

THE ECONOMY-WIDE IMPACTS AND RISKS OF MALAWI'S FARM INPUT SUBSIDY PROGRAM

CHANNING ARNDT, KARL PAUW, AND JAMES THURLOW

We estimate the impact of Malawi's Farm Input Subsidy Program using an economy-wide approach. This approach yields benefit-cost ratios about 60% higher than existing partial equilibrium studies, a result of our accounting for indirect benefits. Fertilizer response rates remain the determining parameter for benefit-cost ratio levels. Even with lower-end response rates, the program is pro-poor and generates double-dividends through higher and more drought-resilient yields. Overall, for macro-economically significant programs, our approach strongly complements survey-based evaluations. For Malawi, our results buttress arguments for a focus on program improvements.

Key words: Program evaluation, risk assessment, economy-wide model, farm subsidies, Malawi.

JEL codes: C68, O13, O22, Q18.

A large body of literature has emerged that considers *ex post* evaluation of policy interventions. This program evaluation literature typically focuses on the merits of alternative survey-based techniques in attributing outcomes (Bamberger, Rao, and Woolcock 2010). However, even when an evaluation is well-designed and executed, general equilibrium impacts resulting from large-scale interventions can be difficult to capture using micro-level survey data. The potential for these effects to substantially influence project outcomes has long been recognized in the benefit-cost analysis literature (see Gittinger 1984; Baum and Tolbert 1985; and Brent 1990). Programs may generate spillovers that benefit non-recipients or may compete for resources and so indirectly affect other programs. Small-scale pilot programs, if successful, are typically intended to be scaled-up, at which point they may generate spillovers and

encounter resource constraints. Large-scale programs may also influence, for example, external balance or fiscal policy. Evaluations that do not consider these economy-wide effects may reach incorrect conclusions.

Malawi's Farm Input Subsidy Program (FISP) is a prime example of a large-scale, national program with potentially significant economy-wide effects. The FISP's budget accounts for 3–6% of Malawian GDP and two-fifths of the population are direct beneficiaries. Most FISP evaluations are based on micro-level surveys or partial equilibrium models in which it is hard to control for or identify all impact pathways.

In this article, we present a comprehensive evaluation of Malawi's FISP. To do so, we develop an approach for incorporating economy-wide effects within a program evaluation framework. Specifically, we use a detailed computable general equilibrium (CGE) model calibrated to empirical evidence from household-level evaluations. This model is linked to a survey-based micro-simulation module for poverty analysis. In addition, we illustrate how the approach can accommodate stochastic agricultural production levels by linking to results from a hydro-meteorological crop-loss model for weather risk analysis. Finally, we conduct sensitivity analysis with respect to principal program risks.

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Amer. J. Agr. Econ. 1–19; doi: 10.1093/ajae/aav048

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Our approach follows from a series of studies that employ CGE models, often in combination with other techniques, for *ex post* evaluation (see Arndt et al. 2012; Dyer and Taylor 2011; Horridge, Maddan, and Wittwer 2005). Here, our mixed methods approach harnesses the strengths of *ex post* evaluation data, triangulates this information with other sources, and addresses inherently *ex ante* design elements and risks in order to generate a comprehensive and, to our knowledge, unique method of program evaluation.

In the next section, we describe Malawi's FISP by drawing upon existing evaluation studies. We then specify the economy-wide model, describe its calibration to survey and other data, and outline our evaluation approach. We then present evaluation results. We find that, using a fertilizer yield response of 16.8 kilograms of maize per kilogram of nitrogen, which is the value employed in what is popularly referred to as the "official" program evaluation (Dorward et al. 2008), FISP generates an economy-wide benefit-cost ratio of 1.62, compared to a partial equilibrium ratio of about one. This differential indicates that an economy-wide approach, such as the one proposed here, is essential for large-scale programs like FISP.

The return to fertilizer use by program recipients represents a critical parameter, and the value of 16.8, while not extraordinary by African standards, is towards the top end of the estimated range for Malawi. However, because of positive spillover effects, the economy-wide benefit-cost ratio falls below one only at a fertilizer yield response rate of about 13, which is above but reasonably close to the more pessimistic response rate estimates in the literature. Further, at a response rate of 13, the FISP program remains significantly pro-poor.

Hence, unless one views fertilizer yield response rates above 13 as fundamentally unattainable, our analysis offers a fairly positive assessment of FISP, at least prospectively. Under plausible parameter values, FISP is pro-poor with the potential to generate substantial economy-wide gains and to help mediate most weather shocks. This contrasts with the view, set forth by Jayne and Rashid (2013) and based on partial equilibrium assessments, of fertilizer subsidy programs having low potential and being fundamentally grounded in political motivations. Our results indicate that the FISP can form a part of a viable development strategy.

Of course, positive outcomes are not guaranteed. Jayne and Rashid (2013) correctly emphasize the potential for operational problems and other shocks to reduce program benefits, potentially dramatically. Principal program risks identified in this analysis include the following: potential failure to attain fertilizer efficiency levels required to generate net economy-wide benefits; failures in program management that dampen the impact of the program on overall fertilizer use; substantial increases in fertilizer prices (particularly relative to world maize prices); and macroeconomic adjustment costs related to excessive program size.

In light of this potential for operational failures and other risks to undermine program performance, as well as the potential for the behavior of the actual Malawian economy to diverge from the behavior of the model, the penultimate section provides additional comparisons of model results to available data and places the results obtained within a coherent narrative of the evolution of the Malawian economy. The final section summarizes and concludes.

Malawi's Farm Input Subsidy Program

Agriculture is Malawi's main sector, generating one-third of gross domestic product (GDP), half of total export earnings, and two-thirds of employment (Douillet, Pauw, and Thurlow 2012). The sector is dominated by rain-fed maize and tobacco grown by smallholders. Maize is particularly vulnerable to frequent droughts (Pauw et al. 2011). As such, improving maize yields, as well as the robustness of maize yields to adverse climatic conditions, is a priority for poverty reduction and food security.

Program Design

Since inception in 2005, FISP has targeted approximately 1.5 million rural smallholders, or about half of all farmers in Malawi. The FISP is designed to provide each farmer with two coupons, which are redeemable for two 50-kilogram bags of fertilizer. Beneficiaries pay a small redemption fee, equating to a subsidy of two-thirds or more of the commercial fertilizer price. Recipients are supposed to be the "productive poor," meaning smallholders who cannot afford fertilizer at commercial prices but have sufficient

land and human resources to make effective use of subsidized inputs (Chibwana, Fisher, and Shively 2012). Overall, planned fertilizer distribution has been between 150,000 and 170,000 metric tons each year, although actual distribution peaked at 216,000 tons in 2007/08.

Farmers are also provided with free improved seeds: starting at 2–3 kilograms per farmer in 2005/06 and rising to 5–10 kilograms in 2009/10, with the size of the seed packet depending on the seed type chosen. Farmers can, in principle, choose between composite and hybrid seed varieties. Composites are lower-yielding and require a higher seeding rate, but can be recycled at the end of the season. Higher-yielding hybrids cannot be recycled. Initially, about 60% of the seeds under FISP were hybrids, but this rose to almost 90% in 2009/10. While FISP has at times included subsidies for other crops, these components have been small compared to maize. Consequently, we focus on the maize seed and fertilizer subsidy components of the program.

Program Implementation

Identifying the productive poor is challenging. In practice, farmers' eligibility is determined by local leaders who do not always apply the same criteria, leading to inconsistent targeting across districts and over time. Evaluation studies consistently show that resource-poor farmers are less likely to receive subsidies (Dorward et al. 2008; Chibwana, Fisher, and Shively 2012; Ricker-Gilbert, Jayne, and Chirwa 2011). On average, beneficiaries receive less than the intended 100 kilograms of fertilizer (Dorward et al. 2008), probably because local leaders allocate fertilizer more broadly across communities (Holden and Lunduka 2010).

Some of the fertilizer provided under FISP goes to farmers who would have purchased fertilizer without the subsidy, thus leading to the displacement of commercial fertilizer. In addition, some FISP fertilizer is stolen or "diverted" and then sold. The nature and magnitude of these displacement and diversion rates are critical parameters for determining program success. Jayne et al. (2013) estimate an 18% fertilizer displacement rate for FISP, which means each kilogram of subsidized fertilizer leads to a 0.82 kilogram net increase in fertilizer use. Diversion is, by its nature, more difficult to

estimate, and its presence could bias estimated displacement rates, as Jayne et al. (2013) point out (detailed discussion of the issues surrounding estimation of displacement and diversion rates is relegated to the supplementary appendix online). However, the available evidence indicates that the subsidy program has stimulated overall demand for commercial fertilizers, even though the private sector has been excluded from the retailing of subsidized fertilizers (Chirwa and Dorward 2013). Similarly, seed may have also been displaced, but the direct involvement of private sector firms in production and distribution of FISP seed has meant that benefits from increased sales have outweighed displacement, at least for the sector as a whole. Our analysis endogenously determines a fertilizer displacement rate of about 25%. Although the model used in this article does not distinguish between FISP and commercially supplied seed, the model's design means that the displacement rate for seed is likely to be of a similar magnitude.

