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Unconditional cash transfers, risk attitudes and modern inputs demand

We estimate the effects of cash transfers on modern inputs demand, while isolating the role of output risk and risk preferences in channeling these effects. We use data from an RCT collected for the evaluation of Zambia's Social Cash Transfer. We employ a moments-based method to estimate farmers' risk attitudes from revealed preferences through production decisions and the impact of cash transfers on modern input demand. We find that the program increases demand for risk-increasing modern inputs but this does not happen as a result of a transfer-induced reduction in farmers' risk aversion.

Keywords: cash transfers; risk attitudes; output risk; input demand; SEM; 3SLS.
JEL classification: C21; Q12; D81.

1. Introduction

Strategic objectives, such as increasing food security and reducing poverty, which top the policy agenda of most governments across Africa, hinge on increasing farm output and productivity. The primary pathway to increased agricultural productivity passes through the adoption of modern inputs, especially improved seeds varieties and chemical fertilizers. A major obstacle to the adoption of modern inputs and of new technologies in general is farmers' risk aversion (Binswanger, 1981; Feder et al., 1985; Lamb 2003). Since formal insurance schemes are almost absent in rural areas in Sub Saharan Africa, investing in new production techniques with higher payoffs and higher risks exposes farmers to the consequences of output risks due to weather shocks or other random occurrences, which may have severe consequences in terms of food security or destitution, pushing farmers below a critical asset threshold from which recovery is difficult. For example, farmers may use inputs less intensively to reduce exposure in a risky investment and reduce losses in case things go bad (Rosenzweig, Binswanger, 1993; Mendola, 2007). Hence, poor farmers may become blocked in risk-induced poverty traps, whereby to avoid extreme destitution they are forced to forgo profitable but risky opportunities, and with it the opportunity to move out of poverty. In this paper, we investigate whether unconditional social cash transfers could induce riskier production decisions through higher demand for modern inputs. More specifically, the aim is to estimate the impact of cash transfers on input demand while assessing the role of production risk and risk preferences in mediating the farmers' response to the government transfer.

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Economic theory suggests that if credit and insurance markets are complete, farm households should make income-earning choices that produce the highest expected profits, and, after shocks occur, use market instruments to achieve consumption smoothing and insulate consumption patterns from income variability. In this scenario, farmers smooth consumption by borrowing and saving and by employing insurance instruments. Thus, when perfect consumption smoothing is possible production and consumption decisions are separable and production choices are made to maximize profits without concern for risk. When markets for consumption smoothing are missing or incomplete, households anticipate being unable to borrow or insure and the interplay of risk preferences and production risks can lead to considerable impacts on farm production. In this case, farmers engage in income smoothing, i.e. they tend to reduce income variability before income shocks materialize by making conservative input and output choices. This, in turn, implies sacrificing high return for low risk activities and underinvesting (Morduch, 1995). To the extent that farmers choose traditional inputs over modern inputs in order to lower risk ex-ante, any instrument that allows farmers to smooth consumption ex-post could raise the use of modern inputs (Lamb, 2003). One such instrument that can ease credit and insurance constraints allowing farmers to avoid income smoothing is given by unconditional cash transfers.

To the best of our knowledge, no previous study has analyzed the risk-related effect of unconditional government transfers on modern input use in the context of developing countries. We use data from the household surveys originally conducted for the impact evaluation of the Child Grant (CG) model of the Social Cash Transfer (SCT) Program — the flagship social protection program in Zambia. We exploit a randomized experiment and the resulting exogenous variation in income to estimate systems of seemingly unrelated equations (SURE) and of simultaneous equations model (SEM) aimed at capturing the effects of transfers on farmers' risk aversion and demand for modern inputs. We find that unconditional cash transfers lead farmers to invest more in modern inputs, namely, chemical fertilizer and commercially purchased seeds, but such impacts are not due to reduced risk aversion.

2. Literature review

Hennessy (1998) developed a comprehensive framework to analyze the production impacts of government transfers under uncertainty in the agricultural sector. Hennessy identifies a *wealth effect* that arises when farmers are risk averse and face production risk. The government payment changes the total wealth of the farmer and this increase in wealth can affect the farmers' risk aversion. Assuming that the risk aversion decreases with the level of wealth (Decreasing Absolute Risk Aversion), Hennessy shows that the transfer, by increasing a farmer's wealth, will induce them to make riskier investments through increasing the quantity of inputs used. The drop in risk aversion is going to be greater for poorer farmers compared to what will happen to their «richer» counterparts since the government transfer increases the wealth of the former by a larger share. An extensive literature has shown that government transfers can affect economic agents' risk attitudes by altering farm household wealth (Sandmo, 1971; Bar-Shira et al., 1997; Hennessy, 1998; Serra et al., 2006).

However, the conclusion that unconditional government transfers will yield an increase in input use does not consider the effects that inputs can have on farm production variability. Agricultural inputs can increase or decrease output risk by influencing production variability

(Just, Pope, 1978). Serra et al. (2006, 2011) dig one layer deeper into the relationship between risk aversion and input use and establish that a farmer will increase the use of a certain input after an increase in exogenous income through a transfer, only if the input increases output variability and, with it, the chances of getting a higher return. However, if the input has the effect of reducing output variance, farmers will use less of it. In their empirical analysis Serra et al. (2006) find that unconditional government transfers to farmers in the USA motivate an increase in input use (pesticides and fertilizers), although elasticity values are very small.

