Addressing the "Wicked Problem" of Input Subsidy Programs in Africa: A Review

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Some problems are so complex that you have to be highly intelligent and well informed just to be undecided about them. — Laurence J. Peter

1. Introduction

After having been a major plank of agricultural development strategies in the 1970s and 1980s, and then largely phased out in response to World Bank and IMF imposed structural adjustment programs in the 1990s, large-scale input subsidy programs have re-emerged across sub-Saharan Africa (SSA). Their reintroduction gained momentum following the first African Fertilizer Summit, which was held in Abuja, Nigeria in 2006. Today, seven African governments alone spend roughly US$2.0 billion on fertilizer promotion programs each year.[1] These programs account for a substantial share of public spending on agriculture in these countries. A major rationale for the re-introduction of large input subsidy programs has been that mistakes of the past have been identified and can be corrected. The approaches taken in the 1970s and 1980s tended to rely on universal coverage, leading to diffuse benefits and high costs. In contrast, current efforts are said to rely on new institutions and improved implementation strategies that can encourage private sector development and target intended beneficiaries in a "smart" way.[2]

[1] Nigeria, Ethiopia, Kenya, Zambia, Malawi, Tanzania, and Ghana account for roughly 2.1 million tons of fertilizer distributed through government fertilizer promotion programs in 2012; available data indicate that the costs of importing, distributing and managing these programs are, conservatively, US$950 per ton. The Government of Ethiopia does not categorize its public fertilizer distribution system as one that features subsidies, yet it procures fertilizer for farmers at roughly 80% the landed cost borne by private fertilizer distributors in other countries in the region.

[2] Morris et al. (2007) identify ten specific criteria for a "smart subsidy" program. That the program: (i) promotes the factor or product as part of a wider strategy that includes complementary inputs and strengthening of markets; (ii) favors market-based solutions that do not undermine incentives for private investment; (iii) promotes competition and cost reductions by reducing barriers to entry; (iv) insists on economic efficiency as the basis for fertilizer promotion efforts; (v) recognizes that effective demand from farmers is critical for long-run sustainability; (vi) devises an exit strategy to limit the time period of public interventions; (vii) emphasizes sustainability as a goal when designing interventions; (viii) promotes pro-poor growth, in recognition of the importance of equity considerations; (ix) empowers

Arguments over the relative merits of fertilizer subsidy programs constitute one of the most contentious policy debates in Africa. Much is at stake, and the literature on these programs is sharply divided and inconsistent (Morris et al. 2007; World Bank 2008; Sachs 2012). African policy makers often note that analysts from outside the continent question the merits of subsidizing agriculture, even while costly agricultural subsidies feature prominently in their own countries. That many of these same analysts might strongly question the current and historical role of agricultural subsidies in their own countries seems irrelevant. Outside criticism, no matter how well-intentioned, can be viewed as hypocritical meddling, influenced by the actions and aims of outside governments. In addition, reaching a common understanding regarding the value and impacts of input subsidy programs in Africa has been hindered by differences in beliefs, values and worldviews. As a result, the debate over the effectiveness of large-scale input subsidy programs has taken on a range of political and ideological overtones that characterize the broader class of policy issues known as "wicked problems".

A central feature of wicked problems (see Rittel 1992; Conklin 2006) is indeterminancy, i.e., there are no definitive conditions or tests to resolve problems,[3] and even a lack of basic agreement about what constitutes the *real* problem. Every wicked problem is a symptom of another, "higher level," problem – for example, poverty and underdevelopment in the case of input subsidies. For every wicked problem there is always more than one possible explanation or pathway to resolution, with each depending on the "core beliefs" of those involved. Wicked problems resist resolution by an appeal to the facts.

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farmers to make the decisions about soil fertility management; and (x) pursues regional integration in order to benefit from the economies of market size.

[3] It is important to note that indeterminacy is quite different from undetermined.

Despite the indeterminacy and difficulty associated with wicked problems, Batie (2008) has argued that agricultural economists can still usefully address such problems through the way that research is organized and carried out. She proposes interdisciplinary systems approaches and the involvement of boundary organizations between research and policy makers that can work synergistically with methodologically rigorous disciplinary approaches for generating evidence-based insights on specific components of the overall problem. We share this perspective. Furthermore, our past and on-going research on input subsidies in Africa leads us to view the issue as a wicked problem. Like Batie, however, we acknowledge that, while solid disciplinary work is unlikely to prove sufficient for the effective resolution of a wicked problem, it is nevertheless likely to be very necessary in finding reasonable and workable solutions. As a result, in this paper we assesses the recent empirical evidence on fertilizer subsidy programs and identify a number of major methodological challenges facing agricultural economists who aim to generate evidence-based insights regarding them. If these challenges can be surmounted, we believe applied economists could contribute greater clarity and understanding to the set of policy problems surrounding input subsidy programs in sub-Saharan Africa. Below we outline what we view as the most important conceptual and empirical hurdles that arise in the analysis and evaluation of input subsidy programs. Subsequent sections draw upon the latest studies to define the frontier of current evaluation methods and ways that future studies might improve upon the current state of evaluation.

