES function. Infrastructure and learning externalities affect production like Hicks-neutral technical progress. Learning depends on capital accumulation (Arrow, 1962), which serves as a vehicle for the introduction of new technology. Spillovers from learning are confined to firms in the industry. Physical infrastructure, however, is a pure public good that enhances productivity in all sectors.

It will be noticed that there are five sectors but six production functions. The reason is that small and medium/large farms operate distinct production functions in the market for foodstuffs. This is the only sector where small and large farms compete head-to-head (Benin et al., 2008). Smallholders do not produce any export crops.[2]

2.2 Prices and Trade Taxes

Tobacco accounts for 50-60% of total exports. Most of the remaining 40-50% is spread across textiles, sugar, cotton, and tea. Imports comprise machinery and equipment, intermediate inputs, and a mix of agricultural and manufactured consumer goods (processed food and other manufactures).

Bringing output from the producer to the consumer entails marketing costs. These take the form of sj units of nontradable services per unit sold for final consumption. Depending on the spatial distribution of producers and consumers, the wedge sjPn may reflect either marketing + transport costs (in which case kj = 0) or just marketing costs. (See the discussion in Section 3.)

Equations (4a)-(4b) set the supply prices for private capital and infrastructure. All capital assets are assembled by combining structures with imported machinery in fixed proportions. Structures are built by construction firms using labor and imported intermediates. We choose units so that one imported machine is required to produce one capital good. When the model is calibrated, the higher cost share of construction in building infrastructure vs. factories is reflected in higher input-output coefficients for labor and intermediates.

2.3 Sectoral Factor Demands

Equations (5a)-(10c) employ cost functions to specify factor demands. We assume that firms view input prices as parametric, that technology exhibits constant returns to scale, that private capital stocks and land are sector-specific, and that skilled and unskilled labor earn the same wage in each sector. Since firm owners choose the path of the capital stock, equations (5a), (6a), (7a), etc. are not genuine factor demand equations. Rather they help to pin down the capital rental at each point in time. (This information is needed to solve the firm's intertemporal optimization problem. See the next section).

There are three different prices for fertilizer. P_h, P_{hg}, and P_{hs} denote, respectively, the market price paid by large farms, the subsidized price charged for fertilizer distributed to smallholders in AISP, and the *shadow price* of fertilizer in the smallholder sector. Since usage of fertilizer by smallholders is fixed exogenously in AISP, the shadow price enters the cost function. The difference between the shadow price and the world price (P_{hs} -1) measures the efficiency gain from application of the last ounce of fertilizer. The gain for the smallholder is $P_{hs} – P_{hg}$.

Equations (11) and (12) refer to the construction sector. Factor demands in this sector take a different form because input-output coefficients are fixed and the scale variable is investment instead of output. The terms $v(I_j/K_j – \delta)^2K_j/2$ capture adjustment costs incurred in changing the capital stock.

2.4 Agents, Capital Accumulation, and Intertemporal Optimization

The model is populated by unskilled labor, skilled labor, small farms, large farms, and capitalists. We combine unskilled labor and smallholders in a single poor agent who consumes all of their income each period. This is consistent with the data for Malawi. The poorest agricultural households that own less than one hectare of land receive 67% of income earned by unskilled labor (Wobst et al., 2004). The saving rate must be close to zero for this group as it derives only 1-2% of total income from capital (Wobst et al., 2004; Thurlow et al., 2008).

Skilled labor, capitalists, and owners of medium- and large-scale farms form a second agent.[3] The representative capitalist (short for capitalists + skilled labor + large landowners) chooses consumption and investment to maximize a time-separable utility function. Purchases of individual consumer goods are subsumed in the indirect utility function V(•) and capital accumulation is subject to increasing, strictly convex adjustment costs. The budget constraint includes rents $[(P_h - P_{hg})H_1]$ obtained on subsidized fertilizer + seed packs that village authorities "mistakenly" allocated to non-poor farmers. The rents are entirely inframarginal (i.e., subsidized inputs simply displace commercial purchases, leaving total purchases unchanged). Finally, equation (15) simply relates growth of the capital stock to net investment.

2.5 Preferences and Demand Functions

Preferences are described by three-tiered CES utility functions that allow for different degrees of substitution between domestic and imported foodstuffs (bottom tier), between processed and unprocessed food (middle tier), and between food, manufactures, and services (upper tier). The demand functions in equations (16a)-(16f) and (17a)-(17f) are retrieved via Roy's Identity $[D_j = (\partial V/\partial P_j)/\partial V/\partial E]$.

The poor differ from the rich in two ways. First, they spend much more on food relative to other items. (The exact consumer price indices for the two agents mirror the differences in their consumption baskets.) Second, they are net buyers of food, whereas the rich (a group that includes medium and large farms) are net sellers. This explains why the price of foodstuffs is different in the agents' indirect utility functions. Consider the budget constraint for the poor agent:

$$P_{ac}\underbrace{(D_{aw} - Q_g)}_{\substack{\text{net food}\\ \text{purchases}}} + P_{xc}D_{xw} + P_{ic}D_{iw} + P_{bc}D_{bw} + P_{aic}D_{aiw} + P_n D_{nw} = wL_u - P_{hg}H_g.$$

Move $P_{ac}Q_g$ to the right side:

$$P_{ac}D_{aw} + P_{xc}D_{xw} + P_{ic}D_{iw} + P_{bc}D_{bw} + P_{aic}D_{aiw} + P_n D_{nw} = wL_u + P_{ac}Q_g - P_{hg}H_g. \quad (1)$$

This leads to a standard indirect utility function, with aggregate expenditure E_w equaling income as defined on the right side of (1). Production for own-consumption by the poor implies that P_{ac} (the consumer price) multiplies Q_g. The logic is obvious: when an extra unit of own-production replaces maize purchased on the market, the saving in expenditure on foodstuffs equals $P_{ac}\Delta Q_g$.