Fertilizer subsidies may also have implications for factor markets. Implications for land allocation (or crop diversification) and wages have been of particular interest in the literature. Higher maize yields achieved under the program might prompt farmers to diversify into other crops; for example, Holden and Lunduka (2010) use panel data and find that farmers' average share of land allocated to maize declined significantly from 2006 to 2009. This result is corroborated by Kankwamba, Mapila, and Pauw (2012), who find that FISP beneficiaries have higher crop diversification indices. In contrast, Chibwana et al. (2010) find a shift in area towards maize and tobacco in their sample. In general, land reallocation effects may contribute to the displacement of commercial fertilizer and seed, particularly when land is reallocated away from crops that use these inputs intensively (such as maize).

Program Financing

The FISP's main cost components are fertilizer, seeds, transport, and logistics. Donors have typically made direct contributions towards FISP for seeds and logistics, amounting to 10–15% of FISP's total annual costs (Dorward and Chirwa 2011). The government has paid for all other costs, including fertilizers, which are by far the largest expenditure item. Farmers' redemption

prices have not been fixed to world prices, and so government payments for fertilizers ballooned in 2008 when the world price more than doubled (maize prices also rose by more than 50%). This accounts for most of the wide gap between planned and actual costs. The range of planned costs was US\$51–139 million per year during 2005/06 and 2009/10, whereas the range of actual costs was US\$81–228 million.

The FISP has accounted for about 9% of the national budget, except in 2008/09 when this share doubled. This has prompted large cuts to other agricultural programs such as irrigation, research, and extension, and to other economic sectors, including roads, industry, and the environment. While FISP may benefit the maize sector, it has potentially substantial opportunity costs with economy-wide implications. It also bears emphasizing that, while donors only provide 10–15% of FISP's budget directly, the foreign exchange that arrives from donors in the form of budget support and support to other projects/programs (approximately 40% of government expenditure in Malawi is donor funded) is critical to FISP. Cuts in overall donor support would require both substantial internal realignment to match government expenditures with revenues (including remaining aid flows) and substantial external realignment to match the supply and demand for foreign currency. Since cutting FISP would assist with both of these realignments simultaneously, Malawi may, in the face of more limited donor support overall, find very few realistic alternatives to downscaling FISP.

Measuring Economy-wide Impacts of the Subsidy Program

To measure economy-wide impacts of FISP, we employ a computable general equilibrium (CGE) model of Malawi. Such CGE models have a number of features that make them suitable for program evaluations. For example, they simulate the functioning of a market economy, including markets for land, labor, capital, and products, and offer insights into how a program's impacts are mediated through prices and resource reallocations. Further, they ensure all resource and macroeconomic constraints are respected, which is essential for large-scale programs. Finally, CGE models provide a detailed “simulation

laboratory” for quantitatively examining the interaction of impact channels and spillovers. The model employed follows [Lofgren, Harris, and Robinson \(2002\)](#) in its basic structure, and is briefly summarized below.

Malawi's economy is divided into 58 producer and 30 household groups, who act as individual economic agents. Producers maximize profits subject to input and output prices. Output is supplied to national markets, where it may be exported and/or combined with imports, and there is imperfect substitution between domestic and foreign goods. A constant elasticity of transformation function determines the quantity of domestically-produced goods supplied to export markets. Similarly, a constant elasticity of substitution function determines the quantity of imported goods and combines these with domestic production for sale in domestic markets. The model includes domestic and foreign transfers, which are exogenous in real terms.

The government is a separate agent in the model. Government revenues are used to pay for public services, including input subsidies, and government receipts from donors earmarked for FISP are included on the revenue side of the government equation. Donors pay a share of the total cost of the subsidies for seeds and fertilizers; hence, this revenue component is proportional to the size of FISP. To balance the government budget, we assume that indirect tax rates adjust through additive increases in sales tax rates across commodities to ensure that revenues equal total spending less borrowing/aid. This captures the macroeconomic effects of FISP when foreign aid does not fully finance program costs.

Our model assumes that the exchange rate adjusts to clear the external account. Thus, if the price of imported fertilizer increases and this additional cost is not covered by foreign aid, the exchange rate is expected to depreciate to encourage exports and discourage imports. Labor is fully employed due to seasonal labor constraints in Malawi ([Wodon and Beegle 2006](#)). The total supply of capital is also fixed. In equilibrium, factor returns adjust such that, for each factor, total factor supply equals the sum of factor demands. Product market equilibrium requires that the composite supply of each good equals total private and public consumption and investment demand, and the sum of intermediate demands. Market

prices for commodities adjust to maintain equilibrium. Finally, we adopt a “balanced” closure in which private and public consumption and investment spending are fixed shares of total nominal absorption (see Lofgren, Harris, and Robinson 2002). This closure spreads macroeconomic adjustments across the components of absorption. The national consumer price index is the numéraire.

To estimate impacts on consumption poverty, we use a top-down “macro-micro” approach to measuring poverty changes (see Arndt et al. 2012). In the poverty module, individual households in the underlying survey dataset are linked to their corresponding representative household groups in the CGE model. Observed consumption changes in the model are then applied proportionally to survey households, each with a unique consumption pattern. A post-simulation consumption value is calculated and compared to an absolute poverty threshold to determine if a household's poverty status has changed from the base.

Data Sources

The model's parameters are given values from survey and other data. A social accounting matrix (SAM) was estimated for 2003, which is the closest “normal” weather year prior to FISP's implementation in 2005.¹ The SAM reconciles data from national and government accounts, balance of payments data, and industrial and household surveys. An input-output table for the model's 58 sectors was estimated using farm budgets from the Ministry of Agriculture and Food Security (MoAFS) and Annual Economic Surveys from the National Statistical Office (NSO). The 2004/05 Integrated Household Survey (IHS2) was used to divide labor into five education categories and households into 30 groups (NSO 2005).² Households earn incomes based on reported wages and profits from farm and nonfarm enterprises. The IHS2 includes detailed household expenditure patterns, which are used to calibrate the poverty module.

Agricultural sectors are divided into estate farms and smallholders using production data

from MoAFS. Crop land is separated from agricultural capital and includes farm profits and the implicit returns to unpaid family labor. Smallholders are separated by farm size, that is, small (≤ 0.5 hectares), medium (≤ 2.5 hectares), and large (> 2.5 hectares). Farmers can reallocate their land and labor in response to relative price changes. The exception is land allocated to FISP maize, which is controlled exogenously in our simulations. Smallholders can also choose between producing local (traditional), composite, and hybrid maize varieties, but the maize they produce is perfectly substitutable once supplied to the commodity market.³ Table 1 summarizes the maize technologies for local (LOC), composite (COM), and hybrid (HYB) maize varieties derived from surveys by Dorward et al. (2008) and value-chain analysis by Tchale and Keyser (2010). Farm-level input use is consistent with national seed production and fertilizer imports both in the pre-FISP period and during FISP. Finally, household income elasticities are econometrically estimated using IHS2 (available in table A.2 of the supplementary appendix online). Trade substitution elasticities are taken from Dimaranan (2006).

Evaluation Approach

Table 1 shows the maize technologies that FISP intended for its recipients (i.e., COM+ and HYB+). Prior to FISP, these new technologies produce negligible amounts, such that all maize in the model is effectively produced using existing technologies (note that ALL in table 1 represents the weighted average across existing LOC, COM, and HYB varieties).

To simulate FISP, we exogenously increase the land allocated to COM+ and HYB+ technologies. Producing these new maize varieties requires resources that must be drawn from existing maize (LOC, COM, and HYB) and non-maize crops, and from non-farm activities. Final land allocations for

¹ The 2003 SAM was constructed following the approach described in Douillet, Pauw, and Thurlow (2012).

² Groups include farm and nonfarm households in rural and urban areas. Rural farm households are further separated by farm size, that is, small, medium, and large. Each group is disaggregated by national expenditure quintiles.

³ Households may prefer local maize varieties (Lunduka, Fisher, and Snalpp 2012; Smale, Heisey, and Leathers 1995) and so perfect substitution may not be entirely accurate. However, composite and hybrid varieties were 70% of maize production in 2003. For modeling purposes, so long as pre-FISP and post-FISP composites and hybrids are close substitutes in consumption, our principal results are not materially affected by a perfect substitution assumption across all varieties.

