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Abstract: This paper studies the effects of land use consolidation on consumption growth of farm households in Rwanda. Data on 1 920 households, observed in two time periods, are used to estimate a first-differenced model using an instrumental variables estimator, which allow the analysis to account for selection bias and placement effects. Results show no significant effect of land use consolidation on consumption growth and the results are robust to changes in model specification and estimation method. Rather, the results point to the importance of factors such as education, rural infrastructure and market linkages in the consumption growth process. These results highlight the need to consider that alternative public investments, that reduce households' transaction costs, may be better able to target rural farmers that operate under conditions such as land scarcity, high population pressure and high risk linked to rapidly changing climate conditions.

Keywords: land consolidation; consumption; Rwanda; first-difference
JEL codes: Q15; Q18; O12

1. Introduction

Improving the productivity of the agricultural sector is often seen as an important mean to obtain poverty alleviation and improved food security in developing countries (Johnston and Mellor, 1961; Kurosaki 2003). This stems from the fact that most poor households live in rural areas and depend on agriculture for their survival, combining small scale food cropping and livestock with a diverse set of agricultural related activities. This is particularly true in Rwanda where 80 percent of the population live in rural areas and have agriculture as their primary source of income and where rural poverty is estimated to be almost three times as high as urban, 44 percent vs. 16 percent (Pritchard, 2013). The common view that agricultural growth leads to rural development and poverty reduction has motivated public investments with the aim to create the necessary conditions for improved agricultural productivity. In Rwanda, owing to limited land resources and demographic pressure, land use consolidation and subsidized inputs (e.g., chemical fertilizers, irrigation and improved seeds) have been introduced in the framework of the on-going Crop Intensification Programme (CIP). The basic idea is that the farmers synchronize the cultivation of one crop per consolidated plot to form larger and more efficient holdings, which should lead to an increase of production and food security.

From the start of Asia's Green Revolution, there is ample evidence that investment induced agricultural growth, through crop intensification and land consolidation, has been important for rural poverty reduction and aggregate incomes in many parts of the developing world (Timmer, 1997; Rae and Zhang, 2009; Dethier and Effenberger, 2012). However, this evidence tends to apply to developing regions that have favorable agroecological conditions and a high share of irrigated land. Considerable concern remains about the importance of such investments for poverty reduction in the context of sub-Sahara where small scale farmers depend on rain fed agriculture and face high risk and uncertainty linked to external shocks via rapidly changing climate conditions (Tilman et al., 2002; Dorward et al., 2004; Ali et al., 2014). Under such conditions, less is known of the extent to which land use consolidation can benefit the average small farmer and there is a need for further studies that address these issues on wealth indicators at the level of households. Blarel and Bruce (2001), for instance, argue that land use consolidation programs tend to overlook the benefits associated with land fragmentation and that diversified farming practices are often coupled with a greater degree of flexibility and better management of risk and seasonality. Bizoza and Havugimana, (2013) focus on Rwanda and emphasize that mixed cropping should have some advantages, especially for small scale farmers, as it allows them to avert risks and bridge agricultural seasons in terms of food availability.

Assessing the impact of policies for agricultural growth on welfare indicators, such as consumption growth, is challenging for several reasons. Better skilled farmers are more likely to seek the possibility to take part of such opportunities, which can give rise to selection bias. There is also the possibility that the assignment of agricultural programs may not be randomly dispersed, but concentrated to better endowed areas or larger farms, which can give rise to placement effects. If these effects are not accounted for, it may lead to misleading conclusions on the importance of such policies for consumption growth (Dercon et al., 2009). The empirical approach to handle confounding factors is to use the Integrated Household Living Conditions Survey (EICV) of 2010-2011 and 2013-2014, and the sub-sample of the 1 920 households that were observed in both surveys. Having access to survey data that follow the same households allows the analysis to control for latent household-specific factors by applying the first-difference estimator. The empirical model also considers the potential endogeneity caused by unobserved heterogeneity linked to external conditions by applying an instrumental variables (IV) estimator using a set of exogenous agroecological indicators as instruments for programme participation.