The literature on the risk-related productive impacts of government transfers is very scant and has mainly focused on developed countries. Research focusing on the common agricultural policy (CAP) in the European Union has found that European farmers are risk averse with constant relative risk averse preferences, but income support measures consisting of direct unconditional government transfer tend to have a small impact on risk aversion and on production (Sckokai, 2003; Sckokai, Anton, 2005). Sckokai and Moro (2006) investigate the impacts on acreage of the introduction of unconditional income support to Italian farmers. They find that acreage can increase up to 7 percent as a result of farmers' reduced risk aversion induced by the government transfer. Serra et al. (2006) focuses on the impact of direct government transfers to US farmers and find no effects on input demand. Goodwin and Mishra (2006) studying the Federal Agriculture Improvement and Reform that introduced unconditional income support transfers for US farmers, arrive to similar conclusions. Their results suggest that productive impacts that are channeled through changes in risk preferences are very modest. The study from Lin and Dismukes (2007) investigates the role of risk in US farmers' acreage decision. This study reaffirms that an increase in initial wealth due to unconditional government transfers would lead to greater acreage of major field crops. In the context of Decreasing Absolute Risk Aversion preferences, an increase in initial wealth reduces producers' risk aversion and leads to a positive but modest wealth effect on soybean acreage. Just (2011) investigates whether unconditional transfers increase production by decrease farmers' risk aversion. The study concludes that measurable changes in production are possible through changing levels of risk aversion only when wealth changes due to the transfer are substantial. Similar results for US farmers are found by McIntosh et al. (2007). Serra et al. (2011) find that unconditional government transfers to farmers in the USA lead to a minor increase in farm production, channelled through decreased farmers' risk aversion that in turn stimulates the use of more variable inputs. Femenia et al. (2010) look at the channels through which direct government transfers can affect production focusing on the one that passes through reductions in farmers' risk reduction. The study is a lone voice in finding sizable effects on production levels of transfer-induced reductions in risk aversion. We contribute to this strand of literature by providing evidence on the risk-related effects of unconditional government transfers on productive choices in developing countries. A notable exception of this kind of study in the developing world is given by Bianchi and Bobba (2012) who study whether a cash transfer stimulates non-farm entrepreneurship by relaxing liquidity constraints or risk constraints. Using a model of occupational choice the study finds that transfers increase entrepreneurial activity by increasing risk taking rather than by liquidity constraints. Karlan et al. (2014) study a randomized experiment in Ghana in which farmers were randomly assigned to receive cash grants, grants of rainfall index insurance, or a combination of the two. They find that farmers who received a rainfall index insurance grant cultivated more land and spent more on fertilizer and labour than those who received cash grants, implying that risk — not lack of access to capital — is a primary constraint for farm production.

A related branch of studies has looked into the effects of cash transfers on coping strategies aimed at smoothing consumption once negative shocks materialize, showing that transfers do act as consumption smoother and reduce negative coping practices (Dercon, Krishnan, 2000; Yamano et al., 2005; De Janvry et al., 2006; Skoufias, 2007). Our study complements this literature by providing experimental evidence on the impact of transfers on households' exante risk exposure through investments in riskier production inputs.

One last related strand of literature is the one focusing on the effects of risk on the adoption of new technologies by farmers (Smale, Heisey, 1993; Nkonya et al., 1997; Roosen, Hennessy, 2003; Knight et al., 2003). The bulk of their evidence suggests that risk aversion slows the adoption of improved seed varieties, depresses the use of fertilizer, and results in farmers choosing production activities that lead to lower, though less variable, returns.

3. Data and summary statistics

In 2010, the Zambia's Ministry of Community Development and Social Services began the implementation of the Child Grant, one of the four existing models of the SCT program. The CG aims to alleviate poverty among the poorest households by increasing consumption and block its intergenerational transmission through increased spending in health and schooling.

The pilot evaluation of the CG was implemented in three districts that had not previously received any cash transfer and with highest rates of mortality, morbidity and stunting among children under 5 years of age. The CG was based on a categorical targeting mechanism, reaching any household with a child under 5 years old. Only households with children under three years old were enrolled in the program to ensure that every recipient household receives the transfers for at least two years after the program's introduction into the district. Beneficiary households received 60000 kwacha (ZMK) a month[2]. The planned transfer size is constant regardless of household size and amounts on average to about 28 percent of a household's monthly consumption expenditure.

CG's impact evaluation was designed as a longitudinal randomized controlled trial (RCT) with random assignment at the community level[3]. The random assignment of the communities into treated and control groups occurred in two steps. In the first step, 30 Community Welfare Assistance Committees (CWACs) were randomly selected in each of the three districts — out of roughly 100 CWACs in each district. After this, all eligible households with at least one child under 3 years old were identified in all 90 randomly selected communities. Based on the list of eligible households, a random sample of 28 households from each CWAC were interviewed for the baseline survey. When the survey fieldwork was completed, the second step of randomization process took place in which half of the previously randomly selected CWACS in each district were allocated into the treatment group, which would start participating in the programme in the following month (January 2011) and the other half into the control group that would en-

[2] On January 1, 2013 the new Zambian kwacha was introduced at a rate of 1000 old kwacha = 1 new kwacha, a move that was aimed at strengthening the local currency against major convertible currencies. In our data, variables are denominated in the old base.

[3] A detailed description of the evaluation design can be found in (American Institutes for Research, 2011) and in (Davis, Handa, 2016).

ter the programme at a later stage (by the end of 2013)[4]. The final sample for the impact evaluation survey has 2515 households which amounts to 14565 individuals.

In this paper, we are interested in estimating the effects of unconditional transfers on input use, while isolating the role of production risk and risk preferences in channeling these effects. Identification of the program effects relies on the comparison of average outcomes between the treated and the control group at follow-up. This allows to capture the effect of the program through the coefficient of the program dummy rather than through the interaction between a program dummy and a follow-up period dummy, as would be the case in a typical difference-in-difference setup based on both baseline and follow-up values of the outcome. Some parts of our analysis require to identify how the program effects vary with certain characteristics which is usually done by including interactions. However, interaction variables have low power and taking a single difference at follow-up allows to keep the order of the interaction variables at two throughout our analysis. Moreover, comparing outcomes at follow-up instead of taking double differences is justified when there are no statistically significant differences between the outcomes at baseline. This condition is satisfied in our context thanks to the randomization of treatment. The bottom part of Table 1 shows that the three outcomes variables are equally distributed at baseline among treated and controls.

Table 1. Descriptive statistics

	Control	Treated	Diff
	Controls		
HH size	5.674	5.785	–0.112
Female headed	0.995	0.991	0.004
Education of head	3.786	4.456	–0.670***
Age of head	30.586	30.930	–0.344
Dependency ratio	1.826	1.767	0.059
Operated land	0.552	0.673	–0.121***
TLUs	0.243	0.471	–0.228**
Draught	0.479	0.462	0.017
Crop disease	0.115	0.096	0.019
Price of fertilizer (ZMK)	0.033	0.041	–0.009***
Price of seed (ZMK)	0.047	0.054	–0.006**
Price of output (ZMK)	1259.081	1224.849	34.232*
	Outcomes		
Expenses for seeds (ZMK)	1.170	1.271	–0.100
Expenses for fertilizers (ZMK)	5.215	5.929	–0.714
Value of harvest (ZMK)	327.696	358.524	–30.828
Observations	1145	1153	2298

Note. Significance levels: * — $p < 0.1$, ** — $p < 0.05$, *** — $p < 0.01$. ZMK is the Zambian currency.