In the case of the rich agent, production for own-consumption implies that the effective price of domestic foodstuffs is the producer price net of transport costs. The budget constraint of the rich agent is

$$P_{xc}D_{xc} + P_{ic}D_{ic} + P_{bc}D_{bc} + P_{aic}D_{aic} + P_nD_{nc} = (P_a - k_aP_n)(Q_a - D_{ac}) + (P_b - k_bP_n)Q_b \ldots$$

Move $(P_a - k_aP_n)D_{ac}$ to the left side:

$$(P_a - k_aP_n)D_{ac} + P_{xc}D_{xc} + P_{ic}D_{ic} \ldots = (P_a - k_aP_n)Q_a + (P_b - k_bP_n)Q_b \ldots \quad (2)$$

Income is defined in the normal way by valuing output at the net producer price. The net producer price is also the price in the indirect utility function because an extra unit of own-consumption reduces net sales, costing the agent $P_a - k_aP_n$.

2.7 Public Sector Investment and the Government Budget Constraint

The government collects revenue from tariffs and aid donors. It invests in infrastructure and pays out $(1 - P_{hg})(H_g + H_l)$ in the AISP. Lump-sum taxes/transfers balance the budget at the initial equilibrium.

Many policy instruments appear in equation (19). To maintain a tight focus, we limit the analysis to scenarios in which either lump-sum taxes or public investment adjusts to satisfy the government budget constraint. Analysis of these scenarios goes to the heart of the disagreement between donors and the GOM, suggesting answers to two key questions: (1) After general equilibrium effects play out, are input subsidies pro-poor and pro-development? (2) If input subsidies are desirable *per se*, do they remain desirable when purchased at the expense of investment in infrastructure?

2.7 Zero-Profit and Market-Clearing Conditions

The model is closed with the zero-profit conditions for producers and the conditions that demand equal supply in the markets for services, labor, and domestic foodstuffs.

Equation (26) is the national income accounting identity that the current account inclusive of aid equals zero. This is not an independent equation in the model. It is derived by aggregating the budget constraints of the private agents and the government.

3. REMARKS ON THE SPECIFICATION OF THE MODEL

The current formulation of the model imposes many restrictions: tariffs on intermediate inputs, tariffs on capital goods, the supply price of capital, and elasticities of substitution in production are the same in all sectors; expenditure shares differ but substitution elasticities are the same for rich and poor consumers; infrastructure is a pure public good used by all producers, etc. It is easy to relax these and other restrictions by adding subscripts to variables already in the model. We have not done so because we do not want to get lost in too much detail and taxonomy. Three variables drive the results and deserve the most attention in sensitivity analysis: (i) the spread between the shadow price and the world price of fertilizer (which determines the magnitude of the productivity gain on smallholder farms); (ii) the percentage of subsidized inputs sold to non-poor farmers (which merely displace commercial purchases, contributing nothing to productivity); and (iii) the return of public infrastructure investments that lose funding when input subsidies claim a larger share of government revenue.

It may also be worthwhile to defend more vigorously our decision to ignore capital accumulation in smallholder agriculture. As noted in the introduction, Malawi has experimented with numerous fertilizer + seed subsidy programs since independence. Many of the programs have been associated with large increases in maize harvests but none has triggered a perceptible increase in smallholder investment. The income share of capital on smallholder farms remains a paltry 1-2% (Wobst et al., 2004). The non-response of investment may reflect the extreme poverty of smallholders, the formidable barriers posed by small farm size and lack of credit, or the inherently ambiguous effect of fertilizer subsidies on the return to capital (the marginal product of capital increases, but the output price falls). Moreover, even if the model predicted a positive and unrealistically large response of investment, the small income share of capital means that the impact on smallholder income would be trivial. Abstracting from investment in smallholder agriculture is thus a useful and realistic simplification. The first-order effects on smallholder welfare are the effects on productivity, food prices, and unskilled wages. These are the effects tracked by the model and the effects judged to be most important by informed observers: "These changes centered around maize price impacts and ganyu [casual labor] supply and demand and wage rates. The interplay between the input subsidy programme, ganyu, maize prices and how these affect household livelihoods and well-being, and the wider rural economy came out strongly in the qualitative data, focus group discussions and key informant interviews." (Dorward et al., 2008, p.83)

4. CALIBRATION OF THE MODEL

Calibration of the model requires data on cost shares, elasticities of substitution, consumption shares, wage differentials, depreciation rates, sector shares in GDP, and marginal rates of return on infrastructure at the benchmark equilibrium. Once values are set for these parameters, all other variables that enter the model can be tied down by budget constraints, the first-order conditions associated with the solution to the private agents' optimization problems, and various adding-up constraints.

The values in Table 2 are based on a mixture of data and guesstimates. We discuss below the rationale for the value assigned to each parameter:

- *Sector shares in GDP*. Three of the six sector shares can be set directly. The others have to be derived residually within the model. Our calibration is based on IFPRI's 2004 Social Accounting Matrix, with sector shares calculated as a percentage of GDP net of public administration and financial services.[4] Production of foodstuffs is dominated by maize but also includes pulses, nuts, and root crops. Output of smallholders (sector g) equals production of these crops on small farms (< .75 ha) plus 25% of production on medium-sized farms (.75-3 ha).[5]

- *Consumption shares*. Consumption patterns differ sharply across different income groups. The shares in Table 2 are in line with the data in the 2004-05 Integrated Household Survey, IFPRI's 2004 SAM, and the expenditure weights in the rural CPI and the CPIs for low-, middle-, and high-income households.[6]

- *Factor (value added) shares*. IFPRI's 1998 SAM reports factor shares for small- and medium-scale producers of maize. We use this data to set factor shares for smallholders in sector g. The data source for factor shares in all other sectors is IFPRI's 2004 SAM. There is no data, of course, on rents earned by entrepreneurial talent in manufacturing. Our guess is that they account for 15% of profits.

- *Elasticities of substitution in production*. Estimates of the elasticity of substitution between capital and labor generally lie between .4 and 1. For LDCs, not much is known about substitution elasticities involving other inputs or about the degree of substitutability between skilled and unskilled labor. Absent such information, we set the elasticity of substitution at .50 in the main tier of the production function and at .75 in the tier for the composite labor input.

- *Marketing and transport margins*. The numbers for marketing + transport margins in the two agricultural sectors are the same as the guesstimates Conforti, Ferrari, and Sarris (2009). The 50% margin for export agriculture is high but plausible – Malawi is a landlocked country with poor transport infrastructure.