Table 1. Maize Production Technologies (Inputs and Output per Hectare)

	Existing maize crops, 2002/03				FISP maize crops	
	LOC	COM	HYB	ALL	COM+	HYB+
Fertilizer (50 kg bags)	0.7	2.5	3.3	1.8	6.0	6.0
Traditional seeds (kg)	23.7	0	0	12.1	0	0
Improved seeds (kg)	0	20.0	15.0	8.3	20.0	15.0
Hired labor (days)	35.0	47.0	58.4	44.3	56.8	60.8
Family labor (days)	44.0	44.0	44.0	44.0	44.0	44.0
Revenues (USD)	152	273	388	246	446	551
Seed and fertilizer costs (USD)	23	80	93	55	41	41
Value-added (USD)	83	125	220	133	324	421
Hired labor costs	50	66	76	61	92	106
Capital (hand equipment rental)	14	14	14	14	14	14
Profits (attributed to land)	20	45	130	58	218	300
Maize yield (tons/hectare)	0.76	1.37	1.94	1.23	2.23	2.76
From fertilizer use	0.14	0.63	0.97	0.44	1.49	1.78
Base yield according to seed variety	0.62	0.74	0.97	0.79	0.75	0.97
Marginal return to fertilizer	12.0	15.0	18.0	14.4	15.0	18.0

Source: Own calculations using evaluation data from Dorward and Chirwa (2011) and value-chain data from Tchale and Keyser (2011).

Notes: LOC, COM, and HYB are local, composite, and hybrid maize varieties, respectively, and ALL is an average weighted according to land area. The marginal return to fertilizer use is expressed as the quantity of maize produced per kilogram of fertilizer applied, assuming a fertilizer nitrogen content factor of approximately one-third for FISP fertilizer.

all other crops are determined endogenously by technologies, resource constraints, and relative prices. Since FISP's targeting criteria were vague and inconsistently applied, we distribute FISP vouchers across smallholder maize farmers in a manner that does not alter their income distribution, meaning that targeting is essentially random.⁴ Household outcomes will vary depending on their cropping patterns and diversification options, as well as the contribution of farm earnings to their total income. Non-farm households are affected through changes in consumer prices and wages. Taxes may also change depending on the fertilizer import price and the share of FISP's cost financed by foreign aid.

To evaluate weather effects, we draw on the hydro-meteorological crop-loss models in Pauw et al. (2011). The loss exceedance curves (LECs) in figure 1 show estimated production losses during droughts of different return periods (RPs). The RP is a measure of both the likelihood of occurrence

and severity of a drought event.⁵ For example, local-variety maize production is 33.8% lower in a one-in-twenty year drought (RP20) than it would have been in a "normal" year (represented by RP1). Composite and hybrid varieties not only have higher yields (see table 1), they are also more drought-resistant, with losses of 12.8% and 18.2%, respectively, in an RP20 year. The crop losses in the figure are econometrically-estimated using historical district-level production and weather data, and then extrapolated across unobserved drought events using a stochastic weather model.

For the weather risk scenarios, we select an RP event from the LECs and apply the productivity losses to each maize variety. Weather shocks are distributed to non-maize crops using crop yield correlation coefficients derived from historical data (see Pauw et al. 2011).⁶ To reflect farmers' decision-making and difficulty in predicting weather, we assume that farmers allocate land to crops at

⁴ An assessment of outcomes under alternative household targeting mechanisms falls beyond the scope of the analysis given the focus on macroeconomic aggregates. While possible, this would require significant changes to the model setup, in part because the subsidy is available to producers (or activities) in the model. Households are only linked indirectly to these activities via the factor market.

⁵ A weather "hazard" is defined by the severity of an event and the probability of that event occurring within a given year (Pauw et al. 2011). An event's "return period" is the expected length of time between the reoccurrence of two events with similar characteristics. An event with a higher RP is more severe but less frequent than a low RP event.

⁶ Correlation coefficients: non-maize cereals (1.0); horticulture (0.05); cotton and tobacco (0.2); irrigated sugarcane (0.0); and roots, pulses, and other crops (0.25).

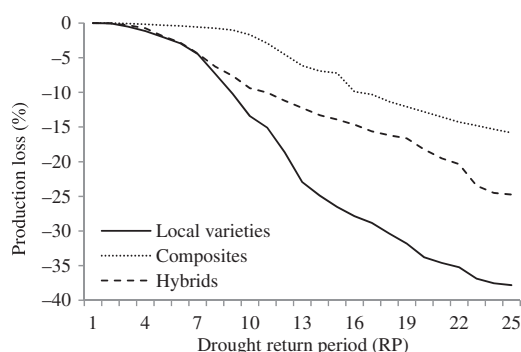


Figure 1. Drought loss exceedance curves for maize varieties

Source: Own calculations using the stochastic weather and crop model from Pauw et al. (2011).

Notes: Return period is the expected length of time between the reoccurrence of two events with similar magnitude and severity.

the start of the season and cannot reallocate land in response to weather-induced production losses (i.e., droughts are considered unexpected and “rapid-onset” events). To evaluate the full distribution of outcomes, we simulate the effects of FISP under RP1 to RP25 events. We restrict our weather analysis to a maximum RP25 event. This is similar to the most severe nationwide drought recorded in Malawi’s historical weather data (Pauw et al. 2011). Estimating crop losses beyond RP25 is speculative, although we expect that the LECs in figure 1 would eventually converge at some threshold event greater than RP25. At this threshold, production would be functionally the same (and very low), regardless of which seed variety or how much fertilizer is used, implying that, for a sufficiently severe drought, the FISP would provide zero returns.⁷

Evaluation Results

We use the model to replicate the maize component of Malawi’s FISP, loosely styled on the 2006/07 program, that is, 150,000 tons of fertilizer is distributed to smallholders together with improved maize seeds, of which 60% are hybrid varieties.⁸ In order

to simulate FISP in the model, we must determine how much maize land was affected by the program. If we assume the recommended application rate of six 50 kg bags of fertilizer per hectare (see Benson 1999), then FISP provided fertilizer to 500,000 hectares (i.e., 150,000 mt/300 kg). This fertilizer application rate generates yields of 2.2 and 2.8 tons per hectare for composite and hybrid maize, respectively (see table 1) under normal climate conditions. Note that the same amount of fertilizer is applied to composite and hybrid seeds, but fertilizer yield effects are larger for hybrids.⁹ While the fertilizer response rates in table 1 are taken from Dorward et al. (2008), we later test alternative values for this critical parameter.

At recommended application rates of six bags of fertilizer and 20–25 kilograms of seed per hectare, each beneficiary household receives sufficient inputs for approximately 0.33 hectares of maize. This is close to the average of 0.38 hectares of maize cultivated by poor farmers in 2004/05 (Benin et al. 2012). Under these conditions, about 500,000 hectares is affected by FISP (1.5 million beneficiaries \times 0.33 hectares). Our analysis assumes a program designed as intended, where fertilizer is applied at recommended rates on 500,000 hectares of land.

Table 2 reports our simulation results. In this section we focus on simulation A (column 2), which replicates the scale and composition of the 2006/07 FISP. To be consistent with the existing official FISP evaluation, which did not consider the effects of domestic financing, we initially assume that all program costs are financed by additional foreign aid. We also apply the fertilizer dose-response rate used in the official evaluation (as noted), hold import prices constant, and assume a “normal” year without weather-related production losses (i.e., RP1 in figure 1). All these assumptions are later tested in order to gauge the sensitivity of simulation A’s outcomes.

The immediate or direct effect of FISP is an increase in maize yields and production,

⁷ Fertilizer applied during a severe drought year may provide benefits in a subsequent season.

⁸ Following the crop year 2006/07, fertilizer prices increased drastically on world markets, driving up program costs (this is analyzed in a later section). An even more ambitious modeling effort than the one presented here would attempt to track

the FISP program through time, including movements in world prices. Maize prices also rose substantially, which would positively influence direct benefits.

⁹ The seed planting rates in table 1 are based on the 2009/10 program, which distributed 8,500 tons of subsidized seed. This is almost twice the amount of seed distributed in 2006/07, but ensures consistency between the seed and fertilizer components of our modeled program as far as land coverage is concerned.

