Policy Research Working Paper 10399

Detox Development: Repurposing Environmentally Harmful Subsidies

Background Paper

The Effect of Agricultural Input Subsidies on Productivity

A Meta-Analysis

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WORLD BANK GROUP
Sustainable Development Practice Group
Office of the Chief Economist
April 2023

Policy Research Working Paper 10399

Abstract

This paper systematically analyzes the effect of agricultural input subsidies in developing countries on yield and income, using a meta-analysis. From three databases, the analysis identifies 12 studies with 32 estimated effects on yield and 23 estimated effects on income. The findings show that programs that provide subsidized fertilizer and improved seeds are associated with average increases of 18 percent in yields and 16 percent in farming household incomes. These findings suggest that agricultural subsidies can lead to increased yields and contribute to improved living standards.

This paper is a product of the Office of the Chief Economist, Sustainable Development Practice Group. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at lnguyen2@bates.edu, mtriyana@worldbank.org, and Jruss@worldbank.org.

The Effect of Agricultural Input Subsidies on Productivity: A Meta-Analysis

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Keywords: *systematic review, meta-analysis, input subsidies, developing countries, agriculture*

JEL codes: O13 O23 O33 Q18

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1. Introduction

The adoption of modern agricultural inputs like fertilizers and improved seeds has been credited with the quadrupling of agricultural yields in Asia and South America. In countries like India, Mexico, Pakistan, and Türkiye, the Green Revolution—spurred by the increased application of these inputs—has transformed the agriculture sector, significantly increased farming household incomes, and reduced food insecurity. Generous agricultural input subsidies, as well as investments in research and development, irrigation, and rural infrastructure have accelerated this transformation.

Unlike most of the rest of the developing world, however, countries in Sub-Saharan Africa have seemingly failed to realize a Green Revolution. Here, yields continue to lag the rest of the world, as do fertilizer application and adoption of other modern inputs (Carter, Laajaj, and Yang 2021a). In response, many countries in Sub-Saharan Africa began implementing input subsidies in the 1990s, with the goal of increasing agricultural productivity. In 2016, government budgets allocated to input subsidy programs in Sub-Saharan Africa ranged from US$13 million in Rwanda to US$1.1 billion in Kenya.[3] Understanding the impact of input subsidies in agriculture on outcomes such as yields and income remains an important policy question for many countries that continue to allocate resources to such programs or attempt to reform existing programs. There is a large literature that has shown the effects of input subsidy programs on various outcomes of interest, including input usage (Duflo, Kremer, and Robinson 2011; Kim et al. 2021), technology adoption (Koppmair, Kassie, and Qaim 2017; Mason and Smale 2013), yields (Carter, Laajaj, and Yang 2021; Wossen et al. 2017), income (Mason et al; 2017, Yi et al, 2016), welfare (Gemessa, n.d.) and labor market outcomes (Ricker-Gilbert 2014), but a synthesis of the impacts of input subsidies is limited (Jayne et al. 2018; Ricker-Gilbert, Jayne, and Shively 2013).

We contribute to this literature by conducting a meta-analysis to summarize the impact of widely implemented subsidies for fertilizer and improved seeds on agricultural productivity in developing countries. A meta-analysis allows for a systematic summary of the results and conclusions from an overall body of evidence from multiple studies. The method is a statistical technique that combines results from existing studies to create a "pooled" common estimate and also identify sources of disagreement. Our approach is similar to a recent meta-analysis that examines the impact of digital agricultural programs on yields (Fabregas et al. 2019; Fabregas, Kremer, and Schilbach 2019).

The program effects vary depending on the program details, institutional details, and other factors. For instance, input subsidy programs are sometimes administered using vouchers, and in more recent years, e-vouchers (Wossen et al. 2017), while a few programs use cash (Yi, Lu, and Zhou 2016). The interventions and programs that provide input subsidies vary in their design and target populations. For instance, beneficiary targeting can be done at the community level or at the household level, based on land ownership (Osorio et al. 2011; Chirwa and Dorward 2013). The methods used to evaluate the

[3] The numbers presented are the Total Support Estimate, obtained from Gautam et al. (2022), originally from the Food and Agriculture Organization's Monitoring and Analysing Food and Agricultural Policies (MAFAP) program (Angelucci et al. 2013).

programs also vary as some programs were evaluated based on randomized trials, while others are observational studies.

One of the primary objectives of input subsidy programs is technology adoption to increase agricultural productivity. Specifically, input subsidies can begin a 'virtuous cycle' for farmers to adopt new technology or better farming practices. Some programs provide fertilizers and improved seeds to allow farmers to learn through experience, while others include agricultural extension services to encourage good farming practices. Some fertilizer subsidy programs provide free distribution or full subsidy, so that farmers have no out-of-pocket payments, while others provide partial subsidy, thus requiring farmers to share the cost of the fertilizer. The distortion due to subsidies can lead farmers to use suboptimal input mix, which may lead to no productivity gain, or even a reduction in productivity. Additionally, overuse of fertilizer may generate a negative environmental externality, which can then lead to water pollution, which subsequently can adversely affect health outcomes (Brainerd and Menon 2014; Zaveri et al. 2020). In this study, we focus on the effect of agricultural input subsidies on productivity. Another common policy objective of agricultural subsidy programs is poverty reduction. By targeting the subsidy to poor farmers, their productivity increase could also increase their income and living standards. At the aggregate level, this could then lower poverty. To examine living standards, our secondary outcome of interest is farming household income or expenditure to capture living standards.

We initially identified 655 articles for title and abstract screening. After the full text screening, 12 studies were used in the meta-analysis regression. Based on these articles, we find that input subsidy programs are associated with an 18% increase in yield. While this suggests an improvement in production per unit of cultivated land, we are unable to examine the overall productivity impacts (i.e. total factor productivity), nor the external impacts such as environmental externalities. For our secondary outcome of interest, we find that input subsidy programs are associated with a 16% increase in farming household income or expenditure, which suggests that the increase in yields translates to improvements in living standards. The analysis includes four articles from Malawi, so we perform back-of-the-envelope calculations based on our estimates and Malawi's input subsidy program costs. In this example, we find a benefit-to-cost ratio of 1.2, which implies that a $1 subsidy is associated with $1.20 of benefits.