4 Random assignment of the communities to treated and control groups occurred only after baseline data were collected to avoid anticipation effects in the baseline data. In doing so, neither the respondent nor the enumerator knew the treatment status of the former. The 24-month follow-up data collection occurred in September and October 2012 exactly 24 months from the baseline study, ensuring that households are being compared in the same season as at the baseline, avoiding seasonal effects (American Institutes for Research, 2011).

In fact, the randomization mechanism of the RCT design should ensure comparability at baseline along every observed and unobserved dimension between the treated and the controls. This allows attribution to the intervention of any observed post-treatment differences resulting from the comparison of the average outcome between the treatment and control groups. The official baseline evaluation report uses the full set of observed characteristics providing evidence of success of the binary randomization process that foreran the implementation of the CGP program (American Institutes for Research, 2011). The report establishes that treated and controls are actually observationally equivalent. The upper part of Table 1 shows sample means and cross-arm differences for the variables that are used as controls in our analysis. Since here we focus on a restricted group of variables instead of the full set, we find a higher share of statistically significant differences than what would be expected if they were due to chance alone. The average household size is high (5.7 members) due to the targeting mechanism of the program that was aimed at households with children under 5. Farm size is generally small with an average area of operated land below one hectare and a herd size below one Tropical Livestock Unit. Almost half of the communities suffered some negative shock related to drought while ten percent were subject to crop diseases in the last season.

Our three outcomes are expenditures for seeds, expenditures for fertilizers and the value of crop production. To build a measure of the monetary value of crop production we sum the values of all major crops. The latter are computed by multiplying the physical quantity of harvest for the crop by the corresponding market price at the community level. The value of expenditures for seeds and fertilizer incurred by farmers is taken directly from the questionnaire. We have aggregated the harvested quantities of all crops into the value of output in order to use it in a single-output production function. Similarly, we need to combine the prices of all crops together to get some aggregate price index that refers to the whole output. We follow Kumar (2007) to compute a single output price through the following quantity-weighted average $P_j = \frac{\sum P_{ij} Q_{ij}}{\sum Q_{ij}}$ where i is the crop index and j is the household index. The price index for the j-th household is obtained by multiplying the j-th farmer's price obtained for each crop by the quantity sold of each crop and dividing the sum of all crops by the sum of quantities sold for all crops. We follow the same approach to compute a single price for all seeds and for the different types of fertilizers.

4. Theoretical framework

The theoretical framework adopted in this paper follows Serra et al. (2006). We explicitly take into consideration production risk, which consists in output variability due to random weather conditions, technological innovations or government policies related to input use. Moreover, when choices are made under uncertainty, farmers' risk preferences play a key role in shaping production decisions on input use. Hennessy (1998) shows that farmers with decreasing absolute risk aversion — those who tend to assume more risks as their wealth increases — will react to a government transfer that boosts their wealth by increasing input use. However, this conclusion ignores the effects that a certain agricultural input can have on production risk, by increase (*risk increasing*) or decreasing (*risk decreasing*) output variability (Just, Pope, 1978).

This framework establishes that farmers will increase input use following a transfer-induced reduction in risk aversion only if an input is risk increasing.

Let y be the output produced by a single-output farm. Following Just and Pope (1978) the stochastic production function is given by

$$y = f\left(x_1, x_2, Z, \alpha\right) + h\left(x_1, x_2, Z, \beta\right)\varepsilon, \tag{1}$$

where α and β are parameter vectors, x_1 and x_2 are two variable inputs of interest, commercial seeds and fertilizer in our case, Z includes other factors that influence farm output supply, $f\left(x_1, x_2, Z, \alpha\right)$ is the deterministic component of production and $h\left(x_1, x_2, Z, \beta\right)$ is a function that captures the relationship between inputs and output variability since $\mathrm{V}\left(y\right) = \mathrm{E}\left(y - \overline{y}\right)^2 = h^2\left(x_1, x_2, Z, \beta\right)$. Finally, ε is a random shock such that $\mathrm{E}\left(\varepsilon\right) = 0$ and $\mathrm{E}(\varepsilon^2) = 1$. The function $h(\cdot)$ models the interaction of input levels with random fluctuations in production (ε). The magnitude of this random disturbance is mediated by the vector of inputs. Examples of studies that have used the Just–Pope function are Love and Buccola (1991) and Kumbhakar (1993). An input will cause production risk to increase (decrease) if $\partial \mathrm{V}\left(y\right)/\partial x > 0$ $\left(\partial \mathrm{V}\left(y\right)/\partial x < 0\right)$. The impacts of the main inputs on output variability have been widely analyzed in the literature with no clear-cut conclusions. While evidence on the risk impact of seeds is scant, fertilizers have been found to be risk-decreasing by some studies, while many others find that these inputs increase output risk (Just, Pope, 1978; Just, Zilberman, 1983; Horowitz, Lichtenberg, 1994).

In a non-deterministic world, farmers take their decisions with the objective to maximize the expected utility of wealth, $\max_{x_1, x_2} \mathrm{E}\left[u\left(W\right)\right] = \max_{x_1, x_2} \mathrm{E}\left[u\left(W_0 + py - w_1 x_1 - w_2 x_2 + G\right)\right]$ where W is the farmer's total wealth, W_0 is initial wealth and is a known quantity, p is the market price of the output, w_1 and w_2 are the prices of the variable inputs and G represents the amount of the government transfer. In this model, only one of the two main sources of risk is modelled, namely output risk, while we ignore price uncertainty and assume that output and input prices are known variables. The argument of the utility function is the sum of initial wealth plus net farm income (ignoring livestock activities). Antle (1987) points out that the net income distribution is equivalent to a revenue or output distribution, if input and output prices are non-stochastic as in our case.

