WIDER Working Paper 2014/099

The economywide impacts and risks of Malawi's farm input subsidy programme

Channing Arndt,[1*] Karl Pauw,[2] and James Thurlow[2]

July 2014

Abstract: We estimate the impact of Malawi's Farm Input Subsidy Programme using an economywide approach. We find potentially substantial net benefits with indirect benefits accounting for about two-fifths of total benefits. Due to these indirect benefits, the cut-off at which lower fertilizer yield response rates lead to net programme losses is much lower than the value suggested by existing partial equilibrium evaluations. Benefits decline with domestic financing and real fertilizer price increases. Abstracting from extreme events, Malawi's programme potentially generates double dividends through higher and more drought-resilient yields. Overall, our results buttress arguments for patience and a focus on programme efficiency improvements.

Keywords: programme evaluation, risk assessment, economywide model, farm subsidies, Malawi
JEL classification: C68, O13, O22, Q18

---

[1]University of Copenhagen and UNU-WIDER [2]International Food Policy Research Institute; corresponding author: channing@wider.unu.edu

This study has been prepared within the UNU-WIDER project 'Development under Climate Change', directed by Channing Arndt, James Thurlow, and Finn Tarp.

ISSN 1798-7237 ISBN 978-92-9230-820-9

Typescript prepared by Fiona O'Brien for UNU-WIDER.

UNU-WIDER gratefully acknowledges the financial contributions to the research programme from the governments of Denmark, Finland, Sweden, and the United Kingdom.

The World Institute for Development Economics Research (WIDER) was established by the United Nations University (UNU) as its first research and training centre and started work in Helsinki, Finland in 1985. The Institute undertakes applied research and policy analysis on structural changes affecting the developing and transitional economies, provides a forum for the advocacy of policies leading to robust, equitable and environmentally sustainable growth, and promotes capacity strengthening and training in the field of economic and social policy-making. Work is carried out by staff researchers and visiting scholars in Helsinki and through networks of collaborating scholars and institutions around the world.

UNU-WIDER, Katajanokanlaituri 6 B, 00160 Helsinki, Finland, wider.unu.edu

1 Introduction

A large literature has emerged that considers ex post evaluation of policy interventions in both developed and developing countries. This programme evaluation literature typically focuses on the merits of alternative survey-based techniques in attributing outcomes (Bamberger, Rao and Woolcock 2010). However, even when a programme's evaluation is well designed and executed, general equilibrium impacts resulting from large-scale programmes can be difficult to capture using micro-level survey data. In fact, the potential for general equilibrium effects to substantially influence the outcome of a project has long been recognized in the benefit-cost analysis literature (see, for example, Gittinger 1984; Baum and Tolbert 1985; Brent 1990). Programmes may generate spillovers that benefit non-recipients or may compete for resources (e.g. land, labour and water) and so indirectly affect non-recipients and other programmes. Even if the programme under study is small, these pilot programmes are, if successful, typically intended to be scaled up. Once at scale, the same programme may generate spillovers and/or encounter resource constraints. Large-scale programmes may also influence other macroeconomic variables such as when external balances are affected or when financing a programme alters fiscal policy. Evaluations that do not account for these design elements may reach incorrect conclusions about a programme's desirability, sustainability and overall impacts.

Malawi's Farm Input Subsidy Programme (FISP) is a prime example of a large-scale, national programme with potentially significant economywide effects. FISP's budget accounts for between three and six per cent of Malawian gross domestic product (GDP) and its direct beneficiaries include more than two-fifths of Malawi's population. Most of the impact evaluations for FISP reviewed in this study are based on micro-level surveys or partial equilibrium models, which typically fail to identify all the pathways through which households are impacted, or ignore the spillover or economywide effects altogether.

In this paper, we present a comprehensive evaluation of Malawi's FISP. In so doing, we develop an approach for incorporating economywide effects within a programme evaluation framework. Specifically, we use a detailed economywide 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 a conduct simple sensitivity analysis with respect to the world price for fertilizer, which constitutes a principal programme risk.

Our approach is in line with a series of studies that employ economywide 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 programme evaluation.

In the next section, we describe Malawi's FISP drawing upon existing evaluation studies. We then specify the economywide model, describe its calibration to survey and other data, and outline our evaluation approach. Our findings are then presented and compared to existing analyses.

We find that FISP generates substantial economywide impacts indicating that an economywide approach, such as the one proposed here, is essential for programmes of the relative magnitude of FISP. Similar to partial equilibrium ex ante evaluations undertaken to date, the marginal return to fertilizer use by programme recipients represents a critical parameter. However, because of positive spillover effects, the economywide benefit-cost ratio falls below one only at a fertilizer yield response rate substantially below the rate used in what is popularly referred to as the 'official' programme evaluation (Dorward et al. 2008) (i.e. around 16.8 kilogrammes of maize per kilogramme of nitrogen). At this level of fertilizer efficiency, the programme achieves an 'economywide' benefit-cost ratio of 1.62. This ratio falls to one at a fertilizer yield response rate of around 13, which is above but reasonably close to the more pessimistic response rate estimates in the literature.

Overall, the analysis paints a picture of the FISP as a relatively high potential policy. Under plausible parameter values, it is pro-poor, with the potential to generate substantial economywide gains and to help mediate most weather shocks (extreme weather shocks are not considered). This contrasts with the view, set forth by Jayne and Rashid (2013) and based on partial equilibrium assessments, of fertilizer subsidy programmes as low potential and grounded fundamentally in political motivations. Our results indicate that the FISP can form a part of a viable development strategy. Nevertheless, positive outcomes are not guaranteed. Jayne and Rashid (2013) rightly emphasize the potential for operational problems to reduce programme benefits, potentially dramatically. Principal programme risks identified in the analysis include the potential failure to attain the fertilizer efficiency levels required to generate net economywide benefits; failures in programme management that dampen the impact of the programme on overall fertilizer use; substantial increases in world fertilizer prices; and macroeconomic adjustment costs imposed by excessive programme size.