2. Data and methods

A meta-analysis begins with a database search—based on pre-identified keywords—using at least two databases, followed by title and abstract screening, full text screening, and finally the meta-analysis regression. For the database search, we used a query search in the three following databases: *Web of Science*, *Scopus*, and *jstor*. The search is restricted to articles in Economics published between the years 2000 and 2021.[4] We further restrict the setting to low- and middle-income countries based on World Bank classification. Observational studies and experiments are included in this meta-analysis since few studies using experimental evidence are available. The keyword search generally aims to search for input subsidy programs in agriculture and their impacts on productivity or income or expenditure. We

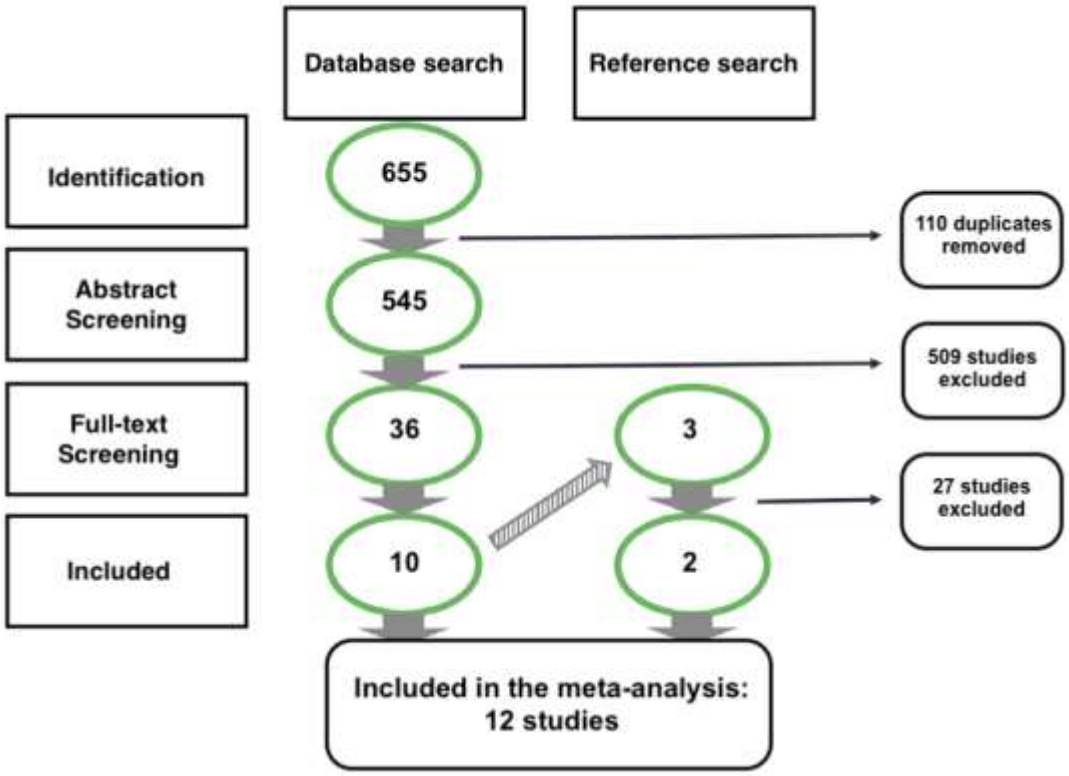
[4] While it is possible to examine studies from before 2000, we believe more recent studies would be more similar to current policy settings.

include other possible synonyms for subsidies by including 'discount' and 'vouchers' in the database search. Our search criteria are described in more detail in the appendix. Our main productivity measure is yield, output, or the value of yield or output. We also include income or expenditure as an additional outcome of interest to capture changes in living standards, which should relate to poverty. Figure *1* describes the number of articles at each screening stage. The initial search yielded 655 articles across the 3 databases: 213 articles from *Web of Science*, 149 articles from *Scopus*, and 293 articles from *jstor*.

The title-and-abstract screening stage was performed simultaneously by two individuals based on the following exclusion criteria: meta-analysis or review article, subject matter is not agriculture, setting is not a low- or middle-income country, simulation or calibration study, not an input subsidy intervention or program. Conflicts in inclusion and exclusion between the two screens were then reconciled to yield 36 articles for the full text screening stage.

The full screening stage was conducted to obtain the standardized effect of input subsidies on productivity. For consistent comparison, we collected the estimates for the percentage increase in yields as a result of participating in an input subsidy program. After reading the full-text articles, we excluded articles that do not involve specific input subsidy programs, or if one of the following was not included: the number of observations, baseline or comparison group mean, and confidence interval or standard errors. Studies that use simulation or calibration methods, non-causal methods, and non-quantitative methods were also excluded. After full-text screening, 9 articles remained. The references of these 9 articles were reviewed to find additional relevant articles. This step identified another 3 eligible studies, of which 2 articles were included in the meta-analysis. The entire screening process yielded a total of 11 articles that we include in the meta-analysis. Lastly, to obtain additional estimates, we reached out to the authors of several studies which included data on subsidies and productivity or income, but did not report the program effect on productivity or income in the articles. We received a response from Abman and Carney, and include this study (Abman and Carney 2020) in our analysis. The final sample includes a total of 12 articles.

Figure 1 *Number of articles at each screening stage*



Notes: The initial database search yielded 213 articles from Web of Science, 149 articles from Scopus, and 293 articles from JSTOR. Searching the references of the 9 articles yielded 3 additional potentially relevant articles, 2 of which were included in the meta-analysis. Contacting authors yielded one study, which brings the total to 12 studies for the meta-analysis. Top three reasons for exclusion in the abstract screening stage are "Not an input subsidy or price intervention" (199 articles), "Not a low- or middle-income country" (82 articles), and "Not related to agriculture" (39 articles). Top three reasons for exclusion in the full-text screening stage are "Non-causal method" (11 articles), "not impact on output, yield, or income" (8 articles), and "non-original research" (5 articles).

