Policy changes, input supply liberalization, and missing markets: evidence from smallholder farms in Malawi

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ABSTRACT. The response of smallholder farm households to policy changes in Malawi is studied, using a farm household model that accounts for the relationship between nutritional intake and labor productivity, as well as seasonal labor and working-capital constraints. The model is calibrated using data from a 1997/98 survey of 800 farm households in Malawi. Two main policy changes are examined: implementation of the Starter Pack Scheme to distribute seeds and fertilizer, and an input-market liberalization program for tobacco and other crops. Simulations demonstrate that liberalization of input markets improves smallholder welfare. But nutritional and marketing constraints are projected to remain binding despite reforms. In the context of these constraints, the Starter Pack Scheme is shown to be highly productive. It generates an internal rate of return of about 50 percent. We conclude that nutritional and working-capital constraints provide an important economic rationale for input-supply programs such as Malawi's Starter Pack Scheme. Such policies can circumvent missing markets and help lift resource-poor households out of extreme poverty.

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1. Introduction

Over the last two decades many countries of Sub-Saharan Africa (SSA) have undertaken economic policy reforms. In agriculture, reforms have focused on removing price controls and privatizing state-owned marketing agencies. Their purpose has been to provide farmers with higher relative product prices and improved marketing conditions, so as to induce higher levels of production through increased use of labor, purchased inputs, and new farming techniques (World Bank 1981). In SSA, rural poverty typically accounts for 80 percent or more of total poverty (Sahn, Dorosh, and Younger 1996; Basu and Stewart 1995). Thus it has been argued that reforms which tilt the terms of trade in favor of rural agricultural producers may alleviate poverty and improve income distribution at the same time they encourage productivity growth (Addison and Demery 1989; World Bank 1994). Unfortunately, experience in many countries has shown that while price policy reforms may be necessary to improve agricultural performance, they are rarely sufficient. In most cases price reforms are effective only when combined with public goods investment and the production and distribution of appropriate technology packages (Chhibber 1989; Commander 1989; Lele 1990; Mellor and Ahmed 1988).

In Malawi, several important policy changes have been undertaken since the mid-1990s to spur agricultural growth. Two occupy our interest in this paper: the relaxation of constraints on smallholder production of burley tobacco and the introduction of subsidized inputs programs. The former was widely anticipated and closely watched (e.g. Peters and Herrera 1994; Sahn and Arulpragasam 1991; Sahn, van Frausum, and Shively 1994). Subsidized inputs programs, which began with the Starter Pack Initiative in 1998 with funding from the World Bank and various European Union donors, has been less exhaustively studied. In 1998 every one of Malawi's smallholders was entitled to receive a free Starter Pack that contained seeds (for maize and other crops) and fertilizer to cultivate a 0.1 ha plot (ADMARC 1998). The program originally generated considerable controversy due to concerns that it would divert seed demand away from nascent private distribution channels and perpetuate unwillingness among smallholders to pay for inputs (Blackie et al. 1998).

Our objective in this paper is to study the effects of the SPS and tobacco liberalization on food-deficit households in Malawi. We ask two related questions: (1) what changes in agricultural output and food sufficiency are likely to result from such policy changes, given existing conditions; and (2) what supplemental policies might help smallholders adopt productivity-enhancing techniques? We approach our task by conducting a series of policy experiments using a farm household model. The model has been developed and calibrated using data from a survey of 800 rural households, covering the 1997/98 growing season and all agricultural districts in Malawi. We simulate farmers' responses to past and potential policy changes. The model is especially useful for guiding policy in sub-Saharan African countries because it incorporates several features of African smallholder households that are valuable in tracking their responses to policy changes. These features include a link between food intake and work capacity, constraints on borrowing, and seasonal disaggregation of labor requirements and labor availability. Before presenting an overview of the model and our results, we briefly review relevant policy reforms that have been undertaken in Malawi.

2. Background

2.1 Policy reforms in Malawi

Malawi was one of the first countries in SSA to undergo macroeconomic adjustment. Although reform of agricultural marketing was initiated in Malawi in 1981, until the early 1990s little tangible progress had been made for the smallholder sector (Smith 1995; Sahn and Arulpragasam 1991; Lele 1990). From independence until the mid-1990s, government parastatals or private companies with monopoly powers supplied and distributed smallholder inputs. The state-owned Agricultural Development Marketing Corporation (ADMARC) was the sole fertilizer supplier for smallholders (SFFRFM 1998) until 1993/94, when the private sector was allowed to participate in production, importation and distribution of seeds and fertilizer for them. Parastatals continue to dominate the market, but a private input-supply sector serving smallholders is beginning to emerge (ADMARC 1998; SFFRFM 1998).

From independence to the early 1990s the technology used to produce maize changed very little in Malawi. In 1990 two promising hybrids, MH17 and MH18 were released to farmers. These hybrids were well received (FEWS 1998; Smale and Heisey 1997), but in the aggregate maize yields did not increase in the 1990s—due in part to intermittent shortages of fertilizer and poor distribution of inputs generally. At the national level, data show a steady decline in per capita maize production from 317 kg (1970-74) to 260 kg (1980-84) to 179 kg (1990-94) (Jayne et al. 1997). An occasional exporter of maize to neighboring countries in the 1980s, Malawi had a 206,000 metric ton maize deficit in 1997/98 (MOA 1998). This crisis in maize productivity has been made all the more acute by smallholders' limited income with which to purchase food; until recently smallholders were banned from producing Malawi's most lucrative cash crop, burley tobacco. But in 1990/91 the Special Crops Act was amended giving smallholders the right to grow burley tobacco (Ng'ong'ola et al. 1997). Complementary to this were devaluations and smallholder access to auction floor prices for tobacco. These increased the price of all tradables relative to non-tradables, and in particular the farm-gate prices of tobacco. In short, the climate for agricultural intensification in Malawi became more favorable than ever:

all input and output markets were liberalized, private firms became active, smallholders were allowed to grow burley tobacco, prices of all commodities except maize became market-determined, and fertilizer-responsive maize seeds become more widely available.