2. Conceptual and Empirical Challenges in Evaluating Input Subsidy Programs

It is useful, if somewhat arbitrary, to distinguish between “conceptual” and “empirical” challenges in evaluating input subsidy programs. While the dividing line between conceptual and empirical challenges is not always clear, here we separate our discussion between those issues that arise in formulating analysis and those that confront the analyst with data in hand.

The first conceptual challenge to evaluating an input subsidy program arises when one attempts to define the program and, in particular, the program "treatment". Participation in subsidy programs can be defined and modeled in several ways. As an example, in Malawi input subsidies were initially operationalized through the physical distribution of inputs (e.g. packets of seed and fertilizer) but more recently have been implemented by distributing paper vouchers to farmers. These vouchers, which are largely but not entirely focused on maize production, give recipients the right to purchase a fixed amount of inorganic fertilizer and hybrid maize seed at price that differs substantially from the "market" price. A recipient household is then expected to travel to a government depot to redeem the voucher and take delivery of the subsidized fertilizer. The stated intent of the program is for households that receive a voucher to redeem it, and then to use the associated seed and fertilizer to plant and grow maize.

As the reader can recognize, however, the voucher recipient has a number of options. Although transfer is officially illegal, it is not uncommon. In practice, the voucher recipient can (1) sell, barter or give away the voucher, (2) use the voucher to purchase fertilizer and seed and then sell, barter or give some or all of the inputs away, or (3) acquire the inputs and apply the subsidized fertilizer to crops other than maize.[4] Therefore if a researcher wants to evaluate the basic fundamental question of how input subsidies affect maize production it becomes a challenge to determine exactly what constitutes "participation" in the program. Participation may be characterized by (A) receipt of the voucher, (B) the quantity of input purchased, or (C)

[4] As an extreme example, in an early subsidy program implemented in Malawi via direct delivery of seed and fertilizer, Fisher and Shively (2005) found that some recipient households sold their fertilizer and consumed the seed, in part because delivery occurred after the planting season.

the quantity of input directly applied to maize production. Clearly, one's estimate of the impacts from the subsidy program will depend upon whether A, B, or C is chosen as a point of evaluation. Complicating matters is that program roll-out may result in mixed combinations of interventions. Chibwana et al. (2011) evaluate Malawi's subsidy program in terms of categories representing the number and combination of vouchers received by the household.[5] In contrast, Holden and Lunduka (2012) evaluate Malawi's subsidy program as a binary indicator of whether or not recipients received a voucher of any kind, and Ricker-Gilbert et al. (2011) define Malawi's program as the number of kilograms of subsidized fertilizer acquired by a household. Shively et al. (2012) also follow Fisher and Shively (2005) by using the total monetary value of all vouchers received as an indicator of program intervention. To date, however, no study directly compares program impacts using different definitions or points of evaluation. Doing so would likely enhance the robustness of program impact estimates.

A related problem that accompanies this "program definition" issue is that the choice of how to define program participation may have implications for whether participation is considered to be exogenously determined, endogenously or co-determined with an outcome variable of interest, or a household choice. We return to this concern under the empirical heading below.

An additional conceptual challenge to evaluating an input subsidy program involves identifying a suitable counterfactual scenario for comparison to the program intervention. Subsidy programs may have the potential to generate both direct and general equilibrium effects, and to possibly result in positive or negative "externalities," i.e. unintended effects. For example,

[5] In their case, the categories included (a) seed coupon only; (b) 50 kg fertilizer coupon; (c) seed and 50 kg fertilizer coupon; (d) 100 kg fertilizer coupon; (e) seed and 2 x 100 kg fertilizer coupons; (f) seed and more than 100 kg worth of fertilizer coupons.

direct benefits go to recipient households in the form of lower fertilizer prices. This, in turn, should induce these households to use greater quantities of fertilizer, produce more food, and generate higher incomes. This scenario creates the conditions under which indirect or general equilibrium effects from the subsidy can occur. In principle, these indirect effects can reach many or even all households in the country in which the subsidy program is implemented. Two main types of general equilibrium effects are particularly relevant. First *ceteris paribus*, increased agricultural production will lower staple crop prices. This should benefit anyone who is a net consumer/purchaser of staple crop, and adversely affect net sellers.