2.1 Estimation strategy

The meta-analysis regression uses a random effects model, weighted by the inverse of the variance so that more weight will be given to results that are more precisely estimated (Fabregas, Kremer, and Schilbach 2019; Fabregas et al. 2019). For each experiment, the observed treatment effect is given by:

$$\hat{T}_j = \theta_j + e_j$$

where θ_j is the true effect for study j and e_j is the within study error, where $e_j \sim N(0, \sigma_j)$, and σ_j is the sampling variation in estimating θ_j. The technique assumes that $\theta_j = \mu + \delta_j$, and $\delta_j \sim N(0, \tau^2)$, where τ^2 is the between-study variance, estimated by the DerSimonan and Laird method (DerSimonian and Laird 1986). The estimated μ is given by:

$$\hat{\mu} = \frac{\sum w_j T_j}{\sum w_j}$$

where w_j is study-specific weight given by the inverse of the variance, which is given by:

$$w_j = \frac{1}{(\hat{\tau}^2 + \widehat{\sigma_j^2})}$$

If the article includes several estimated effects, the intent-to-treat parameter is the preferred estimate (Croke et al. 2016). The intent-to-treat parameter is the estimated effect of participating in the subsidy program (i.e. receiving vouchers/cash) on yield or income, and not the effect on people who actually buy subsidized inputs with the vouchers. Ideally, the parameters in the meta-analysis would come from randomized trials, which is the gold standard for program evaluation, but there are few such studies, so we also include quasi-experimental studies in this meta-analysis. We examine the relationship between experimental estimates and effect size for robustness in Section 3.3.

3. Results

3.1 Sample characteristics

A description of the 39 articles at the full text screening stage is included in Table 1. The top three reasons for exclusion at the abstract screening stage were "Not an input subsidy or price intervention" (199 articles), "Not a low- or middle-income country" (82 articles), and "Not related to agriculture" (39 articles). At the full-text screening stage, the top three reasons for exclusion were "Non-causal method" (11 articles), "Not impact on output, yield, or income" (8 articles), and "Non-original research or review article" (5 articles). Of the 39 articles, 28 examine countries in Sub-Saharan Africa, and the final meta-analysis sample includes 11 articles with data from Sub-Saharan countries and 1 from a non-African country (China). Our primary outcome of interest, productivity, is examined in 21 of the 39 articles, and 11 of them are included in the meta-analysis. Our secondary outcome of interest, income or expenditure, is studied in 8 articles, and 7 are included in the meta-analysis.

The methods used to analyze program impact varies in the articles we have identified. Studies using non-causal and non-quantitative methods are excluded. Some studies employ multiple methods to show robustness and estimate several treatment effects. Whenever possible, we use the intent-to-treat estimate (Croke et al. 2016). All 3 studies that conducted randomized trials are included in the meta-analysis. Most studies that use instrumental variable (IV), propensity score matching, and difference-in-differences are included in the meta-analysis. The meta-analysis includes 3 papers using IV, 5 papers using propensity score matching, 1 paper using difference-in-differences, and 3 papers using fixed effects. Of the 13 studies that use other quantitative methods, 4 are included in the meta-analysis.

The articles at the full text screening stage vary in program characteristics. Of the 39 articles we have identified, 16 studies examine programs that provide a full subsidy (free distribution) of fertilizer and improved seeds, while another 16 examine programs that provide partial subsidies. The remaining 7 are excluded because the interventions do not include input subsidies. Among the 12 studies included in the meta-analysis, 7 of them examine a full subsidy program and 5 examine a partial subsidy program where the subsidies range from 50% to 93%. In terms of the distribution mechanism, 26 studies examine programs that use vouchers, including e-vouchers, and 4 studies examine programs that use cash transfers. Eleven studies that examine voucher programs and one study that examines a cash transfer program are included in the meta-analysis. The cash transfer study (Yi, Lu, and Zhou 2016) analyzes a program that provided direct payments and input subsidy to grain producers in China. The subsidy to an average household is approximately 2 percent of its total income, or about 5 percent of its agricultural

income. Even though most of the studies examine programs that distribute subsidized fertilizer and improved seeds, there are 3 studies that analyze electricity subsidies for agriculture in India. However, one of these studies is not quantitative and the remaining two use simulation analyses, and are therefore excluded. There are 28 studies that examine input-subsidy-only programs and 7 studies examine programs that include both input subsidies and other interventions. Of these, 10 input-subsidy-only programs and 2 with other interventions are included in the meta-analysis. First, a program in Northern Ghana called Planting for Food and Jobs (PFJ) consists of input subsidy, and the following services: "free extension services to farmers, marketing opportunities for produce after harvest, and E-Agriculture, a technological platform to monitor and track activities and progress of farmers" (Tanko, Ismaila, and Abu Sadiq 2019, 3). The second article studies the Wheat Initiative in Ethiopia. The estimate is based on an RCT that gave the first treated group agronomic practice training and marketing assistance together with input subsidy, while the second treated group only received marketing assistance (Abate et al. 2018). The study finds that the marketing assistance intervention alone did not affect yields.

Table 1 Characteristics of articles included in the full text screening

	Number of studies at full text screening	Number of studies included in final analysis
Total	39	12
Region		
Africa	28	11
Non-Africa	11	1
Outcomes (not mutually exclusive)		
Yield or productivity	21	11
Income	6	5
Expenditure	2	2
Other	17	2
Method (not mutually exclusive)		
Randomized control trial (RCT)	3	3
Instrumental variable (IV)	5	3
Propensity score matching (PSM)	6	5
Difference-in-Differences	1	1
Fixed Effects	9	3
Other quantitative methods	13	4
Non-quantitative method	11	0
Subsidy level		
Full subsidy	16	7
Partial subsidy	16	5
N/A (no price intervention)	7	0
Distribution mechanism		
Voucher	25	11

Cash	4	1
N/A	10*	0
Program characteristics		
Input subsidy	29	10
Input subsidy & other interventions	6	2
N/A	4	0

Notes: Other quantitative methods include ordinary least squares (OLS) and median regressions. *In addition to the 7 articles that do not have a specific price intervention, 3 articles examine electricity subsidy (free distribution). It is neither distributed via voucher or cash, therefore, they are labeled "N/A".

Table 2 provides more details on the 12 articles that are included in the meta-analysis. One article examines a subsidy program in China and the remaining 11 articles examine programs in countries in Sub-Saharan Africa. The evidence on yield is based on the 11 articles from countries in Sub-Saharan Africa while the evidence on income and expenditure includes one study from China and 4 from countries in Sub-Saharan Africa. Four articles report results for both yields and income or expenditure, 6 articles only report results for yields, one article only reports results for income, and one article reports results for yields based on an additional, unpublished analysis. Three articles report results from randomized controlled trials, allowing us to use the intent to treat parameter directly, while the remaining articles report the intent to treat parameter using other methods.