Table 2. Results from the FISP Impact and Financing Scenarios

	Pre-FISP baseline value, 2003	Deviation from pre-FISP baseline		
		Donor funded (marginal return 16.8) (A)	Sales tax funded (marginal return 16.8) (B)	Donor funded (marginal return 11.8) (C)
Maize production (1000mt)	1,982.8	307.3	289.2	174.3
Maize land (1000ha)	1,501.9	−236.8	−248.9	−151.4
Maize yield (average mt/ha)	1.32	0.49	0.49	0.28
Net maize exports (1000mt)	65.0	86.0	122.5	44.9
Crop diversification index	0.613	0.036	0.040	0.024
Real maize price index (%)	100	−4.26	−3.15	−2.33
Real food prices index (%)	100	−3.32	−2.71	−2.00
Real exchange rate index (%)	100	−2.74	0.72	−1.75
Tobacco production (1000mt)	94.3	−1.5	12.8	1.5
GDP at factor cost (%)	187.7	4.65	4.69	2.74
Agriculture	61.8	14.96	15.37	9.99
Non-agriculture	125.8	−0.41	−0.57	−0.82
GDP market prices (%)	199.9	1.93	1.89	−0.40
Absorption	226.0	3.89	2.07	2.07
Exports	51.2	−0.87	4.64	−1.78
Imports	77.3	5.82	3.81	5.23
Farm employment share (%)	65.6	0.13	0.26	0.46
Average farm wage (%)	86.1	7.02	4.42	4.07
Average land return (%)	84.4	8.47	7.39	4.35
Household welfare (%)	177.8	5.00	2.79	2.58
Farm	151.7	6.00	4.16	3.47
Non-farm	352.9	2.17	−1.10	0.06
Poverty headcount rate (%)	52.4	−2.72	−1.78	−1.58
Rural	55.9	−2.69	−1.82	−1.54
Urban	25.4	−2.90	−1.45	−1.96
Economy-wide benefit-cost ratio (EBCR)	—	1.62	1.62	0.76
Production-based benefit-cost ratio (PBCR)	—	0.99	0.92	0.56
Total cost (mil. USD)	—	65.9	67.2	66.1
Financed by foreign aid (%)	—	100.0	16.4	100.0

Source: Economywide model results.

Notes: Assumes a 60 percent hybrid FISP as in 2006/07. Base year GDP values are in USD per capita. Crop diversification index is a modified entropy measure ranging from zero to one, where higher values indicate increased number of crops grown and/or more equitable allocation of land across crops. Total benefit is the undiscounted value of total absorption and includes economywide spillovers. Welfare is measured using equivalent variation – reported base year values are average per capita consumption (in unadjusted USD). The marginal return to fertilizer use is expressed as the quantity of maize produced per kilogram of fertilizer applied.

and a decline in real maize prices due to marketing and demand constraints. These effects are consistent in direction with recent analyses such as Ricker-Gilbert (2014) and Mason et al. (2013). Farmers respond to falling relative maize prices by reallocating land to non-maize crops that earn better returns. This spillover from maize to other crops causes the crop diversification index to rise, which is consistent with the findings

of Holden and Lunduka (2010). Taking this land reallocation into account, FISP's net effect is an increase in maize production of 307,300 tons, representing about a 15% increase from base level maize production. This is smaller than the production gains reported in Dorward and Chirwa (2011). One reason for this difference is that those authors assume that only 10% of pre-FISP fertilizer is displaced, which is below the

24.6% displacement rate determined endogenously by our model and the 18% estimated by Jayne et al. (2013).

Unlike survey-based studies, our model captures how FISP affects Malawi's current account. About 80% of the cost of the program is payment for imported fertilizer, while the remainder consists of domestically-produced improved seed and transport and logistics costs. Hence, in our donor-funded scenario, most of the additional foreign aid brought into the country to cover the program cost leaves the country again to pay for fertilizer, and has little effect on external balances. Overall, there is a 2.7% appreciation in the real exchange rate and a decline in total exports, even though maize exports increase.¹⁰ The effect of FISP on non-maize exports via the exchange rate is an important spillover and macroeconomic effect of the program.

The FISP increases land productivity and releases agricultural land to other crops, many of which are of higher value than traditional maize. In fact, the roughly 15% gain in maize production occurs despite a slightly greater than 15% reduction in the total area allocated to maize. This is the major source of indirect benefits from FISP that has been largely unaccounted for in partial equilibrium studies.

Farm employment, wages, and the total returns to crop land all increase. This leads to higher welfare for farm households (measured using equivalent variation). Non-agricultural GDP falls slightly as resources are drawn into agriculture. However, nonfarm households' welfare still improves due to lower food prices and higher real wages for less-skilled workers. The national poverty rate falls by 2.7 percentage points as a result of the increase in the supply of goods driven by the 2006/07 FISP. This is a substantial decline in the context of a static CGE model. Nevertheless, it is essentially a one-off gain highlighting the importance of viewing FISP as a lever designed to induce a development process. While critical, these dynamics are left to future research.

Returning to the comparative static poverty rate reduction, recall that our simulation does not attempt to target the vouchers,

so poor and non-poor maize farmers benefit equally from the subsidy.¹¹ Because poor urban households are typically net food consumers, the urban poverty rate falls slightly more than the rural poverty rate due to lower food prices and higher wages. Finally, the total cost of the FISP, as modeled here, is US\$65.9 million (measured in 2002/03 prices), which is comparable in real terms to the actual program cost in 2006/07.¹²

One approach to measuring program benefits is to value the increase in maize production at base year prices. This produces a "production-based" benefit-cost ratio (PBCR) of 0.99, implying that FISP's benefits effectively equal its costs. This is broadly consistent with Dorward and Chirwa (2011) average PBCR of 1.06 for the 2006/07 program.¹³ However, a production-based approach captures only the *direct* impact of FISP and ignores *indirect* benefits, such as diversification into higher value crops, downstream processing, and positive spillovers from increased productivity resulting in rising incomes and consumer spending.

To account for FISP's indirect impacts, we measure economy-wide benefits using total real absorption, which is a measure of national welfare (i.e., private and public consumption and investment). In a purely donor-funded scenario, the benefit-cost ratio is simply the absorption gain divided by the foreign aid inflow. This calculation produces an "economy-wide" benefit-cost ratio (EBCR) of 1.62, which means that each dollar spent on FISP generated US\$1.62 dollars in national welfare improvements. This result indicates that, under the assumptions imposed, FISP should generate positive returns once indirect effects are included. By not including indirect benefits, survey-based evaluations fail to capture almost 40% of FISP's total benefits (i.e., $1.62 - 0.99/1.62$).¹⁴

¹¹ Very poor targeting, where a relatively few elites capture a large share of the benefits, would reduce the poverty impact. Improved targeting has the potential to drive more powerful reduction, unless poorer households achieve lower than average returns to fertilizer use (see Harou et al. 2014).

¹² This is net of the fertilizer redemption price paid by farmers to the government.

¹³ Dorward and Chirwa (2011) report a PBCR range of 0.76–1.36, with estimates varying depending on assumptions about the marginal return to fertilizer use, weather outcomes, output and input prices, and fertilizer displacement.

¹⁴ There is an opportunity cost to using the foreign aid given to Malawi to finance FISP. A correct assessment should compare FISP to the returns generated by other program options. We simulated a universal cash transfer program and found that

¹⁰ We do not simulate the 225,000 tons of net maize exports after the 2006/07 season, since this was a once-off arrangement with neighboring Zimbabwe.

Some “back-of-the-envelope” calculations may help in understanding the principal real economy effects. Suppose, for simplicity, that technology improved by 15% in the maize sector (Hicks-neutral technical change). If resources were fixed in all sectors, then maize value added would increase 15% and economy-wide value added (GDP) would increase by about 1.35% (since maize is about 9% of value added). Now suppose that the technical advance not only produces 15% more maize, but also uses 15% fewer factors of production. If these resources are reallocated to other sectors and the productivity of those sectors is equivalent to (improved) maize, then one would expect GDP to increase by about 2.7% (2×1.35). In GDP terms, the direct effects of the productivity shock on maize production would be approximately equal to the indirect effects of gains experienced elsewhere in the economy due to resource reallocations.

In simulation A, even though about 15% more production of maize is occurring on about 15% less land allocated to maize, we expect indirect effects to be smaller than direct effects. As shown in table 1, the new maize varieties demand about 17% more labor per hectare than traditional technologies. Summing across labor types and maize technologies, the model only projects a modest 1.3% decline in total labor demand by the maize sector. Since labor represents about 45% of maize value added in the baseline, we expect indirect gains to be roughly 59% of direct gains [i.e., $0.55 + 0.45 \times (0.013/0.15) = 0.589$].