The first order conditions for the maximization of the expected utility can be cast as: $\partial \mathrm{E}\left[u\left(W\right)\right]/\partial x_i = \mathrm{E}\left[u_w\left(py_{x_i} - w_i\right)\right]$ where subscripts denote partial derivatives. Since no functional form assumptions were made for the utility function, the first derivative of utility with respect to wealth (u_w) is unknown. To make the FOC-s operational, a first-order Taylor expansion around the expected wealth is applied so that $u_w = \overline{u}_w + \overline{u}_{ww}\left(w - \overline{w}\right) = \overline{u}_w + \overline{u}_{ww} p\left(y - \overline{y}\right)$, where to $\overline{u}_w$ and $\overline{u}_{ww}$ are the first and second-order derivatives of the utility function evaluated at the expected wealth ($\overline{w}$) and $\overline{y}$ is expected output. Substituting the series expansion into the FOC-s we obtain $p\mathrm{E}[y]_{x_i} + \frac{\overline{u}_{ww}}{\overline{u}_w} p^2 \mathrm{E}\left[\left(y - \overline{y}\right) y_{x_i}\right] = w_i$. Transforming the FOC-s further we are able to highlight the role of the two major risk channels analyzed in this study. First, the ratio of the second to the first derivative of the utility function is the Arrow–Prat coefficient of absolute risk aversion, $R\left(W\right) = -\overline{u}_{ww}/\overline{u}_w$, which is a standard measure of individual risk attitudes. A negative (positive, null) coefficient of absolute risk aversion implies that the farmer is risk averse (seeking, neutral). Depending on how R reacts to changes in wealth, a farmer has Decreasing (Increasing, Constant) Absolute Risk Aversion if $dR\left(W\right)/dW < 0$ $(> 0, = 0)$. Secondly, $\mathrm{E}\left[\left(y - \overline{y}\right) y_{x_i}\right]$ is equal to half of the derivative of the output variance with respect to the variable input, i.e. $0.5 \cdot \mathrm{V}[y]_{x_i}$. Substituting these expressions we obtain the standard form of the FOC-s when output risk and individual risk preferences are explicitly considered in the model.

$$p\mathrm{E}[y]_{x_i} - w_i - 0.5 \cdot Rp^2 \mathrm{V}[y]_{x_i} = 0, \; i = 1, 2. \tag{2}$$

The first two terms on the left hand side of equation (2) represent the expected marginal income given by the difference between the value of expected marginal product and the marginal cost of the input as given by its price, $\mathrm{E}[MI_i] = p\mathrm{E}[y]_{x_i} - w_i$. The last term is a well-known second-order Taylor approximation of the risk premium, $RP_i = 0.5 \cdot Rp^2 \mathrm{V}[y]_{x_i}$. Before proceeding with the analysis, it must be observed that theoretical production functions explain quantities of output through quantities of inputs. However, in empirical applications quantities of output and inputs are replaced with values. The main reason for doing so is to aggregate quantities of heterogeneous crops. To make this explicit in the remaining exposition we use the value of production, $Y = py$. From the last equality we have that $\mathrm{E}[Y]_{x_i} = p\mathrm{E}[y]_{x_i}$ and $\mathrm{V}[Y]_{x_i} = p^2 \mathrm{V}[y]_{x_i}$. Substituting into equation (2) we obtain the FOC-s in terms of monetary values,

$$\mathrm{E}[Y]_{x_i} - w_i - 0.5 \cdot R\mathrm{V}[Y]_{x_i} = 0, \quad i = 1, 2. \tag{2a}$$

In a world without uncertainty, or with risk-neutral farmers, the FOC-s consists typically of equating the value of marginal output to the input price, i.e. $\mathrm{E}[Y]_{x_i} = w_i$. Equation (2a) shows that, when farmers take decisions under uncertainty and they are risk-averse, their behavior deviates from the one described by neoclassical theory and depends on the size and the sign of the risk premium associated with inputs (Antle, 1989). The risk premium depends in turn on the degree of risk aversion, measured by *R*, and the effects inputs have on the variance of output, measured by $\mathrm{V}[Y]_{x_i}$. Taking the total differential of the FOC-s with respect to *G*, we have that (Serra et al., 2005),

$$\frac{dx_i}{dG} = \frac{1}{2\mathrm{E}[U(W)]_{x_i x_i}} R_G V[Y]_{x_i}, \quad i = 1, 2, \tag{3}$$

the impact of the transfer on input use depends on the change in risk aversion induced by the transfer and the change in output variability induced by a change in input use. Here $\mathrm{E}[U(W)]_{x_i x_i}$ is the second derivative of expected utility with respect to *x,* while $R_G = dR/dG$ represents the change in a farmer's risk aversion due to a wealth increase from the government transfer. Assuming that risk aversion is characterized by DARA we have that $\mathrm{E}[U(W)]_{x_i x_i} < 0$ and it follows immediately that $R_G < 0$. As a result, the sign of equation (3) depends on the sign of $\mathrm{V}[Y]_{x_i}$. If $\mathrm{V}[Y]_{x_i}$ > (=) [<] 0 then dx_i/dG > (=) [<] 0. An increase in government transfers will result in an increase in the household's wealth, which will induce a reduction in the farmer's degree of risk reduction. Given this change in risk attitudes farmers will increase the use of a certain input if it is risk-increasing ($\mathrm{V}[Y]_{x_i} > 0$) and will use less of the input if it is risk-decreasing ($\mathrm{V}[Y]_{x_i} < 0$).

5. Empirical strategy

The aim of the empirical application is to estimate the impact of an unconditional social cash transfer on input demand while assessing the role of output risk and risk preferences in mediating the farmers' response to the government transfer. The estimation strategy has three parts, each corresponding to one of the derivatives in equation (3). In the first part, we use the stochastic production function in (1) to estimate the marginal contribution of the two variable inputs — seeds and fertilizers — to average output $\mathrm{E}[Y]_{x_i}$ and, most importantly, to output variability $\mathrm{V}[Y]_{x_i}$. The results of the first part are the building blocks of the second part. We substitute into the FOC-s (2a) the marginal effects of the inputs on the mean and the variance of output and estimate R_G from the resulting system of equations. In the third part we use the FOCs to estimate the impact of the government transfer on input use dx_i/dG.