- *Time preference rate and the depreciation rate*. Across steady states, the return on private capital equals $\rho + \delta$ in all sectors. We set δ at .05 and assume private capital earns a net return of 10%. (The social return is higher when the learning externality operates.)

- *Elasticities of substitution in consumption*. We fix β_2 at .50 as estimates of compensated elasticities of demand tend to be small at high levels of aggregation, especially when food claims a large share of total consumption.[7] Higher value are assigned to β_0 and β_1 on the assumption that it is easier to substitute between different types of food than between food and other goods.

- *Intertemporal elasticity of substitution*. The assigned value of .29 equals the point estimate for Malawi in Ogaki, Ostry and Reinhart (1996).

- *Cost shares of labor and imported intermediate inputs in the production of capital goods*. The values for α_{k1}-α_{k3} [which map into the input-output coefficients a_{k1}-a_{k3} in equation (4a) in the model] are computed from data in IFPRI's SAM on cost shares in construction and domestic capital goods industries and from national income accounts data on the ratio of imported machinery to gross fixed capital formation. The values for α_{z1}-α_{z3} and α_{j1}-α_{j3} assume that physical infrastructure (e.g. roads) is built almost entirely by the construction sector.

- *q-elasticity of investment spending*. Evaluated at a steady state, the elasticity of investment with respect to Tobin's q (the ratio of the demand or shadow price of capital to the supply price of capital) is $\mathbf{\Omega} = 1/\delta v$, where δ is the depreciation rate and v is the parameter that determines adjustment costs to changing the capital stock.[8] There are no reliable estimates of this elasticity for LDCs. The assigned value of ten yields plausible dynamics.[9]

- *Initial rate of return on infrastructure*. The initial return on infrastructure 10-30%. Thirty percent is high, but there is plenty of evidence that the return on investment in roads and other types of physical infrastructure is of this order of magnitude in LDCs (Pohl and Minaljek, 1992; Fann, Thorat and Rao, 2003). The weak implementation capacity of local and central governments raises doubts, however, about whether projects that should yield a high return will actually yield a high return.[10] We also carry out runs therefore with a low return of 10%.

- *Wages*. The ratio of the skilled wage to the unskilled wage is consistent with the data for other African countries (e.g., Thurlow et al., 2004) and with the data in the Integrated Household Survey for 2004-05.

- *Initial trade taxes*. Malawi generally operates an open trade regime (although, from time to time, the government bans exports of sensitive food items). There are no export taxes or subsidies, and tariffs are less than 10%.

- *Fertilizer subsidies*. Dorward et al. (2008) contains a wealth of information about agricultural input subsidies. In keeping with the findings reported there, smallholders pay 28% of full cost and receive 65% of subsidized fertilizer + seed packs. The cost shares of fertilizer for smallholders and large farms are computed from data for 2004/5 on total fertilizer imports and the share of subsidized fertilizer distributed through the Extended

Targeted Input Program. In 2004/5 the fiscal cost of the input subsidies was a modest .5% of GDP. This figure surged to 2.2% of GDP when the government launched the AISP in 2006/7.[11]

- *Production for own-consumption*. The share of consumption met through own-production is residually determined. At the initial equilibrium, own-production accounts for 44% of consumption of foodstuffs by the poor agent (smallholders + unskilled workers). This is close to the figure cited in Dorward et al. (2008). Net sales of foodstuffs by the rich agent (which includes large farms, urban farms, and most medium-sized farms) counterbalance net purchases by the poor.
- *Miscellaneous parameters*. Lump-sum taxes are paid by the rich agent. To the best of our knowledge, there are no data or empirical studies suggestive of a ballpark value for η, the parameter that controls the elasticity of the return on investment in infrastructure. After ten seconds of reflection, we fixed η at .25. Ceteris paribus, therefore, public investment in physical infrastructure is subject to steep diminishing returns.

5. BEST CASE SCENARIO: AGRICULTURAL INPUT SUBSIDIES FINANCED BY HIGHER LUMP-SUM TAXES

AISP increased the supply of subsidized fertilizer by 334% from 2004/5 to 2006/7. In this section we analyze the effects of the program under the optimistic assumption that the increase in fertilizer subsidies is financed entirely by higher lump-sum taxes.

Table 3 shows the long-run percentage changes in the price of domestic foodstuffs (P_a), real wages, real income of the poor, real output, and the aggregate capital stock for alternative ratios of the initial shadow price of fertilizer to the world price. The runs in the upper panel assume, per the estimate in Dorward et al. (2008), that 35% of fertilizer subsidies miss the target group (smallholders who would not otherwise purchase fertilizer). In the lower panel, perfect marginal targeting ensures that all incremental sales go to smallholders. The column headed All Poor reports the percentage change in real income of smallholders + all unskilled workers (the representative poor agent in the model); the entries for Smallholders A-B pertain to smallholders who derive 36% or 60% of their income from wage employment.[12]

Scaling-up from Extended TIP to AISP greatly increases production by smallholders. Total supply of foodstuffs increases much less, however, because medium- and large-scale producers withdraw from the market as the price falls. Strong growth in labor demand on smallholders farms ($L_g \uparrow$ 18-48%) and at food processing plants ($L_x \uparrow$ 7-15%) bids up the wage for unskilled labor 1-2%. This and the fall in food prices increase real income of landless labor and nonagricultural unskilled workers 2-4%. The gains for smallholders are much larger (they incorporate the productivity gain and the transfer component of the subsidy), ranging from 11% to 32% for Smallholder A and from 7% to 22% for Smallholder B. Aggregate real income of the poor rises 3-9%. In the hypothetical scenario with perfect marginal targeting, these numbers increase to 13-41%, 9-28%, and 4-12%, respectively.