These simple calculations lead to numbers similar to those produced by the model. Tracing the exact indirect benefit increment (0.63) generated by the model is complex. Broadly, the low productivity of traditional maize relative to most other agricultural sectors certainly plays a strong role. This effect is mitigated by the small but noticeable flow of labor from relatively high productivity non-agriculture into agriculture. The technological advance embodied in the seed and fertilizer package distributed under FISP is, as noted, not Hicks-neutral. Even though the technical packages rely on higher intermediate purchases per hectare, the yield

gains from FISP maize (in this scenario) outweigh these cost increases such that the cost share of intermediates in the value of maize production actually declines relative to the pre-FISP average. Finally, there are compositional effects across multiple land and labor types that are not accounted for in the simple calculations undertaken above.

Domestic Financing Options

The FISP was not directly paid for by increments to foreign aid. In this section, we consider a mainly domestically financed FISP. Our formula for the EBCR sets total program cost equal to the cost borne by foreign donors and the internalized cost achieved through tax increases or budget cuts elsewhere. Total benefit is equal to the real absorption gain plus the internalized cost. Internalized costs are added in the numerator because the absorption gain in the model is already net of tax increases and/or budget reallocations. The resulting formula is shown below.

$$\begin{aligned} EBCR &= \frac{\text{Total benefit}}{\text{Total cost}} \\ &= \frac{\text{Absorption gain} + \text{Internalized cost}}{\text{Foreign aid cost} + \text{Internalized cost}} \end{aligned}$$

As mentioned earlier, foreign aid has directly covered only a relatively small portion of FISP's total cost. In simulation B (column 3 in table 2), we again model a 500,000 hectare program distributing 150,000 tons of fertilizer; but the government uniformly raises all sales tax rates to cover their share of the costs.

In reality, Malawi's government financed FISP through a reorganization of its economic services budget including, as noted earlier, budget cuts to other government programs alongside efforts to raise revenue. In short, the differential budgetary contours between with and without FISP scenarios are difficult to know. Even if they were known, evaluating the associated opportunity costs would require an assessment of the efficacy of programs foregone including, in many domains, discounted future benefit streams derived from investments undertaken today (e.g., education). In this respect, financing options involving domestic taxes are attractive in that they involve current period

it produced an EBCR close to one. This means our EBCR results can be interpreted as being relative to a universal cash transfer program, which can be used as a basic counterfactual or opportunity cost of funds (see also Filipinski and Taylor 2012).

trade-offs including a marginal cost of public funds greater than one. In addition, the chosen financing option has the advantage of being a relatively distribution-neutral option, allowing some decomposability between incidence of program expenditure and incidence of program finance.¹⁵

In contrast to the complete details of program financing arrangements, the model fully captures implications for external balance. Without incremental foreign aid, Malawi must generate or reallocate foreign exchange in order to pay for imported fertilizer. This is achieved by encouraging the production of tradeables via a depreciation of the real exchange rate. This differs sharply from the real appreciation in the donor-funded scenario. Despite more maize exports, land is still reallocated to non-maize sectors. However, while diversification under donor funding was into food crops, the depreciation now shifts resources into export crops. The choice of financing option therefore has implications for program spillovers.

Agriculture is Malawi's main export sector, so the need to generate foreign exchange prompts a larger shift out of relatively high productivity nonfarm activities, and a rise in relatively low productivity farm employment. The displacement of imports and increases in exports as a result of increased production of tradeables implies fewer overall goods available within the economy. This reduction in the supply of goods, illustrated by reduced absorption gains between columns A and B of table 2, also implies smaller increases in real factor prices and smaller gains in household welfare.

Some obvious but important points on program finance are also pertinent. While the burden of higher indirect taxes falls fairly evenly across all households, since the increase in tax rates is uniform across products, urban and non-poor households form the bulk of the direct tax base. If simulation B had proportionally raised direct rather than indirect taxes, the incidence of the tax would have fallen almost exclusively on these households with concomitant negative welfare effects (results not shown). These differential impacts highlight how domestically-financed programs like FISP

can adversely affect households that are not direct beneficiaries. Accounting for these effects is important for comprehensive program evaluations when the programs have macroeconomic implications.

Switching to domestic financing reduces absorption but has little effect on the size of the GDP gain and the EBCR since maize productivity gains are of the same magnitude. There is a small decline in FISP's PBCR, which falls from 0.99 to 0.92 due to reallocations of resources to export crops and declines in food demand as a consequence of higher indirect taxes. It is the composition of GDP, rather than its level, that principally changes under domestic financing with a reallocation towards tradeable goods.

Marginal Returns to Fertilizer Use

Simulation C (column 4 in table 2) illustrates that outcomes are sensitive to fertilizer yield response rates. As shown in table 1, our baseline assumption is 15 and 18 kilograms of maize produced for each kilogram of nitrogen applied to composite and hybrid seeds, respectively. With 60% hybrid seeds, the average fertilizer response rate for FISP sectors (COM+ and HYB+) is 16.8, which is similar to the base response rates assumed by Dorward et al. (2008).

While a range of 15 to 18 kilograms of grain per kilogram of nitrogen is generally accepted as reasonable when fertilizer is used at recommended rates and in conjunction with modern maize seed varieties, the recent available evidence for Malawi, and particularly from the FISP-related literature, suggests that the actual rates achieved may have been much lower. Simulation C shows the results for a fertilizer yield response rate of 11.8, which is within the range of evaluations by Ricker-Gilbert and Jayne (2011) and Chibwana et al. (2010). The supplementary appendix online summarizes the literature on fertilizer yield response and illustrates our approach for estimating marginal returns to fertilizer use from studies where these were not directly reported.

As expected, outcomes in simulation C are uniformly less favorable than outcomes in its direct comparator, simulation A. Nevertheless, the program remains pro-poor, contributing to poverty reduction in both rural and urban areas. The pro-poor result, alongside the orientation of household welfare gains to farm households, is maintained

¹⁵ This choice does not mean that the authors believe that the Malawian government should or even could raise taxes to cover FISP. Financing issues are taken up again in the discussion of program size.

Table 3. Results from Rescaling and Fertilizer Dose-Response Scenarios

Program scale (ha)	Economywide benefit-cost ratio (EBCR) and production-based benefit cost ratio (PBCR) (in parentheses)				
	Marginal returns to fertilizer use				
	11.8	13.4	15.1	16.8	18.5
100,000	0.82 (0.49)	1.11 (0.64)	1.41 (0.78)	1.70 (0.92)	1.99 (1.06)
200,000	0.81 (0.49)	1.10 (0.63)	1.39 (0.78)	1.68 (0.92)	1.97 (1.06)
300,000	0.80 (0.49)	1.09 (0.63)	1.37 (0.77)	1.66 (0.92)	1.94 (1.06)
400,000	0.79 (0.49)	1.07 (0.63)	1.36 (0.77)	1.64 (0.92)	1.92 (1.06)
500,000	0.78 (0.49)	1.06 (0.63)	1.34 (0.77)	1.62 (0.92)	1.90 (1.06)
600,000	0.77 (0.49)	1.05 (0.63)	1.33 (0.77)	1.60 (0.91)	1.88 (1.06)
700,000	0.76 (0.49)	1.03 (0.63)	1.31 (0.77)	1.59 (0.91)	1.86 (1.06)

Source: Economywide model results using column B from Table 2 as a baseline.

Notes: The marginal return to fertilizer use is expressed as the quantity of maize produced per kilogram of fertilizer applied.

regardless of the financing scheme (alternative financing schemes not shown). Sensitivity to the fertilizer yield response rate is further explored in table 3, which reports EBCRs with PBCRs in parentheses.¹⁶ At the baseline scale of 500,000 hectares, a response rate of about 13 is required to achieve an EBCR of about one. This is more than 20% below the baseline value employed in the evaluation by Dorward et al. (2008), which yielded a benefit-cost ratio (somewhat analogous to the PBCR calculated here) of about one. This implies that, when economy-wide effects are included, a substantially lower level of efficiency of fertilizer use can still be associated with an economy-wide benefit-cost ratio greater than one.

Rescaling the Program

All simulations analyzed to this point consider 150,000 tons of fertilizer spread over

500,000 hectares. While keeping the fertilization rate constant at 16.8, we now vary the scale from 100,000 hectares (30,000 tons of fertilizer) to 700,000 hectares (210,000 tons of fertilizer). Results are shown in column 4 in table 3. Changing the scale of FISP has little effect on the PBCRs since the value of maize production, measured in base year prices, rises proportionally with the amount of subsidized fertilizer. In other words, fertilizer and land displacement rates remain fairly constant across programs of different scales. In contrast, EBCRs fall as FISP is scaled-up. This is because marketing and macroeconomic constraints are more pronounced for larger programs. In particular, it becomes increasingly difficult for Malawi to find the export opportunities and foreign exchange needed to pay for imported fertilizers. In addition, the larger sales taxes required to finance the program result in a higher marginal cost of public funds.