A second general equilibrium effect from subsidizing fertilizer is that the program may affect agricultural wage rates. The exact impact on labor demand and wages will depend on the nature of production, and the extent to which fertilizer and labor work as complements or substitutes, but it is easy to imagine labor market effects arising because the subsidy program lowers the price of fertilizer for recipient households, and relieves their credit constraint, which leads them to spend more time on their own farm. Furthermore, other households who receive the subsidy and are presumably less poor might demand more agricultural labor to spread fertilizer, weed, and harvest the additional output. This simultaneous reduction in labor supply and increase in labor demand has the potential to raise agricultural wages in contexts where the fertilizer subsidy program is widely implemented. The benefits from higher agricultural wages will likely accrue to non-recipients of the subsidy, especially those who are generally poor, credit-constrained, and with too little land to be targeted by fertilizer subsidies. However, as in the case of the net buyer/net seller divide, higher wage rates could reduce the welfare of less poor households who hire others to work on their land.

That potential general equilibrium effects may arise from a large-scale input subsidy programs raises the conceptual issue of whether a researcher will approach the subject in a partial equilibrium or general equilibrium framework, or – if a partial equilibrium approach is used – what variables are to be studied. Thinking more broadly, a methodological question arises, namely how to identify a reasonable counterfactual scenario. Comparing the changes in food production or incomes of recipient and non-recipient households might omit the general equilibrium effects of the subsidy program on these variables, both positive and negative. In such cases, the identification of a control group may be problematic. This issue has been raised in several articles evaluating input subsidy programs and highlights the possibility that a simple benefit/cost calculation ignores some of the potentially substantial impacts of input subsidy programs (Dorward et al. 2008, Dorward and Chirwa 2011). Ricker-Gilbert (2012) examines the impact of the fertilizer subsidy program on agricultural labor supply and wage rates in Malawi. He finds that when looking across the entire population of smallholders, acquiring subsidized fertilizer does not have a statistically significant effect on a household's decision to participate in the agricultural labor market. However, for the sub-population of households who worked as agricultural laborers before the subsidy program was scaled up, acquiring 100 kilograms of subsidized fertilizer reduced the probability that a household supplied agricultural labor by 3 percentage points, on average. In addition, he finds that a 10 kg increase in the average amount of subsidized fertilizer acquired per household in a community raises that community's median agricultural wage rate by 1.5 percent. More evaluation needs to be conducted that quantifies the indirect benefits from input subsidy programs, in order to provide a complete picture of their benefits, although designing such an evaluation likely requires a broad, general economy perspective that goes well beyond studying recipient households only.

Two final issues present conceptually difficulties. The first is related to the issue of "learning by doing." One often finds arguments in favor of fertilizer subsidies that rely on the idea that farmers currently exhibit low fertilizer utilization rates, or low up-take of improved seed varieties that would be more responsive to fertilizer than traditional varieties, because they have not been exposed to these practices or have limited or no experience with them. Establishing whether subsidies might generate knowledge, improved practices or knowledge spillovers, and what the benefit of these impacts might be requires a conceptual framework that is sensitive to temporal and spatial dimensions, and is designed to follow "treatment" and "control" groups of farmers for substantial periods of time. To date, we are not aware of studies that clearly address this issue.

The issue of "crowding out" and "crowding in" is also conceptually thorny, so much so that we devote an entire subsequent portion of this paper (section 4) to the topic. "Crowding out" simply refers to the phenomenon of subsidized fertilizer directly displacing fertilizer purchases that would have been made in the absence of the subsidy. In principle, if subsidies are allocated in a way that leaves farmers' demand for commercial fertilizer unchanged, then there is no crowding out, and the program would generate a one ton increase in total fertilizer use for each ton of subsidized fertilizer. In contrast, if farmers receiving subsidies also decide to purchase fertilizer or other inputs that they otherwise would not have purchased, then the program is said to "crowd in" such purchases. Measuring the degree to which fertilizer subsidies crowd out commercial sales is difficult, but essential for understanding how fertilizer subsidy programs affect total fertilizer use.

Empirical Challenges

Empirical challenges to evaluating input subsidy programs are every bit as substantial as the conceptual issues that define the problem. The major empirical problem for a researcher in possession of data (or planning data collection) is establishing the causal impacts of an input subsidy program on various outcomes of interest. Outcomes of interest may include fertilizer use, agricultural production, land allocation and use, labor allocation and use, household income, and poverty. A major factor determining the impact of a fertilizer subsidy program is the average and marginal physical product of fertilizer application on recipient farmers' fields. Accurate estimates of crop response rates on farmers' fields will likely be confounded by missing data on soil quality, the quantity and distribution of rainfall, labor input, and management ability. Moreover, even if data on all other inputs were available, it has long been known that it is difficult to accurately measure the average product of a particular input when it is highly complementary with other inputs and management practices (Johnson 1950). Recent empirical estimates of the response of maize to nitrogen range from 2.1 kgs per kg of N to over 30kg, even in the same villages and agroecological zones in the same year (Xu et al. 2009; Burke 2011; Sheahan et al. 2012; Shively et al. 2012). Crop response rates across time are similarly variable owing to differences in growing conditions. With variations of this magnitude in crop response rates, it is perhaps not surprising that the calculated benefit/cost ratios of fertilizer subsidy programs are subject to similar variations in magnitude.

