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One cow per poor family: effects on consumption and crop production in Rwanda

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Abstract: A random sample of households in Rwanda are used to estimate the effects of the one cow policy on consumption and crop production during 2010-2014. A first-differenced model that takes into account the selection bias and placement effect associated with the policy and heterogeneity across households is estimated. Findings show a positive effect of receiving a cow on crop production, indicating that fertilizers provided by the cattle has enabled households to increase their agricultural production. Findings also point to the importance of knowledge and experience of rearing livestock for the outcome on consumption to realize.

Keywords: Girinka; consumption; crop production; CEM; Rwanda.

JEL-codes: R12; R20; O12

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1. Introduction

In intent to pursue development of their countries, governments initiate programs and introduce policies linked to the priority areas of their economies. Given the importance of agriculture, and particularly livestock for the welfare of the rural poor, the Government of Rwanda has committed to a growth strategy in which agriculture play a key role (Republic of Rwanda, 2000). A policy included in the strategy is the ‘One cow per poor family’ program, also referred to as Girinka. This is a program that distribute dairy cows with the overall goal to reduce malnutrition and provide a source of fertilizers and additional income for the poor households.

Since its introduction in 2006, Girinka has distributed around 300 000 livestock assets in the form of dairy cows, with a goal to distribute more than 350 000 by the end of 2017. Despite the significant amount of public resources allocated through the program, the evidence of its economic impact is still scarce, particularly its ability to improve the economic welfare of households. Klapwijk et al. (2014), study the ‘One cow per family’ program in Rwanda, and show that poor households are unable to provide sufficient fodder to feed a cow. They suggest that a shift to animals that require less fodder, such as goats, would better target the poor and improve the effectiveness of the program. Argent et al. (2014), address the training aspects of the program and show that the transfer of livestock assets has a positive impact on milk production and other indicators of household wealth. Particularly of those households that are also offered training on how to utilize the livestock.

This study aims to contribute to the knowledge of the Girinka program by estimating the effects of receiving a cow on household consumption and crop production. Previous literature show that consumption and crop production are key indicators of wealth and food security among households in the context of developing countries (Dercon et al. 2009; Islam & Maitra, 2012; Banerjee et al., 2016). The main focus is on heterogenous treatment effects which is an attempt to examine if there are outcome differences of program participation depending on household characteristics. Having access to data that track households over time enables us to unravel whether such effects exist while taking into account time-invariant unobservables. We also estimate if the results are sensitive to natural conditions. Besides topography and climate variability across Rwanda, the strong heterogeneity in soil fertility may influence fodder production and the ability to reproduce livestock (Byiringo & Reardon 1996). Our estimates show a positive effect of receiving a cow on crop production. This indicate that fertilizers (organic manure and soil nutrients) provided by the cow has enabled households to increase their agricultural production. The effect of program participation on consumption, which is a broader measure of economic wealth, is different. In particular, the effect depends importantly on households' ownership of land and livestock, indicating the presence of learning effects and the role of knowledge and experience of rearing livestock.

Assessing the impact of policies on welfare indicators is challenging from a methodological point of view. Better skilled individuals are more likely to participate in welfare enhancing governmental programs, which increases the risk of a skill bias. It is also difficult to interpret the effect of policies as they tend not to be randomly dispersed. They are targeted to certain types of households, with the risk of placement effects. The approach to handle these issues is to apply first difference estimations and the recently developed Coarsened Exact Matching (CEM) method to approximate a randomized experiment using observational data. Iacus et al. (2011) show that the CEM method is a more reliable method for causal inference as it reduces the imbalance between the treated and control group and reduces the degree of model dependence, compared with other more frequently applied matching methods. With access to representative household-level data across Rwanda, through the integrated household living conditions survey (EICV) of 2010 and 2014, the study estimates the average treatment effect on treated. This means a comparison of the outcome between households receiving a dairy cow between 2010 and 2014 and those who never received a dairy cow from Girinka.

This approach is useful from a methodological as well as a policy perspective. It applies a new matching technique to handle selection bias and can thereby provide new evidence on the heterogeneous effects associated with policy induced livestock transfer. As opposed to prior studies, the present paper uses household-level data across Rwanda instead of samples from smaller geographical areas (e.g., Klapwijk et al. 2014). More extended data offer an analysis with the opportunity to draw more general conclusions.

2 The role of livestock in poverty reduction

Improving the productivity of the agricultural sector is traditionally seen as one of the most important means of poverty alleviation in developing countries (Johnston & Mellor, 1961). This follows the evidence that there are backward and forward linkages between the productivity of the agricultural sector and other sectors of the economy (Jalan & Ravallion, 2002; Haggblade et al., 2010). It is also a fact that most poor households live in rural areas and depend on agriculture, combining small scale food cropping and livestock with a diverse set of agricultural related activities. This is particularly evident in Rwanda. More than 80 percent of the population live in rural areas with agriculture as their primary source of income and rural poverty is almost three times as high as urban, 44 percent versus 16 percent (NISR, 2016). Hence, poverty and living standards of rural households in Rwanda, as in most of sub-Sahara (SSA), are very much related to agricultural asset, such as land and livestock holdings (Abdulai & CroleRees, 2001).