The short- and medium-run effects are qualitatively similar to the long-run effects. There are some important quantitative differences, however. Most notably, the price of foodstuffs, real GDP, and the real unskilled wage all overshoot their long-run equilibrium levels (see Figure 1). This reflects gradual capital decumulation on the transition path from the old to the new steady state. With capital stocks predetermined, all of the efficiency gains from increased fertilizer sales show up in real GDP at t = 0. Furthermore, while most of the increase in smallholder production occurs immediately, large farms adjust more slowly, lowering the capital stock and output in stages. Consequently, the price of foodstuffs drops twice as much at t = 0 as across steady states. Overshooting in the price of food in turn accounts for most of the overshooting of the real unskilled wage. (The nominal wage changes little on the transition path.)

6. WORST-CASE SCENARIO: INFRASTRUCTURE INVESTMENT DECREASES TO FINANCE AGRICULTURAL INPUT SUBSIDIES

It is not clear from the data which items in the government budget have adjusted to finance the AISP. Nevertheless, there is an undeniable tradeoff between input subsidies and public investment in social and physical infrastructure. Malawi is woefully short of roads, irrigation, communication facilities, power, and schools (World Bank, 2007; Government of Malawi, 2008). Any funds allocated to input subsidies could be spent instead on a long list of worthy infrastructure projects.

Shifting the burden of adjustment from lump-sum taxes to infrastructure investment does not cause problems in the short run. For a while, AISP delivers pro-poor growth (Tables 4-5, Figures 2-3). Food prices decline, and GDP, private investment, unskilled wages, and smallholder income all increase. And the immediate gains may be quite large: in the runs for $P_{hs} = 5$ and R = .30, GDP increases 2.5-3% at t = 0, while the real unskilled wage and aggregate real income of the poor jump 4-6% and 9-11%, respectively.

The long run is another matter. Decreases in the stock of infrastructure eventually lower the return on private investment and the equilibrium capital stock. Across steady states, the combined effects of less infrastructure and less private capital reduce GDP by 2-4% when R = .10 and by 6-12% when R = .20-.30. Equally disturbing, despite the large increase in smallholder output, total domestic production of foodstuffs *falls* in all ten of twelve runs where the initial return on infrastructure is high and in two of the runs where it is low. Input subsidies certainly enhance food security in the short run; in the long run, however, the link is very tenuous.

A similar caveat applies to the impact on poverty. All poor groups gain in the short run, but, over time, decreases in the stocks of infrastructure and private capital lead to lower labor demand and lower unskilled wages. Consequently, the long-run effect on the poor depends on the share of income derived from off-farm employment. Smallholder A always wins, landless laborers and nonagricultural workers always lose; the aggregate poor lose in all runs for R = .30, in four of the six runs for R = .20, and in the two runs where R = .10 and $P_{hs} = 2$.

Although the negative signs in Tables 4 and 5 are troubling, they do not by themselves refute the case for generous input subsidies. Much depends on the time horizon and one's priors as to the true values of P_{hs} and R. The gains in GDP and the real unskilled wage disappear after only 2-10 years in the runs where P_{hs} = 2-3 and R = .20-.30 (see Table 6). But when R = .10 and P_{hs} = 5, the positive signs last 16-18 years for GDP and 29-47 years for the real unskilled wage; moreover, the real income gains for smallholders – the poorest of the poor – are permanent and large. Input subsidies may have a place therefore in a broad-based program that deploys multiple instruments to fight poverty and promote growth. In essence, the subsidies help the poor today by borrowing against future growth. If the productivity gains from greater fertilizer use are very large and the return on infrastructure comparatively low, the borrowing occurs on favorable terms: sacrificing a small amount of future growth purchases large gains for the current generation of poor.

7. Concluding Remarks

In this paper we have analyzed how agricultural input subsidies affect poverty and economic development in a dynamic general equilibrium model fully grounded in optimizing behavior. Our results are not easy to categorize. They straddle views expressed by both supporters and detractors of input subsidies.[13]

The answer to the question posed in the title of the paper depends on the counterfactual. If elimination of fertilizer subsidies would merely increase government consumption or reduce taxes, then the subsidies should be maintained. They buy a substantial increase (17-41%) in smallholder income along with a small but significant rise (2-5%) in the real unskilled wage. GDP also increases one or two percentage points as long as fertilizer use is not pushed beyond the point at which its shadow price equals the world price.[14] The subsidies do all good and no harm.

The tradeoffs are more difficult to evaluate when revenues saved on subsidies are invested in productive infrastructure. In this case, long-run increases in GDP and real unskilled wages have to be weighed against losses suffered by smallholders (reverse the signs Tables 4 and 5). The tradeoff may be acceptable in a straight comparison of steady states, but the transition path is a problem. In the short run, GDP decreases and all poor groups lose. This phase lasts 20+ years when the shadow price of fertililizer is high (P_{hs} = 5) and the return on infrastructure is 10-20%. (Decreases in GDP are short-lived when P_{hs} = 2-3, but the adverse effect on poverty lasts 12-18 years.) Since the future gains are relatively small (1-3% for unskilled labor and 2-4% for GDP) and accrue to a country that should be significantly better off than today's Malawi, a present-value calculation with reasonable welfare weights for current and future generations would return a negative number. The subsidies are defensible, in other words, because they greatly improve the inter-generational distribution of income.

Our best guess is that the relevant counterfactual involves a nearly one-for-one tradeoff between subsidies and infrastructure investments that pay a high return on the order of 20-30%.[15] Defending the subsidies by appeal to inter-generational equity does not work in this counterfactual as the wait time for positive effects is “only” 3-9 years for GDP and 7-15 years for the real unskilled wage (see the upper panel in Table 6). But a recommendation from the welfare arithmetic to cut subsidies does not count for much given the other difficulties policy makers face. Two problems loom large. First, the increase in the real unskilled wage is sizable but not big enough to offset the loss in farm income for smallholders.[16] Reallocating funds from input subsidies to infrastructure investment thus redistributes income from smallholders to unskilled labor, the middle class, and the rich. Although the odds favor an increase in aggregate real income of the poor (the outcome in 10 of 12 runs for R = .20-.30), the GOM would probably be loath to endorse a policy package that has mixed effects on the poor, helping some and hurting others. Second, as Harrigan (2008) emphasizes, the GOM is more sensitive than donors to transition problems. The transition path with high infrastructure returns is considerably better than the transition path with modest returns, but it is still difficult to negotiate. Regardless of future benefits, most governments would not find it easy to sustain a reform that starts with 5-10 years of higher food prices, lower GDP, and lower real income for all poor groups.