The second challenge associated with estimating the impacts of fertilizer subsidies on outcomes of interest results from the non-random process by which program beneficiaries are selected or targeted. Governments do not randomly distribute subsidized inputs to farmers, so any study that attempts to produce reliable results must deal with this selection issue as part of the empirical modeling effort. For example, due to relatively unclear targeting guidelines in many countries, government officials in some areas may distribute fertilizer to households who are more productive, while in other areas fertilizer may be targeted to less productive households. Therefore, it is likely that the amount of subsidized fertilizer that a household receives is correlated with poverty status, household income, or underlying features that influence these outcome variables. As a result, variables such as income may be both determined by access to input subsidies and a determinant of subsidy receipt. As a concrete example, consider a farmer who benefits from good soils and a solid knack for farming, but in ways that cannot be easily observed or measured by the researcher. In the absence of an input subsidy, one might expect such a farmer to be more productive, on average, than his cohorts. Such a farmer might be recognized by whoever is distributing the subsidies as deserving, and likely to generate good results. If so, then at least part of the observed return to this farmer from the input subsidy will be a return to the unobservable features and characteristics of the farmer, and not to the subsidy itself. In such a situation, if distribution is systematically biased toward better farmers, an inability to control for the latent or hidden characteristics that make them "better than average" farmers will lead the researcher to overestimate the impact of the subsidy, by not accounting for the underlying factors that precipitated selection or participation. Conversely, if a subsidy program systematically targets low-productivity farmers, in ways that are unobservable to the researcher, the effects of the program may be underestimated.

Of course random assignment of farmers to subsidy and non-subsidy groups could potentially solve the attribution problem, but because subsidy programs do not rely on random assignment, most studies evaluating the impacts of input subsidy programs have relied on observational data and employed instrumental variables (IV) techniques to deal with the endogeneity of subsidies and their impacts. This approach creates the common and widespread challenge in moving from correlation to causation of trying to locate an instrument that is correlated with acquiring subsidized inputs, but uncorrelated with unobservable factors that affect outcome variables of interest. Thus far, studies evaluating the impact of input subsidies have used a variety of instruments including number of years the household head has lived in a village (Chibwana et al. 2011, Ricker-Gilbert et al. 2011; Shively et al. 2012), fixed costs of acquiring fertilizer (Holden and Lunduka 2012), whether a member of parliament resides in the community (Ricker-Gilbert and Jayne 2011), the official quantity of subsidized inputs distributed to a household's district (Mason and Ricker-Gilbert 2012), and past voting outcomes of the constituency (Mason 2012; Mather and Jayne forthcoming). Researchers generally make a reasonable case for why their IVs are valid, and often subject their models to tests of the exclusion restrictions, however it is possible that someone reading or reviewing these articles could come up with a reason why these instruments are themselves endogenous. Though indirect tests of exogeneity exist (Hansen et al. 1996), ultimately exogeneity of an IV is a maintained hypothesis that cannot be tested directly. In at least one case (Fisher and Shively 2005) researchers were able to exploit as a natural experiment the fact that subsidy distribution occurred somewhat randomly, but such opportunities are rare.

Identification of causal impacts can be strengthened if panel data are available. Ideally the first wave of the panel would have been collected before the subsidy program was implemented. If the same households are interviewed at two or more points in time, then the researcher can use household fixed-effects, first-difference, or correlated random effects (CRE) estimators that remove correlation between time-constant unobservable factors and covariates in the model(s). When unobserved heterogeneity has been eliminated, then the only responsibility of the IVs is to control for correlation between subsidized fertilizer and time varying unobservable factors in the outcome models of interest, which would include some of the general equilibrium effects discussed earlier.

As indicated above, it may be appealing to consider evaluating the impacts of an input subsidy program through a randomized control trial. For example, through a pilot program households could be randomly chosen to be eligible for a voucher that gives them the right to acquire subsidized fertilizer and/or seed at a reduced price. A randomized experiment makes it possible to argue that receipt of subsidized input is independent of the outcome of interest, and hence the error term in the regression model, and thus it becomes easier to argue that the study has estimated causal impacts of the program. However, evaluating input subsidy programs through randomized voucher eligibility is subject to the Localized Average Treatment Effects (LATE) critique (Imbens and Angrist 1994, Wooldridge 2010). For example, such a study would be evaluating the effects of input subsidies on households who obtain vouchers, but wouldn't otherwise obtain subsidized fertilizer by any other means. It is certainly possible that households who do not obtain vouchers may obtain subsidized fertilizer either as gifts or through purchases from household's who obtain vouchers. Indeed, Holden and Lunduka (2010) find evidence of voucher resale in Malawi. Therefore it is not clear that randomly distributing vouchers to households necessarily allows one to evaluate program effects on a population in an unbiased manner.