But were Malawi's price policy reforms and new seed varieties enough to spark the use of modern inputs? Or have market failures that call for input-supply policies persisted? These questions are relevant throughout sub-Saharan Africa, and there is some evidence on them from other countries. Most studies focus on fertilizer use, as low fertility has been identified as one of the main factors limiting productivity increases in SSA agriculture (Kumwenda et al. 1997; Sanders et al. 1996). Based on a number of case studies from SSA, the World Bank (1994) concludes that fertilizer supplies have often been subject to quantity rationing, limiting the effect of price reforms on fertilizer use. For Sahelian countries, Reardon et al. (1997) argue that a key factor facilitating increased input use, in addition to price incentives, is the availability of working capital from sales of cash crops. Cash crops provide retained earnings to buy inputs for food crops, and may also serve as collateral for farmers' access to credit, thereby enabling them to buy capital goods such as animal traction equipment. This, in turn, increases productivity—both for cash and food crops. Likewise, cash crop production can provide a source of income and food security to facilitate purchases of modern inputs.[1] Minot et al (2000), for example, finds a positive relationship between adoption of tobacco, and maize fertilization rates in Malawi, although Orr (2000) raises concerns that small farms may be less well suited than large farms to engage in tobacco production. Furthermore, nutritional constraints may limit farm productivity: if farmers do not maintain threshold levels of health over time, they may not have the physical stamina to engage in some activities (Strauss 1986). These constraints represent inter-temporal market failures, which may prevent farmers from undertaking productivity-enhancing investments.

2.3 Smallholder purchasing power, access to credit, and the starter pack scheme

A number of policies have been undertaken in Malawi to overcome capital market constraints. Until the early 1990s the Smallholder Agricultural Credit Administration (SACA) supplied inputs on credit to smallholders, primarily through credit clubs or farmer associations whose members generally were the better off smallholders ((Ng'ong'ola et al. 1997; Smale and Heisey 1997). These groups had excellent repayment rates—among the highest in the third world—and generally thrived until the credit system collapsed following political changes in 1993 (MOA 1998). Although SACA has been replaced with the Malawi Rural Finance Company (MRFC), progress in rebuilding the credit system has been slow. Unlike SACA, which subsidized interest rates, MRFC uses market-determined rates. In 1995/96 these were 52 and 54 percent per year for old and new farmers' clubs respectively (Ng'ong'ola et al. 1997). Ensuring that smallholders have sufficient cash to purchase inputs is a challenge. As Blackie et al. (1998) argue, even better-off smallholders face difficulties raising the cash necessary to buy hybrid seeds and fertilizers.

One policy that has aimed to address market failures in input and credit markets together are subsidized input arrangements. In 1998/99 the Malawi government introduced the Starter Pack Scheme (SPS), a large-scale inputs initiative wherein all households in the smallholder sector were given a fixed package of modern inputs. The distributed packs contained a sufficient quantity of fertilizer and improved maize seeds for a 0.1 hectare plot, in addition to 2 kg of seeds of a leguminous crop (ADMARC 1998; Longley, Coulter and Thompson 1999; MOA 1998). The potential impact is small but important: where hybrid maize seed and fertilizer replace unfertilized local maize, use of the Starter Pack can provide a household with an additional 100kg of maize. While seemingly modest, this amount can feed a family for more than a month during the hungry season (Blackie et al. 1998). But equally important is the opportunity such a package gives a poor household to build capital at low risk. Jump-starting the accumulation process by giving households such a "best bet" technology may improve agricultural productivity on a permanent basis, by overcoming missing markets for both fertilizer and credit (Mann, 1998; Boahene, Snijders and Folmer, 1999).

Due to credit and marketing constraints, the inputs in an SPS-type package may have a far higher social marginal product on the farm than its cost to donors of K.430. But there are several potential concerns with using a SPS approach to raise productivity. The same market failures that prevent poor farmers from buying seeds and fertilizers may lead them to sell their starter packs or apply them to lower-value uses. Therefore, in an environment characterized by continued market failures, the question of how much a package might raise smallholder production remains an open question.[2] To address it, we turn now to a study of resource allocation by a set of representative smallholder households.

3. Model

We use a single year, deterministic household model to conduct our policy experiments. The model is similar in structure to a class of farm-household models used for policy analysis in African contexts (Dalton and Masters 1999; Lilja, et al. 1996; Sadoulet and de Janvry et al. 1995; Sanders et al. 1996). The model captures a number of key features of smallholder households including gender-disaggregated labor supply, inter-seasonal credit constraints, and food security and diet composition constraints. The model represents a single production cycle for a household that both produces and consumes agricultural goods.

To begin, we divide the agricultural calendar into six, two-month periods. These periods are indexed by t and represent the *off* season (winter), the *planting* season, a *slack* season (the period between planting and the first harvest season), and three *harvest* seasons (the tobacco harvest season, the harvest season for maize and legumes, and the harvest season for tuber crops). The household allocates available land to these four different crops, which we index by i. Crops are defined over j different production practices. Available labor, which may be allocated to both on- and off-farm activities, is defined over l categories. We assume the household allocates land and labor to maximize full income, defined as the money value of what is available for household consumption.

The objective is specified as a profit equation, defined as total revenues minus total costs. The household has three main categories of income: (1) remittances R and earnings from non-agricultural self employment E; (2) wage employment defined as the daily wage times days of adult-equivalent work $w\lambda L$ (where λ is a parameter that converts worker effort into adult equivalent effort); and (3) own-farm agricultural production (where p represents the selling price for output, p^P represents the purchase price for goods, Q represents quantities produced, Q^S represents quantities sold, and m represents market transaction costs. We assume the household consumes some goods from the farm and some goods purchased from the market. Although the household is a price-taker in each market, it may face substantial marketing costs so that the price paid when buying an output or input may exceed the price received when selling it. In addition, we assume the household incurs transportation costs to reach input and output markets. These limit the level of market participation for some households.[3]

Although the model is designed to focus on farmers' choice of technique and use of purchased inputs for crop production, these choices may be closely linked to conditions in credit markets, factor markets, or markets that define farmers' other activities. We assume two types of costs are incurred in production: (1) costs of purchased inputs *X* used in agricultural production (where inputs and input prices are indexed by *k*); and (2) credit costs *rB* (where *r* is an interest rate and *B* is the amount borrowed. Incorporation of a credit constraint adds an additional temporal dimension to the model. Credit use is limited by the interest cost of seasonal borrowing and also by a credit ceiling that limits a farmer's total outstanding debt.[4] Opportunities for off-farm work are captured in the wage. Because we focus on small farms, the model used in this study does not allow households to hire labor. This assumption is consistent with hiring patterns reported by Alwang and Siegel (1999).