The second part of the paper outlines the applied model of consumption growth and discusses its relevance for the present purpose. This is followed by an overview of the data and summary statistics of some key facts observed in the data. The fourth part present the results and discusses their relevance in relation to theory and prior literature. The fifth part concludes by discussing the implications of the results for policies aimed to reduce poverty and improve food security in Rwanda.

2. Theoretical and empirical framework

The basic idea of this paper is to assess if land consolidation and the use of improved agricultural inputs leads to poverty reduction and increased food security among farm households. For this purpose, the paper adopts a micro model of consumption growth inspired by studies such as Jalan and Ravaillon (2002), Dercon et al. (2009) and Islam and Maitra (2012), who studied the role of external shocks, rural infrastructure and other locational and household specific factors on consumption growth in the context of developing countries.[1] Using consumption growth to indicate material wealth follows the argument that income likely underestimates the material wealth of households in the context of developing countries (Deaton and 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 and Katz, 1991). These temporary fluctuations do not necessarily reflect changes in wealth with the implication that current consumption should be a more reliable measure to capture long-run changes, compared to current income (Meyer and Sullivan, 2003). Consequently, given that consumption expenditure is adjusted for changes in the cost of living across space and time (Jalan and Ravallion, 2002), it should provide a reliable indicator of poverty reduction and food security, which can be used to assess the overall goals of the CIP 2008 strategic plan for agricultural transformation in Rwanda.

The empirical framework of this paper is based on a random sample of N households observed in two time-periods $(T = 2)$, which result in a balanced panel with 8340 observations. Having access to information about the degree of program participation for a set of households observed in two time periods enables an empirical model in which household consumption depends on unobserved time-invariant and time-varying factors, this can be written as:

$$c_i = \beta_0 + \gamma_0 d2_t + \beta_1 X_{it} + Z_i + \varepsilon_{it} \tag{1}$$

[1] There is also a substantial literature on the importance of agriculture in the growth process and on the contrasting views on the relative importance of the measures appropriate to spur economic development. For brevity, this paper does not review this literature since recent comprehensive reviews on the debates can be found in Dorward et al. (2004), Diao and Hazell (2010), Jayne et al. (2010) and Dethier and Effenberger (2012).

where c_i denote consumption of household i, Z_i denote fixed characteristics of the household, and X_{it} denote a vector of time-varying factors that reflect programme participation. Moreover, $d2_t$ denote a time dummy and $Z_i + \varepsilon_{it}$ is the composite error term. In this setting, the first-difference approach provides a method to handle correlated unobserved heterogeneity and the two-period data can be rewritten as (see e.g. Liker et al., 1985):

$$c_{i2} = (\beta_0 + \gamma_0) + \beta_1 X_{i2} + Z_i + \varepsilon_{i2} \quad \ni \quad t = 2 \tag{2}$$

$$c_{i1} = \beta_0 + \beta_1 X_{i1} + Z_i + \varepsilon_{i1} \quad \ni \quad t = 1 \tag{3}$$

First-differencing yields:

$$(c_{i2} - c_{i1}) = \gamma_0 + \beta_1 (X_{i2} - X_{i1}) + (\varepsilon_{i2} - \varepsilon_{i1}) \tag{4}$$

$$\Delta c_{i2} = \gamma_0 + \beta_1 \Delta X_{i2} + \Delta \varepsilon_{i2} \tag{5}$$

where the unobserved fixed effect Z_i in (2) and (3) is differenced away in (5) and assumed uncorrelated with the observed variable $E(Z_i X_{i2} = 0)$. Given the assumption that ε_{i2} is uncorrelated with ΔX_{i2} (which holds if ε_{it} is uncorrelated with ΔX_i in both time periods), the first difference method allows for consistent estimation of the effect of program participation (β_1). Hence, should there be any selection bias resulting from time-invariant factors, equation (5) should address this.