2 Malawi's Farm Input Subsidy Programme

As in most low-income countries, agriculture is Malawi's main sector, generating one-third of GDP, half of total export earnings and two-thirds of employment (Douillet, Pauw and Thurlow 2012a). The sector is dominated by rainfed 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 (Benin et al. 2012). After severe droughts and famine in the early 2000s, the government decided to implement FISP.

2.1 Programme design

FISP was first implemented during the 2005/06 cropping season and has continued in subsequent years. The programme targets 1.5 million rural smallholders or about half of all farmers in Malawi. FISP is designed to provide each farmer with two coupons, which are redeemable for two 50 kilogramme 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 tonnes each year, although actual distribution peaked at 216,000 tonnes in 2007/08.

Farmers are also provided with free improved seeds: starting at 2–3 kilogrammes per farmer in 2005/06 and rising to 5–10 kilogrammes 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, whereas higher-yielding hybrids cannot be recycled. Initially, about 60 per cent of the seeds under FISP were hybrids, but this rose to almost 90 per cent in 2009/10. Finally, FISP has at times included subsidies for tobacco, coffee and tea fertilizers, chemicals, and cotton and legume seeds, although all of these components have been small compared to maize. Consequently we focus on the maize seed and fertilizer subsidy components of the programme.

2.2 Programme implementation

Identifying the productive poor presents a challenge. In practice, farmers' eligibility has been determined by local leaders who do not always apply the same criteria, leading to inconsistent targeting across districts or 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); moreover, there is evidence that subsidized fertilizers have been targeted towards less efficient households (Holden and Lunduka 2010). On average, beneficiaries receive less than the intended 100 kilogrammes 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 displaced commercial fertilizer used in Malawi before the programme was implemented. This is indicative of a programme that targets farmers who would have purchased fertilizer even in the absence of the subsidy. Jayne et al. (2013) estimate an 18 per cent fertilizer displacement rate for Malawi's FISP, implying that every kilogramme of subsidized fertilizer provided leads to a 0.82 kilogramme net increase in fertilizer use. However, the authors argue that traditional econometric methods underestimate true displacement rates when subsidized fertilizer is diverted (or stolen) and sold to unsuspecting consumers at commercial prices. Since these consumers think they are buying commercial fertilizer they would also report it as such, and the econometric model would not detect the fact that commercial fertilizer is in fact displaced; hence, the authors argue, both diversion and displacement should be taken into account when measuring the net increase in fertilizer use.

One way to measure diversion is to estimate total subsidized fertilizer receipts from household surveys, with the diversion rate then equal to one minus the ratio of actual receipts to official disbursements. Drawing on studies in Zambia, Malawi and Kenya, Jayne et al. (2013) believe a plausible range of diversion rates in large subsidy programmes is 16.5 to 40 per cent, and hence an 'adjusted' range of net increases in fertilizer use for Malawi would be 0.42 to 0.66 kilogramme (rather than 0.82). Available published estimates of diversion rates in Malawi are at the upper end of this range; for example, most recently Lunduka, Ricker-Gilbert and Fisher (2013) estimate a rate of 42 per cent using the 2009/10 Integrated Household Survey (IHS3).

Estimating diversion rates in this manner is fraught with challenges for several reasons. Firstly, IHS3 data on subsidized fertilizer quantities received substantial cleaning with frequent subjective judgement calls required. Lunduka, Ricker-Gilbert and Fisher (2013), for example, drop households that report having received more than 600 kilogrammes of subsidized fertilizer (compared to the FISP guideline of 100 kilogrammes per farmer). The fact that the survey was conducted over two FISP implementation periods also complicates such an aggregation exercise. To illustrate the point, our own estimate of diversion rate is only 33 per cent when we use IHS3 subsidized fertilizer receipt data cleaned by the National Statistics Office (NSO) (which includes perceived outliers). Second, it is plausible that beneficiary households would have a tendency to under-report subsidized fertilizer receipts in the same way that income is generally under-reported in household surveys, especially for those receiving more than the permissible amount. This would lead to an overestimation of the diversion rate. Finally, a corrupt official using diverted fertilizer on his/her own land or those knowingly buying diverted fertilizer (usually at a steep discount) are unlikely to report having received subsidized fertilizer, but at the same time would not necessarily claim to have bought that fertilizer from a private retailer; they are more likely to keep completely quiet about any illicit transactions, which means displacement rates are not necessarily underestimated and diversion rates are probably overestimated. The method of summing diversion and displacement rates would be appropriate if *all* diverted fertilizer were purchased by unsuspecting consumers who believe they are purchasing commercial fertilizer and report it as such.

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 programme 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 during 2006–09, a result corroborated by Kankwamba, Mapila and Pauw (2012) finding that FISP beneficiaries have a higher crop diversification index even though overall crop diversification has declined in Malawi. 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 displacement of commercial fertilizer, particularly when land is reallocated away from fertilizer-intensive crops such as maize to crops that require less fertilizer. Finally, Ricker-Gilbert (2012) finds that, while FISP did not influence farmers' decisions to hire out their own labour, it did raise average wages for hired workers in rural areas reflecting increased labour demand.

2.3 Programme financing

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 per cent 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 2008/09 when the world price more than doubled. 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 2005/06–2009/10, whereas the range of actual costs was US$81–228 million.

FISP has accounted for about 9 per cent of the national budget, except in 2008/09 when this share doubled. This has prompted large cuts to other agricultural programmes, such as irrigation, research and extension, and to other economic sectors, including roads, industry and the environment (Douillet, Pauw and Thurlow 2012b). While FISP may benefit the maize sector, it has potentially substantial opportunity costs with economywide implications. In the next section, we describe an economywide model that captures many of the above design, implementation and financing aspects of FISP.

3 Measuring economywide impacts

To measure economywide impacts, we employ a computable general equilibrium (CGE) model of Malawi. CGE models have a number of features that make them suitable for programme evaluations. They simulate the functioning of a market economy, including markets for land, labour, capital and products, and offer insights into how a programme's impacts are mediated through prices and resource reallocations. They ensure all resource and macroeconomic constraints are respected, which is essential for large-scale programmes. Finally, they 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. The model 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. 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 services such as public administration, health and education. 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 programme 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. Labour is fully employed due to seasonal labour 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 numeraire.