Given these definitions, the household is assumed to maximize:

(1)
$$\begin{aligned}\pi = &\sum_t \left(R_t + \sum_t E_{lt} \right) + w \sum_l \sum_t \lambda_l L_{lt}^W \\ &+ \sum_i \sum_t \left(\left(Q_{it} - Q_{it}^S \right)\left(p_{it}^P + m \right) + Q_{it}^S \left(p_{it} - m \right) \right) \\ &- \sum_k X_k \left(p_k^P + m \right) - r \sum_t B_t\end{aligned}$$

subject to a set of inequality constraints. The first block of constraints relate to the physical limits given by the availability of resources. The household has a limited land area ($\overline{A}$); total area allocated to cropping activities cannot exceed the size of this holding:

(2) $$\sum_j A_j \leq \overline{A} \,.$$

We assume that the available quantities of some purchased inputs are rationed. Quantity constraints apply to tobacco seeds, hybrid maize seeds, and chemical fertilizer:

(3) $$\sum_{j} \mathrm{X}_{\text{k=seeds, j=tobacco technologies}} \leq \overline{X}_{\text{tobacco seeds}}$$

(4) $$\sum_{j} \mathrm{X}_{\text{k=seeds, j=hybrid maize technologies}} \leq \overline{X}_{\text{hybrid maize seeds}}$$

(5) $$\sum_{j} \mathrm{X}_{\text{k=fertilizer}} \leq \overline{X}_{\text{fertilizer}}.$$

The total amount of input available includes the amount purchased X_{kjt}^{P} plus the amount donated X_{kjt}^{SP}, where donated inputs are those associated with a Starter Pack. Households can also use own seeds stored from a previous harvest, Z_{kjt}^{S}, for the production of food crops. Hence the input constraint is:

(6) $$X_{kjt} \leq X_{kjt}^{P} + X_{kjt}^{SP} + Z_{kjt}^{S}.$$

Use of donated inputs cannot exceed amounts donated, and use of own seeds cannot exceed the quantity in storage, less what the household consumes for food:

(7) $$\sum_{t} \mathrm{X}_{kjt}^{SP} \leq \overline{X}_{kj}^{SP}$$

(8) $$\mathrm{Z}_{it}^{S} \leq \mathrm{Z}_{iT} - \mathrm{Z}_{it}^{F}.$$

Similarly, credit is limited, and cannot exceed a borrowing constraint:

(9) $B_t \leq \overline{B}$.

Following Lilja et al. (1996), we keep separate account of labor provided by women, men and children. We compute effective adult-equivalent labor availability by appropriate weighting the household roster. Total labor days for each type of labor available in the household is allocated to own-farm production, L_{lt}^{A}, non-agricultural self-employment, L_{lt}^{N}, and wage work, L_{lt}^{W}. The sum cannot exceed the amount of labor days available in each period $\overline{L}_{lt}$.

To capture the detrimental impact of food deficiency on the working capacity of household labor, we assume available labor days are affected by food sufficiency in both the present and the immediately preceding period. The survival constraint represents food consumption needs, in an adapted safety-first principle (Low 1974). We require the household to achieve a subsistence level of consumption for basic foods. We allow the minimum required level of food availability to be either purchased or produced on farm, and we allow the decision maker to choose the source of food. We use estimates of caloric density to convert each crop into food values, and use food-density constraints to maintain a minimum of balance in the diet. We value consumption of own-production at the buying price. To ensure that consumption of own-production does not occur at unrealistic levels, we impose a maximum on food consumption. Following Dasgupta (1993), we underscore the circular linkage between labor productivity and food consumption by explicitly modeling labor availability as a function of current and past consumption levels. This constraint adds a non-linearity to the model of the form:

(10) $L_{lt}^{A} + L_{lt}^{W} + L_{lt}^{N} \leq \eta_t \eta_{t-1} \overline{L}_{lt}$

where η_t represents food sufficiency, defined as food consumption as a percentage of recommended food intake for the period.

We also account for limits on non-agricultural self-employment and wage employment. We assume both of these are given by the state of the rural economy and the existing markets for labor and for products from self-employment:

(11) $$\sum_l \sum_t E_{lt} \le \overline{E}$$

(12) $$L_{lt}^W \le \overline{L}_{lt}^W .$$

Crop sales from own farm production in a period, Q_{it}^S , cannot exceed what the household maintains in storage:

(13) $$Q_{it}^S \le Z_{it} .$$

Food consumption, N_{it}^C , cannot exceed available food in each period, N_{it}:

(14) $$N_{it}^C \le N_{it} .$$

Cash expenditures cannot exceed available cash in each period. Cash expenditures include food purchases (price x quantity of food), costs of purchased inputs, and loan repayments. Available cash includes savings from previous period, remittances and borrowing, wage income, and earnings from non-agricultural self-employment and from crop sales:

(15) $$\sum_i F_{it}\left(p_{it}^P + m\right) + \sum_k X_{kt}\left(p_{kt}^P + m\right) + (1+r)B_{t-2} \\ \le\ C_{t-1}^A - C_{t-1}^B + R_t + B_t + \sum_l \left(L_{lt}^w w \lambda_l + E_{lt}\right) + \sum_i Q_{it}^S\left(p_{it} - m\right).$$