While these EBCRs point to relatively mild declines in returns from scaling up if taken at face value, it should be remembered that the model ignores adjustment costs associated with resource reallocations, as well as the tendency for actors to evade taxes as tax rates increase (Arndt and van Dunem 2009), thus increasing the marginal cost of public funds. These costs come on top of the already noticeable declines in the EBCR predicted by the model. Indeed, as mentioned, Malawi encountered significant financial difficulties while implementing the FISP, driven in part by difficulties in raising sufficient revenue to cover program costs, despite a high degree of popular support for the program. In reality, Malawi would likely experience greater difficulties than the model suggests if it attempted to increase program size. Similarly, the net gains to the EBCR from a smaller program, due to reductions in adjustment pressures as well as less burdensome operations, may be understated.

Weather Risks

Weather shocks affect program benefits by reducing agricultural production, including maize. As shown in figure 1, maize production losses caused by negative weather shocks (principally droughts) vary according to maize variety. The top panel of figure 2 reports maize production losses for the baseline and FISP scenarios. In 2002/03, 21% and 48% of maize was produced using composites

¹⁶ We use column B of table 2 as a baseline (the joint-funding option with distribution-neutral indirect tax rate increases). As such, a 500,000 hectare program with the baseline fertilizer dose-response rate of 16.8 produces the same 1.62 EBCR reported for simulation B in table 2.

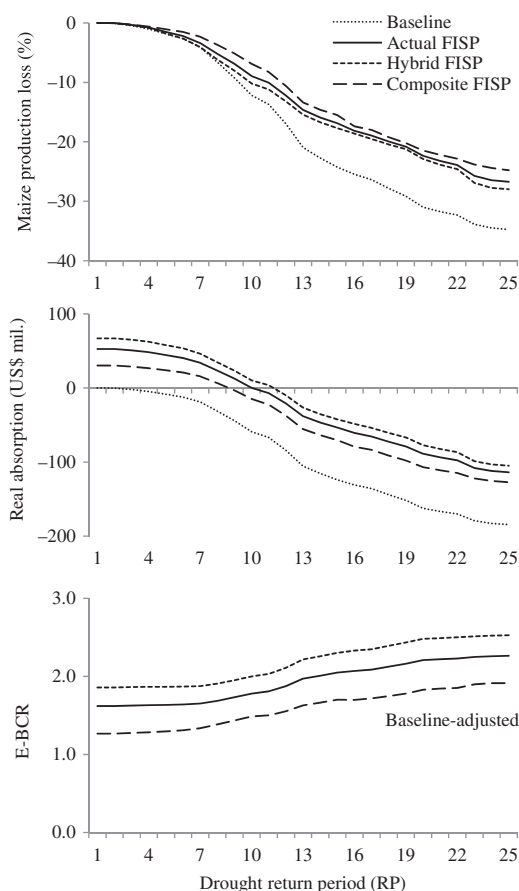


Figure 2. Results from the weather risk scenarios

Source: Economywide model results.

Notes: The acronym "EBCR" is the economy-wide benefit-cost ratio. Composite and Hybrid FISP scenarios use entirely composite and hybrid maize varieties, respectively, while Actual FISP is the 60% hybrid 2006/07 program. Total benefit is the undiscounted value of total absorption.

and hybrids, respectively, while the rest were local varieties. The baseline production losses (lower grey line in figure 2) are therefore a weighted combination of the exogenous production losses from figure 1, and the endogenous adaptation to weather events within the model. To illustrate, a severe RP20 drought will likely lead to baseline maize production losses of 31.2%.

As shown in figure 1, improved seeds are more drought-tolerant than local varieties within the range of our analysis, RP1 to RP25. By expanding the use of these seeds, FISP improves the drought tolerance of Malawi's maize sector. Note that FISP does *not* improve the tolerance of non-maize crops, and so the crop diversification caused

by FISP offsets improvements in drought tolerance within the maize sector. We again model a program in which 60% of the seeds were hybrids. Maize production losses during an RP20 event now fall to 22.3%, or about two-thirds of baseline losses (see solid line in top panel of figure 2). We also experiment with programs that provide only composite or hybrid seeds. Production losses are smaller for composite-only programs since this is the more drought-resistant of the two seed varieties. These results suggest that FISP generates "double dividends," that is, higher maize yields generally, as well as a maize system that is more resilient during droughts.

As weather shocks become more severe, output falls relative to a normal year but program costs remain virtually unchanged. However, baseline levels of output and absorption are not the appropriate counterfactual. For the weather-risk scenarios, the appropriate baseline is the absorption level that would have been achieved if the pre-FISP maize system had been subjected to the same weather shock as the with-FISP system. In other words, the incremental benefit of the program is defined as domestic absorption with FISP and a given weather outcome, less domestic absorption without FISP and the same weather outcome. This differential is shown by the gap between absorption in the baseline and FISP scenarios in the middle panel of figure 2. If we impose weather-related losses on the baseline and compare the FISP scenarios to this baseline adjusted counterfactual, then the EBCRs *increase* as weather events become more severe (see the lower panel) due to FISP's added benefit of drought-tolerant seed. This emphasizes the need to disentangle external risks from observed program outcomes, and to include changes in risk when calculating program benefits and costs.

Fertilizer Price Risks

Increases in world fertilizer prices also constitute an obvious program risk. As noted, high global fertilizer prices in 2008 clearly contributed to the financial difficulties faced by Malawi. These price increases were only one element of a confluence of highly unfavorable macroeconomic shocks that occurred between 2008 and 2010. Other elements included rises in fuel prices and sharp declines in world tobacco prices.

With fertilizer being the main cost component of FISP, higher world fertilizer prices inflate program costs considerably (internal balance). In addition, at higher fertilizer prices, more foreign exchange is required, which in turn necessitates larger real exchange rate depreciations in order to finance a constant level of FISP purchases (external balance).¹⁷ Actual world fertilizer prices increased approximately 140% between 2007/08 and 2008/09 (Heady and Fan 2011). As shown by Ott (2012), the price increases of 2008 represent one of two major fertilizer price spikes that have occurred in the past half century (the other occurred in 1974). Importantly, cost push factors are insufficient for explaining the more recent price spike. The price of energy, a critical input into fertilizer, did rise substantially, but only by about 50–75%, which is far less than the price rise for fertilizer. Higher crop prices, which spurred fertilizer demand, combined with fertilizer production capacity constraints, explain half or more of the fertilizer price spike.

As there is little reason to believe that huge profits in the fertilizer industry, due to output prices well above levels justified by input costs, would persist, there is little rationale for Malawi to structurally adjust its economy to cope with these extremes. Other means for coping are preferred, such as allowing the transmission of world fertilizer prices, use of reserves, or temporary borrowing. The FISP can be legitimately criticized for failing to incorporate mechanisms that aim to preserve macroeconomic stability, such as circuit breakers that allow domestic subsidized fertilizers prices to rise in the presence of steep world price increases.

Permanent increases in energy prices, which should pass through to fertilizer prices and are likely to drive up global crop prices via the biofuels link, are a different matter. Adjusting to a new global price environment is required. Table 4 illustrates implications when prices for oil, fertilizer, and major traded crops (except tobacco) increase by common percentages. In these simulations, area to tobacco is constrained to increase

by no more than 20% on the assumption of structural rigidities. Finally, to isolate the interaction effects of FISP and world price changes, we impose the world price shocks on both the baseline and FISP scenarios.

These results indicate that FISP's returns are exposed to the risk of structurally higher world fertilizer prices. Among other considerations, this makes the timing of surveys crucial for impact evaluations. For example, programs implemented in 2006/07 and 2008/09 would produce different EBCRs even if they shared the same program design and implementation. Studies that rely on PBCRs for their final assessments are even more likely to produce non-comparable results. Ultimately, being able to control for and experiment with external risks is a major advantage of using economy-wide *ex ante* models.

Validating General Equilibrium Effects

A parsimonious paraphrasing of Box (1976) might be: "All models are wrong but some are useful." While comparisons of model results with actual observations have been presented throughout the text, this section seeks to place salient model results within a coherent narrative. Before doing so, it is worth reiterating that the comparisons undertaken here involve a series of static model simulations from a 2003 base structure on the one hand, and nearly one decade of fairly tumultuous actual experience on the other. Persistent data weaknesses complicate not only the task of narrowing down a set of reasonable outcomes against which we can compare our results, but also that of calibrating the CGE model in the first place. The CGE model employed has, in addition, certain limitations related to assumed behavioral foundations that will not fully represent behavior of producers and/or consumers. As such, the model fails to capture certain features of livelihoods and markets.

In summary, the model is certainly wrong, but is it useful? The FISP's indirect effects in the model arise through changes in land allocation, maize prices, labor wages, and household consumption levels. We validate these general equilibrium mechanisms by comparing model results to observed changes in these four variables.