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 can then be calculated and compared against an absolute poverty threshold to determine if a household's poverty status has changed from the base.

3.1 Data sources

The model's parameters are given values from survey and other data. A social accounting matrix (SAM) was estimated for 2003,[1] which is the closest 'normal' weather year prior to FISP's implementation in 2005, and is the baseline used by Dorward et al. (2008). The SAM reconciles data from national and government accounts; customs and revenue services 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 NSO. The 2004/05 Integrated Household Survey (IHS2) was used to divide

[1] The 2003 SAM was constructed following the approach described in Douillet et al. (2012a).

labour into five education categories and households into 30 groups (NSO 2005).[2] Households earn incomes based on reported wages and profits from farm and non-farm enterprises. 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 the MoAFS. Crop land is separated from agricultural capital and includes farm profits and the implicit returns to unpaid family labour. Smallholders are separated by farm size, i.e. small (≤ 0.5 hectares), medium (≤ 2.5 hectares) and large (> 2.5 hectares). Farmers can reallocate their land and labour in response to relative price changes. The exception is land allocated to FISP maize, which is done exogenously in our simulations to exactly replicate the size of FISP. 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. 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- and post-FISP periods. Finally, household income elasticities are econometrically estimated by rural and urban quintiles using IHS2, and trade and factor substitution elasticities are from Dimaranan (2006).

Table 1: Maize production technologies (inputs and output per hectare, ha)

	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 labour (days)	35.0	47.0	58.4	44.3	56.8	60.8
Family labour (days)	44.0	44.0	44.0	44.0	44.0	44.0
Revenues (US$)	152	273	388	246	446	551
Seed and fertilizer costs (US$)	23	80	93	55	41	41
Value added (US$)	83	125	220	133	324	421
Hired labour 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 (tonnes/ha)	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

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 kilogramme of fertilizer applied, assuming a fertilizer nitrogen content factor of approximately one-third for FISP fertilizer.

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

3.2 Evaluation approach

Table 1 shows the new maize technologies adopted by FISP recipients (i.e. COM+ and HYB+). Prior to FISP, these new technologies produced negligible amounts, such that all maize is

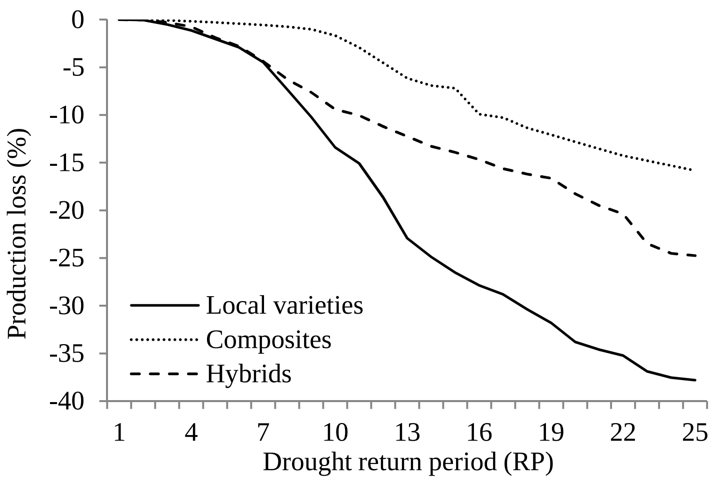
[2] Groups include farm and non-farm households in rural and urban areas. Rural farm households are further separated by farm size, i.e. small, medium and large. Each group is disaggregated by national expenditure quintiles.

effectively produced using existing technologies (note that ALL in Table 1 represents the weighted average across LOC, COM and HYB varieties).

To simulate FISP, we exogenously increase the land allocated to COM+ and HYB+ technologies. Producing this new maize requires resources that must be drawn from existing crops, including traditional maize and from non-farm activities. Final land allocations for all other crops are determined endogenously by technologies, resource constraints and relative prices. Given that 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. 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.[3] For example, local variety maize production is 33.8 per cent 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), but they are also more drought resistant, with losses of 12.8 and 18.2 per cent, 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.

Figure 1: Drought loss exceedance curves for maize varieties



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

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

[3] 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' (RP) 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.

For the weather risk scenarios, we select an RP event from the LECs and apply the productivity losses to each maize variety. To reflect farmers' decision-making and difficulty in predicting weather, we assume that farmers allocate land to crops at 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 a threshold event greater than RP25. At this threshold, production would be similar regardless of which seed variety (or how much fertilizer) is used, implying that, for a sufficiently severe drought, the FISP would provide zero returns.[4]

4 Evaluation results

We use the model to replicate the maize component of Malawi's 2006/07 FISP, i.e. 150,000 tonnes of maize fertilizer distributed to smallholders together with improved maize seeds, of which 60 per cent are hybrid varieties. In order to simulate FISP in the model, we must determine how much maize land was affected by the programme. If we assume the recommended application rate of six 50 kilogramme bags of fertilizer per hectare (see Benson 1999), then FISP provided fertilizer to 500,000 hectares (i.e. 150,000 metric tonne/300kg). This fertilizer application rate generates yields of 2.2 and 2.8 tonnes 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 dose-response rates differ across varieties. The yield effect is largest for hybrids.[5]

Dorward and Chirwa (2011) report that, in 2006/07, 54 per cent of 2.47 million eligible farmers received subsidized fertilizer. This implies that 1.32 million farmers were given 2.3 vouchers each (113 kg of fertilizer). Using IHS2, Benin et al. (2012) estimate that poor farmers planted an average of 0.38 hectares of maize in 2004/05. If we maintain this land allocation, then FISP affected 507,500 hectares (i.e., 1.32 million × 0.38). This is very similar to our own estimate. However, Dorward and Chirwa (2011) identify discrepancies in population estimates and suggest that there may be as many as 3.48 million farmers. This means that FISP gave farmers only 1.6 vouchers each (80 kilogrammes of fertilizer) and affected 715,500 hectares (i.e., 54 per cent × 3.48 million × 0.38). In this case, subsidized fertilizer was spread over a larger land area, but obtained lower yields than are shown in Table 1.