The household is assumed to have subsistence needs other than those for food. These can be met through cash purchases only. As a result, the household is precluded from spending all available cash on food. Some cash must be generated and allocated to non-food purchases. The amount of food purchases is not allowed to exceed a fixed proportion of cash income:

$$(16) \quad \sum_i F_{it}\left(p_{it}^P + m\right) \leq \delta \; C_t^A$$

where δ is the maximum marginal propensity to consume food out of cash income. In the final period, the household must leave no less food in storage and no less cash in savings than it was endowed with at the beginning of the first period:

$$(17) \quad N_{\mathrm{i,\, t=6}} - N_{\mathrm{i,\, t=6}}^C \geq d_i Z_{i,t=0}$$

$$(18) \quad C_{t=6}^A - C_{t=6}^E \geq C_{t=1}^A \, .$$

Food consumption is restricted by several rules regarding dietary balance. The three major food groups—maize, tuber crops and legumes—must be represented in the diet in at least some minimum proportions of total food consumption. This balance is allowed to vary between periods, but must hold for total food consumption during the year:

$$(19) \quad \sum_t N_{it}^C \geq \gamma \mu_i \sum_t \overline{F}_t \; .$$

Furthermore, we require that the household avoid starvation in the hungry period by smoothing food consumption over the year. Food consumption may vary within the limits given by a maximum that represents full nutritional satisfaction, $\overline{F}_t$, and a minimum that is given by the household’s ability to avoid starvation, namely $\theta \overline{F}_t$. The minimum food consumption level for survival represents the lowest possible value this floor can take if the household is to survive. The bounds on consumption are therefore given by:

(20) $$\theta\overline{F} \leq \sum_i N_{it}^C \leq \overline{F} \ .$$

The household must also fulfill requirements imposed by available activities. These requirements are expressed mathematically by a set of equality conditions. First we specify the input requirement sets, by technology. Technologies are specified as Leontief production functions, wherein input levels $\left(\overline{\overline{X}}, \overline{\overline{L}}\right)$ correspond to the amounts required by the selected technology, multiplied by the area allocated to each technology:

(21) $$X_{fertilizer} = \sum_j A_j \overline{\overline{X}}_{j,\, fertilizer}$$

(22) $$X_{seeds} = \sum_j A_j \overline{\overline{X}}_{j,seeds}$$

(23) $$\sum_l L_{lt}^A \lambda_l = \sum_j A_j \overline{\overline{L}}_{j,t} \ .$$

Likewise, output of each crop Q_i equals the sum of yields for each chosen technology, y_{ij}, multiplied by the area allocated to each technology:

(24) $$Q_i = \sum_j A_j y_{ij} \ .$$

Earnings from non-agricultural self-employment equals the number of labor days invested in the activity, L_{lt}^N, multiplied by returns to labor in non-agricultural self-employment w^N. Labor is the only resource used in non-agricultural self-employment. Non-agricultural earnings are:

(25) $E_{lt} = L_{lt}^{N} w^{N}$.

Finally, the total quantity of nutrition (food) available is denoted N_{it}. This is a function of food in storage and the calorie density of the food, d_i :

(26) $N_{it} = d_i Z_{it}$

The quantity of each crop in storage at time t, Z_{it}, is a function of overall production, purchases, carryover storage, sales out of current production, consumption out of storage and sales out of storage. The accounting identity for storage completes the model, and can be written:

(27) $Z_{it} = Q_{i,t} + F_{i,t} + Z_{i,t-1} - Q_{i,t}^{S} - Z_{i,t}^{F} - Z_{i,t}^{S}$.

The model consists of 313 single equations and 328 unknown variables. GAMS code used to implement the model is available from the authors upon request.

4. Data and calibration of the model

4.1 Data

Data used to implement the model were obtained primarily from a 1998 household survey carried out by the International Food Policy Research Institute (IFPRI) in collaboration with the Malawian Agricultural Policy Research Unit (APRU). The sample includes 800 randomly selected households distributed over 40 randomly selected Extension Planning Areas (EPAs). Table 1 contains summary statistics for the IFPRI-APRU data. The median reported farm size was approximately 1.2 hectares; the median household size was 5 persons; and the mean reported annual household income was K. 9800 (including the value of agricultural production retained for home consumption).[5] Prices used as parameters in the model also were derived from IFPRI-APRU survey data, which contains buying and selling prices of all inputs and outputs (including labor), as well as transport costs. Consumer and producer prices for food commonly vary seasonally through the year, and in Malawi prices typically reach almost double their harvest season level in the pre-harvest season (Alwang and Siegel 1999; Longley, Coulter and Thompson 1999). Accordingly, food prices in the model follow a seasonal pattern, increasing linearly between low, harvest season prices and high, pre-harvest season prices.[6]

Labor endowments were calculated using the average numbers of male and female adults, aged 16 or older, and children aged between 12 and 16 years. Work capacity for children was assumed to be 40 percent of that of a male adult. Due to their other responsibilities, women's work capacity was assumed to be 60 percent of that of an adult male. Labor endowments represent the maximum number of labor days a household can mobilize from its own ranks during periods of peak labor demand.

Data for resource constraints are also based on observed data. The land constraint parameter, i.e. the total area operated by the household, is based on mean farm size observed in the sample. Labor is constrained by the observed average labor endowment. For reproduced seeds use is constrained by endowment at the start of the cropping year, again derived from amounts reported in the IFPRI-APRU survey. The average loan duration observed in the sample was 4.5 months. For those farms reporting repayment information, the average interest rate was 65 percent. In the model we impose the condition that loans must be repaid within four months (2 periods) at 65 percent interest. Finally, constraints specifying minimum and maximum levels of food to be consumed by the representative household (weighted by age and gender composition) are based on FAO (1974) and Guthrie (1983). To convert food into calories we use data for caloric density reported by Pennington (1989). Parameters that describe the Starter Pack come from a report prepared for the ODI by Longley, Coulter and Thompson (1999).

4.2 Derivation of production parameters

The two crops of greatest concern in Malawi are the major staple crop, maize, and the most important cash crop, tobacco. Analysis of the survey data revealed that most crops other than maize and tobacco could be aggregated into two other composite crops: tuber crops and legumes. Tobacco, maize, tuber crops, and legumes account for approximately 92 percent of cultivated area among farms in the 0.5-1.0 hectare category.

Production technologies were derived econometrically using plot-level input and output data. Regressions reported in Shively, Hogset, and Masters (2000) were used to create a series of crop-specific fixed-coefficient (Leontief) production functions. This approach captures in a simple way the non-linearity observed in yield responses to chemical fertilizer and pre-harvest labor. Production functions are presented in tables 2-4.