There are several reasons why livestock is a key determinant to achieving development goals among households in SSA. Livestock improves food security through high value protein in terms of milk and meat, which are often limited in the diets of the poor (Rawlins et al., 2014). Livestock is also a productive asset on the farm as organic manure and soil nutrients can be used as a cost-effective and sustainable fertilizer. The water retention capacity of organic manure also has an effect of reducing the risk of soil erosion, which is a significant problem in SSA and in Rwanda (Byiringo & Reardon, 1996; Tilman et al., 2002). Livestock is therefore a good combination with crop production. However, context matters and households may prefer to sell parts of the animal sourced food, which can provide additional income from by-products. Livestock can also spur entry into nonfarm earnings and entrepreneurship as it can be used as collateral for loans (Reardon et al., 1992). Effects can be non-economic, in the form of increased independence, self-esteem and social status, so called “soft factors”. Rugema et al. (2014) show this through qualitative field studies in Rwanda but they also emphasize the insufficiency of introducing Girinka as an isolated poverty program. Increased livestock in villages also need to be supported by infrastructure such as schools and health care but also veterinary expertise.

Following from above, livestock is considered a key factor in economic development and several countries have introduced policy programs, alike the Girinka, to increase livestock ownership among poor households (e.g., the ‘Chickens for poverty alleviation’ in Eastern Uganda and the promotion of dairy cattle, meat and dairy goats, and poultry among targeted smallholder farmers in Malawi). In Rwanda, livestock is considered a key factor in poverty reduction and in Rwanda, the combination of livestock and land holdings has led to six categories of poverty indicators according to the Ubudehe classification, as shown in Table 1. The classification shows that the lack of livestock is associated with a higher level of poverty and that ownership of livestock can imply a move away from poverty.

Table 1. The Ubudehe classification

Group	Poverty status	Explanation
Umutindi nyakujya	Abject poor/most vulnerable	Destitute with no land, no animals and must beg for food
Umutindi	Destitute	Very poor, may have some land but no animals
Umukene	Poor	Poor, has land for food production but no savings
Umukene wifashije	Salaried poor	Poor, some more land and some animals, has more income than only for subsistence, for other needs.
Umukungu	Rich without money	Rich in terms of food security, has land, keeps animals and possibly paid employment.
Umukire	Rich	Rich, has land, animals and paid employment to maintain good living standard.

Source: Howe and McKay (2007)

2.1 The Girinka program- purpose and expected outcome

The overall purpose of the policy is to reduce malnutrition and assist poor households to improve their economic statues. The program was implemented in November 2006, as a part of the Rwandan vision 2020 to move from a low-income country to a middle-income country. The program should work in the way that one poor household receive a cow and, as a refund to the government, they give their first calf to their neighbor, whereas the subsequent calves are kept. To be relevant for the program, the household needs some land and some shed for the animal. This means that the very most poor and vulnerable household cannot enter the program, following Table 1. But, households that own some land has enough means to also feed a cow so they can move one further step away from poverty. The selection of Girinka beneficiaries is conducted at a local level and each local community together decide which households should benefit from Girinka, given a set of criteria.

There are some challenges related to Girinka, which have also been subject of critique. Firstly, how to own a cow and get the most out of it is not common knowledge in all parts of the population. Argent et al (2014) show that there is a significant additional benefit of receiving training in combination with receiving a cow. Foster and Rosenzweig (1995) show that imperfect knowledge is a significant barrier to adopt new crop varieties and related new technologies in rural parts of India. They also show the presence of local knowledge spillovers, which means that an overall increase of knowledge in the neighborhood might be more effective than increasing knowledge for only some specific targeted households. Lack of knowledge has also been a problem in the implementation, communication and monitoring of the program which has resulted in some corruption where cows are distributed to rich, rather than poor families (IMF, 2008). It is important to evaluate poverty programs and to scrutinize whether they reach the target groups but also if they result in an, on beforehand expected outcome. In terms of targeted households, Girinka program does not aim to target the poorest households, since they lack economic ability to take care of livestock. One way to target the poorest is to, as an initial step into the Girinka program, distribute smaller ruminants, such as goats and sheep. Distributing goats, specifically dairy goats, has proven more successful than dairy cattle when distributed to the poor, although such effects are not yet well documented in literature (Klapwijk et al. 2014).

Since the focus of the present paper is on the effect associated with distributed cows through Girinka, we do not address the effects among the poorest parts of the population. Regarding the construction of Girinka and the effects on household economic wealth, it may also be necessary to control for initial land holdings. Households with more land is potentially better equipped to manage a cow but also better suited to handle additional livestock transfer, which is one of the expected positive outcomes of the program. One may therefore expect that previous knowledge of livestock rearing (such as goats and smaller rudiments) and learning effects through program participation is important in unraveling the effects on household consumption and agricultural production.