The model suggests that FISP causes a reallocation of maize land to other crops,

¹⁷ Maize prices may be correlated with world fertilizer prices (Baffes 2007). Higher world maize prices would increase the value of Malawi's maize exports, thereby alleviating some of the foreign exchange constraints caused by higher fertilizer prices. We do not, however, simulate higher maize prices, but note that this might reduce Malawi's exposure to higher fertilizer prices.

Table 4. Results of the Fertilizer Price Risk Scenarios

	Deviation from baseline without FISP			
	+0% (B)	+10% (D)	+20% (E)	+50% (F)
Real world fertilizer prices				
Economywide benefit-cost ratio (EBCR)	1.62	1.51	1.41	1.22
Production-based benefit-cost ratio (PBCR)	0.92	0.68	0.49	0.07
Total costs (mil. USD)	67.2	74.7	82.3	105.3
Public funding share (%)	83.6	85.3	86.6	89.6
Real exchange rate index	0.72	0.93	1.12	1.67
Tobacco production (1000mt)	12.8	20.3	27.9	50.2
Household welfare (%)	2.79	2.63	2.47	2.00
Farm	4.16	4.07	3.99	3.75
Non-farm	-1.10	-1.46	-1.82	-2.98
Poverty headcount	-1.78	-1.51	-1.37	-0.90
Rural	-1.82	-1.54	-1.42	-1.02
Urban	-1.45	-1.24	-0.98	-0.01

Source: Economywide model results using column B of Table 2 as a baseline.

particularly export crops. Official crop estimates produced by MoAFS, while frequently criticized as being unreliable, point to a relative decline in the share of crop land allocated to maize from 51.7% in 2003/04 to 43.9% in 2011/12. This 14.4 percentage point decline is similar to the 16.6 percentage point decline in simulation B in table 2 (i.e., a 248,900 hectare decline out of a total 1.5 million hectares). During the same period, the share of land used for export crops (e.g., tobacco, oilseeds, and cotton) increased from 33.7 to 39.5% (a 17% increase). In short, the data suggest a more pronounced orientation towards tradeables in the actual agricultural sector than suggested in the model. This is consistent with the strong price increases observed for food crops, fuel, and fertilizer over the past decade (but not present in simulation B), all of which should push the Malawian economy towards the production of tradeables.

Higher maize production should reduce real maize prices, *ceteris paribus*. Ricker-Gilbert et al. (2013) estimate that doubling the size of FISP would reduce real maize prices by 1.2–2.5%. While not directly comparable, this range is not drastically different from our estimated 3.2% real price decline in simulation B (table 2). Measuring real price changes is complicated by substantial inter-annual variability in nominal prices and the generalized statistical fog mentioned above, which includes revisions to inflation

estimates. For example, the NSO (2012) almost doubled its inflation estimate for the period 2004 to 2011 for the national poverty study, causing estimated real maize prices to fall by 12.6% over this period, instead of rising by 12.8%.

Increased maize production should increase labor demand, especially during harvest season. Ricker-Gilbert (2014) estimates that a ten kilogram increase in the average amount of subsidized fertilizer per household increases median hired farm laborer's wages by 1.4%. Since FISP distributed an average 40–60 kilograms of fertilizer to about half of all farmers, this would imply, assuming linear effects, a roughly 2.8–4.2% increase in farm wages. This is a bit smaller than the 4.4% increase in average farm wages in simulation B. Differences may be due to the scale of labor markets being studied (village versus national), and our inclusion of family farm workers and not just hired farm labor.

Finally and importantly, household consumption should rise with higher maize productivity. Pauw, Beck, and Mussa (2014) estimate a seven percentage point decline in the national poverty headcount rate between 2004/05 and 2010/11, with more pronounced declines in poverty in rural areas. These observed declines in the poverty rate are consistent in direction and pattern with simulation B. These consumption poverty gains are corroborated by improvements in non-monetary dimensions of welfare.

Conclusions

Household surveys are often used to evaluate government and donor programs. However, this approach to program evaluation often overlooks economy-wide program design elements such as spillovers, scaling and macroeconomic effects including taxation, and risk factors such as weather and world price shocks, all of which can be important, particularly for large-scale programs. These elements may prove to be crucial in deciding whether a program is desirable and/or sustainable. We show that this is true for Malawi's Farm Input Subsidy Program, which is a large-scale and costly program exposed to droughts and world fertilizer prices. To conduct our economy-wide impact assessment, we developed a computable general equilibrium model that combined empirical evidence from survey-based studies with detailed macro-structural information about the Malawian economy and its behavior.

We find that, using fertilizer response rates corresponding to those in the official evaluation, FISP generates modest *direct* returns in the form of higher maize productivity and production, which is modulated by increased crop diversification. Using official fertilizer response rates, our finding of a direct benefit-cost ratio of about one is consistent with Dorward et al. (2008). However, our economy-wide analysis indicates that FISP also generates *indirect* benefits that are either not captured by small-scale "farm" surveys, or extremely hard to identify in more comprehensive ones (e.g., nationally representative household surveys). The corresponding economy-wide benefit-cost ratio is estimated at 1.62. As such, accounting for indirect benefits increases the benefit-cost ratio by about 60%. These indirect returns arise principally from the release of resources, especially land, permitted by more efficient maize production.

Fertilizer use efficiency rates are key determinants of FISP's benefits. As in all previous studies, a lower marginal return to fertilizer use substantially reduces both direct and indirect returns. For studies focused only on direct benefits, a minor decline in fertilizer use efficiency drives the benefit-cost ratio to less than one. In contrast, a marginal return to fertilizer use at 80% of our baseline value of 16.8 remains consistent with an economy-wide benefit-cost ratio greater than one due

to positive spillover effects. Even under the lower-end response rates near to the survey-based estimates of Ricker-Gilbert and Jayne (2011) and Chibwana et al. (2010), where economy-wide benefit-cost ratios decline to less than one, the FISP still generates poverty reduction. Assuming that these two lower-end estimates are correct, only relatively small improvements in the marginal return to fertilizer use would be required to achieve an overall gain. At the same time, the estimates of Dorward et al. (2008) and Harou et al. (2014) are also plausible and are associated with large economy-wide gains.

Benefits decline when FISP is financed using domestic taxes rather than donor funding, as has been the case since the program was first implemented. Without a large supply response from exporters, Malawi finds it difficult to import fertilizers using taxes collected in the local currency. This problem compounds itself for larger-scale programs. Moreover, financing FISP influences distributional outcomes, potentially making some households worse off after the program due to higher taxes. Our findings suggest that addressing macroeconomic constraints is essential for the future returns and sustainability of FISP.

Importantly, economy-wide benefits of FISP rise with worsening weather outcomes because the improved seeds distributed under the FISP program are more drought-tolerant than local varieties. By expanding the use of these seeds, FISP generates "double-dividends" in the form of higher yields and a more drought-resilient maize sector.

Generally, a comprehensive program evaluation should consider both direct and indirect benefits and costs, particularly for large programs. Our economy-wide approach not only captures indirect effects, but also complements survey-based studies by allowing experimentation with alternative program design elements and risks. For example, a rise in the fertilizer price, particularly relative to the maize price, constitutes a program risk that was explicitly evaluated. We conclude that the approach forms a valuable part of the evaluation toolkit.

In contrast to Jayne and Rashid (2013), who characterize existing fertilizer programs in Malawi as low potential distractions that siphon resources from more beneficial development initiatives, we find relatively high

potential in a country with limited alternatives. As emphasized in this study and the existing literature, there are risks. Nevertheless, our results buttress arguments for patience and a focus on improving results within FISP.

There remain ample areas that merit further research. First, the fundamental fertilizer delivery elements of the program remain of interest. This includes more accurate estimation of marginal returns to fertilizer use, as well as more analysis to measure the extent to which fertilizer is diverted and the extent to which diverted fertilizer has a displacement effect on commercial fertilizer sales (similar for seed). Second, while our analysis points to macroeconomic constraints, there is room for more detailed analysis, for example, of policies designed to cope with fertilizer price spikes. Lastly and importantly, in order to lock in durable development gains, we do not consider how fertilizer subsidies could be packaged with other interventions, such as companion policies on soil fertility management practices, investments in rural roads, and export opportunities, nor do we consider exit strategies over the longer run.

Supplementary material

Supplementary material is available at http://oxfordjournals.org/our_journals/ajae/online.