As discussed, there are additional confounding factors that could violate the assumption of strict exogeneity. One issue concerns placement effects e.g., if the assignment of agricultural programs is not randomly dispersed, but concentrated to larger farms and better endowed areas. There are several reasons to be concerned about such effects in the context of Rwanda. Cioffo et al. (2016) show that the increase in agricultural production that is attributable to the CIP apply to medium and large farms that have the possibility to invest in capital intensive agricultural techniques. Based on what has emerged from the previous literature, it also seems like the CIP have varying impact on agricultural productivity across districts and that subsidized inputs are provided in greater supply to those districts that have better agricultural potential (Bizoza and Havugimana, 2013). Should these program placement effects not be accounted for, estimates will be biased (Robins et al., 2000).

Over the three-year period that households are observed, it is also reasonable to expect that consumption may change because of household-specific factors. For example, if household members become more educated or if the household is accumulating assets through credit and/or remittances (via social ties or migrated family members (Bigsten, 1996)). They could also improve their connectivity via more extended use of ICT or via improved access to markets through better roads (Smith et al., 2001). These factors lower transaction costs and information barriers and provide access to financial capital (Ellis, 2000). The diversity of industries present in an area should also assists households to gain ideas, skills and information which increases their capacity to accumulate wealth by taking part of nonfarm income generating activities (Jalan and Ravaillon, 2002; Ali and Peerlings, 2011). These correlations are addressed by including time-varying household characteristics, time-invariant local conditions, and by applying an instrumental variables (IV) estimator using a set of agroecological indicators as instruments for programme participation in the following:

$$X_{it} = \alpha_0 + \rho A_{it} + \varepsilon_{it} \tag{6}$$

$$\Delta c_{i2} = \gamma_0 + \beta_1 \Delta\rho\widehat{X}_{i2} + \beta_2 \Delta I_{i2} + \beta_3 E_{it-3} + \Delta\varepsilon_{i2} \tag{7}$$

Where A_{it} in the first-stage equation (6) denotes agroecological factors and I_{i2} and E_{it-4} in (7) denote household-specific factors and initial locational controls. The theoretical motivation for including a set of agroecological factors as instruments (precipitation, temperature and altitude) is that they should be exogenous to the market, but likely important in the production process. One concern is that there are backward and forward linkages between the agricultural and the non-agricultural sector (Haggblade et al., 2010). Higher output from agriculture could bring benefits to the non-farm sector by stimulating demand for production inputs, consumer goods and opportunities for trade. It is thus possible that areas with better agroecological conditions could have greater prospects for non-farm growth. The causal chain is difficult to unravel, but controlling for the share of household non-farm income could address this potential bias. Another concern is that local conditions may not be time-invariant as indicated in (7). Given the fact that local and regional variables are often semi-fixed, changes slowly over time, treating them as time-invariant should still capture the locational characteristics in focus, and more importantly their relative importance. In addition, the variables that can be used to measure such conditions are typically only available from population or enterprise surveys which are done infrequently, implying that the only option at hand is to treat external local conditions as time-invariant (Jalan and Ravallion, 2002).

3. Data and variables

The household-level data are obtained from two rounds of the Integrated Household Living Conditions survey (EICV) done by the National Institute of Statistics in Rwanda (NISR). The most recent EICV, conducted in 2013/14, is combined with the earlier survey, performed in 2013/14. This is a nationwide survey that collect welfare indicators of a random sample of around 14 400 households across Rwanda, with considerable efforts made to ensure representativeness trough stratification and weighting (Howe and McKay, 2007). The data used for the empirical analyses include only those 1 920 households that were included in the 2010/11 EICV and was revisited in the subsequent survey in 2013/14. The sample of panel households were 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 (NISR, 2016). The questionnaire remained essentially the same in the two surveys, and the calculation of consumption was done consistently and with respect to subgroup (depending on poverty), time, and the place of residence (urban/rural), which follows the procedure used in previous literature (e.g., Ravallion, 2004). The dependent variable is defined as real consumption adjusted for the spatial and temporal differences in the cost of living and summary statistics (Table 1) show that the average real consumption has increased by 13 percentage points, from 340 thousand Rwandan francs in 2010/11 to 384 in 2013/14. Based on this estimate of consumption, the share of the population whose total consumption is below the total poverty line (159 375 Rwandan francs), that is, the share of the population that are classified as poor, is 28 percent in 2013/14 compared to around 38 percent in 2010/11 (Table 1).