Identifying causal impacts of input subsidy programs deal with the issue of how to establish estimates of program impacts that are both internally valid, but also have external validity. Internal validity speaks to establishing accurate estimates of fertilizer subsidy impacts for the sample of households that are being evaluated. External validity relates to establishing estimates of program impacts that can be generalized to other places beyond the sample of households that are being evaluated.

Empirical studies often face a trade-off between internal and external validity. For example, studies that use nationally representative data sets and/or that have empirical models based on household behavior are likely to produce results that are more generalizable to a broader context then studies using smaller data sets with reduced form models. However, studies that are nationally representative use observational data and are thus subject to identification issues and potential endogeneity bias that can affect the internal validity of their estimates. Conversely, a study that uses randomized voucher distribution would likely produce an internally valid estimate of subsidy program impacts for the households in the study. However, it is not clear whether these results would be generalizable to a broader population.

In conclusion, substantial conceptual and empirical challenges are associated with estimating the impacts of input subsidy programs. Even with a number of studies that have been recently completed and are in process, it must be acknowledged that some uncertainty remains given the complexity in estimating impacts of input subsidy programs.

3. Estimates of Targeting Effectiveness

One of the reported major innovations associated with "smart subsidies" is that they are targeted to recipient households who meet certain criteria. Often these targeting mechanisms are decentralized, where local officials or communities themselves decide who should receive the subsidy. Targeted subsidies are meant to improve upon universal subsidies of past decades. Empirical evidence from Asia and high-income countries finds that the costs of universal subsidies often outweigh the benefits, and that input suppliers usually capture a large part of those benefits, because the cost savings are not fully passed on to farmers (Brooks, Dyer, and Taylor 2008). However, smart subsidies have their own drawbacks, such as difficulty in determining program objectives and targeting guidelines, and the administrative burden and cost of targeting itself. For example, Kelly et al. (2011) point out that it is difficult for fertilizer subsidy programs to target the poorest households, and at the same time achieve major increases in staple crop production, because those in greatest need may be the least able to use the fertilizer effectively.

Estimating characteristics of households who acquire subsidized fertilizer is a fundamental issue associated with the effectiveness of "smart subsidies". It is also perhaps one of the most straightforward components of these programs to model empirically, so a number of studies have addressed this issue across Africa. Malawi's subsidy program has received the most substantial evaluation of any country's program. The general finding from Malawi is that the most vulnerable households are not sufficiently included in the subsidy program, and that the targeting system does not work particularly well (Holden and Lunduka 2010, Chibwana et al. 2011, Ricker-Gilbert et al. 2011). Although targeting poor and female-headed households is a stated program objectivein Malawi, both Chibwana et al. and Ricker-Gilbert et al. find evidence that female headed households are not specifically targeted in practice, and that wealthier households acquire significantly more subsidized fertilizer on average. Holden and Lunduka find evidence of leakages of vouchers from small farmers to larger farmers. Equity issues aside, whether such leakages constitute potential improvements in fertilizer effectiveness is questionable, since both Holden and Lunduka and Shively et al. (2012) find strong evidence of sharply diminishing maize/fertilizer ratios.

The targeting issues in Malawi are consistent with those found in Tanzania by Pan and Christiaensen (2011) who find that decentralized targeting in the Kilimanjaro region leads to distribution favoring the political elite. They also find that wealthier households capture a larger share of subsidized fertilizer than poor, less politically-connected households. They also find that extension agents target the subsidy away from non-fertilizer using households and towards more productive households who have used fertilizer in the past.

Banful (2011) also provides evidence that political motives affect how vouchers for subsidized fertilizer are allocated in Ghana. The author finds that districts where the ruling party lost the previous election acquire 2 percent more vouchers for each percentage point by which the ruling party had lost the previous election. In addition, district-level poverty is found not to be a significant factor in determining voucher allocation. Mason (2012), using nationally representative panel data from Zambia, finds that households were more likely to receive subsidized fertilizer in districts that voted for the winning political party in prior elections, and that the amount of fertilizer received was positively related to the winning party's margin of victory. Jayne et al. (2011) also finds that fertilizer subsidies are disproportionately targeted to farmers with greater assets and incomes. Households with 10-20 hectares of land received seven times more subsidized fertilizer, on average, than households controlling 2 hectares of land or less.

Liverpool (2012) uses data from the Kano district of Nigeria and presents results on subsidy targeting that are a bit different from those of other studies in Africa. She finds that farmers who participate in the subsidy voucher program tend to be poorer than non-participants, and that the voucher program in Nigeria has helped to develop links between rural farmers and input suppliers. The reason that findings on targeting in Nigeria may differ from those in other

African countries could be due to the way the Nigerian program is implemented, as well as farmer familiarity with fertilizer. One possible explanation may be found in the fact that in Nigeria, subsidized fertilizer is distributed through farmer organizations. This distribution channel could favor smaller and poorer farmers, although it need not; in Zambia, subsidies are also distributed through cooperatives, but these seem to target better-off farmers. Another explanation may be the high private sector utilization rate in Nigeria. Liverpool finds that nearly 80% of the farmers in her sample participate in the private fertilizer market.