3 Data, model and methods

The empirical approach is to use household data from the two latest rounds of the Integrated Household Living Conditions survey (EICV), which is conducted by the National Institute of Statistics in Rwanda (NISR). The EICV is a nationwide survey that collect welfare indicators of a random sample of around 14400 households across Rwanda, with several efforts made to ensure representativeness trough stratification and weighting. The most recent EICV survey of 2013-2014 (EICV4) is combined with the earlier survey of 2010-2011 (EICV3) and only those households that where visited in both are included in the dataset. Hence, the data used for the empirical analysis is a balanced panel of 3840 observations and the sample of the 1920 panel households are selected to be representative at the national and urban/rural levels and households that relocated or split were tracked to obtain current information for the corresponding household members (see NISR (2016) for a detailed description). Having access to a sample of the same household observed in two points in time, our baseline equation is:

$$y_{it} = \lambda_0 + \gamma_0 d2_t + \lambda_1 T_{it} + Z_i + \varepsilon_{it} \quad (1)$$

, where y_{it} denote the dependent variable of household i at time $t = 1{,}2$, (corresponding to years 2010 and 2014, respectively), Z_i denote fixed characteristics of the household, and T_{it} denote program participation. Moreover, $d2_t$ denote a time dummy and $Z_i + \varepsilon_{it}$ the composite error term. Following the first-difference approach to handle correlated unobserved heterogeneity, the two-period data can be expressed as (Liker et al., 1985):

$$y_{i2} = (\lambda_0 + \gamma_0) + \lambda_1 \mathrm{T}_{i2} + Z_i + \varepsilon_{i2} \quad \forall \quad t = 2 \quad (2)$$

$$y_{i1} = \lambda_0 + \lambda_1 \mathrm{T}_{i1} + Z_i + \varepsilon_{i1} \quad \forall \quad t = 1 \quad (3)$$

First-differencing yields:

$$(y_{i2} - y_{i1}) = \gamma_0 + \lambda_1(\mathrm{T}_{i2} - T_{i1}) + (\varepsilon_{i2} - \varepsilon_{i1}) \quad (4)$$

$$\Delta y_{i2} = \gamma_0 + \lambda_1 \Delta \mathrm{T}_{i2} + \Delta \varepsilon_{i2} \quad (5)$$

, where the unobserved fixed effect Z_i is differenced away and assumed uncorrelated with the observed variable $E(Z_i G_{i2} = 0)$, and where T_{i2} is the treatment dummy that indicate program participation of household i at time $t = 2014$. Specifically, the treatment dummy takes the value one if the household has received a cow sometime in-between 2010-2014, but not in 2010, and zero if the household never received a cow through Girinka. Should there be any selection bias resulting from factors that are time-invariant, the formulation of equation (5) should address this (Hsiao, Pesaran & Tahmiscioglu, 2002).

Additional factors could violate the assumption of strict exogeneity, for example if the assignment of livestock through the program is not random, but targeted to specific households. As discussed, the distribution of dairy cows through Girinka is coupled with eligibility conditions and should these not be accounted for, the estimated effect of program participation will be biased (Robins et al., 2000). Hence, the desired effect is the counterfactual mean difference in the outcome variables i.e., the average treatment effect on treated.[2] But, the counterfactual outcome cannot be directly observed using observational data and simple mean value comparisons between the treated and non-treated yields biased estimates (Rosenbaum and Rubin, 1983). The empirical approach to

[2] This can be formally expressed as: $ATT = E(y_1 - y_0|\boldsymbol{X}, T = 1) = E(y_1|\boldsymbol{X}, T = 1) - E(y_0|\boldsymbol{X}, T = 1)$. Where $E(\cdot)$ denotes the expectation operator, $\boldsymbol{X}$ is a vector of relevant control variables, and $\mathrm{T} = 1$ indicates participation in Girinka. Further, y_1 denotes the outcome for a household in case it received a cow, and y_0 denotes the outcome for the same household in case it did not receive a cow.

handle this is to estimate a control group with distributional characteristics as similar as possible to the treated households. The approach in this paper follows Gustafsson et al. (2016) and Nilsson (2017), who uses the CEM method rather than propensity score matching (PSM). Following Iacus et al. (2009, 2011), the main justification for CEM is that it allows the balance between the treatment and the control group to be chosen ex-ante rather than being revealed through an iterative process of ex-post balance checking.[3] This matching procedure guarantees that adjusting the imbalance on one variable has no effect on the balance of other covariates. And since the matching is done before the regression analysis, it reduces the degree of model dependence (Ho et al., 2007).

To improve the balance between treatment and control group the CEM approach is to temporarily and ex-ante coarsen each pre-treatment covariate used in the matching, exact match on the coarsened data and then use the uncoarsened values of the matched units in the subsequent regression analysis. Iacus et al. (2011) define the overall imbalance using the $L1$ statistic, which measures global imbalance based on the multivariate distance between the multidimensional histogram of all pretreatment covariates in the following:

$$L_1(f,g) = \frac{1}{2}\sum_{\ell_{1..,,\ell_k}} \left| f_{\ell_{1..,,\ell_k}} - g_{\ell_{1..,,\ell_k}} \right| \quad (6)$$

where $f_{\ell_{1..,,\ell_k}}$ and $g_{\ell_{1..,,\ell_k}}$ denote the relative frequencies for the treated and untreated units. Perfect balance is indicated by $L_1 = 0$, and larger values indicate more imbalance with a maximum $L_1 = 1$ that indicate complete imbalance (heterogeneity) between the groups. Hence, the treated households are matched using CEM and variables that are indicated to produce the most heterogeneity between the groups. The matching procedure generates the following weights, which are used in the subsequent weighted regression model.

$$w_i = \begin{cases} 1, if\ T_i = 1 \\ 0,\ if\ T_i = 0\ and\ i \in M_2^A for\ all\ A, \\ \frac{m_1^A}{m_2^A}\frac{m_2}{m_1}, if\ T_i = 0\ and\ i \in M_2^A\ for\ one\ A. \end{cases} \quad (7)$$

where $T_i = 1$ and $T_i = 0$ indicate the treated and untreated units respectively and A denote the subset of pre-treatment covariates used in the matching. Moreover, m_1^A and m_2^A denote the number of treated units per strata and M_2^A denote all the matched observations for the treatment level $T_i = 0$ within stratum A. Iacus et al. (2011) show that including the weights