Table 1. Average consumption. Summary statistics from the EICV surveys

	2010/11	2013/14
Average real consumption	340	384
Percentage poor	37.8	28.2
Sample size	1 920	1 920

Note: Average real consumption is reported in thousand Rwandan francs and January 2014 prices. Detailed summary statistics are reported in Table A1 in appendix A.

3.1 Independent variables

Summary statistics for key variables are presented in Table 2 and show signs of the structural constraints to poverty reduction discussed in the introduction e.g., decreasing per capita land area, coupled with population growth. Average per capita land holdings are less than 1 hectare (in 2010/11) and decreasing, while the population continues to grow at an average annual rate of around 2.5 percent (NISR, 2016). The key feature of these data for the present purpose is that they contain information about land consolidation and the amount of household expenditure on improved inputs. Summary statistics show that the average number of land plots of each household that is in consolidation has increased from 0.39 plots to 0.42 from 2010/11 to 2013/14. The adoption of improved water management (irrigation) and efforts to soil conservation (protection against erosion) tend to be coupled with consolidated lands and larger farms, since it is labor intensive to construct such infrastructures for small and fragmented land holdings (Bizoza and Havugimana, 2013). A variable indicating the number of plots that are protected against erosion is therefore included. Average real expenditure on fertilizers has increased from 4500 Rwandan francs to 8000, but expenditure on improved water management (irrigation) is indicated to be low. Expenditure on improved seeds has declined slightly, which may be due to changing input requirements of households due to changing crop patterns or agricultural techniques, as well as to changes in the supply. The EICV surveys does not capture information that would allow identification of the reasons for the change.

Table 2. Programme participation. Summary statistics from the EICV surveys

	2010/11	2013/14
Per capita land area	0.99	0.83
Land lots in consolidation	0.39	0.42
Land lots protected against erosion	2.7	2.3
Expenditure on improved inputs		
Chemical fertilizers	4.5	8.0
Irrigation	0.03	0.04
Improved seeds	1.4	1.0
(Total expenditure on inputs	6.27	9.0)

Note: Expenditure is reported in average real expenditure in thousand Rwandan francs and January 2014 prices. Detailed summary statistics are reported in Table A1 in appendix A.

One issue is that these data do not inform about the quality or the source of the inputs. Given the data at hand, it is not possible to observe the quality of the subsidized fertilizers or the seed varieties, which could lead to measurement error and misleading conclusions on their importance in the production process. However, fertilizers have been shown to be more effective for some of the priority crops grown in certain districts (Cioffo et al., 2016), controlling for the presence of intra-cluster correlation using districts could thus capture part of this variation. In addition, there are perspectives of the CIP that are difficult to address with these data, such as households access to extension services and the social and environmental dimensions of the programme. Having these limitations in mind, the underlying assumption of the CIP is that land consolidation should lead to economies of scale in production and that the improved inputs, supplied at subsidized prices, should improve the impact of households` expenditures on such inputs for crops production, which should lead to poverty reduction and improved food security.