4. Crowding Out Estimates

The effectiveness, or ineffectiveness, of input subsidy programs to target recipient farmers who meet certain criteria has a direct effect on how the program affects demand for commercial inputs. In principle, if subsidized fertilizer is allocated in a manner that does not affect farmers' demand for commercial fertilizer, then crowding out would be negligible and the program would result in a one ton increase in total fertilizer use for every ton of fertilizer distributed under the program. Other factors constant, this would maximize the contribution of a subsidy program to net farm income and national food production. Measuring the degree to which targeted fertilizer subsidies crowd out commercial sales is essential for understanding the contribution of fertilizer subsidy programs to total fertilizer use and their ultimate impacts on farm incomes and food production.[6]

Crowding out of commercial fertilizer by subsidized fertilizer has been estimated in four African countries to date. Ricker-Gilbert et al. (2011) estimates that in Malawi one kilogram of

[6] Although it is beyond the scope of the current paper to review specific econometric approaches, it is worth noting that a number of econometric techniques have been applied to the measurement of crowding out, including double-hurdle models and control function approaches.

subsidized fertilizer crowds out 0.22 kilograms of commercial fertilizer on average between 2003 and 2007. The authors also find that, at 0.18 kg displaced, crowding out is smaller for the poorest quintile of the sample, compared to the wealthiest quintile, with 0.31 kg displaced.

In Zambia Xu et al. (2009) find evidence that subsidized fertilizer crowds out commercial fertilizer almost completely in areas where the private sector has been active, but crowds in commercial fertilizer in areas where the private sector is weak. Findings from Kenya indicate that crowding out is roughly 0.65 (i.e., a kg of fertilizer received by a farmer under the subsidy program adds only 0.35 kgs to the farmer's field) in the high-potential maize zones of western Kenya where commercial fertilizer use has long been established. By contrast, in areas of eastern Kenya where a substantially lower percentage of households purchase commercial fertilizer, one kilogram of fertilizer distributed under the subsidy program adds close to 0.70kgs to total fertilizer use. Liverpool (2012) finds that in Kano, Nigeria, establishing retail points closer to farmers increased access to fertilizer for farmers in more remote locations with high transactions costs. Liverpool also finds that participation in the subsidy program does not affect a farmer's demand for commercial fertilizer, but once the participation decision has been made the subsidy program has a positive effect on how much commercial fertilizer that farmer purchases.

It is possible that these estimates may underestimate the degree of crowding out in cases where a substantial portion of subsidized fertilizer is diverted by program implementers for sale. While anecdotal stories are common, Mason (2012) was able to measure the degree to which Farm Inputs Support Program fertilizer was diverted in Zambia by comparing nationally representative estimates of receipts of subsidized fertilizer by rural households with official program estimates from the Ministry of Agriculture.[7] Over a six-year period, farmers reported receiving 64.5 percent of the official quantity of subsidized fertilizer distributed to farmers according to the Ministry of Agriculture. This implies that many households purchasing fertilizer from retailers were actually purchasing recycled program fertilizer diverted from the subsidy program. After accounting for the leakage of program fertilizer, Mason's estimates of crowding out increased from 0.xx to 0.xx. Estimates of this magnitude, if they can be considered representative of most fertilizer subsidy programs in SSA, would seriously influence the benefits of such programs relative to their cost.

Mason and Ricker-Gilbert (2012) conduct a cross-country analysis of how Malawi and Zambia's seed subsidy program affects demand for improved maize seed varieties in the two countries. The authors estimate seed crowding out via correlated random effects tobit and find that on average, each additional kilogram of subsidized maize seed acquired by a household reduces its commercial improved maize seed purchases by 0.56 kg in Malawi and by 0.49 kg in Zambia.

Holden and Lunduka (2012) estimate the impacts of fertilizer subsidies on organic manure use in Malawi. The authors find some evidence of that subsidized fertilizer crowds in organic manure. On average a 1% increase in fertilizer use intensity leads to a 1.94-1.96% percent increase in manure use intensity outside the subsidy program and a 0.62%-1.66% increase within the subsidy program.

[7] This Crop Forecast survey of roughly 14,000 rural farm households is the same database from which the government of Zambia derives its national annual estimates of crop production.

5. Estimates of Impacts on Production, Income and Other Variables of Interest

Several studies have estimated how input subsidy programs impact maize production. Most of the work focuses in Malawi, but additional work has been conducted in Zambia and Kenya. Holden and Lunduka (2010) find that in Malawi there is a significant positive trend in maize yields from 2006 to 2009 with an increase in mean yields of about 600 kg/ha from 1440 to 2040 kg/ha for hybrid maize and from 1120 to 1680 kg/ha for local maize. However, the authors do not directly tie this incremental increase to the subsidy program.