References

- Arndt, C., M.A. Hussain, E.S. Jones, V. Nhate, F. Tarp, and J. Thurlow. 2012. Explaining the Evolution of Poverty: The Case of Mozambique. *American Journal of Agricultural Economics* 94 (4): 854–72.
- Arndt, C., and J. Van Dunem. 2009. Estimating the Elasticity of Evasion. *Journal of Development Studies* 45 (6): 1010–25.
- Baffes, J. 2007. Oil Spills on Other Commodities. *Resources Policy* 32 (3): 126–34.
- Bamberger, M., V. Rao, and M. Woolcock. 2010. Using Mixed Methods in Monitoring and Evaluation: Experiences from International Development. Washington DC: World Bank Policy Research Working Paper 5245.
- Baum, W.C., and S.M. Tolbert. 1985. *Investing in Development: Lessons of World Bank Experience*. London and New York: Oxford University Press for the World Bank.
- Benin, S., J. Thurlow, X. Diao, C. McCool, and F. Simtowe. 2012. Malawi. In *Strategies and Priorities for African Agriculture: Economy-wide Perspectives from Country Studies* Diao, X., J. Thurlow, S. Benin, and S. Fan, eds, 245–79. Washington DC: International Food Policy Research Institute.
- Benson, T. 1999. Area-specific Fertilizer Recommendations for Hybrid Maize Grown by Malawian Smallholders: A Manual for Field Assistants. Report prepared for the Maize Productivity Task Force by Chitedze Agricultural Research Station, Malawi.
- Box, G.E.P. 1976. Science and Statistics. *Journal of the American Statistical Association* 71 (356): 791–99.
- Brent, R.J. 1990. *Project Appraisal for Developing Countries*. Hertfordshire, UK: Harvester Wheatsheaf.
- Chibwana, C., M. Fisher, W. Masters, and G. Shively. 2010. Measuring the Impacts of Malawi's Farm Input Subsidy Program. Paper presented at the 3rd Association of African Agricultural Economists' Conference, Cape Town, South Africa.
- Chibwana, C., M. Fisher, and G. Shively. 2012. Cropland Allocation Effects of Agricultural Input Subsidies in Malawi. *World Development* 40 (1): 124–33.
- Chirwa, E., and A. Dorward. 2013. *Agricultural Input Subsidies. The Recent Malawi Experience*. Oxford, UK: Oxford University Press.
- Dimaranan, B.V. 2006. *Global Trade, Assistance, and Production: The GTAP 6 Database*. West Lafayette: Center for Global Trade Analysis, Purdue University.
- Dorward, A., and E. Chirwa. 2011. The Malawi Agricultural Input Subsidy Programme: 2005/06 to 2008/09. *International Journal of Agricultural Sustainability* 9 (1): 222–47.
- Dorward, A., E. Chirwa, V. Kelly, T. Jayne, R. Slater, and D. Boughton. 2008. Evaluation of the 2006/07 Agricultural Input Subsidy Programme, Malawi. Final Report submitted to the Ministry of Agriculture and Food Security, Government of Malawi, Lilongwe.
- Douillet, M., K. Pauw, and J. Thurlow. 2012. A 2007 Social Accounting

- Matrix for Malawi. Washington DC: International Food Policy Research Institute. Available at: <http://hdl.handle.net/1902.1/18578>.
- Dyer, G.A., and J.E. Taylor. 2011. The Corn Price Surge: Impacts on Rural Mexico. *World Development* 39 (10): 1878–87.
- Filipski, M., and J.E. Taylor. 2012. A Simulation Impact Evaluation of Rural Income Transfers in Malawi and Ghana. *Journal of Development Effectiveness* 4 (1): 109–29.
- Gittinger, J.P. 1984. *Economic Analysis of Agricultural Projects*. Baltimore: Johns Hopkins University Press.
- Harou, A., Y. Liu, C.B. Barrett, and L. You. 2014. Variable Returns to Fertilizer Use and Its Relationship to Poverty: Experimental and Simulation Evidence from Malawi. Discussion Paper 01373. Washington DC: International Food Policy Research Institute.
- Heady, D., and S. Fan. 2011. Reflections on the Global Food Crisis. Research Monograph 165. Washington DC: International Food Policy Research Institute.
- Holden, S., and R. Lunduka. 2010. Too Poor to be Efficient? Impacts of the Targeted Fertilizer Subsidy Program in Malawi on Farm Plot Level Input Use, Crop Choice and Land Productivity. Noragric Report 55. Norwegian University of Life Sciences, Ås, Norway.
- Horridge, M., J. Maddan, and G. Wittwer. 2005. The Impact of the 2002–2003 Drought on Australia. *Journal of Policy Modeling* 27 (3): 285–308.
- Jayne, T.S., D. Mather, N. Mason, and J. Ricker-Gilbert. 2013. How Do Fertilizer Subsidy Programs Affect Total Fertilizer Use in Sub-Saharan Africa? Crowding Out, Diversion, and Benefit/cost Assessments. *Agricultural Economics* 44 (6): 687–703.
- Jayne, T.S., and S. Rashid. 2013. Input Subsidy Programs in Sub-Saharan Africa: A Synthesis of Recent Evidence. *Agricultural Economics* 44 (6): 1–16.
- Kankwamba, H., M.A.T.J. Mapila, and K. Pauw. 2012. Determinants and Spatiotemporal Dimensions of Crop Diversification in Malawi. Project Report produced under a co-financed research agreement between Irish Aid, USAID and IFPRI, Paper No. 3 of 4.
- Lofgren, H., R.L. Harris, and S. Robinson. 2002. A Standard Computable General Equilibrium (CGE) Model in GAMS. Washington DC: International Food Policy Research Institute.
- Lunduka, R., M. Fisher, and S. Snapp. 2012. Could Farmer Interest in a Diversity of Seed Attributes Explain Adoption Plateaus for Modern Maize Varieties in Malawi? *Food Policy* 37 (5): 504–10.
- Mason, N., T.S. Jayne, F.A. Darko, and S. Tembo. 2013. What are the Effects of Input Subsidy Programs on Equilibrium Maize Prices? Evidence from Malawi and Zambia. Paper for American Association of Agricultural Economics annual meetings. Washington DC.
- National Statistics Office. 2005. Integrated Household Survey 2004–2005. Zomba, Malawi: National Statistics Office.
- . 2012. Integrated Household Survey 2010–2011. Zomba, Malawi: National Statistics Office.
- Ott, H. 2012. Fertilizer Markets and Their Interplay with Commodity and Food Prices. Joint Research Centre Scientific and Policy Report EUR 25392 EN. European Commission, Institute for Prospective Technological Studies, Seville, Spain.
- Pauw, K., U. Beck, and R. Mussa. 2014. Did Rapid Smallholder-led Agricultural Growth Fail to Reduce Rural Poverty? Making Sense of Malawi's Poverty Puzzle. WIDER Working Paper No. 2014/123. Helsinki: UNU-WIDER.
- Pauw, K., J. Thurlow, M. Bachu, and D.E. Van Seventer. 2011. The Economic Costs of Extreme Weather Events: A Hydro-meteorological CGE Analysis for Malawi. *Environment and Development Economics* 16 (2): 177–98.
- Ricker-Gilbert, J. 2014. Wage and Employment Effects of Malawi's Fertilizer Subsidy Program. *Agricultural Economics* 45 (3): 337–53.
- Ricker-Gilbert, J., and T. Jayne. 2011. What Are the Enduring Effects of Fertilizer Subsidy Programs on Recipient Farm Households? Evidence from Malawi. Staff Paper 2011–09, Department of Agricultural, Food and Resource Economics, Michigan State University.
- Ricker-Gilbert, J., T.S. Jayne, and E. Chirwa. 2011. Subsidies and Crowding Out: A Double Hurdle Model of Fertilizer Demand in Malawi. *American Journal of Agricultural Economics* 93 (1): 26–42.

- Ricker-Gilbert, J., N.M. Mason, F.A. Darko, and S.T. Tembo. 2013. What are the Effects of Input Subsidy Programs on Maize Prices? Evidence from Malawi and Zambia. *Agricultural Economics* 44 (6): 671–86.
- Smale, M., P.W. Heisey, and H.D. Leathers. 1995. Maize of the Ancestors and Modern Varieties: The Microeconomics of High-yielding Variety Adoption in Malawi. *Economic Development and Cultural Change* 43 (2): 351–68.
- Tchale, H., and J. Keyser. 2010. Quantitative Value Chain Analysis: An Application to Malawi. Washington DC: Policy Research Working Paper 5242, The World Bank.
- Wodon, Q., and K. Beegle. 2006. Labor Shortages Despite Underemployment? Seasonality in Time Use in Malawi. In *Gender, Time Use and Poverty in Sub-Saharan Africa*, Blackden, C.M., and Q. Wodon eds., 97–116. Washington DC: World Bank.