3.2 Household and locational controls

Table A1 in Appendix A display summary statistics for the household and locational control variables and for the climate and altitude variables used as instruments. The selection of individual household controls and their definitions broadly follows the approach of prior literature and are hypothesized to improve households' capacity to improve their wealth as they lower transaction costs and information barriers and provide access to financial capital (Ellis, 2000; Abdulai and CroleRees, 2001; Smith et al., 2001). These include measures of human capital (education and age), asset endowments (e.g., ownership of means for communication and transportation), access to capital through credit and remittances and agricultural assets (e.g., per capita landholdings and livestock).

Besides household–specific factors, there are also external factors that may influence households' consumption growth, such as access to urban areas and to diversified economic environments (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). Clustering of local nonfarm firms that encourage the diffusion of knowledge and information should also assists households to gain ideas, skills and information which increases their capacity to take part of nonfarm income generating activities (Ali and Peerlings, 2011). To include 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):[2]

$$D_r = \sum_{g=1}^{G} E_g lnE_g \quad (8)$$

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 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.[3] The data used to calculate the diversity measure comes from the Establishment census of 2010, implying that it reflects initial conditions. The advantage of combining the household EICV data with this establishment survey that the data sources are largely independent, which can mitigate concerns about correlated measurement errors when aggregating survey data from relatively small samples. Lastly, three variables are included to instrument for program participation measured as the average change in temperature and precipitation measured over the last 10-year period (to capture district level variations in climate conditions) and altitude (to capture district level variations in soil quality and prerequisites for crop production).

4. Results

The results from estimating (7) are reported in table 3 in the last two columns. The results in the first column are from estimating the first-differenced equation excluding the IVs, which are displayed for comparison. All estimations have growth in consumption as the dependent variable and include household and locational controls. For brevity, the results of some of the most relevant control variables are included in Table 3 and are discussed, whereas the remaining controls are reported in Table C1 in Appendix C.[4]

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[2] 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).

[3] The measure is calculated using the district level as reference, which is the key administrative and political unit in Rwanda.

[4] Variables are transformed to correct for heteroscedasticity and summary statistics of the transformed variables are presented in Table B1 in Appendix B and a correlation matrix for the transformed variables is displayed in Appendix D.

The results show that out of the variables that reflect land consolidation and households' expenditure on improved inputs, it is only improved seeds that is positively and significantly related to consumption growth when it is treated as endogenous.[5] The use of chemical fertilizers is positively and significantly related to consumption growth, but only when the instruments are excluded. The test statistics indicate that the instruments, reflecting agroecological conditions (temperature, precipitation and altitude), are good in the relevance sense. The Sargan-Hansen overidentification test shows that the null, that instruments can be excluded from the second stage regression for consumption growth, cannot be rejected. Given that this test tends to over-reject the null in the presence of intra-cluster correlation (Baum et al., 2003), the model (7) is estimated correcting for such correlations by clustering on both districts and agroecological zones. These results are presented among the other robustness tests in Table 5 (row 2 and 3) and show no real difference to the results.

Taken together, these results lend little support to the idea that land consolidation leads to consumption growth for farm households in Rwanda. Rather, they are supportive of the view that land use consolidation and its tendency towards monocropping may not necessarily be the most optimal choice under conditions of land scarcity, high population pressure and high risk linked to changing climate condition (Blurel et al. 1992), which is the situation facing farm households in Rwanda. Results could also suggest, but do not prove, that land fragmentation could be beneficial from the perspective of the household, as it is associated with a greater degree of flexibility and therefore better management of risk and seasonality (Blarel and Bruce, 2001). Results are quite in line with what has emerged from the previous literature for Rwanda, emphasizing that agricultural intensification may not be a one-size-fits-all solution for poverty reduction and alternative investments that are better able to target the rural poor may be required (Huggins, 2014; Cioffo et al., 2016).

[5] Since the estimations automatically drops all the observations that report missing values for agricultural variables (e.g., land, livestock), the estimated sample include only farm households. This implies that X households are excluded in the regressions, most notably those in Kigali City that rely on other income generating activities (e.g., public sector employment, service and manufacturing).