Table 2 Characteristics of articles included in the meta-analysis

Study ID	Reference	Country	Program description	Method	Outcome(s)
1	Carter, Laajaj, and Yang (2021)	Mozambique	Input subsidy via voucher	RCT	Maize yield
2	Tanko, Ismaila, and Abu Sadiq (2019)	Ghana	Input subsidy via voucher, extension service, produce marketing, E-Agriculture	PSW	Rice productivity, rice income, consumption expenditure
3	Abate et al. (2018)	Ethiopia	Input subsidy via voucher, training, guarantee of output purchase	RCT	Yield
4	Ragasa and Mazunda (2018)	Malawi	Input subsidy via voucher, agricultural advice	MC/CRE, MC CF, MC IV	Increase in yield/ha for every kg/ha increase of subsidized fertilizer
5	Wossen et al. (2017)	Nigeria	Input subsidy via e-voucher	PSM, IPWRA, IV	Yield, income, expenditure
6	Mason et al. (2017)	Kenya	Input subsidy via voucher	DID, FE, PSW	Output, income
7	Funsani et al. (2016)	Zambia	Input subsidy via voucher	PSM	Output, income

8	Yi, Lu, and Zhou (2016)	China	Input subsidy via cash transfer (10% agriculture income)	Median regression	Income
9	Karamba and Winters (2015)	Malawi	Input subsidy via voucher	PSW, FE	Output
10	Beaman et al. (2013)	Mali	Input subsidy via voucher	RCT	Output value
11	Ricker-Gilbert and Jayne (2017)	Malawi	Input subsidy via voucher	OLS	Increase in yield for every kg/ha increase of fertilizer used
12	Abman and Carney (2020)	Malawi	Input subsidy via voucher	IV	District-level increase in yield for increase of subsidized fertilizer

Notes: IPWRA: inverse propensity weighting adjusted regression; IV: instrumental variable; MC: Mundlak-Chamberlain device or CRE: Conditional Random Effects; MC CF: Mundlak-Chamberlain device and control function approach; MC IV: Mundlak-Chamberlain device and IV approach; OLS: ordinary least squares; PSM: propensity score matching; PSW: propensity score weighting; RCT: randomized control trial.

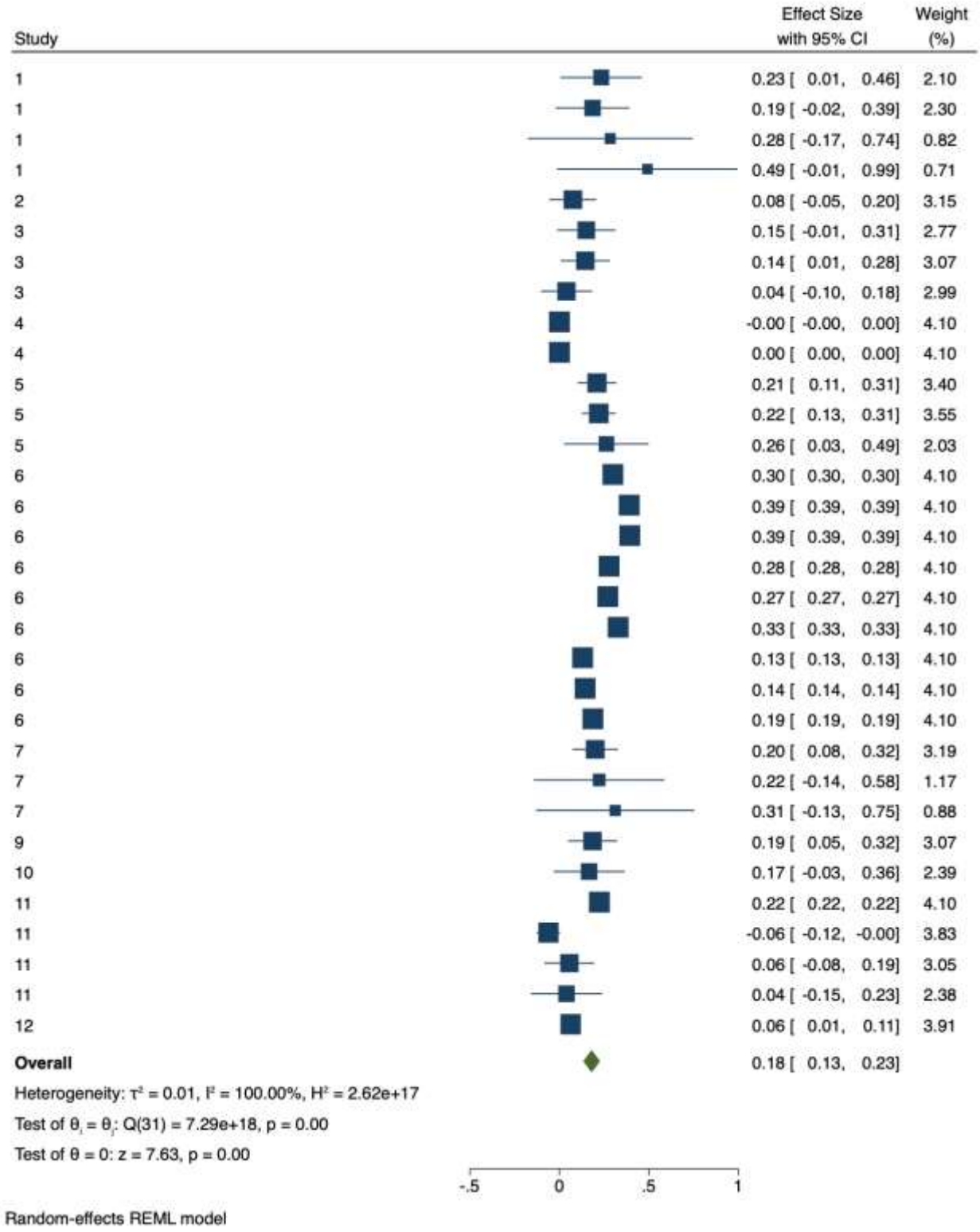
3.2 Estimated effect of input subsidy programs on yield and income