[3] See Iacus et al. (2009, 2011) for a formal derivation of the model and its implementation in Stata.

in the subsequent regression analysis is equivalent to a difference-in-difference and yields an unbiased estimate of the average treatment effect on treated. Since there will naturally remain imbalance even after the matching, as it is impossible to obtain an exact match on all covariates, including a set of household and locational controls in the regression model reduces the remaining heterogeneity between the groups. The following model is estimated:

$$\Delta y'_{i2} = \gamma'_0 + \lambda_1 \Delta T'_{i2} + \lambda_{i2} \Delta \boldsymbol{X}'_{i2} + \Delta \varepsilon'_{i2} \qquad (8)$$

, where y_{i2} denote the dependent variable of household i, T_{i2} denote program participation and $\boldsymbol{X}_{i2}$ is a vector of household and locational controls. Moreover, the asterisk denote that the variable is weighted using the pre-estimated CEM weighs defined in equation 7.

3.1 Dependent variables

The first dependent variable is household consumption expenditure adjusted for the spatial and temporal differences in the cost of living. Using consumption expenditure to indicate household wealth follows the argument that income likely underestimates the material wealth of households in the context of developing countries (Deaton & Zaidi, 2002). Current income is typically vulnerable to temporary fluctuations due to factors such as layoffs or changes in family status, which causes current income to vary more than consumption (Cutler & Katz, 1991). These temporary fluctuations do not necessarily reflect changes in wealth. Following the view that current consumption is a more reliable measure to capture changes in household wealth, given that it is adjusted for changes in the cost of living (Jalan & Ravallion, 2002; Meyer & Sullivan, 2003), the approach is to examine if program participation lead to changes in household consumption.[4]

The second dependent variable is crop production, defined as total real value of households' crop production, included to assess if participation results in higher crop yields. A total of 122 household in the sample where granted a dairy cow through the Girinka program between 2010-2014, of which 45 percent are in the Eastern province, 19 percent in the Northern province and 8 percent in the capital province Kigali City. Table 1 show a decomposition of the households by province. While the number of households in the sample that participate in Girinka may seem small, it corresponds to almost 8

[4] The questionnaires remained essentially the same in the two surveys and the calculation of household consumption is consistent and with respect to subgroup (depending on poverty), time, and the place of residence (urban/rural).

percent, which can be compared the national average which correspond to around 1.5 percent of the population (in 2015).

Table 1. EICV3 and EICV4 panel households' participation in Girinka

	Number of households that received a cow between 2010-2014
Kigali City	10
North province	25
South province	23
East province	51
West province	13
Total number of households	122

3.2 Household and geographical controls

The selection of individual household controls and their definitions generally follows the approach of prior literature and include measures of human capital (education and age), asset endowments, access to capital through credit and remittances and land and livestock holdings. These factors lower transaction costs and information barriers and provide access to financial capital, which allows households to accumulate wealth (Ellis, 2000; Barrett et al. 2001). There are also locational factors that may influence the growth of consumption and crop production. Access to urban areas and to diversified economic environments is one well used determinant (Reardon, 1999). For example, farm households located in areas with a more diversified industrial structure should have a greater potential to develop economies of scope in production, which makes them more flexible to adapt to changing external conditions (Hansson et al., 2013; Barnes et al., 2015). To account for such effects, this study uses an entropy measure of industrial diversity (D_r), calculated with respect to the share of employees that work within different industries using the four–digit and the two–digit ISIC codes in the following (e.g., Frenken et al., 2007):[5]

$$D_r = \sum_{g=1}^{G} E_g ln E_g \tag{9}$$

, where E_g denote the share of total employment in each district that belong to the same two–digit level where $g = 1, \dots, G$. Hence, the measure captures variety in industry

[5] ISIC codes refer to the customized international standard industrial classification of all economic activities in Rwanda. In the calculation of the diversity index this study relies on the classification manual of 2012 developed by National Institute of Statistics of Rwanda (NISR).

composition for the district as a whole and ranges from 0 to lnG, where zero industrial diversity is reached when all employees are working in the same 2-digit industry. The measure is calculated using the district level as reference, which is the key administrative and political unit in Rwanda.[6] Variable definitions are presented in table A1 in Appendix A and table 2 present the summary statistics, split by the treated and untreated households.

The summary statistics in Table 2 show that the treated are not a random sample of households. Wealth indicators are higher among the households that never received a cow through Girinka, compared to those that received a cow between 2010 and 2014. Specifically, the consumption of non-treated households is approximately 1.6 times higher compared to the treated. Turning to the agricultural variables, land and livestock, we observe that treated households have on average more animals and land. This is because the summary statistics are based on the entire sample of the 1920 households, including nonfarm households.[7] The variation of most variables is larger in the non-treated group, in some cases as much as twice or three time as high the variation. So, one may expect that non-participating households are either 'too poor' or having a 'too high income', which is an expected outcome given the selection criteria. Overall, there has been a small reduction in the percentage of households raising livestock and owning land in Rwanda, while the absolute numbers have increased slightly due to population growth.