Transfer payments can protect real income of smallholders, obviating the need to redistribute among the poor, and a policy package that reduces input subsidies slowly and increases infrastructure investment quickly can deliver continuously higher GDP and unskilled wages on the transition path. But these solutions cost money. Hopefully donors will recognize the government’s dilemma and be willing to do their part (i.e., write checks) to support reform.

NOTES

1. Absent sector-specific human capital, the two manufacturing sectors use the same list of inputs. Since output prices are fixed by world prices, changes in factor prices can drive the equilibrium capital stock to zero in one sector before reallocation has equalized returns. This causes technical problems because the structure of the economy changes abruptly at some point on the transition path to the new steady state. Sector-specific human capital resolves the difficulty: the two manufacturing sectors always survive, although one sector may become very small.

2. Only the bigger medium-sized farms produce tobacco and other export crops (Harashima, 2008). These are part of the large farm sector in the model.

3. The data support this grouping of agents: 66% of income from large farms flows to urban skilled labor households (Wobst et al., 2004).

4. Public administration and financial services account for 23.2% of GDP in the IFPRI SAM. The value-added shares in Table 2 are the shares in GDP – public administration – financial services- construction. (Hence they are larger than the sector shares in GDP.) The numerical results reported later include the contribution of construction to real output.

5. Many medium-scale farmers are very poor. It is important to distinguish, however, between medium-scale farmers who own .75-1.5 hectares and those who operate bigger plots. For purposes of the model, only medium-scale farmers who could not afford to buy unsubsidized fertilizer should be counted as part of the small-farm sector.

6. The data reported in Harrigan (2008) and the weights in the CPIs for rural households and for low-income households put the consumption share of food at 65-80% for the poor. This is a fair bit higher than the shares in the IFPRI SAM and the Integrated Household Survey for 2004/5. For three reasons, we decided to use a high value close to the CPI weights: (i) it agrees with the data for other African countries where per capita income is higher than in Malawi; (ii) in the model, consumption shares for the poor are computed at P_{ac} (see Preferences and Demand Functions in Section 2), whereas the actual data probably measure food produced for own-consumption at a lower price; and (iii) with a lower consumption share for food, the share of consumption accounted for by own-production is unrealistically small.

7. See Lluch et al. (1977, chapter 3), Deaton and Muellbauer (1980, p.71), Blundell (1988, p.35), and Blundell et al. (1993, Table 3b).

8. In each sector, the first-order condition for investment reads $[1 + v(I/K - \delta)]V_E P_k = \psi$, where ψ is the multiplier associated with the constraint $\dot{K} = I - \delta K$. Since ψ/V_E is the shadow price of K measured in dollars, $\psi/V_E P_k$ is effectively Tobin's q, the ratio of the demand price to the supply price of capital. Adopting this notation, we have that at a stationary equilibrium $v\delta\hat{I}/\hat{q} = 1$. Define $\Omega \equiv \hat{I}/\hat{q}$ to be the q-elasticity of investment spending. Then $v = 1/\delta\Omega$.

9. This is higher than most estimates for developed countries. There are good reasons to believe, however, that existing studies have substantially underestimated the q-elasticity of investment spending (Barnett and Sakellaris, 1998).

10. Policy makers acknowledge that implementation capacity is a potential problem (Government of Malawi, 2008).

11. Part of the increased cost owed to higher prices. The volume of subsidized fertilizer sales increased 334% (Dorward et al., 2008).

12. Different sources report/suggest different figures for the share of off-farm employment in total income of smallholders. Dorward and Kydd (2003) cite a figure of 65%, while the IFPRI SAM and Lofgren et al. (2001) report figures of 50% (approximately) and 36.5%. The share of wage income in farm + wage income for the poorest two quintiles is 36% in the Integrated Household Survey for 2004/5.

13. The large gains for smallholders in Table 3 agree with the view expressed by the Government of Malawi, Chirwa (2005), Dorward et al. (2008), and Benin et al. (2008) that input subsidies are highly effective in reducing smallholder poverty. The smallish numbers for the increases in GDP and the real unskilled wage in Table 2 and the large negative numbers in Table 3, however, support the criticisms voiced by Dorward et al. (2004) Wobst et al. (2004), and the donor community that a narrow focus on production of foodstuffs does not foster broad economic development or significantly help other poor groups.

14. Small positive numbers replace the small negative numbers for the impact on GDP in the runs for $P_{hs} = 2$ in Table 3 when the supply of subsidized fertilizer increases 200% instead of 300%. Also, once P_{hs} drops below the world price, smallholders gain more from direct transfers than from the input subsidy.

15. Limited implementation capacity of the central government and local governments may constrain the increase in infrastructure investment in the short run. All we see in this, however, is an argument for phasing-out subsidies slowly.

16. This statement is not entirely accurate. The run for $P_{hs} = 2$, $R = .30$, and inefficient targeting implies that Smallholder B would gain in the long run from a reallocation of subsidies to infrastructure investment.

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TABLE 1: THE MODEL

Sectoral Structure and Technology

$$Q_a = Min[N_a / k_a, \phi^a(Z, K_a) F^a(K_a, L_a, A_a, H_a)] \quad (1a)$$

$$Q_x = Min\{G(G_a, G_{ai})/c,\ N_x / k_x, \phi^x(Z, K_x) F^x[K_x, L(L_{sx}, L_x), H_x, S_x]\} \quad (1b)$$

$$Q_i = Min\{N_i / k_i, \phi^i(Z, K_i) F^i[K_i, L(L_{si}, L_i), H_i, S_i]\} \quad (1c)$$

$$Q_n = \phi^n(Z, K_n) F^n[K_n, L(L_{sn}, L_n), H_n]\} \quad (1d)$$

$$Q_b = Min\{N_b / k_b, \phi^b(Z, K_b) F^b[K_b, L(L_{sb}, L_b), A_b, H_b]\} \quad (1e)$$