Figure 2 summarizes the effects of input subsidy programs on yield and income or expenditure. Panel A presents the estimated effect of input subsidies on yield. There are 32 estimates from 11 studies; some of them come from different methods within a study, some are long-run effects (more than one year post subsidy), and one study estimates spillover effects. The spillover effect is defined in the study as the effect of being "more connected" to a treatment group member, based on the indicator of having above-median number of people who received subsidies in one's social networks, regardless of whether that person is treated or not (Carter, Laajaj, and Yang 2021). It means that the spillover effect is calculated based on both beneficiaries and non-beneficiaries of the subsidy program. Except for study 4 (Ragasa and Mazunda 2018) and one estimate in study 11 (Ricker-Gilbert and Jayne 2017), all of the estimated effects on yields are positive. The largest effect measured is in study 1 (Carter, Laajaj, and Yang 2021), which is the spillover effect post subsidy. Based on these 12 studies, the meta-analysis shows an average effect of receiving input subsidies on yield is 18%, with a 95% confidence interval between 13% and 23%.

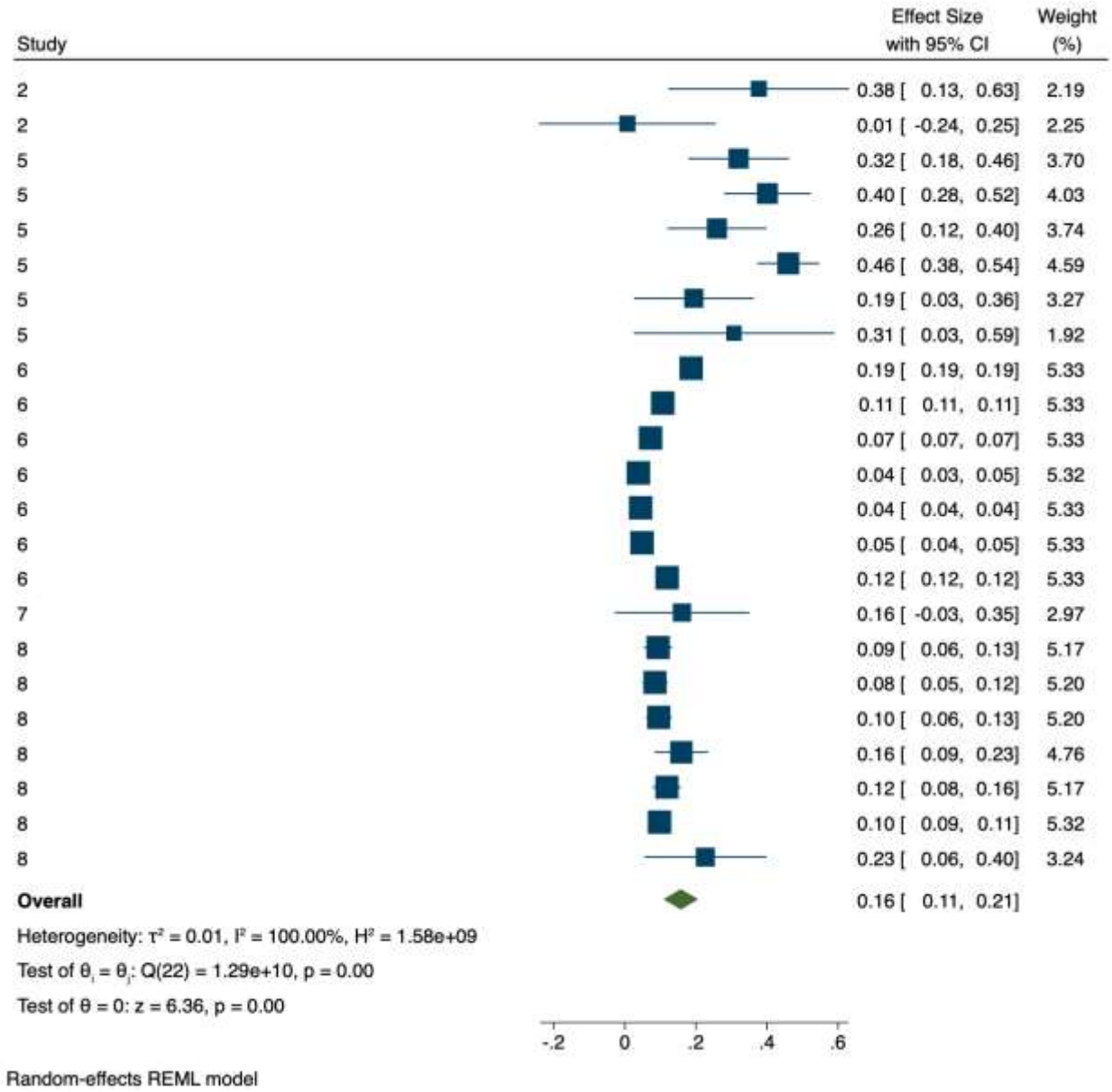
Panel B presents the effects of subsidy programs on income or expenditure using 23 estimates from 5 studies. The outcome variables include household income in all seasons or only in the main season, income per capita per day, agricultural income, and consumption expenditure. All the point estimates are positive, ranging from 1% to 46% increase in income or expenditure. The average effect across 5 studies is 16%, with a 95% confidence interval between 11% and 21%. The effect of input subsidies on income is similar to the effect of subsidy programs on productivity, which suggests that the increase in crop yields translate into higher living standards for beneficiary households.

Figure 2 Summary of the effects of input subsidies

Panel A. Effect on yield



Panel B. Effect on income or expenditure



Notes: Meta-analysis regression using random effects. The 32 estimated effects of the subsidy programs come from 11 articles that report yield or productivity, two of which report program effect as the effect of a one-kilogram increase in fertilizer use (ITT effect is calculated based on the estimates). Studies 1, 3 and 10 are RCTs and the rest are the mix of different methods including IV, propensity score matching, DiD and FE. Five studies report the effect of subsidy programs on income (studies 2, 5, 6, 7, and 8), two studies use expenditure (studies 2 and 5).