Table. 2. Summary statistics and difference in mean between treated and untreated households

Non-treated (never received a cow from Girinka)	N	Mean	Standard dev.	Min	Max	% Δ2010-2014
Consumption	3689	368R	642R	10.95R	1860R	14
Crop production	3689	286.61R	287.03R	0	1000R	42
Size	3689	4.67	2.22	1	22	-4
Age	3689	44.25	15.68	16	98	0
Gender (1=female)	3689	0.27	0.44	0	1	-3
Higher education	3689	0.06	0.18	0	1	3.5
Savings	3689	676.11R	199R	0	1200R	9
Credit	3689	349.37R	369.32R	0	1800R	-0.05
Remittances	3689	32.79R	20.18R	0	8681R	34
Internet access	3689	0.02	0.15	0	1	1.8
Land	3689	6.08	21.22	0	809	3
Livestock[a]	3689	3.70	26.74	0	1232	-11
Distance road	3689	6.71	9.38	0	60	-
Industrial Diversity	3689	0.80	0.16	0.46	1.05	-
Kigali City	3689	0.24	0.43	0	1	-
North province	3689	0.22	0.41	0	1	-
East province	3689	0.18	0.38	0	1	-
West province	3689	0.20	0.40	0	1	-
South province	3689	0.23	0.42	0	1	-

[6] Data used to calculate the diversity measure comes from the Establishment census of 2010, implying that it reflects initial conditions.
[7] These are controlled for in the estimations.

Treated (received a cow from Girinka in-between 2010-2014, but not in 2010)						
Consumption	122	217.73R	188.21R	272.45R	1654.60R	-26
Crop production	122	313.03R	207.93R	0	8619.0R	32
Size	122	5.35	2.29	1	11	1
Age	122	50.89	16.15	21	94	11
Gender (1=female)	122	0.32	0.46	0	1	-1
Higher education	122	0.03	0.08	0	0.5	0.05
Savings	122	240.71R	795.26R	0	6000.0R	0.9
Credit	122	37874	69311	0	500R	-1.8
Remittances	122	20.18R	84.40R	0	750000	-0.18
Internet access	122	0.04	0.20	0	1	1.3
Land	122	7.08	8.77	0	40	26
Livestock[b]	122	3.90	5.06	0	24	-2
Distance road	122	5.56	8.77	0	40	-
Industrial diversity	122	0.75	0.14	0.46	1.04	-
Kigali	122	0.12	0.33	0	1	-
North province	122	0.18	0.38	0	1	-
East province	122	0.39	0.49	0	1	-
West province	122	0.10	0.29	0	1	-
South province	122	0.20	0.40	0	1	-

Notes: R in thousand Rwandan Francs (RWF, 100=2014). [a]Include goats and other animals like sheep, pigs and chicken, but not the cow received through Girinka. [b]Include cattle, goats and other small animals.

Coarsened exact matching

The CEM method is used to pre-estimate weights which are used in the subsequent regression analysis. The selection of match variables is based on imbalance tests (Iacus et al., 2011) and preliminary logit estimations on the determinants of the likelihood to participate in the program.[8] The results of the matching are presented in table B1 and B2 in Appendix B.

5 Regression results

Results using consumption expenditure and crop production as dependent variables are reported in table 3 in five model specifications. The first estimation (column A) is included for comparison and reports the results from estimating a naïve model using equation 8, but excluding the pre-estimated weights in equation 7. The subsequent columns in Table 3 show the estimations with the weight using growth in consumption as the dependent variable (column B and C) and the growth in crop production (column D and E). The results in column C and E are from estimating the model using the cluster robust option to control for spatial heterogeneity in natural conditions, linked to district belonging, as an alternative to the province fixed effects in column B and D.

[8] These results can be attained on request.

5.1 Effects of the 'One cow per poor family' policy

Results from simple mean value comparison reported in the first column show a significant and negative correlation between program participation and household consumption. These results are different compared to those obtained by estimating equation 8 with the weights. Including the weights, the treatment effect is indicated to be positive, but not significantly different from zero (column B). This could indicate that the effect of program participation is biased when the treated households are compared to all other households that did not receive a cow, most likely because the estimated effect captures features that are linked to the assignment of the Girinka cow i.e., that the policy targets households that have a lower level of consumption and other indicators of economic wealth. Hence, the coefficient reported in the first column can only be a correlation, whereas the coefficient of the weighted least square estimations in the remaining columns reflects a causal effect, which is more reliable for policy impact analysis.

Results in column B show that the effects of Girinka participation on consumption is positive but not significantly different from zero (column B and C). This indicate that households that received a dairy cow do not have a significantly higher level of consumption expenditure compared to similar households that did not receive a cow. Results using agricultural production as the dependent variable are reported in column D and E show that crop production is positively and significantly affected by program participation. This reflect that livestock is a productive asset on the farm that can be used to extend cropping practices and because it provides improved access to cost efficient manure and soil nutrients. An important aspect is that the fertilizers provided via the cattle is organic, which makes it a more sustainable option compared to chemical fertilizers (Tilman et al., 2002), which are heavily subsidized in Rwandan. In particular, the water retention capacity of organic manure, which reduces the risk of soil erosion, makes it a more sustainable alternative (Byiringo & Reardon, 1996). Comparing the results, it could seem surprising that consumption expenditure is not statistically significant in the same way as crop production. In this paper, consumption is used as a proxy for income, as is usual when estimating poverty (Jalan & Ravailon, 2002). The implication is that it proxies a much broader aspect of monetary welfare compared to crop production, which is a measure of household agricultural activities. Hence, it seems like the transfer of cattle through Girinka can increase the agricultural productivity of smallholder farmers in Rwanda, but it is not enough to cause an increase in their overall economic welfare.[9]

Table 3. Impact of 'One cow per poor family' programme on household consumption (A-C) and crop production (D, E).