In order to estimate the partial effect of the variable inputs on the mean and variance of the output distribution we need to specify functional forms for the mean $f(\cdot)$ and the variance $h(\cdot)$ functions of the stochastic production function in equation (1). Following previous literature we use a quadratic form in the inputs for both functions (Antle, 1983; Groom et al., 2008; Vollenveider et al., 2011; Serra et al., 2011). The mean output is approximated through the following quadratic function $f(x_1, x_2, Z, \alpha) = \alpha_0 + \alpha_Z Z + \sum_{i=1}^{2} \alpha_i x_i + \sum_{i=1}^{2} \alpha_{ii} x_i^2$ and the variance function is approximated by $h(x_1, x_2, Z, \beta) = \beta_0 + \beta_Z Z + \sum_{i=1}^{2} \beta_i x_i + \sum_{i=1}^{2} \beta_{ii} x_i^2$. The other factors in Z include the area of operated land in hectares and household size. The area of land controls for the amount of fixed capital that contributed to the production of farm output and is a proxy for household wealth. Household size directly determines the amount of labor supply that can be employed on the farm.

Unbiased OLS estimates of the parameter vector α can be obtained by regressing the value of farm production on input expenditure, their squares and the controls for operated land and household size as shown the following equation, where we have omitted the household subscript to avoid confusion.

$$Y = \alpha_0 + \alpha_Z Z + \sum_{i=1}^{2} \alpha_i X_i + \sum_{i=1}^{2} \alpha_{ii} X_i^2 + u, \quad i = 1, 2, \tag{4}$$

where Y is the value of farm output, $X_i = w_i x_i$ represents expenditure for input i and $u = h(X_1, X_2, Z, \beta)\varepsilon$. The residuals from this stage ($\hat{u}$) are a consistent estimate of the true error distribution (u) and are therefore used to compute the variance of the output distribution. In fact, we have that $\mathrm{E}[u^2] = h^2(X_1, X_2, Z, \beta)$ since $\mathrm{E}[\varepsilon^2] = 1$ and ε is an independent shock. At this point, in order to obtain an unbiased estimate of the parameter vector β of the variance function we follow Antle (1983) and regress the square of the estimated residuals from (4) on the same set of covariates included in the estimation of the mean effect,

$$\hat{u}^2 = \beta_0 + \beta_Z \boldsymbol{Z} + \sum_{i=1}^{2} \beta_i X + \sum_{i=1}^{2} \beta_{ii} X_i^2 + v, \quad i = 1, 2, \tag{5}$$

where $\mathrm{E}[v] = 0$. In a final step, we re-estimate equation (4) by weighted least squares where the weights are given by the reciprocal of the output standard deviation (Just, Pope, 1978; Antle, 1983, 1987, 1989). This procedure that amounts to feasible generalized least squares (FGLS) allows to correct the biased standard errors of α due to the heteroscedastic error term in (4).

In the second part of the estimation strategy we want to estimate how farmers' risk attitudes measured by the coefficient of absolute risk aversion (R) change in the population of the beneficiaries relative to the control group as a result of the cash transfer. The econometric estimation of risk attitudes based on production decisions has produced a significant literature (Antle, 1987; Love, Buccola, 1991; Saha, 1997; Groom et al., 2008; Serra et al., 2011). Here we follow a non-structural approach proposed by Antle (1987, 1989) which has fewer data requirements and avoids making assumption on the form of the utility function, on the coefficient of absolute risk aversion or on the distribution of the random shock ε. The fundamental idea is that when making an optimal input choice the farmer engages in a trade-off between marginal increases in mean output and marginal increases in the output variance. This is expressed formally by the FOC-s in equation (2a) where the average marginal change in income ($\mathrm{E}\left[MI_i\right]$) due to a marginal change in input *i* is compensated by a change in the variance of the output value ($\mathrm{V}[Y]_{x_i}$) induced by the same change in input *i*. The mean-variance trade-off is mediated by the coefficient of risk aversion *R* so that the impact of each input mix on each farmer's income and risk, helps trace his risk profile. Risk averse farmers tend to select input combinations that decrease the variance of income at the cost of a lower expected income, for example, by adopting diversification strategies at the cost of economy of scale or by adopting too few new technologies. In terms of farm production, this translates in less efficient use of labor, smaller production scale and off-farm jobs to diversify the sources of income (Vollenweider et al., 2011).

The implicit assumption in this model is that income smoothing takes place as there are no insurance or credit mechanisms at all (Antle, 1987; 1989). In that case, income translates directly to consumption, and production choice will fully reflect the tradeoff between risk aversion and expected profit maximization. Since profit maximization implies that the marginal products of inputs will equal their prices, measures of risk aversion can be quantified by estimating the degree to which marginal products and prices depart. In our context, the cash transfer is the only means that introduces a consumption smoothing differential between the treated and the controls. The assumption of no alternative consumption smoothing is, of course, a strong one, and questionable. Even in a rural context with rudimentary financial markets, households will be able to achieve some level of consumption smoothing by accumulating and depleting assets or using informal mechanisms. Given some consumption smoothing, measures of risk aversion taken from this methodology will be understated. As for the difference in risk aversion between the treated and controls, it should be unbiased as access to consumption smoothing means other than the cash transfer should be equal for both groups due to randomization.

Estimation proceeds with the assembling of the system of FOC-s in (2a), $\hat{\mathrm{E}}\left[MI_i\right]=\hat{\mathrm{E}}\left[Y\right]_{x_i}-w_i$[5]. To do so, first we need to construct estimates of $\mathrm{E}[y]_{x_i}$ and $\mathrm{V}[y]_{x_i}$. We use the estimates of α and β obtained in the first part and the functional form for $f(\cdot)$ and $h(\cdot)$ to construct the marginal effects of the inputs on the first and the second moment of the output distribution. Since we used the value of output instead of physical quantities we obtain directly the input's *i* marginal product as $\hat{\mathrm{E}}\left[Y\right]_{x_i}=p\hat{\mathrm{E}}\left[y\right]_{x_i}=\hat{\alpha}_i+2\hat{\alpha}_{ii}X_i$. Furthermore, the marginal contribution of each input to the variance of output value is given by $\hat{\mathrm{V}}\left[Y\right]_{x_i}=p^2\hat{\mathrm{V}}\left[y\right]_{x_i}=\hat{\beta}_i+2\hat{\beta}_{ii}x_i$. The system of linear equations is then

$$\begin{cases}\hat{\mathrm{E}}\left[MI_1\right]=\gamma_0+\gamma_1\hat{\mathrm{V}}\left[Y\right]_{x_1}+\gamma_2 G+\gamma_3\hat{\mathrm{V}}\left[Y\right]_{x_1}G+e_1,\\ \hat{\mathrm{E}}\left[MI_2\right]=\delta_0+\delta_1\hat{\mathrm{V}}\left[Y\right]_{x_2}+\delta_2 G+\delta_3\hat{\mathrm{V}}\left[Y\right]_{x_2}G+e_2,\end{cases} \tag{6}$$