We use regression analysis to examine the relationship between the evaluation method, program characteristics, and the estimated effect on yield (Table 3). Unfortunately, we are unable to include additional covariates to do the same analysis for income and expenditure due to the small number of estimates included in the meta-analysis. In terms of method, randomization has been used as the gold standard of program evaluation, and ideally, estimates included in meta-analyses are intent to treat parameters that have been estimated experimentally. However, there are only 3 studies using RCTs in this meta-analysis, so we examine whether estimated effects using randomization are systematically

different from estimated effects using other methods (table 3, column 1). If studies using RCTs generate systematically different estimates from studies using other methods, we may be concerned about the potential bias associated with other methods. We include an indicator for estimates from studies that use RCTs and find that the relationship between the estimated program effect on yield and using an RCT is not statistically significant. This result implies that the estimated effect of input subsidies on yield using RCTs is similar to estimates using other methods of evaluation like difference-in-differences, instrumental variable, or propensity score matching.

We also examine how different program characteristics relate to estimated effects full (100%) subsidy (7 studies), bundling input subsidies with other interventions (2 studies), the longer-term effect of input subsidy programs (2 studies), and spillover effects (1 study). First, we examine whether programs that provide full subsidies (100% subsidy) are associated with higher yields by including an indicator for full subsidy. We find a positive but not statistically significant association between full subsidy programs and yield, suggesting that partial and full subsidy programs increase yield by about the same percentage (table 3, column 2).

Second, we examine whether bundling the input subsidies with other interventions, such as extension services, impacts yields. Complementarities between input subsidies and additional services may lead to higher program effectiveness. On the other hand, incorporating other interventions may lead to lower yields relative to providing input subsidies alone if the additional interventions are not effective. We find that bundling input subsidies with other interventions is associated with a reduction in effect size (table 3, column 3). This result would suggest that input subsidies alone might be more effective to improve yields than adding other interventions. To be cautious in how to interpret this result, we look closely at two studies that examine subsidies with additional services. In Abate et al. (2018), the marketing assistance component of the program was shown to have no effect on yields, and the positive impact came from combining marketing and subsidized inputs. Tanko, Ismaila, and Abu Sadiq (2019) evaluate a program that combines input subsidies with other services, without a comparison to a program that provides input subsidies only. Further, the study examines rice productivity in Northern Ghana, which is different than the rest of the studies that examine maize yields.[5] Therefore, based on these two studies, we would not conclude that including other interventions would lead to lower yields.

Third, we examine whether there are persistent effects after the input subsidies are no longer administered. Some farmers may choose to continue to use fertilizers after the subsidy is removed if they learned the benefits of fertilizer adoption on yield and income. However, some farmers may not be able to afford the same amount of fertilizer when the subsidy discontinues. Nonetheless, there may still be some lasting effect of fertilizers previously applied in the soil. Carter, Laajaj, and Yang (2021) observe that "direct impacts on yields remain almost as high in the period following the subsidy, which can be due to the farmers reusing the inputs when not subsidized". This result is consistent with lower longer-term impact that has been well documented in other settings such as capital subsidies for small enterprises and migration subsidies (de Mel, McKenzie, and Woodruff 2008; Bryan, Chowdhury, and

[5] Ghana is also a net importer of rice.

Mobarak 2014).[6] Nevertheless, our indicator for estimated effects after one year is statistically insignificant and negative, implying noisy, but on average lower average effects on yield after the first year of the subsidy program (table 3, column 4).

Lastly, we examine whether input subsidies may be associated with spillover effects. Among the studies included in our meta-analysis, study 1 (Carter, Laajaj, and Yang 2021) is the only one with estimated spillover effects. We include an indicator for estimated spillover effects and find that while the estimated relationship is positive, it is not statistically significant (table 3, column 5). This is likely due to the fact that only 6.5% of the estimates are spillover effects. Nonetheless, the possibility of spillover in this setting could improve the cost-benefit calculations of input subsidy programs since non-beneficiaries may adopt the technology without receiving the program. We also include all indicators in one regression and find similar estimated coefficients.

Table 3 The relationship between program characteristics and estimated effect on yield

	(1)	(2)	(3)	(4)	(5)
	RCT	100% subsidy	Other interventions	Long term	Spillover
Program characteristics	-0.020	0.075	-0.143**	-0.093	0.194*
	(0.053)	(0.054)	(0.051)	(0.096)	(0.099)
Observations	32	32	32	32	32
Mean indep. var.	0.250	0.625	0.188	0.156	0.062

Notes: Each column comes from a separate meta-analysis regression. The indicator RCT takes the value one if the study used a randomized control trial. The indicator in other interventions takes the value one if the input subsidy program includes other interventions such as extension service. Long run takes the value one if the effect is estimated after the first year of the program. Spillover takes the value one if the effect is estimated on non-beneficiaries. Standard error clustered at the study level. Significance: * p<0.10, ** p<0.05, *** p<0.01.

3.3 Robustness

For robustness, we conduct the meta-analysis with several sample restrictions. First, we exclude the long-run effects and spillover effects to focus only on the short-run effects of input subsidy programs, and find an average effect of 19.5%. Second, we drop the effects from study 4 (Ragasa and Mazunda 2018) and study 11 (Ricker-Gilbert and Jayne 2017) where the estimated effects are the increases in yield per kg/ha increase of fertilizer used instead of the effect of program participation. We also exclude effects from study 12 (Abman and Carney 2020) as it is the district-level increase in maize yield in areas with higher subsidy intensity. We find that input subsidy programs lead to an average of 22.8% increase in yield. These estimated effects are similar to our earlier estimated effect of 18%. Third, we use one