Variable	*log of consumption*			*log of crop production*	
	A. Coef. (Std.Err.)	B. Coef. (Std. Err.)	C. Coef. (Std. Err.)	D. Coef. (Std. Err.)	E. Coef. (Std. Err.)
treated	-0.08 (0.059)	0.07 (0.07)	0.08 (0.07)	0.78* (0.21)	0.85* (0.21)
Household and locational controls					
Size	-0.52* (0.02)	-0.50* (0.02)	-0.50* (0.03)	0.62* (0.11)	0.63* (0.11)
Age	-0.04 (0.03)	-0.06* (0.03)	-0.06* (0.04)	0.45* (0.17)	0.44* (0.17)
Gender (1=female)	-0.16* (0.02)	-0.09* (0.03)	-0.09* (0.03)	0.29* (0.13)	0.30* (0.13)
Higher education	0.95* (0.07)	0.93* (0.09)	0.93* (0.09)	-2.50* (0.50)	-2.52* (0.49)
Savings	0.04* (0.002)	0.04* (0.002)	0.03* (0.002)	-0.03* (0.01)	-0.03* (0.008)
Credit	0.01* (0.002)	0.01* (0.002)	0.01* (0.002)	0.02 (0.01)	0.01 (0.01)
Remittances	0.01* (0.002)	0.01* (0.002)	0.01* (0.003)	0.01 (0.01)	0.00 (0.01)
Internet access	0.84* (0.09)	1.20* (0.13)	1.20* (0.14)	-1.63* (0.65)	-1.59* (0.65)
Land	0.07* (0.01)	0.02* (0.001)	0.02* (0.001)	1.63* (0.08)	1.62* (0.08)
Livestock	0.04* (0.01)	0.05* (0.01)	0.05* (0.01)	0.44* (0.04)	0.44* (0.11)
Fertilizers	0.01* (0.002)	0.01* (0.003)	0.01* (0.003)	0.16* (0.01)	0.16* (0.01)
Distance road	-0.007* (0.001)	-0.007* (0.001)	-0.007* (0.001)	0.00 (0.01)	0.001 (0.004)
Industrial diversity	0.82* (0.10)	1.00* (0.12)	-	-0.74 (0.52)	-
Province	Yes	Yes	No	Yes	No
District	No	No	Yes	No	Yes
Constant	12.32* (0.13)	12.17* (0.16)	12.19* (0.16)	5.58* (0.74)	5.33* (0.75)
w_i	No	Yes	Yes	Yes	Yes
Matching algorithm	-	2	2	2	2
R square	0.49	0.51	0.48	0.63	0.63
Obs.	3782	3782	3782	3777	3777

* indicate significance at the five per cent level or lower. Heteroscedasticity consistent standard errors in parenthesis. Independent variables measured on a continuous scale are log transformed.

[9] The value of crop production by harvested area is a common measure of agricultural productivity in prior literature e.g., Matsuyama, (1992).

One issue is that there may be omitted geographical factors that influence households' capacity to produce fodder and reproduce livestock. These can be linked to climate variability, soil fertility, topography and other factors that increases the risk of soil erosion (Helgeson et al., 2012). The adoption of improved water management (irrigation) and efforts to soil conservation (protection against erosion) tend to be coupled with district belonging in Rwanda (Clay et al., 1998). There can also be placement effects i.e., if the assignment of agricultural programs is not randomly dispersed, but concentrated to locations with better agricultural potential. Based on what has emerged from the previous literature, it seems like subsidized inputs are provided in greater supply to those districts that have better agricultural prerequisites (Bizoza & Havugimana, 2013). To address if unobserved correlations linked to economic, political or environmental factors, influences the results, the model in equation 8 is estimated with the cluster-robust option using districts. These results are presented in column C and E and show no difference to the main results.

Another concern is that there may be omitted effects linked to households' managerial capacity and their ability to rear livestock, which can be related to their experiences, discussed in section 2.1. To test this, we introduce interaction effects into equation 8. These results are presented in table 4. Staring with the effects on consumption (column F and G), the interaction terms of livestock and land, indicating the effects on households that have large agricultural asset endowments, are both positive and statistically different from zero. This could indicate that it is not program participation *per see* that result in a positive outcome, but the ability of the households to manage the livestock transfer. Specifically, the positive interaction between livestock and Girinka participation can be reflective of learning effects as it indicates that household that already own livestock, or have a stock that increases over the period, have a positive outcome compared to those that receive a cow, but have no other livestock prior to or after receiving the Girinka cow. Similar arguments can be made to explain the positive interaction between land and Girinka participation. Having access to an additional unit of land makes it easier to support one more livestock, the marginal cost of the extra livestock is smaller while the marginal benefit is large. Hence, results point to the importance of knowledge and experience of caring and handling livestock (goats or other smaller rudiments), which can be applied to the livestock received through Girinka. These results are consistent with the findings in previous studies that focus on the role of training in explaining the success of the 'One cow per poor family program' in Rwanda (Argent et al., 2014). Foster and

Rosenzweig (1995) find that the learning effect, both from learning by doing and learning spillovers enhances the productivity of farmers in India. In the case of Girinka, the programme entails both the actual livestock but also training. It is not possible to disentangle the learning effect from the effect from just receiving a cow. Based on the findings from the interaction variables, the importance of the learning mechanism cannot be understated. Similar arguments can be made to explain the positive interaction between livestock and Girinka participation on crop production. There are no comparable effects for households that increase their stock of land (column H).