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[5] Many of the previous studies of decisions on seed-fertilizer adoption analyzed them separately in a single equation model. From an econometric point of view, a single equation estimation approach could cause biased parameter estimates if decisions were truly simultaneous and/or unobserved heterogeneities were correlated for these decisions.

where e_1 and e_2 are correlated error terms. The coefficient of absolute risk aversion R can be recovered from system (6) as $\frac{\partial \hat{\mathrm{E}}\left[MI_i\right]}{\partial \hat{\mathrm{V}}\left[Y\right]_{x_i}} = \gamma_1 = \delta_1 = 0.5R$, so that $R = 2\gamma_1 = 2\delta_1$. We follow previous literature and impose the cross-equation constraint that farmers exhibit the same level of risk aversion for the whole range of input choices, i.e. $\gamma_1 = \delta_1$ (Groom et al., 2008; Vollenweider et al., 2011; Koundouri et al., 2006). Although each input can affect the moments of output distribution in different ways, the risk coefficient is not associated with specific inputs as it expresses the farmer's preferences in the mean-variance trade-off. A positive coefficient of absolute risk aversion indicates that the farmer is risk averse. Furthermore, we obtain the change in risk aversion at the population level as a result of the cash transfer program by comparing the risk attitude of the treated to that of controls after the program. Formally, we estimate $R_G = \frac{\partial R}{\partial G} = 2\frac{\partial \hat{\mathrm{E}}\left[MI_i\right]}{\partial \hat{\mathrm{V}}\left[Y\right]_{x_i} \partial G} = 2\gamma_3 = 2\delta_3$. We expect a reduction in the risk aversion coefficient in the treated group ($\gamma_3, \delta_3 < 0$) as a result of the increase in exogenous income induced by the cash transfer. The system of linear equations is estimated by a Seemingly Unrelated Regressions (SUR) approach in order to account for inter-equations correlation of the errors and increase efficiency (Bozzola, 2014).

The third and last part of the empirical strategy is concerned with the estimation of the transfer's impact on input demand. The FOC-s equations (2a) from the economic framework presented in the previous section implicitly define the structural relationship between input use and other variables. We may define the input demand functions as $X_1 = g_1\left(X_2, Y\left(X_1, X_2, Z\right), w_1, p, G\right)$ and $X_2 = g_2\left(X_1, Y\left(X_1, X_2, Z\right), w_2, p, G\right)$. These provide the structural form equations for a system that, in general, can be solved simultaneously for optimal input use. However, this requires more structure and assumptions on the functional form of the utility function and of the absolute risk aversion coefficient. This results in complicated estimation procedures of a system of nonlinear equations whose solutions strongly depend on the functional form assumptions. Here, instead, we assume a linear relationship between the input demand and the arguments of the demand function $g_i(\cdot)$ and form a system of linear simultaneous equation (SEM),

$$\begin{cases} X_1 = \pi_0 + \pi_1 X_2 + \pi_2 Z + \pi_3 w_1 + \pi_4 p + \pi_4 G + \zeta_1, \\ X_2 = \varphi_0 + \varphi_1 X_1 + \varphi_2 Z + \varphi_3 w_2 + \varphi_4 p + \varphi_4 G + \zeta_2, \end{cases} \tag{7}$$

where the two errors, ζ_1 and ζ_2, are potentially correlated according to some covariance matrix Σ, since the decisions on both inputs are jointly determined. The defining feature of the linear simultaneous equation model in (7) is that the dependent variable in the first equation appears on the right-hand side of the second equation and, vice versa, X_2 is among the determinants of X_1. This may cause the system OLS estimator to be biased. A popular solution to endogeneity is the instrumental variable approach. This motivates our choice to estimate the parameters of system (7) by two stage least squares and by three stage least squares. The 2SLS is a limited information method since it consists in applying instrumental variable estimation to one equation at time ignoring the cross-equation correlation in the errors and the information contained in other equations. In other terms, while 2SLS is consistent, it is also inefficient. Therefore, we also apply the more efficient 3SLS, a full information estimator that corrects the endogeneity while properly accounting for the fact that system (7) has a non-constant variance covariance matrix correlation and for the resulting cross-equation correlation. The reason we use both estimators is that they present both advantages and disadvantages. Although the systems methods are asymptotically more efficient, they are more prone to misspecifications. Any specification error in the structure of the model will be propagated throughout the system by the 3SLS. The limited information 2SLS will confine a problem to the equation in which it appears. 3SLS and 2SLS yield identical coefficient estimates — although standard errors will be different, when there is no cross-equation correlation (Σ is diagonal) or when every equation is exactly identified. In these cases, there is no informational gain in considering all the equations together. We have more instruments than there are endogenous variables, so we expect coefficients and standard errors to differ between 2SLS and 3SLS (Wacziarg, 2001).

Identification of system (7) hinges on an order and a rank condition. The necessary order condition for identification of a SEM is trivially satisfied in our case since the number of excluded exogenous variables (four) is higher than the number of endogenous variables (two) in each equation. We use the same set of instruments for both equations. These are variables that exogenously shift demand for one input but not for the other. The price of seeds is included in the first equation but can be excluded from the second. The assumption here is that the seeds price can serve as a demand shifter for fertilizers through its influence on seeds expenditure. Similarly, the price of fertilizer is excluded in the first equation so that it shifts seeds demand only through its impacts on fertilizer use. The rest of the exogenous variables used for the estimation of system (7) include the price of the output, a shock dummy that registers the occurrence of a pest or a crop disease outbreak at the community level and a shock dummy for the occurrence of drought at the community level. This brings the number of excluded exogenous variables to four in each equation. The rank condition is in many cases assumed to be satisfied unless there is a failure of the order condition. The rank condition in our model is indeed satisfied.