4.3 Model calibration

The model was calibrated to represent as closely as possible conditions under which small maize farms operate. We calibrated the model with respect to three main features observed in the IFPRI-APRU data: production and food security; input use by season; and household size.

In Malawi, farm size provides a good indication of the level of food security enjoyed by a household.[7] Malawi's smallholder sector is made up of approximately 1.8 million subsistence-oriented farm families cultivating land for which they possess only customary ownership, rather than legal title (Ng'ong'ola et al. 1997). Smallholder agriculture is characterized by small size of landholdings, limited use of modern inputs and techniques, and heavy reliance on the labor of household members, especially women. Production is dominated by maize, which currently accounts for around 85 percent of total cropland, often grown in rotation or association with legumes, groundnuts and other crops (Blackie et al. 1998).[8] Low wages and limited off-farm employment opportunities imply that own-production of food continues to be the least cost method of securing household food needs (Simler 1994). At the same time the use of modern inputs and improved technologies is quite limited implying that availability of cultivable land is central to agricultural production and household food security. Accordingly, we expect that small differences in farm size will translate into large differences in the level of household food security. Longley, Coulter and Thompson (1999) using an ODI survey report that in 1998 households with a little less than one hectare produced on average 161 kilograms of maize per household member. In recognition of these patterns, we calibrated the model using 161kg/person as a target value for total maize output on a 0.9 ha farm.

Regarding input use, both the ODI data and the IFPRI-APRU data contain information about input use on different crops. Longley, Coulter and Thompson found that, in the 1998/99 production year, farms between 0.5 and 0.75 hectares in size planted 37 percent of their maize area in hybrids, and fertilized 34 percent of their maize area. Farms between 1.0 and 1.25 hectares planted 40 percent of their maize area in hybrids, and fertilized 37 percent of their maize area. The IFPRI-APRU data show that farms smaller than one hectare planted about 16 percent of area with hybrid maize. Minot et al (2000) analyzed the IFPRI-APRU data with respect to fertilizer application, and found that fertilizer use is positively correlated to farm size. Only 20 percent of households with less than one hectare of maize used fertilizer. Approximately 27 percent of total maize area was fertilized. Following Longley, Coulter, and Thompson (1999), we calibrated the model so that a 0.9 ha farm planted approximately 40 percent of its maize area in hybrid seeds and fertilized maize at 35 percent of the maximum rate. Dorward (1999) reports that in Northern Malawi, household size and holding size are strongly and positively correlated. We also find positive, though weak, correlation between household size and farm size. Accordingly, household size in the model is a positive linear function of holding size.[9]

5. Policy experiment results

In Malawi a rather broad set of reform measures have been implemented since the 1980s (see Ng'ong'ola et al. 1997 and Fisher and Masters 1998). We conduct two policy experiments focusing on: (1) the Starter Pack Scheme and (2) tobacco liberalization. We also examine the potential impacts of relaxing input and credit constraints in conjunction with these policies. In each case, we test the sensitivity of outcomes to changes in assumptions regarding farm size. The representative household under study cultivates a holding with 0.9 hectares of land. In addition to reporting simulation results for this household, we also include discussion of relevant results obtained for similar households cultivating 0.6 and 1.2 hectares of land.

Before turning to the results from simulated policy experiments we summarize outcomes associated with a base run of the model intended to simulate the status quo without policy reform. In the base run the household has no access to external credit but, consistent with data from the survey regarding access to non-agricultural earnings and remittances, the household has a small initial endowment of cash from external sources. We also assume the household has modest savings, in the form of carry-over income from the previous year's harvest, at the start of period one. It is worth noting that, without these sources of working capital, solution of the model for a 0.9 hectare farm is not feasible.

Results from the base run are summarized in Table 5, where columns represent households of 0.6, 0.9, and 1.2 hectares. For each farm size, Table 5 reports land shares to the four major crop categories (and fallow), indicators of maize intensity, and measures of household welfare including both income and average food sufficiency.[10] Data in Table 5 indicate a concentration of land in maize, followed by legumes, tobacco, and tuber crops. Note that the 1.2 hectare household is unable to plant all available land, leaving 5.8 percent of land fallow. Maize output rises with farm size. In large part this reflects an increase in the area planted to maize, but it also reflects a tendency toward intensification as farm size rises, as indicated by the amounts of hybrid seed and fertilizer utilized. In this base run, no household is self-sufficient in maize.

5.1 Policy experiment 1: the Starter Pack Scheme

Policy experiment 1 focuses on the Starter Pack initiative. Results indicating the impact of a Starter Pack on farms of 0.6, 0.9 and 1.2 hectares are presented in Table 6. Changes in household income, land allocation, and input and output levels are presented in comparison with base run values. The higher productivity of the SPS maize production technology leads all households to reallocate some portion of their land from legumes to maize, but maize output increases by much more than does maize area. Input use rises by the exact amounts found in the Starter Pack. This means the household does not spend released cash on food, but rather on more inputs. For the 0.9 ha household this leads to a 55.6 percent increase in use of hybrid maize seeds and a 29.2 percent increase in use of fertilizer. The calculated 17.5 percent increase in maize output is a result of a combination of increased area allocated to maize and a shift in production technology.

The Starter Pack lifts household income for the 0.9 ha farm by 5.6 percent, from K. 12,087 to K. 12,762. Results therefore suggest that, in 1998 terms, the Starter Pack was worth approximately K. 675 to the household, roughly 60 percent more than its cost to donors. In terms of food security benefits, available carryover of maize at the end of the year increases 18.2 percent for the 0.9 ha farm. For the 0.6 ha farm, maize carryover increases by 29.7 percent. In this sense the SPS provides proportionately larger benefits to small farms than larger farms.

The larger farm (1.2 hectares) has some idle land in the base run. When receiving a Starter Pack, it reallocates land from legumes to maize, while the share of land that is left idle remains unchanged. A shift in technology enables the 1.2 ha farm to increase maize output by much more than maize area. Maize carryover to the subsequent year increases, and household income rises by 9.1 percent. The increase in maize carryover is greater for the smaller farm than for the larger farm, but the percentage change in income is highest on the 1.2 ha farm. Food sufficiency during the simulation year does not change in response to the Starter Pack because the cash that is released is not spent on food, but rather on more inputs. If the household reduced input purchases and increased food purchases in response to a Starter Pack, short-term food sufficiency would rise, but the increase in harvests, incomes, and carryover stocks would fall.