Table 2 reports our simulation results for a 500,000 hectare programme. In this section, we focus on Simulation A, which replicates the scale and composition of the 2006/07 FISP, but, unlike the actual programme, assumes that all costs are financed by additional foreign aid from donors. We maintain baseline fertilizer dose-response rates and import prices, and assume a 'normal' year without weather-related production losses (i.e. RP1 in Figure 1).

[4] Fertilizer applied during a severe drought year may provide benefits in a subsequent season.

[5] The seed planting rates in Table 1 are based on the 2009/10 programme, which distributed 8,500 tonnes 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 modelled programme as far as land coverage is concerned.

Table 2: Results from the FISP impact and financing scenarios

	Baseline value, 2003	Deviation from baseline without FISP		
		Donor funded (marginal return 16.8) (A)	Sales tax funded (marginal return 16.8) (B)	Donor funded (marginal return 11.8) (C)
Maize production (1000 mt)	1,982.8	307.3	289.2	174.3
Maize land (1000 ha)	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 (1000 mt)	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 (1000 mt)	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
Economywide benefit-cost ratio (	-	1.62	1.62	0.76
Production-based benefit-cost ratio	-	0.99	0.92	0.56
Total cost (mil. US$)	-	65.9	67.2	66.1
Financed by foreign aid (%)	-	100.0	16.4	100.0

Notes: Assumes a 60 per cent hybrid FISP as in 2006/07. Base year GDP values are in US$ 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 US$). The marginal return to fertilizer use is expressed as the quantity of maize produced per kilogramme of fertilizer applied.

Source: Authors' calculations based on the economywide model results.

The immediate or direct effect of FISP is an increase in maize yields and production and a decline in maize prices due to marketing and demand constraints. These effects are consistent in direction with recent analyses such as those of Ricker-Gilbert (2012) 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 into account this land reallocation, FISP's net effect is an increase in maize production of 307,300 tonnes. 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 per cent of pre-FISP fertilizer is displaced, which is below the 24.6 per cent displacement rate determined endogenously by our model, as a result of a reallocation of land away from traditional maize, but slightly higher than the 18 per cent estimated by Jayne et al. (2013) using survey data.

Unlike survey-based studies, our model captures how FISP affects Malawi's current account. About 80 per cent of the cost of the programme 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 programme cost leaves the country again to pay for fertilizer and has little effect on external balances. Overall, there is a 2.7 per cent appreciation in the real exchange rate and a decline in total exports, even though maize exports increase.[6] The effect of FISP on non-maize exports via the exchange rate is an important spillover and macroeconomic effect of the programme.

FISP increases land productivity and releases agricultural land to other crops, many of which are of higher value than maize. This is a major source of indirect benefits from FISP that has been largely unaccounted for in partial equilibrium studies and causes agricultural GDP to expand. Farm employment, wages and the 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, non-farm 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 2006/07 FISP. Our simulation does not attempt to target the vouchers, and so poor and non-poor maize farmers benefit equally from the subsidy. Poor urban households are typically net food consumers. In this scenario, the urban poverty rate falls slightly more than the rural poverty rate due to lower food prices and higher wages.

The total cost of the FISP, as modelled here, is US$65.9 million (measured in 2002/03 prices), which is comparable in real terms to the actual programme cost in 2006/07.[7] One approach to measuring programme 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's (2011) average PBCR of 1.06 for the 2006/07 programme.[8] These results suggest that FISP generated modest returns. However, a production-based approach captures only the *direct* impact of FISP and ignores *indirect* benefits, such as diversification into higher value crops and positive spillovers from increased productivity resulting in rising incomes and consumer spending.

To account for FISP's indirect impacts, we measure economywide 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.[9] This calculation produces an 'economywide' 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

[6] We do not simulate the 225,000 tonnes of net maize exports after the 2006/07 season, since this was a one-off arrangement with neighbouring Zimbabwe.

[7] This is net of the fertilizer redemption price paid by farmers to the government.

[8] 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.

[9] 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 programme options. We simulated a universal cash transfer programme and found that it produced an EBCR close to one. This means our EBCR results can interpreted as being relative to a universal cash transfer programme.

generate positive returns once indirect effects are included. By not including indirect benefits, survey-based evaluations fail to capture as much as two-fifths of FISP's total benefits.[10]

4.1 Domestic financing options

FISP was not paid for entirely by foreign aid. In this section, we consider a mainly domestically financed FISP, where some of the programme costs are 'internalized' by raising taxes. Our formula for the EBCR sets total programme cost equal to the cost borne by foreign donors and the internalized cost borne by domestic tax payers. 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 the cost to domestic taxpayers. When all costs are internalized, then the absorption gain is the full net benefit of the programme. The resulting formula is shown below.

$$EBCR = \frac{Total\ benefit}{Total\ cost} = \frac{Absorption\ gain + Internalized\ cost}{Foreign\ aid\ cost + Internalized\ cost}$$

As mentioned earlier, foreign aid has only covered a relatively small portion of FISP's total cost. In Simulation B, we again model a 500,000 hectare programme distributing 150,000 tonnes of fertilizer, but we now assume that the government, rather than donors, pays for the fertilizer component. This is similar to FISP's actual financing arrangement. To pay for its own share of costs (mainly fertilizer), the government must raise tax revenues or cut other expenditures. In Simulation B, the government uniformly raises all sales tax rates. This is a relatively distribution-neutral option since the same percentage point increase in tax rates is imposed on all products.

In reality, Malawi's government financed FISP through a reorganization of its economic services budget, and further attempted to contain rising fertilizer costs by fixing the exchange rate and rationing foreign exchange (see Douillet, Pauw and Thurlow 2012b). This policy contributed to a shortage of foreign currency, which prompted a macroeconomic crisis and the eventual removal of the rationing system. Since we are concerned with evaluating the impact of FISP, and not exchange rationing, we shall restrict our analysis to financing options involving domestic taxes.

Without foreign aid, Malawi must generate the foreign exchange needed 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, there is still a reallocation of land 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 programme spillovers.