$$Q_g = \phi^g(Z) F^g(L_g, A_g, H_g) \quad (1f)$$

Prices and Trade Taxes

$$P_{ai} = 1 + t_a \quad (2a)$$

$$P_x = 1 + t_x \quad (2b)$$

$$P_i = 1 + t_i \quad (2c)$$

$$P_b = 1 + t_b \quad (2d)$$

$$P_h = 1 + t_h \quad (2e)$$

$$P_m = 1 + t_m \quad (2f)$$

$$P_g = 1 + t_g \quad (2g)$$

$$P_{ic} = P_i + s_i P_n \quad (3a)$$

$$P_{ac} = P_a + s_a P_n \quad (3b)$$

$$P_{xc} = P_x + s_x P_n \quad (3c)$$

$$P_{bc} = P_b + s_b P_n \quad (3d)$$

$$P_{aic} = P_{ai} + s_{ai} P_n \quad (3e)$$

$$P_k = P_m + a_{k1} w + a_{k2} w_s + a_{k3} P_h \quad (4a)$$

$$P_z = P_m + a_{z1} w + a_{z2} w_s + a_{z3} P_h \quad (4b)$$

Sectoral Factor Demands

$$K_a = C_r^a (r_a, w, f_a, P_h) Q_a / \phi^a (Z, K_a) \quad (5a)$$

$$L_a = C_{wa}^a (r_a, w, f_a, P_h) Q_a / \phi^a (Z, K_a) \quad (5b)$$

$$H_a = C_p^a (r_a, w, f_a, P_h) Q_a / \phi^a (Z, K_a) \quad (5c)$$

$$A_a = C_f^a (r_a, w, f_a, P_h) Q_a / \phi^a (Z, K_a) \quad (5d)$$

$$N_a = k_a Q_a \quad (5e)$$

$$K_x = C_r^x (r_x, w, w_s, P_h, e_x) Q_x / \phi^x (Z, K_x) \quad (6a)$$

$$L_x = C_w^x (r_x, w, w_s, P_h, e_x) Q_x / \phi^x (Z, K_x) \quad (6b)$$

$$L_{sx} = C_{ws}^x (r_x, w, w_s, P_h, e_x) Q_x / \phi^x (Z, K_x) \quad (6c)$$

$$H_x = C_p^x (r_x, w, w_s, P_h, e_x) Q_x / \phi^x (Z, K_x) \quad (6d)$$

$$S_x = C_e^x (r_x, w, w_s, P_h, e_x) Q_x / \phi^x (Z, K_x) \quad (6e)$$

$$N_x = k_x Q_x \quad (6f)$$

$$G_a = C_{pa}^{xg} (P_a, P_{ai}) G \quad (6g)$$

$$G_{ai} = C_{pai}^{xg} (P_a, P_{ai}) G \quad (6h)$$

$$G = c Q_x \quad (6i)$$

$$K_i = C_r^i (r_i, w, w_s, P_h, e_i) Q_i / \phi^i (Z, K_i) \quad (7a)$$

$$L_i = C_w^i (r_i, w, w_s, P_h, e_i) Q_i / \phi^i (Z, K_i) \quad (7b)$$

$$L_{si} = C_{ws}^i (r_i, w, w_s, P_h, e_i) Q_i / \phi^i (Z, K_i) \quad (7c)$$

$$H_i = C_p^i (r_i, w, w_s, P_h, e_i) Q_i / \phi^i (Z, K_i) \quad (7d)$$

$$S_i = C_e^i (r_i, w, w_s, P_h, e_i) Q_i / \phi^i (Z, K_i) \quad (7e)$$

$$N_i = k_i Q_i \quad (7f)$$

$$K_n = C_r^n(r_n, w, w_s, P_h)Q_n / \phi^n(Z, K_n) \tag{8a}$$

$$L_n = C_w^n(r_n, w, w_s, P_h)Q_n / \phi^n(Z, K_n) \tag{8b}$$

$$L_{sn} = C_{ws}^n(r_n, w, w_s, P_h)Q_n / \phi^n(Z, K_n) \tag{8c}$$

$$H_n = C_p^n(r_n, w, w_s, P_h)Q_n / \phi^n(Z, K_n) \tag{8d}$$

$$K_b = C_r^b(r_b, w, f_b, P_h)Q_b / \phi^b(Z, K_b) \tag{9a}$$

$$L_b = C_w^b(r_b, w, f_b, P_h)Q_b / \phi^b(Z, K_b) \tag{9b}$$

$$H_b = C_p^b(r_b, w, f_b, P_h)Q_b / \phi^b(Z, K_b) \tag{9c}$$

$$A_b = C_f^b(r_b, w, f_b, P_h)Q_b / \phi^b(Z, K_b) \tag{9d}$$

$$N_b = k_b Q_b \tag{9e}$$

$$L_g = C_w^g(w, f_g, P_{hs})Q_g / \phi^g(Z) \tag{10a}$$

$$H_g = C_p^g(w, f_g, P_{hs})Q_g / \phi^g(Z) \tag{10b}$$

$$A_g = C_f^g(w, f_g, P_{hs})Q_g / \phi^g(Z) \tag{10c}$$

$$L_c = a_{k1} I_p + a_{z1} I_z + a_{j1} I_j \tag{11}$$

$$L_{cs} = a_{k2} I_p + a_{z2} I_z + a_{j2} I_j \tag{12}$$

where

$$I_p = I_a + v\frac{(I_a/K_a - \delta)^2 K_a}{2} + I_x + v\frac{(I_x/K_x - \delta)^2 K_x}{2} + I_i + v\frac{(I_i/K_i - \delta)^2 K_i}{2} + I_n + v\frac{(I_n/K_n - \delta)^2 K_n}{2} + I_b + v\frac{(I_b/K_b - \delta)^2 K_b}{2}$$