Table 4. Impact of 'One cow per poor family' programme on household consumption (F, G) and crop production (H, I).

	log of consumption		*log of crop production*	
Variable	F. Coef. (Std.Err.)	G. Coef. (Std. Err.)	H. Coef. (Std. Err.)	I. Coef. (Std. Err.)
treated	0.13 (0.15)	0.06 (0.10)	0.71* (0.11)	0.71* (0.12)
treated×land	0.03* (0.001)	-	0.03 (0.03)	-
treated×livestock	-	0.01* (0.001)	-	0.02* (0.001)
Household and locational controls	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes
Constant	12.17* (0.16)	12.17* (0.16)	5.50* (0.74)	5.50* (0.74)
w_i	Yes	Yes	Yes	Yes
Matching algorithm	2	2	2	2
R square	0.47	0.48	0.63	0.63
Obs.	3782	3782	3777	3777

* indicate significance at the five per cent level or lower. Heteroscedasticity consistent standard errors in parenthesis. Dependent variables independent variables measured on a continuous scale are log transformed

5.2 Control variables

Turning to the household-level predictors. Higher education is important and households with more asset endowments have higher consumption growth. These results are broadly consistent with previous findings on the importance of pull factors, such as education, especially above primary schooling for poverty reduction (e.g., Barrett et al., 2001). The finding that households' access to the internet is important for consumption growth is in line with the idea that improved connectivity is a key factor in rural development (Malecki, 2003). There is also a positive association between households' access to credit and remittances and consumption, which is consistent with the finding that credit and additional income via social ties (migrated family members) are key determinants of household income and risk minimizing strategies (Bigsten, 1996; Ellis, 2000). The positive relationship between a higher initial diversity in industries and consumption point to the importance of market linkages and external economies of scale present in urban areas for the possibility of households to improve their wealth (Ellis, 2000; Ali & Peerlings, 2016). Results also show a negative and significant coefficient for distance to the nearest road. This supports the idea that farmers with better access to transportation infrastructure are in a better position to improve their welfare as this implicitly implies improved possibilities to market their produce.

5.3 Robustness tests

Additional robustness tests are performed to test if changes in model specification and sample affect the results. These estimations are reported in table C1 in Appendix C, with a focus on the main results.[10] One issue concern spatial heterogeneity and the fact that poverty and food security is typically higher in urban areas compared to rural (Reardon et al., 2000). Basic summary statistics confirm that this empirical regularity holds for these data, and it is evident that households in urban areas have higher real values on most indicators of material wealth (e.g., consumption, assets and credit) compared to those in rural areas. Further analyses in this direction is prevented by the relatively small sample size of farm households in urban areas that received a cow (n=17), but the models have been estimated excluding all urban households (n=738), and the results were robust.[11] We also test if the presence of local spillover effects influence the results. As discussed, the program should work in the way that it creates multiplier effects in the local communities e.g., by inducing household to share fertilizers and give away the first calf to a neighboring household. Foster and Rosenzweig (1995) show the presence of local knowledge spillovers, which means that an overall increase of knowledge in the neighborhood might be more effective than increasing knowledge for only some specific targeted households. A simple dummy variable is included to test the presence of such effects, coded 1 in 2014 if the household is located in a village in which a household received a cow in 2010, and zero if the household is located in a village that never received

[10] The complete set of regression results for the robustness tests can be obtained on request.
[11] The definition of urban and rural areas follows the one outlined by National Institute of Statistics of Rwanda. Urban areas include Kigali–Ville, the district capitals and semi-urban areas, which generally correspond to smaller towns that have service facilities and markets. Rural areas are those not included in the urban category, which are generally located on the periphery of urban areas.

cattle through the program. The coefficient of the village effect is positive and significant, and there are no changes to the main results. The set of robustness tests also explores if the results are sensitive to the chosen matching algorithm (see Table b1 in Appendix B) and to outliers by performing a 1 percent trim of the dependent variable and by substituting between the algorithms in the estimations. This does not affect the main results.

6 Conclusions

The government of Rwanda has through several economic and social reforms targeted the development of the poor households where the aim is to put these households on a trajectory that leads to a higher standard of living. The natural target is the agricultural sector, especially in rural areas, as it is the primary source of economic growth and development. One of these implemented agriculture policies is the Girinka programme, also known as the "one-cow-per-poor-household program". As the name entails, beneficiaries received a cow from the government with the aim to empower the households and enhance their development.

In order to assess the outcome of the Girinka programme for the participating household in terms of consumption and crop production growth, this paper uses a matching technique enabling us to control for the selection bias into the programme. The findings show that being part of the Girinka programme enhances the crop production but not the consumption growth of the households. The effect on crop production is translated through the increased supply of organic fertilizers. When allowing for interaction effects with the households previously livestock and land the results point to the importance of knowledge and experience of caring and handling livestock (goats or other smaller rudiments), which can be applied to the livestock received through Girinka.