Agriculture is Malawi's main export sector, so the need to generate foreign exchange prompts a larger shift out of relatively high productivity non-farm activities and a rise in relatively low productivity farm employment. 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. The burden of higher indirect taxes falls fairly evenly across all households, since the increase in tax rates is uniform across products. Conversely, urban and non-poor households form

[10] Donor cash transfers to households yield an EBCR of approximately one, which can be used as a basic counterfactual or opportunity cost of funds (see Filipski and Taylor 2012).

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 (results not shown). These differential impacts highlight how domestically-financed programmes like FISP can adversely affect households that are not direct beneficiaries. Accounting for these effects is important for comprehensive programme evaluations when the programmes have macroeconomic implications.

Switching to domestic financing has little effect on the size of the GDP gain, since maize productivity gains are of the same magnitude. As such there is only 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.

4.2 Marginal returns to fertilizer use

Column C of Table 2 illustrates that outcomes are strongly sensitive to changes in fertilizer yield response rates. As shown in Table 1, our baseline assumption is 15 and 18 kilogrammes of maize produced for each kilogramme of nitrogen applied to composite and hybrid seeds, respectively. With 60 per cent hybrid seeds, the average fertilizer response rate for FISP sectors (COM+ and HYB+) is 16.8 kilogrammes of maize per kilogramme of nitrogen, which is similar to the base response rates used in the official FISP evaluation (Dorward et al. 2008). Marenya and Barrett (2009) report estimates for Western Kenya of about 17.6. A range of 15–18 is generally accepted as reasonable when fertilizer is used at recommended rates and in conjunction with modern maize seed varieties. However, the recent available evidence for Malawi, and particularly from the FISP-related literature, suggests that the actual rates achieved may have been much lower. Column 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 Appendix summarizes the available literature and illustrates our approach for estimating marginal returns to fertilizer use from studies where these were not directly reported.

As one should expect, outcomes in column C of Table 2 are uniformly less favourable than outcomes in its direct comparator, column A. Nevertheless, the programme 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, maintains 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.[11] At the baseline scale of 500,000 hectares, a response rate of a bit more than 13 is required to achieve an EBCR of about one. While this response rate is slightly above the rough estimates derived in the Appendix, it is more than 20 per cent below the baseline value employed in the existing official evaluation by Dorward et al. (2008). As noted, this evaluation yielded a benefit-cost ratio (somewhat analogous to the PBCR calculated here) of about one. This implies that, when economywide effects are included, a substantially lower level of efficiency of fertilizer use can still be associated with a benefit-cost ratio greater than one. Moreover, if response rates are 10 per cent higher than the baseline level of 16.8 (i.e. 18.5 kilogrammes), then even the PBCR rises above one, indicating positive direct returns to FISP while the EBCR increases to a very considerable 1.9.

[11] 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 programme with the baseline fertilizer dose-response rate of 16.8 produces the same 1.62 EBCR reported for Simulation B in Table 2.

4.3 Rescaling the programme

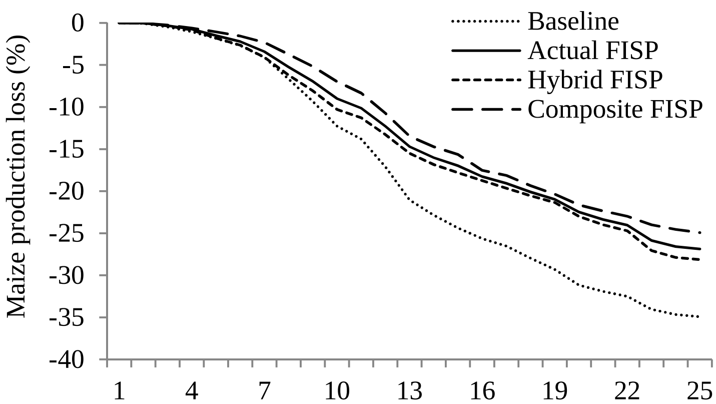
All simulations analysed to this point consider 150,000 tonnes of fertilizer spread over 500,000 hectares. While keeping the fertilization rate constant, we now vary the scale from 100,000 hectares (30,000 tonnes of fertilizer) to 700,000 hectares (210,000 tonnes of fertilizer). Results are shown in 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 programmes of different scales. In contrast, EBCRs fall as FISP is scaled up. This is because marketing and macroeconomic constraints are more pronounced for larger programmes (e.g. it becomes increasingly more 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 programme result in a higher marginal cost of public funds).

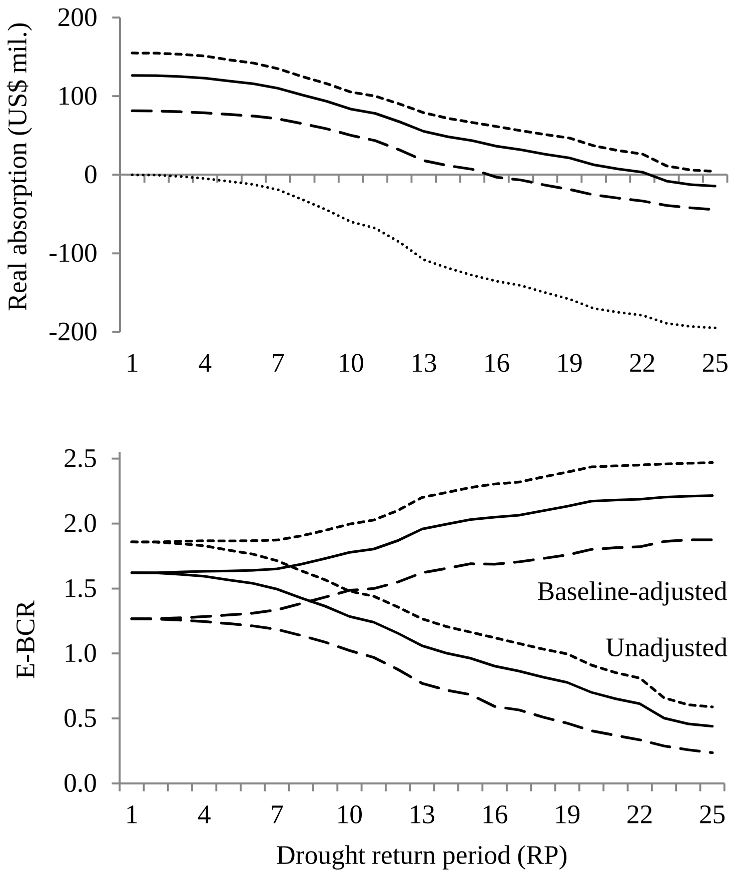
While these EBCRs might suggest relatively mild declines in returns from scaling up if taken at face value, it should be remembered that the model employed ignores adjustment costs associated with resource reallocations as well as the tendency for actors to evade taxes as tax rates increase (Arndt and 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 programme costs despite a high degree of popular support for the programme.