5.2 Policy experiment 2: tobacco liberalization

The relaxation of constraints on smallholder tobacco production has been under way since 1992/93, when the legislation that made tobacco production an estate privilege was changed. Since then, smallholder tobacco production has increased rapidly, demonstrating that Malawian smallholders are indeed responsive to policy changes when they are not held back by other constraints. Yet, the present level of tobacco production among smallholders probably does not represent a maximum. Instead, present levels of tobacco production by smallholders likely represents a situation in which smallholders are constrained by several factors, including lack of cash, poor access to seeds and fertilizer, limited or costly access to markets, and perhaps limited experience with the crop. As an approximation to this bundle of constraints we model constraints on tobacco production in the form of seed rationing, while recognizing that the actual situation is likely more complex. The consequence of this assumption from the perspective of model formulation, however, is that tobacco production is limited by a non-price constraint.

We focus attention on the farm of 0.9 ha and study the impact of tobacco liberalization in three ways. First, scenario 2A reverses the feasibility of tobacco production, as a way of measuring the importance of the recent policy change allowing smallholder households to grow tobacco. Scenario 2B allows unconstrained tobacco production with the understanding that all other constraints remain unchanged. Finally, scenario 2C allows unconstrained tobacco production in a policy package that also includes removal of quantity restrictions on fertilizers and hybrid maize seeds, to reflect the continued development of all input markets.

The results of these three scenarios are presented in Table 7. The results of scenario 2A indicate the benefits of the existing tobacco policy, compared to the situation experienced by smallholders previously. Without tobacco production, household income is 5 percent lower than in the base run, and maize carryover to the subsequent season is 8.9 percent lower. The household is also unable to plant all its land, leaving 2.0 percent of its land idle. It is labor constrained in the planting season, but if given more wage employment opportunities, would have allocated more labor to wage work, at the expense of work on the farm. Maize area is 37.9 percent lower than in base run; legumes area rises by 119.1 percent (albeit from a small base).[11]

In scenario 2B tobacco area is unconstrained. All other base run constraints apply. Compared with the base run, area shifts from maize and legumes to tubers and tobacco. No land is left idle, which indicates the household does not encounter binding cash or labor constraints. Household income increases by 9.3 percent; food sufficiency increases by 2.5 percent. These changes reflect tobacco sales, which enable the household to increase food purchases prior to the food-crop harvest season. Maize output is reduced by 29.9 percent, however, and maize carryover to the subsequent year is reduced by between 16 and 19 percent.

Scenario 2C lifts constraints on fertilizer, hybrid maize seeds and tobacco seeds. Compared to the base run, the 0.9 ha farm more than doubles area allocated to tobacco, at the expense of legumes.[12] Importantly, maize area increases by 10 percent. Tobacco output more than doubles, and maize production is intensified. Intensification allows the household to increase maize output by 58.2 percent. Household income increases by 19.5 percent over the base run, and food output increases enough to raise the household to the point of calorie sufficiency in the subsequent year, because of larger carryover stocks. The increase in maize carryover amounts to 27.4 percent of total calorie requirement for a year for the household, which is more than enough to eliminate the calorie insufficiency observed in the base run.

5.3 Policy Experiment 3: improving smallholder access to credit

Experiments 1 and 2 assume smallholder households have no access to credit, other than their own working capital. This is consistent with the survey data, where only 91 households out of 800 reported using credit, and only 41 percent of those using credit reported that they borrowed money for agricultural purposes. Policy experiment 3 includes two scenarios. Scenario 3A allows unconstrained borrowing with the understanding that all other constraints remain unchanged from base run. Scenario 3B allows unconstrained borrowing in combination with the policies of scenario 2C. In both scenarios any borrowing must be repaid after 4 months, with 65 percent interest. Results of these policy experiments are presented in Table 8. As in experiment 2 we focus attention on the 0.9 ha farm.

In scenario 3A the household borrows K. 793, and increases its objective value by 4 percent over the base run. The borrowed amount corresponds to 6.3 percent of household income. The household increases area allocated to tuber crops, and reduces area devoted to legumes and maize. Tobacco area is unchanged. Both maize output and maize carryover decline. By reducing maize and legume area, the household saves cash, which together with borrowed funds enables the household rely more heavily on food purchases to meet consumption requirements. Greater pre-harvest food purchases boost average food sufficiency by 2.8 percent. The greatest advantage the household derives from using the credit market is an opportunity to smooth food consumption over the year.

In scenario 3B the household borrows K.243 and raises its income by 22 percent compared with the base. The amount borrowed equals 1.7 percent of household income. Compared with scenario 2C, only minor changes occur in activity. The household uses 22 percent more fertilizer, and produces 9 percent more maize, but land allocations remain unchanged. Importantly, the household produces a marketable maize surplus and increases its dependency on legume purchases.[13] The result is that, compared with the base run of the model, the household can be fully food sufficient with decreased total food purchases.[14]

6. Conclusions and policy implications

Our main findings can be summarized as follows. First, when a household receives a Starter Pack, it reallocates land from legumes to maize. This occurs despite the fact that the SPS contains legume seeds, and so it appears that donors and policy makers should closely scrutinize the logic behind bundling legume seeds with other inputs. The Starter Pack enables the household to increase maize output by more than maize area. As a result, household income increases by a small amount and the amount of maize carried to the subsequent year rises. The Starter Pack is progressive in the sense that benefits are relatively greater on smaller farms.

Second, when farmers gain unlimited access to inputs for both tobacco and improved maize production, households increase tobacco production at the expense of legumes, and increase maize output while keeping maize area largely unchanged. Only the smallest farms fail to reach calorie sufficiency with this policy mix. Even in conjunction with improved access to tobacco and inputs, the Starter Pack cannot provide food sufficiency on a 0.6 ha farm.