6. Results

This paper investigates the theoretical hypothesis that the impact of an unconditional social cash transfer program on input use depend on the UCT-induced wealth effects on the farmers' risk attitudes and on the input's contribution to output variability. To capture the impact of modern inputs on the output variability and mean, we estimate the Just–Pope stochastic production function (equations (4), (5)). The choice of the linear/quadratic functional form was influenced both by previous literature and by limitations imposed by our data. First among these limitations was the mass of zeros in the variables measuring expenditure on seeds and fertilizers due to the fact that many farmers do not buy fertilizers and use homemade seeds or borrow these inputs. This rules out a logarithmic transformations of the dependent variables. The quadratic specification allowed the model to reflect diminishing returns for the modeled inputs. In equations (4) and (5), we control for the expenditure in seed and fertilizers and the corresponding square terms and a set of household and community characteristics included in *Z*, such as, household size, area of operated land, herd size, the age and the numbers of years of completed schooling of the household head, the dependency ratio given by the number of not fit to work family member (children, elderly and permanently ill) and the number of working age family members that are fit to work, a dummy for female headship and two dummies for draught and crop disease shocks at the community

Estimation results from the econometric analysis of the stochastic production function are presented in Table 2. Columns 1 and 2 show FGLS estimates of the impacts on mean output (equation (4)), while columns 3 and 4 report the impact on output variability (equation (5)). Both seeds and fertilizers increase output at a decreasing rate[6] as the coefficient of the linear terms are positive and those of the quadratic terms are negative and statistically significant. We find that both inputs are risk-increasing. Increases in the use of seeds and fertilizers are associated with a statistically significant increase in output variability. The finding that modern inputs increase both average output and its variability is in line with previous literature (Just, Pope, 1978; Serra et al., 2006; Paulson, Babcock, 2010; Teklewold et al., 2013). Specifically, land and fertilizers have been found to have a risk-increasing effect in several developing countries (Roll et al, 2006; Yesuf et al., 2009; Kohansal, Aliabadi, 2014). Ligeon et al. (2013) find that the quantity of seeds used increases the output variability among peanut farmers in Bulgaria. As to the effects of the rest of the covariates we notice that households that are larger, have more land or have an older or female head tend to have a higher and more volatile crop production.

Table 2. Stochastic production function coefficients estimates

	Mean (FGLS)		Variance	
	Coefficient	SE	Coefficient	SE
Expenses for seeds	6.498***	[1.549]	0.012***	[0.003]
Expenses for fertilizers	6.928***	[1.254]	0.009***	[0.002]
(Expenses for seeds)^2	–0.011**	[0.005]	–0.000	[0.000]
(Expenses for fertilizers)^2	–0.007***	[0.001]	–0.000***	[0.000]
HH size	35.684*	[19.254]	0.164***	[0.038]
Female head	375.047*	[211.496]	2.023*	[1.021]
Educ of head	13.027	[8.520]	0.098***	[0.027]
Age of head	5.295*	[3.034]	0.028***	[0.008]
Depend ratio	–21.017	[25.047]	–0.036	[0.059]
Operated land (ha)	80.075**	[40.091]	0.264***	[0.086]
TLUs	46.578	[33.683]	0.090***	[0.018]
Draught	–83.063*	[47.677]	–0.315***	[0.118]
Crop disease	–148.698***	[40.070]	–0.193	[0.148]
Constant	–285.307	[234.367]	6.700***	[1.128]
Observations	2297		2297	

Note. Significance levels: * — $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors (SE) in brackets.

Table 3 presents results for the estimation of the Arrow–Pratt coefficient of risk aversion from the system of FOCs in equation (6). The Arrow–Pratt coefficient of absolute risk aversion is constrained to be equal for both inputs as it expresses the risk aversion of the farmer and is equal to twice the coefficient on the variance of the output value. Zambian farmers in our sample exhibit risk aversion with an average Arrow–Pratt absolute coefficient of around 40. This estimate of the coefficient of absolute risk aversion is in the upper bound of the literature (Love, Buccola,

[6] The estimation sample for FGLS is smaller as some observations corresponding to negative weights are lost. This is due to the fact that the linear regression used in the second step is not guaranteed to predict positive values of the variance.

1991; Groom et al., 2008). Since there are no formal criteria to interpret the size of the absolute risk aversion coefficient we simply take a positive and significant estimate as an indication of strong risk aversion in our sample of farmers.

Table 3. Arrow–Pratt coefficient estimates

	Seeds		Fertilizers	
	Coefficient	SE	Coefficient	SE
(1/2) var [y]	4.07e+01***	[15.453]	4.07e+01***	[15.453]
(1/2) var [y] $\cdot T$	8.07e+01	[24.527]	–1.22e+01	[26.524]
T	–6.34e+00***	[1.619]	3.95e+00***	[1.381]
Constant	–1.27e+00	[1.032]	–2.42e+00***	[0.819]
Observations	2298		2298	

Note. Significance levels: * — $p < 0.1$, ** — $p < 0.05$, *** — $p < 0.01$. Standard errors (SE) in brackets.

As we mentioned in the previous section, given some consumption smoothing, measures of risk aversion will be understated. Parameters of low risk aversion may indicate that the households have good consumption smoothing possibilities rather than no concern about risk. However, here we are interested in the difference in risk aversion between the treated and controls. This should be unbiased as access to consumption smoothing means other than the cash transfer should be equal for both groups due to randomization. Table 4 shows that the regression coefficients of the interaction between the output variance and the program dummy are statistically insignificant. As a result, the treated group may not engage in riskier behavior in terms of production decisions and input mix choices as a result of the transfer. Incidentally, the latter result also suggests that farmers' choices are consistent with constant absolute risk aversion, i.e., CARA instead of DARA.

Table 4. Two-stage least squares (2SLS) estimates for input demand

	Coefficient	SE	Coefficient	SE
Expenses for fertilizers	0.240	[0.135]		
Price of seeds	1.001***	[0.079]		
Treatment	7.232***	[1.660]	7.115**	[2.364]
HH size	0.019	[0.557]	2.115**	[0.680]
Female headed	10.807	[11.598]	–0.961	[16.653]
Education of head	0.940**	[0.298]	0.522	[0.426]
Age of head	0.242	[0.141]	0.638***	[0.160]
Dependency ratio	–0.271	[0.947]	–1.535	[1.317]
Operated land	0.623	[1.259]	–1.136	[1.802]
TLUs	–0.479	[0.449]	–0.883	[0.620]
Draught	–2.442	[1.488]	–2.797	[2.085]
Crop disease	1.153	[2.439]	–6.456	[3.321]
Expenses for seeds			0.086	[0.103]
Price of fertilizers			0.481***	[0.118]
Constant	–19.369	[1.501]	–25.833	[17.975]
Observations	2298		2298	

Note. Significance levels: * — $p < 0.1$, ** — $p < 0.05$, *** — $p < 0.01$. Standard errors (SE) in brackets.