4.4 Weather risks

Weather shocks affect programme benefits by reducing maize production. As shown in Figure 1, 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 per cent of maize was produced using composites and hybrids, respectively—the rest were local varieties. The baseline production losses 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 per cent.

Figure 2: Results from the weather risk scenarios





Notes: 'EBCR' is the economywide benefit-cost ratio. Composite and Hybrid FISP scenarios use entirely composite and hybrid maize varieties, respectively, while Actual FISP is the 60 per cent hybrid 2006/07 programme. Total benefit is the undiscounted value of total absorption.

Source: Authors' calculations based on economywide model results.

As shown in Figure 1, improved seeds are more drought tolerant than local varieties within the range of our analysis, i.e. RP1 to RP25. By expanding the use of these seeds, FISP improves the drought tolerance of Malawi's maize sector. We again model the 2006/07 programme in which 60 per cent of the seeds were hybrids. Production losses during an RP20 event now fall to 22.5 per cent or about two-thirds of baseline losses. We also experiment with programmes providing only composite or hybrid seeds. Production losses are smaller for composite-only programmes since this is the more drought resistant of the two seed varieties. These results suggest that FISP generates 'double dividends', i.e. higher maize yields generally as well as a maize system that is more resilient during droughts.

As weather shocks become more severe, programme benefits fall but costs remain virtually unchanged causing the EBCR to decline. This is shown by the 'unadjusted' curves in the lower panel of Figure 2. Composite-only programmes generate lower EBCRs than hybrid-only programmes, because the former's yield gains are smaller and so less additional maize is produced per dollar spent. Using baseline absorption as the counterfactual in the equation (1), the EBCR for the 2006/07 programme falls below 1.00 (from a baseline 1.62) under an RP14 or worse event. Every year the country faces roughly an eight per cent probability of experiencing an RP14 or worse event. Weather patterns therefore greatly influence these EBCR estimates.

However, it is not clear that baseline absorption is the appropriate counterfactual. For the weather-risk scenarios, the appropriate baseline is not the stationary 2002/03 season, which was a normal to favourable weather year (i.e. RP1). The correct counterfactual is the outcomes that would have been achieved if the 'without FISP' maize system had been subjected to the same weather shock as the 'with FISP' system. In other words, the incremental benefit of the programme 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 adjusted counterfactual, then the EBCRs *increase* under more severe weather events (see the lower panel). This is because the EBCR includes FISP's added benefit of greater drought tolerance. The adjusted EBCRs suggest that the average annual returns to FISP are higher than the baseline EBCR of 1.62 once weather risks are accounted for. This emphasizes the need to disentangle external risks from observed programme outcomes, and to include changes in risk when calculating programme benefits and costs.

4.5 Fertilizer price risks

Increases in world fertilizer prices also constitute an obvious programme risk. Indeed, high global fertilizer prices in 2007 and 2008 were a major contributor to the financial difficulties faced by Malawi as a result of the FISP. Table 4 presents results from alternative fertilizer price scenarios. Starting from Simulation B of Table 2, we impose 10, 20 and 50 per cent increases in world fuel and fertilizer prices, which generate Simulations D, E and F, respectively. Our shocks are fairly modest. Actual world fertilizer prices increased approximately 140 per cent between 2007/08 and 2008/09 alone (Heady and Fan 2011). To isolate the interaction effects of FISP and world price changes, we impose the world price shocks on both the baseline and FISP scenarios.

Table 4: Results of the fertilizer price risk scenarios

	Deviation from baseline without FISP			
Real world fertilizer prices	+0%	+10%	+20%	+50%
	(B)	(D)	(E)	(F)
Economywide benefit-cost ratio	1.62	1.51	1.41	1.22
Production-based benefit-cost ratio	0.92	0.68	0.49	0.07
Total costs (mil. US$)	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 (1000 mt)	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: Authors' calculations based on economywide model results, using column B of Table 2 as a baseline.

Fertilizer is the main cost component of FISP and so higher world fertilizer prices inflate programme costs considerably. At higher fertilizer prices, more foreign exchange is required, which in turn necessitates larger real exchange rate depreciations.[12] This encourages a further

[12] 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.

reallocation of resources towards export agriculture, leading to lower maize production levels and smaller PBCRs. Results indicate that a 50 per cent increase in real fertilizer prices virtually eliminates any increase in maize production (i.e. the PBCR is only 0.07). This is due to increased pressure to reallocate resources towards export crops like tobacco in order to generate foreign exchange. The EBCRs also decline as fertilizer prices rise, since it becomes more difficult to generate additional foreign exchange from non-maize exports. Higher fertilizer prices also reduce FISP's welfare gains and poverty reduction.

These results indicate that FISP's returns are exposed to the risk of higher world fertilizer prices. This makes the timing of surveys crucial for impact evaluations. For example, programmes implemented in 2006/07 and 2008/09 would produce different EBCRs even if they shared the same programme design and implementation. Studies that rely on PBCRs for their final assessments are even more likely to produce non-comparable results. This is because higher fertilizer prices lead to greater diversification into export agriculture and lower maize production. Increasing returns to export agriculture may offset some of the decline in total absorption on which EBCRs are based. Ultimately, being able to control for and experiment with external risks is a major advantage of using economywide ex ante models.