Table 3. The impact of land use consolidation on consumption growth of farm households

	FD (1)	FD-IV (2)	FD-IV (3)
	Coeff. (Std.Err)	Coeff. (Std.Err)	Coeff. (Std.Err.)
Consolidation	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)
Irrigation	0.01	– 0.00	– 0.00
	(0.02)	(0.02)	(0.02)
Chemical fertilizers	0.01***	0.00	0.01
	(0.00)	(0.00)	(0.01)
Improved seeds	0.02***	0.01**	0.02***
	(0.00)	(0.00)	(0.00)
Control variables			
Share primary edu.	0.16*	0.11	0.02
	(0.08)	(0.10)	(0.10)
Share secondary edu.	0.38**	0.42**	0.42**
	(0.15)	(0.17)	(0.18)
Share higher edu.	0.69***	0.67***	0.69***
	(0.13)	(0.14)	(0.14)
Credit	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.02)
Remittances	0.01***	0.02***	0.02***
	(0.00)	(0.00)	(0.00)
Distance all weather road	– 0.01***	– 0.02***	– 0.01***
	(0.00)	(0.00)	(0.00)
Industry diversity	0.86***	0.63***	0.65***
	(0.16)	(0.26)	(0.26)
Additional household controls[a]	Yes	Yes	Yes
Province dummies	Yes	Yes	Yes
F-value	51.11	–	–
Sample size	3069	3069	3169
R-squared	0.48	0.37	0.45
Sargan-Hansen	–	0.00	0.00

***, **, and * denote statistical significance at the one, five and ten percent level respectively. Dependent variable: the log of real consumption adjusted for spatial and temporal differences in the cost of living. Heteroskedasticity-robust standard errors in parentheses. [a] Results of additional household control variables reported in Appendix C. FD (1) report the results from estimating a naïve first-difference model excluding the IVs; FD-IV (2) reports results when consolidation is treated as endogenous and instrumented by agroecological variables (average temperature, average rainfall and altitude); FD-IV (3) reports the results when improved seeds is treated as endogenous and instrumented by agroecological variables.

Turning to the household-level predictors reported in Table 3, most of the variables follow what is expected based on theory and findings of prior comparable studies in the context of sub-Sahara. Education is positively associated with consumption growth and is indicated to be one of the most important determinants of consumption growth, particularly after secondary schooling has been reached (Nilsson, 2017). A simple F–test for the significance of the educational variables show that the null cannot be rejected, indicating that differencing has solved the endogeneity concern (e.g., the skill–bias). This follows the approach in Felbermayr and Jung (2009) and is carried out by excluding one or several of the educational variables in the first-differenced equation followed by a F–test for significance of these included variables. Results also lend support to the importance of rural infrastructure (distance to all weather roads) as there is a consistent negative and significant relation to consumption growth. This result is in line with Dercon et al. (2009), who found that public investments that lead to improvement in road quality increases consumption growth in rural Ethiopia. The consistent positive relationship between a higher initial industrial diversity and consumption growth is also interesting as it indicates that diversity generate spillovers (plausibly through knowledge and information flows) to households in the surrounding geography. However, one should be cautious in taking the result of geographical factors at face value since these could also pick up the potential endogeneity due to people choosing their locations, which cannot be ruled out in the context of Rwanda.

4.1 Robustness tests

Table 4 presents the results from a series of robustness tests performed to test if changes in model specification or sample affect the results. One issue is that there may be omitted geographical factors that influence the placement and design of governmental programs. Land consolidation is a part of the CIP which is implemented at the district level, the main political administrative units in Rwanda. To address if unobserved correlations linked to economic, political or environmental factors linked to district belonging influences the results, the model (7) is estimated with the cluster-robust option using districts and agroecological zones. These results are presented in row two and three in Table 4 and show no difference to the main results. Another issue concerns 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.[6] Further analyses in this direction is prevented by the

[6] 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.

relatively small sample size of farm households located in urban areas, but the model is estimated excluding urban households to examine if this influences the results. Comparing these results with the ones presented and discussed above, the conclusion is that the results are robust. The set of robustness analyses also explores how sensitive the results are to outliers and reports (row five) the results of 1 percent trim of the dependent variable. Row six report the results from including a dummy variable to indicate if the household has experience an external weather shock during the last twelve months. External shocks can give rise to correlated error terms due to time-specific factors, as shown by several studies (e.g., Rodrik, 1999). Results are in line with those presented and discussed above, indicating that these potential problems are not a significant concern.