Chibwana et al. (2011) find that in the Kasungu and Machinga districts of Malawi, the average increase in maize yield from accessing subsidized maize seed and subsidized fertilizer is 447kg/ha for hybrid maize and 249kg/ha for local maize. Ricker-Gilbert and Jayne (2011) use six years of data on fertilizer use in Malawi to estimate how acquiring subsidized fertilizer over time impacts maize production and other indicators. The authors find that an additional kilogram of subsidized fertilizer in the current year boosts maize production by 1.82 kilograms in that year on average. In addition an additional kilogram of fertilizer acquired by households in each of the three previous years boosts maize production by 3.16 kilograms in the current year on average. The increase in maize production from receiving subsidized fertilizer in the past could be due to nutrient build up in the soil, or a learning and experimentation process from receiving subsidized fertilizer over a period of time. The general finding from Malawi is that the input subsidy program produces some relatively modest gains to maize production. This finding is perhaps not surprising and is to be expected given the size and scope of the country's input subsidy program.

Using five waves of nationwide household survey data from Kenya covering thirteen years, Sheahan et al. (2012) estimate the relative and absolute profitability of nitrogen application rates on maize fields and compare these profitability conditions to observed nitrogen use patterns over time. In general, they find that farmers are consistently and steadily increasing towards risk-adjusted economically optimal rates of fertilizer application over time and that, in the most agriculturally productive areas, farmers may actually benefit from the reduction in fertilizer application. Fertilizer use rates may nevertheless be profitably raised in many areas, but doing so will require the adoption of complementary practices that raise response rates of grain to fertilizer application. Current fertilizer value-cost ratios range from 1.0 to 2.0 in the main maize-surplus producing areas of Kenya where over 90 percent of farmers are already using fertilizer. Achieving higher returns to fertilizer use will require a more holistic approach to input intensification strategies in the region, paying attention to management practices and complementary inputs that can raise the profitable use of the input.

Chibwana et al. (2011) measure the impacts of Malawi's Farm Input Subsidy Program on the cropland allocation decisions of farmers in Kasungu and Machinga Districts in central and southern Malawi. Using a two-step regression strategy to control for endogenous selection into the program, they find positive correlations between participation in the program and the amount of land planted with maize and tobacco. Their results suggest that households receiving subsidized fertilizer for maize simplified crop production by allocating more of their land to maize and less land to other crops (including groundnuts, soybeans, and dry beans). They found no significant changes in overall land use. However, their work underscores two points of policy relevance. First, their results show that farmers who received coupons for improved maize seed and maize fertilizer allocated 45% more land to improved maize and less land to traditional varieties of maize and other crops than farmers that did not receive a coupon. Hybrid varieties have many advantages over traditional varieties, and therefore the FISP may have promoted food self-sufficiency. However, the increase in land allocated to improved maize (and, in some cases, tobacco, for those who received fertilizer subsidies for that crop) clearly occurred at the expense of other crops. This means that, from a conceptual point of view, program impacts cannot be viewed simply in terms of increased output of the target crop (in this case, maize). In calculating overall impact, one must subtract from these gains the losses in output of other crops. Chibwana et al. (2011) calculate that these reductions in the value of output of other crops may be as much as 50% of the overall gains registered in maize.

Second, and related, is the issue of how the subsidy affects crop diversification. If fertilizer subsidies encourage farmers to concentrate on a narrower portfolio of crops, and if this is viewed as detrimental, programs might have to be redesigned to avoid this unintended effect. From one perspective, crop diversification is an important strategy for resourceful households. By growing a mixture of crops, farmers can reduce potentially negative impacts of labor shortages, seasonal production needs, and uncertain climate conditions (Tripp, 2006). In this sense, the shift toward more simplified cropping systems, dominated by improved varieties of maize, might increase the vulnerability of farm households to vagaries of weather, pests, diseases, and markets. Furthermore, the increase in maize acreage at the expense of relatively drought-tolerant crops, notably cassava and sweet potato, could exacerbate the impact of drought on food security (Holden and Lunduka, 2010). Reduced allocation of land to legumes also has potentially negative consequences for soil fertility. The inorganic fertilizer provided by the FISP coupons could help increase the nitrogen content of the soil, but Akinnifesi et al. (2009) argue that the synergistic effects of fertilizer application and legume cultivation achieve better soil maintenance. Nevertheless, a move toward greater maize specialization is not intrinsically a bad thing, since maize provides labor savings and improved pest control as well as market opportunities, and flexibility in planting and harvesting times. But the current objectives of agricultural policy in Malawi include increased maize production *and* increased crop diversification, which may be difficult to achieve when fertilizer subsidies have incentives that inherently encourage land reallocation.