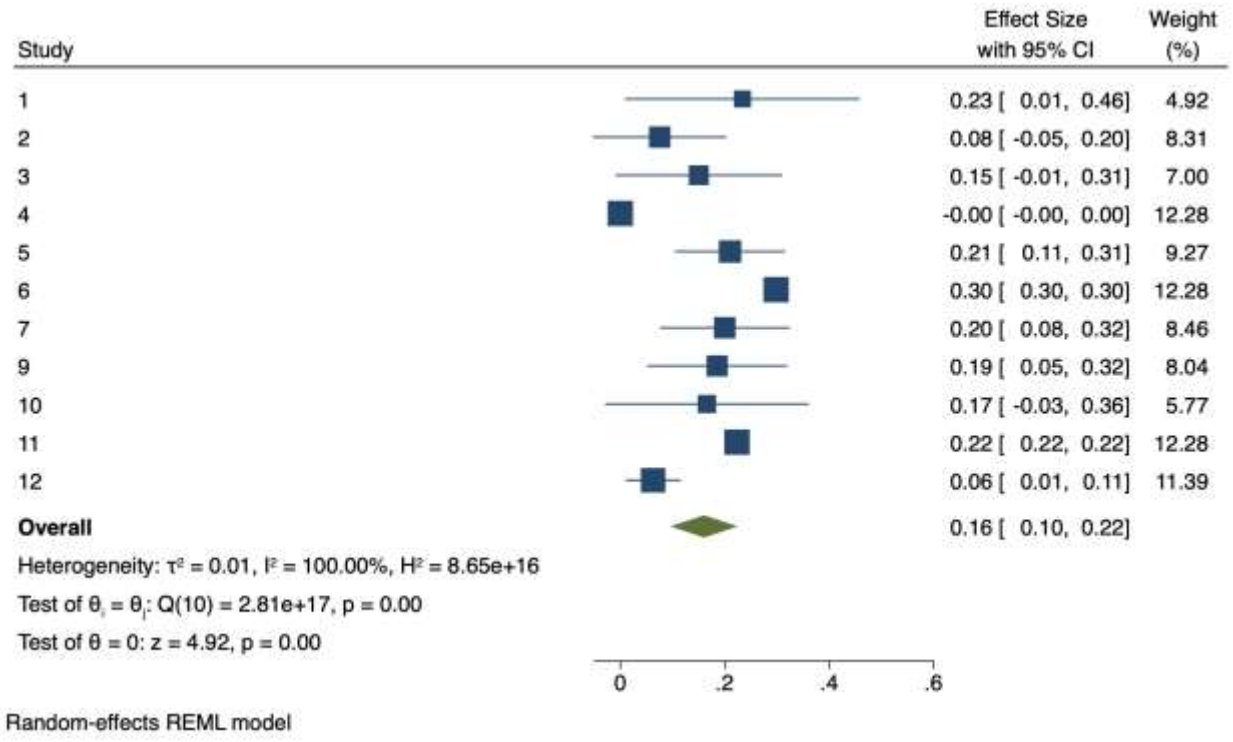
[6] de Mel, McKenzie, and Woodruff (2008) find that the effect of a positive capital shock on profit in 5-8 quarters post treatment is lower than that 1-4 quarters post treatment. Bryan, Chowdhury, and Mobarak (2014) find that the consumption effect of migration one year after the intervention is about 60%-75% as large as the same year effect.

estimate on yield from each study and one estimate on income or expenditure from each study. Using 11 short-term estimates of the effect of in

put subsidies on yield or the value of yield (Figure 3, Panel A), the estimates range from a precisely estimated zero to a high of 30%. Pooling all these estimates, we find that on average, a fertilizer subsidy program increases yield by 16%, with a confidence interval ranging from 9% to 24%. We further exclude two estimates[7] where the program effect is calculated as a one-kilogram increase in fertilizer use instead of program participation and one estimate for district-level effects. Using the remaining 8 estimates, the estimated effect of fertilizer subsidies on yield is 20.4%, which is similar to our earlier finding of 18%. Similarly, we restrict the estimated effect of fertilizer subsidies on income or expenditure as a proxy for living standards to 5 estimates (Figure 3, Panel B). The estimated effects on income or expenditure range from 9% to 38%, with an average effect of 20% from the restricted sample, similar to our earlier finding of 16%.

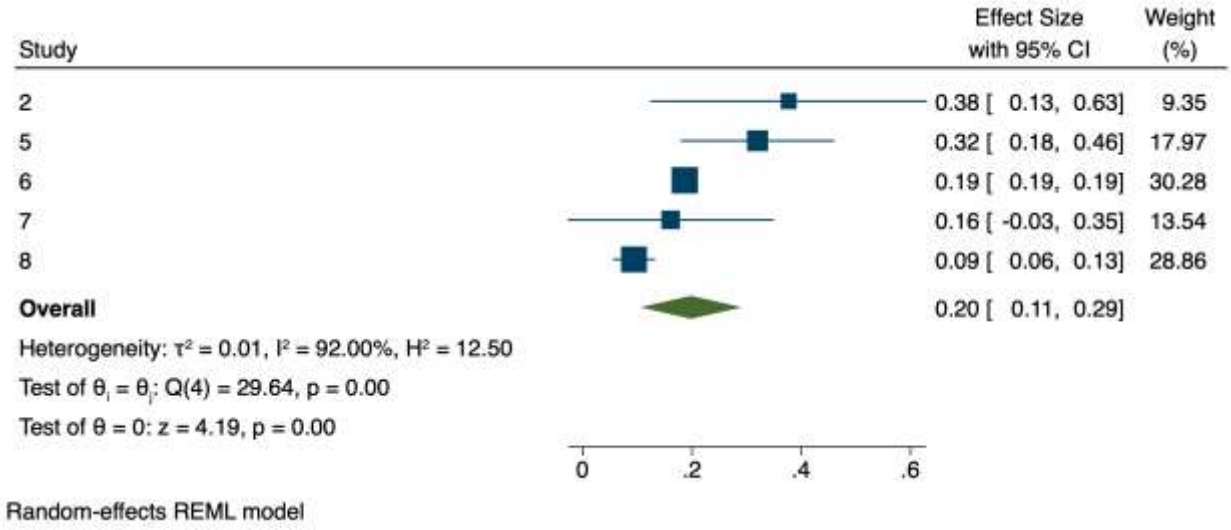
Figure 3 Robustness check – Restricted sample

Panel A. Effect on yield/productivity



[7] From study 4 (C Ragasa and Mazunda 2018) and study 11 (Jacob Ricker-Gilbert and Jayne 2017).

Panel B. Effect on income/expenditure



Notes: Meta-analysis regression using random effects. Panel A reports the effect of input subsidies on yield or the value of yield using 11 short-term estimates (one estimate for each study, except study 8). Panel B reports the effect of input subsidies on income or expenditure using 5 estimates from 5 studies.