Third, when households have access to credit, but input constraints remain in place, they reallocate land from other food crops to tuber crops, while increasing their reliance on the market for other food. Borrowing enables them to smooth, and thereby increase total food consumption. Household income rises slightly, on the order of 3 to 4 percent. When increased access to credit accompanies unlimited access to inputs, borrowing has no immediate impact on food sufficiency, but it enables the household to increase maize output. Again, only the smallest households are unable to achieve food sufficiency with this policy mix. When unlimited amounts of fertilizers and hybrid maize seeds are made available, without complementary improvements in farmers' access to credit, smallholders will increase use of purchased inputs, despite cash and labor constraints that preclude full utilization of land. Higher yielding technologies enable households to increase total output and income, while concentrating production on smaller areas.

In short, this analysis shows how the an SPS-type package creates an opportunity to bridge several “missing markets” simultaneously. The SPS emerges as a very efficient and progressive source of targeted aid, turning K.430 worth of inputs into approximately K.675 worth of benefits to the poor. Nevertheless, the SPS and liberalization fail to make more than a marginal impact in the poorest households. It also appears that the legume part of the SPS is of little value to smallholders. The liberalization of the tobacco policy appears valuable in its own right, and creates synergies with the SPS by boosting available cash, thereby increasing the potential for use of hybrid maize seeds and chemical fertilizers. Our model predicts that these synergies could lead to an overall increase in both income and levels of maize in storage compared with current conditions, and could lead to marketed surpluses on all but the smallest farms.

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Table 1.—Summary data from IFPRI-APRU smallholder survey, 1997/1998

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
Holding size (ha)	1.43	0.98	0.10	11.33	800
Household size	5.1	2.3	1	13	800
Age of HOH (years)	41	14	18	86	800
Annual income (K. including retained production)	9,800	11,875	522	115,399	800
Annual cash income from ag and ag wages (K.)*	3,027	6,720	0	90,000	800
Annual income from non-ag off-farm work (K.)	1,978	6,139	0	77,600	800
Annual income from remittances (K.)	266	1,100	0	15,000	800
Average distance to road (km)	0.31	0.39	0	3.0	800
Fertilizer use (kg/ha)	36.6	72.2	0	741	800
Proportion of land of holdings <1 ha allocated to:					
Maize	0.62	-	-	-	-
Root crops	0.11	-	-	-	-
Legumes	0.15	-	-	-	-
Tobacco	0.08	-	-	-	-
Proportion of households using:					
Chemical fertilizer	0.17	-	-	-	-
Manure	0.15	-	-	-	-
Pesticides	0.02	-	-	-	-
Credit	0.11	-	-	-	-
Average amount borrowed (K.)	637	915	5	4727	91
Average duration of loan (months)	4.5	3.3	1	12	91
Average amount repaid (K.)	784	1160	5	6475	91
Proportion of households:					
with crop sales	0.70	-	-	-	-
female headed	0.26	-	-	-	-

* including non-farm self employment

Table 2.—Leontief Production Functions for Tuber Crops and Legumes.

	Seed (kg)	Labor days			Yield (kg)
		Planting	Harvest 2	Harvest 3	
Tuber Crops	157	46	0	18	676
Legumes	12	24	9	0	162

Source: Computed by the authors using data from the IFPRI-APRU survey.

Note: Input requirements and output in labor days and kilograms per acre. Tuber crops and legumes are harvested at different times. There is no fertilizer use.

Table 3.—Leontief Production Function for Maize

	N fertilizer (kg)	Labor (days)	Yield (kg)
Traditional varieties	0	5	364
	9	7	494
	18	9	601
	27	11	685
High yield variety	0	7	462
	9	9	610
	18	11	735
	27	12	836

Source: Computed by the authors using data from the IFPRI-APRU survey.

Note: Input requirements and output in labor days and kilograms per acre. Pre-harvest labor use is constant at 27 labor days during planting and 2 labor days during the slack season per acre for all technologies. Traditional seeds require 11 kilograms of seed per acre, while hybrid seeds require 8 kilograms of seed per acre.

Table 4.—Leontief Production Function for Tobacco

		Labor (days)			
	N fertilizer (kg)	Planting	Slack	Harvest	Yield (kg)
Low labor use	0	25	15	30	120
	10	25	15	47	187
	20	25	15	59	235
Medium labor use	0	31	19	33	132
	10	31	19	48	193
	20	31	19	59	234
High labor use	0	38	22	38	154
	10	38	22	52	208
	20	38	22	61	244

Source: Computed by the authors using data from the IFPRI-APRU survey.
Note: Input requirements and output in labor days and kilograms per acre. Seed requirement is 0.5 kilograms per acre for all technologies.

Table 5.—Base run simulation values, by farm size

	Farm size		
Variable	0.6 ha	0.9 ha	1.2 ha
Land area in:			
Tuber crops	4.9%	7.6%	6.3%
Legumes	33.6%	24.2%	22.0%
Maize	53.5%	60.2%	57.9%
Tobacco	8.0%	8.0%	8.0%
Fallow	0.0%	0.0%	5.8%
Avg. food sufficiency	0.77	0.85	0.91
Maize output in kilograms	431	721	936
Hybrid maize seeds used (kg)	2.4	3.6	4.8
Chemical fertilizer used (kg)	9.6	15.8	21.0
Maize yield (kg/ha)	1,344	1,330	1,347
Income levels (K.):			
Household income	9,463	12,087	13,896
Income per capita	1,903	2,376	2,671
Income per hectare	15,772	13,430	11,580

Note: Target values are defined as follows: crop shares as reported in Shively, Hogset, and Masters (2000); per capita maize output in 1997/98, and utilization of chemical fertilizers and hybrid maize seeds as reported by Longley, Coulter and Thompson (1999); food sufficiency/food consumption during year calculated as share of recommended food intake, under assumptions presented in Shively, Hogset, and Masters (2000).