A final issue that has received only limited attention in the literature is the potential for fertilizer subsidies to generate unintended off-site effects, either positive or negative. Because rural families engage in a wide range of activities in support of their livelihoods, labor allocation to some activities (e.g. maize intensification) necessarily has implications for other activities (e.g. natural resource extraction). In an early study of Malawi's Starter Pack programme, Fisher and Shively (2005) found evidence that households receiving subsidized seed and fertilizer tended to intensify their maize production and, as a result, placed less pressure on the resources of surrounding forests – a positive externality associated with the program. Similarly, Chibwana et al. (2013) find no evidence that subsidies lead to overall area expansion, and some evidence in favour of the hypothesis that Malawi's fertilizer subsidy for maize promoted intensification. However, the same study suggests that fertilizer subsidies for tobacco had small but negative implications for surrounding forests because expansion of tobacco created a derived demand for poles and timber to construct drying sheds. One can easily envision a range of potential externalities and spill-over effects from fertilizer subsidies – in areas ranging from water and natural resource use to education and health – but to date, researchers have focused very little attention on these issues.

6. Input Subsidies Next to Other Public Investments

It is essential to weigh the benefits and costs of subsidizing fertilizer next to other alternative public investments and policies capable of promoting smallholder food security and poverty reduction. Filipski and Taylor (2011) use household Computational General Equilibrium (CGE) models to compare fertilizer subsidies, cash transfers and price supports in Malawi and Ghana. The authors find that no one policy consistently dominates another. Instead the benefits of each policy depend on the structure of the economy, market conditions, and program design.

Based on evidence from Asia, Fan et al (2007) and the Economist Intelligence Unit (2008) stress the role of other public investments such as R&D, crop science, infrastructural development, education, and health as the most important long-term drivers of agricultural productivity growth and poverty reduction in green revolution Asia. In light of these findings, expenditures on input subsidy programs may have high opportunity costs, particularly if they account for 40-70% of public expenditures on agriculture as has commonly been the case for Malawi's input subsidy program in recent years.

7. Conclusions

This initial review of fertilizer subsidies in Africa points to several broad conclusions. First, our perspective is that the issue of whether fertilizer should be subsidized constitutes a "wicked problem" because such programs are multi-dimensional, there is no clear right or wrong answer as the best way to implement them, and their impacts are often difficult to isolate. Related to this is that it is difficult to model these programs due to conceptual issues related to identifying the point of evaluation or the definition of the program intervention itself. Moreover, data problems and severe endogeneity challenges make it difficult to cleanly estimate the causal impacts of the program on outcomes of interest, including agricultural production and farmer incomes.

In some settings, "smart subsidies" became the "Trojan Horse" for re-introducing large-scale 1970s-style input subsidy programs. Today, in 2012, roughly 2.0 billion is spent each year on input subsidy programs in a small set of African countries. Today's large-scale input subsidy programs have very few characteristics of the smart subsidy design elements outlined in Morris et al. (2007) that were used as rationale in the mid-2000s for reintroducing these programs. This doesn't mean that they are ineffective in achieving important objectives, but it does mean that while the concept of "smart" fertilizer subsidies is very appealing, they can be complex to design and difficult to evaluate. Also, unanticipated implementation problems and unintended effects can cause even well-designed programs to fall short of being "smart" in practice.

Among our general empirical conclusions is that problems with targeting appear to be ubiquitous. These problems stem from the political nature of the programs, and the difficulty or failure to establish clear program objectives. For the researcher, this leads to difficulty in defining the "treatment" group for an analysis of program effects, and introduces the empirical complexity that participation cannot be assumed to be exogenous to outcome variables of interest. One research issue that remains unexplored is a comparison of benefits and costs between targeted "smart subsidies" and more universal subsidies.

One also finds consistent evidence of crowding out in East Africa (Malawi, Zambia, and Kenya) in both seed and fertilizer markets. Some evidence of crowding in has been reported for Nigeria (perhaps due to program design, perhaps due to problems with identification using cross-sectional data). There also seems to be some evidence that the subsidies can crowd in commercial fertilizer in areas where the private sector is less active (Nigeria and Zambia), and that subsidized fertilizer may promote the use of organic manure. At this stage, further research seems warranted to better understand and further describe the conditions under which crowding out and crowding in occur.

That researchers have found evidence of positive but small increases in maize production from fertilizer subsidies in Malawi is perhaps not surprising, given the size and scope of the program. However, impacts of greater maize production must be weighed against the displacement of other crops, and the impact of reduced diversification on agricultural sustainability and smallholder vulnerability. More investigation of the presence or absence of environmental and other spill-over effects, and their magnitude, is also necessary to develop a full picture of the net impacts of subsidies.

Can input subsidy programs really be considered sustainable in light of their high direct costs and opportunity costs? To answer this question more research will be needed that compares results at different points of evaluation and compares methods for robustness. Moreover, we need to recognize that subsidy programs are highly political in nature, so once implemented, they become difficult to remove. For this reason, policy makers need to be all the more careful to establish and articulate clear goals and objectives for these programs.

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