5 Conclusion

Household surveys are often used to evaluate government and donor programmes. However, this approach to programme evaluation usually overlooks economywide programme design elements, such as spillovers, scaling and macroeconomic effects, and risk factors, such as weather and world price shocks, all of which can be important particularly for large-scale programmes. These elements may prove to be crucial in deciding whether a programme is desirable and/or sustainable. In this paper, we showed that this is true for Malawi's Farm Input Subsidy Programme, which is a large-scale and costly programme exposed to droughts and world fertilizer prices. To conduct our economywide 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 behaviour.

We find that, under baseline assumptions, FISP generates modest *direct* returns in the form of higher maize productivity and production, which is modulated by increased crop diversification. Our finding of a direct benefit-cost ratio of about one is consistent with Dorward et al. (2008). However, our economywide 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 economywide benefit-cost ratio is estimated at 1.62. As such, indirect benefits equal about two-fifths of FISP's total benefits. These indirect returns arise mainly from higher factor returns and falling food prices.

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

Fertilizer dose-response 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 per cent of our baseline value remains consistent with an economywide 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 economywide 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. (2013) are also plausible and are associated with large economywide gains.

Not surprisingly, FISP's total benefits decline during drought years. When economywide outcomes are compared with a baseline that reflects a normal weather year without droughts, we find that FISP's benefit-cost ratio falls below one during a one-in-fourteen years or worse drought. However, it is more appropriate to compare economywide outcomes with and without the FISP under the same set of weather events. When this is done, economywide benefits of FISP rise with worsening weather outcomes (out to a return period 25 event) because the improved seeds distributed under the FISP programme are more drought tolerant than local varieties. By expanding the use of these seeds, FISP has the potential to generate 'double dividends' in the form of higher yields and a more drought-resilient maize sector.

This study has shown how a comprehensive programme evaluation must measure both direct and indirect benefits and costs. Our economywide approach not only captures indirect effects, but also complements survey-based studies by allowing experimentation with alternative programme design elements and risks. It is therefore an important part of the evaluation toolkit. Accounting for indirect benefits of the FISP potentially allows for much greater benefits.

Hence, in contrast to Jayne and Rashid (2013) who characterize existing fertilizer programmes as low potential distractions that siphon resources from more beneficial development initiatives, we find relatively high potential in a country with limited alternatives. As the existing literature emphasizes, there are risks. Clearly, if subsidized fertilizer is mainly stolen and then sold commercially, displacing commercial imports, or if the fertilizer provides a very weak boost to production, returns will be low. 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 programme 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 in fact diverted or stolen, and the extent to which diverted fertilizer has a displacement effect on commercial fertilizer sales. Second, while our analysis points to macroeconomic constraints, there is room for more detailed analysis (see Douillet, Pauw and Thurlow 2012b). Lastly, we do not consider how fertilizer subsidies could be packaged with other interventions, such as investments in rural roads and export opportunities, in order to improve the efficacy of the programme in the short and medium term nor do we consider exit strategies over the longer run.

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: 1010–25.

Baffes, J. (2007). 'Oil spills on other commodities'. *Resources Policy*, 32: 126–34.

Bamberger, M., V. Rao, and M. Woolcock (2010). 'Using Mixed Methods in Monitoring and Evaluation: Experiences from International Development'. Policy Research Working Paper 5245. Washington DC: World Bank.

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 X. Diao, J. Thurlow, S. Benin, and S. Fan (eds). *Strategies and Priorities for African Agriculture: Economywide Perspectives from Country Studies*. 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.

Brent, Robert 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 Programme'. Paper presented at the 3rd Association of African Agricultural Economists' Conference, Cape Town, South Africa, 19–23 September.

Chibwana, C., M. Fisher and G. Shively (2012). 'Cropland Allocation Effects of Agricultural Input Subsidies in Malawi'. *World Development*, 40(1): 124–33.

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 (2012a). 'A 2007 Social Accounting Matrix for Malawi'. Washington DC: International Food Policy Research Institute. <http://hdl.handle.net/1902.1/18578> last accessed 19/09/2012.

Douillet, M, K. Pauw, and J. Thurlow (2012b). 'When Food and Macroeconomic Policies Collide: The Case of Malawi's Farm Input Subsidy Programme'. Washington DC: International Food Policy Research Institute.

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 (2013). 'Poverty Rates and the Returns to Fertilizer: Empirical and Simulation Evidence from Malawi'. Unpublished, Cornell University.

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 Programme in Malawi on Farm Plot Level Input Use, Crop Choice and Land Productivity'. Noragric Report 55. Ås, Norway: Norwegian University of Life Sciences.

Horridge, M., J. Maddan and G. Wittwer (2005). 'The impact of the 2002–2003 drought on Australia'. *Journal of Policy Modeling* 27: 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): 116.

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, December.

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., J. Ricker-Gilbert, and M. Fisher (2013). 'What are the Farmer-level Impacts of Malawi's Farm Input Subsidy Programme?' *Agricultural Economics*, 44(6): 563–79.

Marenya, P. C., and C.B. Barrett (2009). 'State-conditional fertilizer yield response on Western Kenyan Farms'. *American Journal of Agricultural Economics*, 92(4): 991–1006.

Mason, N., T.S. Jayne, F.A. Darko, and S. Tembo (2013). 'What are the Effects of Input Subsidy Programmes on Equilibrium Maize Prices? Evidence from Malawi and Zambia'. Paper for American Association of Agricultural Economics annual meetings. Washington DC, August 4–6.

NSO (National Statistics Office) (2005). Integrated Household Survey 2004–2005. Volume I: Household Socio-economic Characteristics. Zomba, Malawi: National Statistics Office.

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. (2012). 'Wage and Employment Effects of Malawi's Fertilizer Subsidy Programme?' Working paper. West Lafayette, Indiana: Department of Agricultural Economics, Purdue University.

Ricker-Gilbert, J., and T. Jayne (2012). 'Do Fertilizer Subsidies Boost Staple Crop Production and Reduce Poverty Across the Distribution of Smallholders in Africa? Quantile Regression Results from Malawi'. Paper prepared for the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18–24 August, 2012.

Ricker-Gilbert, J., and T. Jayne (2011). 'What are the enduring effects of fertilizer subsidy programmes 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.