The findings are important from a policy perspective as it shows the benefits of the program. The findings reveal that a "one-policy-fits-all" is redundant and in order for the best outcome of the programme it needs to be "custom-made" and take account of the possibilities of the household. It is not reasonable to assume that an extremely poor household has the resources to care for a cow. This policy support might end up as a poverty-trap for the household as all the resources of the households are dedicated to caring for the cow and less time is spent on other more productive activities. A policy where the households' characteristics can be used in the initial face of the program is thus more likely to succeed and help the poor to increases their well-being and benefit them in the long-run. The importance of training is also emphasised as an important element when designing similar programmes.

The Girinka program does not target the poorest households, since they lack economic ability to take care of livestock. One way to achieve ability among the poorest would be to distribute smaller ruminants, such as goats and sheep, as a first stage into the Girinka program. Distributing goats, specifically dairy goats, has proven more successful than dairy cattle when distributed to the poor, although such effects are not yet well documented in literature, an exception being Klapwijk et al. (2014). Since the focus of the present paper is on the effects associated with the Girinka program, we are unable to address the poorest parts of the population. The results further add to the literature on transaction costs present in the rural economy (e.g., Dillon and Barrett, 2017), as they show that locational attributes are key factors for economic development.

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Appendix A

Table A1. Variable definitions

Variables	Definition
Consumption	Real consumption adjusted for poverty and spatial and temporal variations in prices (100=2014).
Crop production	Estimated value of total annual crop production (100=2014), estimated by household, divided by the number of hectares of land.
treated	Dummy equals 1 if the household received a cow 2010-2014 through Girinka; zero if the household never received a cow through Girinka.
treated × livestock	Interaction dummy. Treated (equals 1 if the household received a cow 2010-2014 through Girinka) multiplied by Livestock (the total number of livestock owned by the household).
treated × land	Interaction dummy. Treated (equals 1 if the household received a cow 2010-2014 through Girinka) multiplied by Land (number of hectares of land owned by the household divided by number of household members).
Size	Number of household members.
Age	The age of the household head
Gender	Dummy equals 1 if the head of the household is female.
Higher education	Share of household members that have higher education (above secondary, university or advanced secondary).
Savings	Total annual household savings in real terms (100=2014).
Credit	The amount, cash value, of credit (100=2014).
Remittances	The amount, cash value, of remittances (100=2014).
Internet access	Dummy equals 1 if the household has access to internet through mobile phone or wireless network.
Land	Number of hectares of land owned by the household divided by number of household members.
Fertilizers	The total number of expenditure on improved seeds, chemical fertilizers and pesticides.
Livestock	The total number of livestock (cattle, goats and other smaller rudiments) owned by the household.
Distance road	Distance in minutes from the house to the nearest all weather road, estimated by household.
Industrial diversity	The diversity of industries in the district calculated using ISIC codes and with respect to the number of employees (equation 9).
Province	Dummy variables indicating in which province the household is located (Kigali City; North province; South province; East province; West province).

Appendix B

Table B1. Results of the matching algorithms using Coarsened Exact Matching.

	L1	mean	25 %	50 %	75 %
Algorithm 1[a]					
Province	0.064	0.064	0	0	0
Poverty[c]	0.004	0.004	0	0	0
Savings	0.063	5.6e+05	0	0	6.5e+05
L1 (Pre-match imbalance) test	0.898				
Multivariate L1 distance (post-match): 0.187					
Algorithm 2[b]					
Province	0.065	0.065	0	0	0
Poverty[c]	0.004	0.004	0	0	0
Savings	0.054	-4.9e+05	-0.048	-0.096	0.431
Land	0.097	0.179	0	0	0
Livestock	0.196	0.799	0	1	1
L1 (Pre-match imbalance) test	0.884				
Multivariate L1 distance (post-match): 0.754					

Note: Using the scott break method for imbalance.

[a] Number of strata=9, number of matched strata=8.

[b] Number of strata=28, number of matched strata=8.

[c] The poverty categories used in the matching are based on estimates of poverty using household annual consumption expenditures to proxy monetary poverty into the following three categories; non-poor; poor and extremely poor (NISR, 2016). Households that fall in the categories poor and extremely poor have a level of consumption expenditure that is below 159375 Rwandan Francs. Households that are extremely poor have consumption expenditure that is below 105064 Rwanda Francs, in constant January 2014 prices.

Table B2. Number of matched and unmatched observations

	0	1
Algorithm 1		
All	3690	122
Matched	3689	122
Unmatched	1	0
Algorithm 2		
All	3690	122
Matched	3660	121
Unmatched	30	1

Appendix C

Table C1. Results of robustness tests

	treated	Obs.	R square	w_i	Matching algorithm[a]
1. Basic results (specification D in Table 3)	0.78*	3777	0.63	Yes	1
	(0.21)				
2. Exclude urban households	0.75*	3039	0.61	Yes	2
	(0.20)				
3. Village effect	0.79*	3777	0.65	Yes	1
	(0.22)				
4. 1% trim of dependent variable	0.75*	3399	0.63	Yes	2
	(0.19)				

Notes: Dependent variable; the log of crop production. * denote statistical significance at the 5 percent level or lower. See Table B1 in Appendix B for estimation results of the matching algorithms.