Capital Accumulation and Intertemporal Optimization

The representative capitalist solves the problem

$$Max \int_0^\infty V^c(E_c, P_a - k_a P_n, P_{bc}, P_{ic}, P_{aic} P_{xc}, P_n) e^{-\rho t} dt, \tag{13}$$

subject to

$$E_c = \sum_g r_g K_g + e_i S_i + e_x S_x + f_b A_b + f_a A_a + w_s L_s + (P_h - P_{hg}) H_1$$
$$- P_h H_a - \sum_j P_k \left[I_j + v \frac{(I_j / K_j - \delta)^2 K_j}{2} \right] - T, \quad j = a,b,x,i,n \tag{14}$$

$$\dot{K}_j = I_j - \delta K_j, \quad j = a,b,x,i,n. \tag{15}$$

Preferences and Demand Functions

Capitalists' and workers' indirect utility functions are derived from CES-CRRA utility functions in which consumption of the agricultural goods and processed food form CES sub-functions viz.:

$$V^j = \frac{E^{1-1/\tau}}{1-1/\tau} \left[c_{2j}^{\beta_2} P_{ci}^{1-\beta_2} + c_{3j}^{\beta_2} P_{fj}^{1-\beta_2} + (1 - c_{2j} - c_{3j})^{\beta_2} P_n^{1-\beta_2} \right]^{(1-1/\tau)/(\beta_2 - 1)}, \quad j = w,c$$

where

$$P_{fj} = \left[c_{oj}^{\beta_1} P_{bc}^{1-\beta_1} + c_{1j}^{\beta_1} P_{xc}^{1-\beta_1} + (1 - c_{oj} - c_{1j})^{\beta_1} P_{atc}^{1-\beta_1} \right]^{1/(1-\beta_1)}, \quad j = w,c.$$

$$P_{atc} = \left[n_{1c}^{\beta_0} P_{aic}^{1-\beta_0} + (1 - n_{1c})^{\beta_0} (P_a - k_a P_n)^{1-\beta_o} \right]^{1/(1-\beta_0)},$$

$$P_{atg} = \left[n_{1g}^{\beta_0} P_{aic}^{1-\beta_0} + (1 - n_{1g})^{\beta_0} P_{ac}^{1-\beta_o} \right]^{1/(1-\beta_0)}.$$

Demand functions for individual goods by capitalists and workers are

$$D_{jc} = -\frac{\partial V^c / \partial P_j}{\partial V^c / \partial E_c} = D_{jc}(E_c, P_a - k_a P_n, P_{aic}, P_{bc}, P_{xc}, P_{ic}, P_n), \quad j = a,b,x,i,n, \tag{16a)-(16f}$$

$$D_{jw} = -\frac{\partial V^w / \partial P_j}{\partial V^w / \partial E_w} = D_{jw}(E_w, P_{ac}, P_{aic}, P_{bc}, P_{xc}, P_{ic}, P_n), \quad j = a,b,x,i,n, \tag{17a)-(17f}$$

where E_c is given in (14) and

$$E_w = w(L_a + L_b + L_n + L_c + L_x + L_i) + P_a Q_g - P_{hg} H_g. \tag{18}$$

Public Sector Investment and the Government Budget Constraint

$$T = P_z I_z + (1 - P_{hg})(H_g + H_1) - t_a(D_{ai} + G_{ai}) - t_x(D_x - Q_x) \\ - t_b(D_b - Q_b) - t_m M - t_i(D_i - Q_i) - t_h H - X - Aid, \tag{19}$$

$$\dot{Z} = I_z - \delta Z, \tag{20}$$

where

$$D_j = D_{jc} + D_{jw}, \quad j = ai, b, x, i,$$

$$H = H_b + H_i + H_x + H_n + H_a - H_1 + a_{k3} I_p + a_{z3} I_z + a_{j3} I_j,$$

$$M = I_p + I_z.$$

Zero-Profit and Market-Clearing Conditions

$$P_a - k_a P_n = C^a(r_a, w, f_a, P_h) / \phi^a(Z, K_a) \tag{21a}$$

$$P_{ac} = C^g(w, f_g, P_{hs}) / \phi(Z) \tag{21b}$$

$$P_x - k_x P_n - cP_g = C^x(r_x, w, w_s, e_x, P_h) / \phi^x(Z, K_x) \tag{21c}$$

$$P_b - k_b P_n = C^b(r_b, w, w_s, f_b, P_h) / \phi^b(Z, K_b) \tag{21d}$$

$$P_i - k_i P_n = C^i(r_i, w, w_s, e_i, P_h) / \phi^i(Z, K_i) \tag{21e}$$

$$P_n = C^n(r_n, w, w_s, P_h) / \phi^n(Z, K_n) \tag{21f}$$

$$D_{ac} + D_{aw} + G_a = Q_a + Q_g \tag{22}$$

$$D_{nc} + D_{nw} + k_a(Q_a - D_{ac}) + \sum_j k_j Q_{gj} + s_a(D_{aw} - Q_g) + \sum_j s_j D_j = Q_n, \quad j = b, x, i, \tag{23}$$

$$L_a + L_b + L_x + L_i + L_g + L_n + a_{k1} I_p + a_{z1} I_z = \overline{L} - L_s \tag{24}$$

$$L_{sb} + L_{sx} + L_{si} + L_{sn} + a_{k2} I_p + a_{z2} I_z = L_s \tag{25}$$

$$Q_b - D_b + Q_i - D_i + Q_x - D_x - I_p - I_z - H_a - H_x - H_i - H_b - H_n - H_g - D_{ai} - G_{ai} - Aid = 0 \tag{26}$$

Notation

English

Subscripts: a = large-farm, domestic foodstuffs; ai = imported foodstuffs; b = tradable agriculture; x = food processing sector; i = other manufacturing; g = smallholders, domestic foodstuffs; n = services; c = construction.