Tchale, H., and J. Keyser (2010). 'Quantitative Value Chain Analysis: An Application to Malawi'. Policy Research Working Paper 5242. Washington DC: World Bank.

Wodon, Q., and K. Beegle (2006). 'Labour Shortages Despite Underemployment? Seasonality in Time Use in Malawi'. In C.M. Blackden, and Q. Wodon (eds). *Gender, Time Use and Poverty in Sub-Saharan Africa*. Washington DC: World Bank.

Appendix A

Estimating marginal returns to fertilizer often involves complex econometric modelling in which effects of a variety of factors are controlled for, including soil characteristics (slope, organic matter content, and nutrient content), weather and geographic location, and labour and other input use (see for example Marenya and Barrett 2009; Harou et al. 2013). Typically, studies that set out to estimate these marginal returns will explicitly report a measure of kilogrammes of grain produced per additional kilogramme of nitrogen applied. However, in many studies this relationship is implicit in results that show some link between grain production and fertilizer use, whether at the margin or as an average relationship.

In realizing the importance of this parameter in any ex ante evaluation of a fertilizer subsidy programme, Dorward et al. (2008) conducted a survey of studies in which local and hybrid maize yield responses to fertilizer use is measured. Their survey reveals a large variation in response rates, often depending on whether results were obtained from farmer demonstration plots, carefully controlled field trials, or ex post farm survey-based evaluations. They nevertheless conclude that reasonable fertilizer yield response rates lie in the region of 10–12 kilogrammes grain per kilogramme of nitrogen for local (traditional) seed varieties; 15 for composites; and 18–20 for hybrid maize varieties. Since in their evaluation they did not have information on the seed varieties used, they assume a national average response rate of 15 kilogrammes grain per kilogramme nitrogen, with 12 and 18 serving as upper and lower bound estimates. Incidentally, our response rate of 16.8 used in our baseline scenario derives from the weighted average of composite and hybrid fertilizer yield response, assuming a 60 per cent hybrid share in FISP (i.e. $15 \times 0.4 + 18 \times 0.6 = 16.8$).

Harou et al. (2013) also investigate the efficiency of fertilizer use in Malawi with a specific focus on soil quality and fertilizer yield responses. They estimate grain production responses of 11.54 and 9.83 per kilogramme of urea and NPK respectively. Urea has an approximate nitrogen content of 46 per cent, and hence the comparable yield response rate is 25 kilogramme grain per kilogramme nitrogen (i.e. 11.54/0.46). NPK contains 23 per cent nitrogen, and although the grain response here includes a combined response to nitrogen and potassium, we can derive a crude estimate in the same way (i.e. 9.83/0.23 = 42). These estimates are based on field trials conducted in the late 1990s in Malawi and hence are at the upper end of the scale.

Several ex post survey-based evaluations of FISP provide some information on the grain yield response to fertilizer application. The standard FISP benefits package includes one bag of urea and one bag of NPK used in equal quantities. In translating grain response rates to fertilizer use to comparable nitrogen yield response rates needed for our purposes, we once again assume an average nitrogen content of 0.345 kilogrammes of nitrogen per kilogramme of fertilizer, bearing in mind the bias from being unable to control for changes in potassium use. Three studies are of particular interest. Chibwana et al. (2010) conduct a regression analysis of yield response to seed and fertilizer use among FISP beneficiaries. Using a figure relating observed fertilization rates and yields for local and 'improved' maize seeds—an unknown combination of composite and hybrid seeds—we are able to derive the implied marginal returns to fertilizer use (i.e. from the slope of the curve). The implied fertilizer yield response rate for improved varieties is 9.6, with some evidence of a decreasing rate of return to fertilizer use at high levels of fertilizer use. By contrast, and contrary to expectation, the implied response rate for local varieties is slightly higher at 12.0.

Ricker-Gilbert and Jayne (2011) do not control for seed use, but evaluate the so-called 'contemporaneous' (current) and 'enduring' effects of fertilizer application on maize yields in general. The enduring effect measures the current year effect from accessing subsidized fertilizer in three consecutive years, i.e. it measures the potential effect of nutrient build-up and increased efficiency in fertilizer use over time. Their fertilizer yield response rates are reported as kilogrammes of grain per kilogramme subsidized fertilizer. In this instance we first have to account for commercial fertilizer displacement, which based on an earlier study the authors assert to be 22 per cent. Every kilogramme of subsidized fertilizer is therefore equivalent to 0.78 kilogramme net fertilizer increase. They find a contemporaneous effect of 1.65 kilogrammes grain per kilogramme subsidized fertilizer, which translates into a yield response rate of 6.1 (i.e. 1.65/0.78/0.345). Similarly, the enduring effect is 3.16, which is equivalent to 11.7 kilogramme grain per kilogramme nitrogen.

In another study, Ricker-Gilbert and Jayne (2012) use a quantile regression approach to estimate fertilizer yield effects at different points in the maize production income distribution (e.g. the 10th, 50th, and 90th percentiles, as well as at the mean). This study does not control for the enduring effects as does the earlier study, hence the mean could be interpreted as an average effect across new and repeat beneficiaries. Grain responses to fertilizer use are estimated as 0.75, 2.04, and 2.61 at the 10th, 50th, and 90th percentiles. At the mean the response rate is 2.04, which translates to 9.0 kilogrammes grain per kilogramme nitrogen (i.e. 2.04/0.78/0.345).

In summary, there is an important and unresolved divergence in results between estimates of fertilizer yield effects between studies based on field trials and studies based on surveys of farmers with critical implications for the FISP. Both approaches have potential deficiencies. Experimental plots may attain higher yields than farmer's plots for a host of well-known reasons, even if attempts are made to simulate smallholder growing conditions. Surveys, on the other hand, are bedevilled by measurement error and hence the potential for attenuation bias. Furthermore, measurement errors may be systematic. For example, farmers may report fertilizer use in a manner consistent with FISP programme objectives but actually use the fertilizer on crops other than maize (or tobacco) and/or sell the fertilizer on to other farmers. Both of these effects are difficult to control for and could substantially bias downwards survey-based fertilizer efficiency estimates.