4. Discussion

The results show that input subsidy programs improve yields and farming household incomes by almost 20%, which suggests that the increase in yields translates directly to income increases. We conduct a back-of-the-envelope program cost effectiveness for Malawi, using the 4 studies included in the meta-analysis, where the input subsidy program targeted 900,000 farmers and is estimated to cost US$49 million in 2019.[8] These imply that the estimated program cost per farmer is US$54 in 2019. The average maize yield, the country's main staple crop, is 1,782 kilograms per hectare[9] and the average GDP per capita of US$411[10] in 2019. Based on our average estimated effect of an 18% increase in yield, this would translate to 2,100 kilograms per hectare, which would make Malawi's yield comparable to Bolivia's maize yield, moving from 122 to 111 in productivity based on FAO's data. If we were to estimate the effect of an 18% yield increase on income, using the average price of a kilogram of maize across all markets in Malawi in December 2019 (IFPRI Monthly Maize Market Report[11]), which is US$0.39 (284 MWK), the increase of 318 kilograms per hectare in yield will translate to an increase of US$113 per hectare. When we take into account that the average farm size in Malawi is 0.7 hectares,[12] the maize

[8] https://www.oaklandinstitute.org/blog/malawi-failure-input-subsidies-new-path-forward-fight-hunger
[9] http://www.fao.org/faostat/en/#data/QC/
[10] https://datacatalog.worldbank.org/dataset/world-development-indicators
[11] https://reliefweb.int/sites/reliefweb.int/files/resources/IFPRI_Maize%20Market%20Report_December%202019.pdf

[12] https://www.ccardesa.org/malawi

crop value increase will be US$79 per household, which appears to outweigh the cost of the program.[13] Additionally, for program beneficiaries, the 16% increase in income would translate to an average GDP per capita of US$477, close to Mozambique's GDP per capita. The estimated income increase from the program is US$65, implying that a US$1 program cost would result in a US$1.20 income increase, which generates a cost effectiveness ratio of 1.2, similar to the estimated farm input profitability of Africa's input subsidy programs (Jayne et al. 2018).

Although our calculation suggests that the benefits through yield and income increases outweigh the program cost, we are unfortunately unable to determine whether input subsidy programs reduce poverty without additional information on program targeting. Additionally, this calculation does not consider the longer-term issue of whether farmers continue to use fertilizer when they no longer receive the input subsidies. There is considerable evidence that there is a high rate of attrition,[14] raising questions about whether farmers really find the fertilizer to be worth the cost. Nevertheless, even if only a fraction of farmers continue to use fertilizer in subsequent seasons, there can be a long-lasting effect of the fertilizer in the soil. Two articles included in our analysis that examine the longer-term effect of input subsidies have mixed results. While Ricker-Gilbert and Jayne (2017) do not find any long-run effect, Carter, Laajaj, and Yang (2021) find persistent positive impacts. These input subsidy programs also tend to consume a large share of the agricultural public expenditure and may crowd out other programs, such as research or irrigation. Therefore, even if input subsidy programs increase yields by about 18% and the benefit-to-cost ratio is 1.2, the net opportunity costs of these programs may be quite high. Virtually all the studies included in the meta-analysis come from African countries, which is where fertilizer use is relatively low, and there is interest in increasing fertilizer adoption to improve productivity and reduce poverty while minimizing the potential negative externality on the environment. While the evidence shows positive effects on yield and living standards, these results may not translate to higher total factor productivity or lower inequality.

Although we seek to examine the effect of input subsidies in developing countries, the meta-analysis regression only includes 12 articles from 7 African countries, most of them from Malawi, and 1 study from an Asian country. Additionally, the subsidy schemes considered are different and the method of evaluation used in the articles varies. Therefore, our results may not be generalizable to all input subsidy schemes in developing countries. Finally, the debate on how to reform input subsidy programs involves questions beyond the scope of this study, such as how to target poor, productive farmers who are most likely to benefit from the subsidy program.

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[13] We acknowledge that our back-of-the-envelope calculation does not take into account the out-of-pocket costs from farmers. However, the input subsidy in Malawi ranged from 72% to 93%, which means they pay at most about a quarter of the input cost and may pay as little as 7%.
[14] See Duflo et al (2011), for example.

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Appendix

A1. Key word search

Database 1: Web of Science

TS=((input* OR fertilizer* OR fertiliser*) AND (subsidies OR subsidy OR subsidizing OR intervention OR voucher* OR discount*) AND (productivity OR income OR yield) AND (agriculture OR agricultural OR farm*))
Refined by: WEB OF SCIENCE CATEGORIES: (ECONOMICS)

Timespan: 2000-2021. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.

This search yields 213 articles. Date of search: June 3, 2021

Database 2: Scopus

(TITLE-ABS-KEY (input OR fertilizer OR fertiliser) AND TITLE-ABS-KEY (subsidy OR subsidies OR subsidizing OR voucher OR discount) AND TITLE-ABS-KEY (productivity OR yield OR income) AND TITLE-ABS-KEY (agricultur* OR farm*)) AND (LIMIT-TO (SUBJAREA , "ECON")) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2007) OR LIMIT-TO (PUBYEAR , 2006) OR LIMIT-TO (PUBYEAR , 2005) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2000))

This search yields 149 articles. Date of search: June 3, 2021.

Database 3: JSTOR

(((((ab:(input OR fertilizer OR fertiliser) AND (subsidies OR subsidy OR subsidizing OR voucher OR discount)) AND (productivity OR yield OR income) AND (agriculture OR agricultural OR farming))))) AND disc:(economics-discipline)

Restricted to publications between 2000 and 2021. We are unable to include additional search terms due to character restrictions for the search.

This search yields 293 articles. Date of search: June 3, 2021

A2. Abstract screening criteria for exclusion

- Non-original research

- Not related to agriculture

- Published earlier than 2000

- Not developing countries

- Simulation/calibration study

- Not input subsidy/price intervention or programs

- Not quantitative study (eg. meta narrative)

- Meta-analysis or review article

- Non-causal method

- No impact on productivity/yield/income

A3. Full-text screening criteria for exclusion

- Not impact on output, yield, income, or productivity
- Simulation/calibration
- Non-causal method
- Non-original research/review paper/meta-analysis
- Not related to agriculture
- No confidence interval/standard error
- Number of observations not included
- No baseline/comparison group mean
- Not input subsidy/price intervention or programs

A4. Articles included in the full text analysis

Abman, R, and C Carney. 2020. "Agricultural Productivity and Deforestation: Evidence from Input Subsidies and Ethnic Favoritism in Malawi" 103. https://doi.org/10.1016/j.jeem.2020.102342.

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