Table 6.—Policy Experiment 1: Starter Pack Scheme, percentage change over base run

	Farm size		
	0.6 ha	0.9 ha	1.2 ha
Land area in:			
Tuber crops	0.0%	0.0%	0.0%
Legumes	-15.3%	-16.9%	-1.2%
Maize	9.6%	6.8%	0.5%
Tobacco	0.0%	0.0%	0.0%
Fallow	0.0%	0.0%	0.0%
Avg. food sufficiency	0.0%	0.0%	0.0%
Maize output in kilograms	29.7%	17.5%	10.3%
Tobacco output in kilograms	0.0%	0.0%	0.0%
Hybrid maize seeds used (kg)	83.3%	55.6%	41.7%
Chemical fertilizer used (kg)	53.0%	29.2%	21.9%
Maize in storage at end of year (kg)	72.3%	18.2%	13.6%
Income (change)	7.3%	5.6%	9.1%
Income levels (K.):			
Household income	10,156	12,762	15,165
Income per capita	2,042	2,509	2,915
Income per hectare	16,927	14,180	12,638

Note: Average food sufficiency is defined as total food consumption during the year as share of recommended food intake. The change in average food sufficiency is zero because input use rises by the amount in the starter pack; no money is reallocated to food purchases in the pre-harvest season. See text.

Table 7.— Policy Experiment 2: tobacco liberalization, percentage change over base run

	Policy Experiment 2		
	2A	2B	2C
Land area in:			
Tuber crops	0.0%	249.7%	0.0%
Legumes	119.1%	-100.0%	-100.0%
Maize	-37.9%	-32.5%	10.0%
Tobacco	-100.0%	310.0%	226.7%
Fallow*	0.019	0.000	0.000
Maize output in kilograms	-21.5%	-29.9%	58.2%
Tobacco output in kilograms	-100.0%	226.1%	226.5%
Hybrid maize seeds used (kg)	0.0%	0.0%	231.4%
Chemical fertilizer used (kg)	-3.8%	0.0%	170.2%
Avg. food sufficiency	0.0%	2.5%	-0.2%
Maize in storage at end of year (kg)	-8.9%	-19.0%	59.0%
Income (change)	-5.0%	9.3%	19.5%
Income levels (K.):			
Household income	11,484	13,212	14,440
Income per capita	2,257	2,597	2,838
Income per hectare	12,760	14,680	16,044

Notes:

* Area of idle land in hectares when comparing to base run; there is no idle land in base run.

2A: No tobacco production.

2B: Unconstrained tobacco production, other constraints unchanged.

2C: Unconstrained tobacco production, other constraints also removed.

Table 8.—Policy Experiment 3: Improved access to credit, percentage change over base run

	Policy Experiment 3	
	3A	3B
Land area in:		
Tuber crops	253.8%	0.0%
Legumes	-5.9%	-100.0%
Maize	-29.7%	10.0%
Tobacco	0.0%	226.7%
Fallow	0.000	0.000
Avg. food sufficiency	2.8%	-0.2%
Maize output in kilograms	-20.6%	72.9%
Tobacco output in kilograms	0.0%	226.5%
Hybrid maize seeds used (kg)	0.0%	231.4%
Chemical fertilizer used (kg)	0.0%	230.3%
Credit (K.)	793	243
Maize in storage at end of year (kg)	-18.8%	70.8%
Income (change)	4.0%	21.8%
Income levels (K.):		
Household income	12,567	14,725
Income per capita	2,470	2,894
Income per hectare	13,963	16,361

Note:

3A: Unconstrained borrowing, other constraints unchanged.

3B: Unconstrained borrowing, other constraints also removed.

Notes

[1] Evidence from Africa generally suggests food and cash crops are complementary: food crops benefit from application of fertilizer to cash crops and from the re-investment of income into food crop enterprises (Goetz 1992; Jaeger 1992; Kennedy et al, 1992; von Braun and Kennedy 1987).

[2] Of course another relevant question is whether other feasible policies might do better than an SPS-type intervention. For more on this point, see World Bank (1999).

[3] Other analyses in the SSA context also have included measures of marketing and transport costs (e.g. Mwanaumo et al. 1997) to account for the fact that these costs may make up as much as 70 percent of product values (Ahmed and Rustagi 1987).

[4] The imposed constraint is consistent with observed patterns in which borrowing limits are tied to a household's ability to repay loans in the event of a crop failure. These constraints tend to exist even in the context of informal credit markets that function without recourse to formal collateral.

[5] At the time of the survey $1US was worth approximately 45 Kwacha.

[6] An exception was made for tuber crops because harvest of cassava, the dominating tuber crop among sample households, is relatively evenly distributed throughout the year. Tuber prices display no seasonal pattern in our model.

[7] Gender of household head is also important but we do not introduce this as a separate category because headship gender is strongly correlated with farm size. For example in 1992/93 86 percent of female-headed households farmed less than 1 hectare, 12 percent farmed 1-2 hectares, and 2 farmed more than 2 hectares. Corresponding figures for male-headed households were 74, 20 and 6 percent respectively (NSSA 1992/93a).

[8] The agricultural sector in Malawi is highly dualistic, consisting of estate and smallholder sub-sectors. Estates grow mostly cash crops on relatively large landholdings. The overwhelming majority of Malawi's farmers are smalholders (Ng'ong'ola et al. 1997).

[9] Based on observed data we adjust FOODREQ and LABORAVAIL using the OLS-derived relationship $y = 0.93 + 0.07x$, where y is the number of adult male equivalents and x is the size of family holdings, in hectares.

[10] Food sufficiency here corresponds to sufficiency in the year of the simulation. Food sufficiency will increase if the household receives cash before harvest, enabling it to purchase more food in the pre-harvest season.

[11] For the larger farm, maize area is 15.7 percent lower, and legume area 72.4 percent higher than in base run. In contrast, for the smaller farm legumes drop out of the solution, leaving maize and tuber crops as the only crops grown. All three households have idle land in this scenario.

[12] The household is labor constrained in both tobacco planting and tobacco harvesting seasons. The land constraint also binds for the 0.9 ha farm. The land constraint for the 1.2 ha farm is not binding. This farm reduces idle area by 72.3 percent.

[13] The larger household increases maize area at the expense of idle land and legumes, which are still present in the solution with small shares (3.8 and 4.3 percent of available area, respectively). Only the larger farm has any idle land in this scenario.

[14] When the smaller farm gets access to credit in addition to all other inputs, it increases maize production at the expense of tobacco area, leaving area allocated to tuber crops unchanged. The increase in maize carryover over base run corresponds to 15.8 percent of annual food requirement, which will lift the household to a food sufficiency level of more than 90 percent. Only the smallest farm fails to reach food sufficiency with this policy package.