Table 5. Three-stage least squares (3SLS) estimates for input demand

	Seeds		Fertilizers	
	Coefficient	SE	Coefficient	SE
Expenses for fertilizers	0.258	[0.135]		
Price of seeds	1.002***	[0.078]		
Treatment	7.118***	[1.655]	7.113**	[2.357]
HH size	–0.020	[0.555]	2.111**	[0.678]
Female headed	10.790	[11.565]	–1.098	[16.606]
Education of head	0.929**	[0.297]	0.515	[0.424]
Age of head	0.230	[0.141]	0.635***	[0.159]
Dependency ratio	–0.242	[0.945]	–1.527	[1.313]
Operated land	0.635	[1.256]	–1.162	[1.797]
TLUs	–0.462	[0.448]	–0.876	[0.618]
Draught	–2.394	[1.484]	–2.789	[2.079]
Crop disease	1.258	[2.432]	–6.484	[3.312]
Expenses for seeds			0.094	[0.103]
Price of fertilizers			0.504***	[0.117]
Constant	–18.922	[1.470]	–25.767	[17.925]
Observations	2298		2298	

Note. Significance levels: * — $p < 0.1$, ** — $p < 0.05$, *** — $p < 0.01$. Standard errors (SE) in brackets.

We now analyze results from the estimation of the system of input demand equations (7). Table 4 and Table 5 show the findings from the application of the 2SLS and 3SLS estimators, respectively. The 2SLS estimate of the program impacts suggests that farmers in the treated group increased demand for seeds by ZMK 7.2, which in relative terms amounts to 56.8 percent of the average expenditure for seeds at follow-up. Demand for fertilizers increases by ZMK 7.1 because of the cash transfer, or by 81.9 percent in relative terms. The 3SLS estimate are very similar to the 2SLS ones both in magnitude and significance, which we take as an indication of robustness of our estimates. Our findings confirm only in part the predictions stated out in our theoretical framework. We find that an increase in initial wealth from the government transfer does lead to an increase in demand for modern inputs and both inputs increase output variability. However, we don't find evidence of a reduction in farmers' risk aversion as a result of the increased wealth as would be expected if they featured decreasing absolute risk aversion.

As to the rest of the variables we note that own price elasticity is positive for both inputs. Moreover, only the education of the household head has a significant and positive impact on the demand for commercial seeds, while the demand for fertilizers is positively affected by the age of the household head and household size. These findings are consistent with those found in India (Dholakia and Majumdar, 1995), in Bangladesh (Mahmood et al., 1995) and on paddy rice and in Malawi (Likoya, Minagisoni, 2012).

To gauge the validity of the rank condition and the presence of weak instruments we show the common first stage regressions for both the 2SLS and 3SLS estimators. Table 6 presents F-test for the first stage of the 2SLS/3SLS estimators. They test the joint significance of the instruments in the system regressions of the endogenous variables on all exogenous variables. The F-tests for first stages corresponding to our two endogenous variables show that the instru-

Table 6. First stage estimates 2SLS and 3SLS

	Seeds		Fertilizers	
	Coefficient	SE	Coefficient	SE
Price of seeds	1.040***	[0.127]	0.153	[0.164]
Price of fertilizers	0.251	[0.173]	0.568	[0.461]
Price of output	0.006**	[0.002]	–0.007*	[0.004]
Treatment	9.854***	[2.193]	7.719*	[4.220]
HH size	0.439	[0.662]	2.292**	[0.960]
Female headed	9.931	[6.704]	0.625	[19.661]
Education of head	0.953***	[0.302]	0.810**	[0.376]
Age of head	0.402***	[0.130]	0.673***	[0.188]
Dependency ratio	–0.572	[1.291]	–1.671	[1.079]
Operated land	0.333	[1.187]	–1.313	[2.133]
TLUs	–0.715**	[0.278]	–0.924**	[0.412]
Draught	–2.538	[1.737]	–4.120	[3.009]
Crop disease	–1.426	[2.764]	–5.462**	[2.698]
Constant	–32.498***	[8.834]	–21.175	[21.192]
F-statistics (*p*-value)	13.6	0.000	2.59	0.004
Observations	2297		2297	

Note. Significance levels: * — $p < 0.1$, ** — $p < 0.05$, *** — $p < 0.01$. Standard errors (SE) in brackets.
The last but one row shows *F*-statistics and *p*-values of the test that all instruments have jointly no power on the endogenous variable.

ments are strong determinants of the variables they are instrumenting for, thus limiting the potential for weak instruments. F tests reject at greater than the 99% level the null hypothesis that excluded instruments do not have explanatory power. The impact of inconsistency arising from a possible correlation of instruments with errors can be reduced by a strong correlation between the instruments and the endogenous variables.

Thus, from the empirical results above we conclude that, for our sample of Zambian farmers, the cash transfer consisting of a substantial increase in the household's exogenous income and wealth has had the effect of boosting output variance and mean by increasing the use of risk-increasing inputs although there is no evidence that this happens as a result of the cash-transfer-induced reduction in risk aversion.

7. Conclusions

In this paper, we study the effect of unconditional government social transfers in Zambia in helping poor farmers break out of low-risk low-return production choices that can lead to poverty traps. Thus, if we are to understand the dynamics of poverty, we need to understand how social protection policies can help break this cycle through the risk channel.

We use data from the household survey for the evaluation of the Child Grant Program in Zambia to study the effects of unconditional cash transfers on farmers' risk aversion and input demand. In our analysis we also account for the potentially different impact of a certain input on output variability, which in turn mediates the influence of the *wealth effect* on input demand. We find that both seeds fertilizers are risk increasing while increasing average crop production at the same time. The impact of cash transfers on the demand for commercial seeds and chemical fertilizer is positive. However, the government transfers fail to reduce risk aversion among the treated.

Until the underlying causes of failures in credit and insurance markets can be corrected, unconditional cash transfers can be a useful in pushing farmers out of the poverty trap as they offer a stable source of liquidity that allows consumption smoothing and inducing higher-risk higher-return production choices.

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