A_j = stock of land in sector j (j = a, b, g)
a_j = input-output coefficient for unskilled labor in the production of capital of type j (j = K, Z)
a_{j2}= input-output coefficient for skilled labor in the production of capital of type j (j = K, Z)
a_{j3}= input-output coefficient for imported intermediates in the production of capital of type j (j = K, Z)
C^j/ϕ^j = unit cost function in sector j
c = input-output coefficient for raw foodstuffs in the food processing sector
D_j = consumption demand for good j
E_c = consumption expenditure of capitalists
E_w = consumption expenditure of workers
e_x = rental rate paired with entrepreneurial talent in the food processing sector
e_i = rental rate paired with entrepreneurial talent in the non-food manufacturing sector
f_j = land rental in sector j (j = a, b, g)
G = total purchases of foodstuffs the by the food processing sector
G_{ai} = imports of foodstuffs by the food processing sector
G_a = purchases of domestically produced foodstuffs by the food processing sector
h = fraction of lump-sum transfers received by workers
H = total purchases of intermediate inputs other than subsidized fertilizer
H_a = total purchases of fertilizer by sector a
H_1 = subsidized fertilizer used by sector a
H_g = subsidized fertilizer used in sector g
I_j = gross investment in sector j
I_p = total private investment, inclusive of adjustment costs
k_j = input-output coefficient for transportation services in sector j (j = a, x, i, b)
K_j = private capital stock in sector j
L_j = employment of unskilled labor in sector j
L_{sj} = employment of skilled labor in sector j
M = total imports of machinery and equipment
N_j = transportation services purchased by sector j (j = a, x, i, b)
P_a = producer price of domestic foodstuffs
P_{ai} = price of imported foodstuffs
P_b = producer price of tradable crops
P_g = CES index of the price of foodstuffs purchased by the food processing sector
P_{jc} = consumer price of good j (j = a, ai, x, i, b)
P_h = domestic price of imported intermediate inputs in sectors a, b, x, i, and n.
P_{hg} = subsidized price of fertilizer
P_{hs} = shadow price of fertilizer used on smallholder farms
P_i = producer price of the manufactured consumer good

P_k = supply price for private capital
P_n = price of services
P_x = producer price of processed food
P_z = supply price of roads
Q_j = gross output in sector j
R = return on investment in infrastructure
r_j = gross private capital rental in sector j
T = total lump-sum transfers
t_a = trade tax on imported foodstuffs purchased by consumers
t_b = trade tax on export crops and other tradable crops
t_g = trade tax on imports of foodstuffs by the food processing sector
t_h = trade tax on imported intermediate inputs
t_i = trade tax on manufactured consumer good
t_m = trade tax on imported machinery and equipment
t_x = trade tax on processed food
s_j = input-output coefficient for marketing/retailing services in sector j (j = a, x, i, b)
S_i = entrepreneurial talent in the non-food manufacturing sector
S_x = entrepreneurial talent in the food processing sector
v = parameter that determines adjustment costs incurred in changing the capital stock
w = wage for unskilled labor
w_s = skilled wage
Z = stock of physical infrastructure

Greek

β_0 = elasticity of substitution between imported and domestic foodstuffs
β_1 = elasticity of substitution between processed and unprocessed food
β_2 = elasticity of substitution between food, manufactures, and services
ψ = elasticity of skilled labor with respect to the stock of schools
$\Phi^j(\bullet)$ = shift factor in the production for good j
η = elasticity of the shift factor in the production function with respect to the stock of roads
ξ^g = elasticity of the shift factor in the production function for good g with respect to the capital stock.
τ = intertemporal elasticity of substitution

TABLE 2: CALIBRATION OF THE MODEL

Sector Shares in GDP

smallholder foodstuffs = .09, large farm foodstuffs = .181, tradable agriculture = .285, food processing = .076, non-food manufacturing = .05 ,services = .33.

Consumption Shares

Workers: domestic foodstuffs = .40, imported foodstuffs = .03, tradable crops = .20, processed food = .12, non-food manufactures = .15, services = .10.

Capitalists: domestic foodstuffs = .18, imported foodstuffs = .03, tradable crops = .18, processed food = .18, non-food manufactures = .19, services = .24.

Factor Shares in Smallholder Agriculture

unskilled labor = .45, land = .55

Factor Shares in Large-Farm Foodstuffs Sector (sector a)

capital = .24, unskilled labor = .37, land = .39

Factor Shares in Tradable Agriculture

capital = .17, unskilled labor = .42, land = .41

Factor Shares in Food Processing

capital = .34, unskilled labor = .47, skilled labor = .13, entrepreneurial talent = .06

Factor Shares in Manufacturing

capital = .37, unskilled labor = .42, skilled labor = .15, entrepreneurial talent = .07

Factor Shares in Services

capital = .27,   unskilled labor = .49,   skilled labor = .24

Cost Shares of Intermediate Inputs

smallholder foodstuffs = .065, large farm foodstuffs = .15, services = .12
tradable crops = .15,   non-food manufacturing = .20,
food processing = .10 for non-competitive intermediate inputs; .20 for domestic foodstuffs; .10 for imported foodstuffs.

Elasticities of Substitution in Production

Elasticity of substitution between skilled and unskilled labor = .75
Elasticity of substitution between all other inputs = .50

Marketing + Transport Margins

domestic foodstuffs = 20%,   imported maize = 10%,
export crops = 50%,   manufactures = 20%

Total margin is divided equally between transport and marketing margins.

Time Preference Rate (ρ) and the Depreciation Rate (δ)

$\rho = .10$, $\delta = .05$

Elasticities of Substitution in Consumption

Elasticity of substitution between food and other goods = .50
Elasticity of substitution between processed and unprocessed food = .75
Elasticity of substitution between domestic and imported foodstuffs = 1.50

Intertemporal Elasticity of Substitution(τ)

$\tau = .29$ for capitalists

q-Elasticity of Investment (Ω)

$\Omega = 10$ in all sectors

Initial Rates of Return (net of depreciation) on Infrastructure

R = .10-.30 for infrastructure

Initial Wages

unskilled wage = 1

skilled wage = 6

Initial Trade Taxes

$t_{ai} = 0$, $t_x = .09$, $t_h = .05$, $t_g = .05$, $t_m = .05$, $t_i = .08$, $t_b = 0$

Notation: t_{ai} is the trade tax on imported foodstuffs; t_x is the trade tax on processed food; t_i is the trade tax on manufactured consumer goods; t_h is the tariff on imported intermediate inputs/fertilizer; t_g is the trade tax on purchases of imported foodstuffs by the food processing sector; t_m is the tariff on imported machinery; and t_b is the trade tax on export crops and other tradable crops.

Miscellaneous Parameters (η, ξ^g)

Lump-sum taxes are paid by the rich agent

No learning externalities in the base run ($\xi^g = 0$)

Elasticity of the shift factor in the sectoral production functions with respect to the stock of infrastructure (η) = .25