Table 4. Robustness tests and summary of main findings. Dependent variable; growth of real consumption

Robustness tests	Consolidation	Chemical fertilizers	Improved seeds	Higher education	Distance all weather road	Industry diversity
1. Basic results FD-IV (3)	0.01	0.01	0.01***	0.69***	– 0.01***	0.65***
	(0.01)	(0.01)	(0.00)	(0.14)	(0.00)	(0.26)
2. Cluster-robust standard errors	0.01	0.03	0.01***	0.55***	– 0.02***	0.46***
(agroecological zone)	(0.02)	(0.04)	(0.00)	(0.11)	(0.00)	(0.10)
3. Cluster-robust standard errors	0.01	0.02	0.01***	0.55***	– 0.01***	0.46***
(district)	(0.02)	(0.02)	(0.00)	(0.11)	(0.00)	(0.10)
4. Include only rural households	0.01	0.01	0.02***	0.55**	– 0.03***	0.56***
(n=2639)	(0.01)	(0.01)	(0.00)	(0.11)	(0.00)	(0.19)
5. 1% trim of dependent variable	0.01	0.01	0.01***	0.55***	– 0.01***	0.64***
	(0.01)	(0.03)	(0.00)	(0.10)	(0.00)	(0.19)
6. Include external weather shocks	0.01	0.01	0.01	0.53**	– 0.02***	0.67***
	(0.01)	(0.04)	(0.01)	(0.11)	(0.00)	(0.16)

***, **, and * denote statistical significance at the one, five and ten percent level. Basic results (1) are reported for comparison; (2) reports results from estimating FD-IV (3) with the cluster-robust option using agroecological zones; (3) reports results with cluster-robust standard errors using districts; (4) reports results from estimating FD-IV (3) including only those households located in rural areas; (5) report the results from a one percent trim of the dependent variable (excluding 45 observations); (6) report the results from including a dummy variable that indicate if the household was negatively affected by a weather shock during the last twelve months.

5. Conclusions

This paper address the role of policies that aim at agricultural intensification for consumption growth in Rwanda. While most previous studies on this topic focus on farm households in developing regions that have favourable agroecological conditions, this paper argues that there are reasons to consider the extent that such investments may benefit farm households in the context of sub-Sahara. This stems from the view that land use consolidation and its tendency towards monocropping may not be beneficial for smallholders under conditions of land scarcity, high population pressure and high risk linked to changing climate conditions (Blarel and Bruce, 2001; Blurel et al. 1992). To test the empirical relevance of the arguments this paper uses household-level data from the Integrated Household Living Conditions Survey (EICV) of 2010-2011 and 2013-2014, and the sub-sample of the 1 920 households that were observed in both surveys. Having access to data that follow the same household over time allows the analysis to apply the first-difference estimator and control for latent household-specific factors. The empirical approach is to apply an instrumental variables (IV) estimator using a set of exogenous agroecological indicators to instrument programme participation.

Results show no support for the importance of land use consolidation for consumption growth. Of the variables that are used to indicate households' involvement in land consolidation and their usage of improved inputs, it is only improved seeds that is positively and significantly related to consumption growth when it is treated as endogenous. These results are robust to changes in model specification and estimation method. Results also point to the importance of education, rural infrastructure and market linkages for households' consumption growth. These findings support the view of prior studies emphasizing that for those locations where external conditions limit households' ability to increase agricultural productivity, public investments that reduce households' transaction costs may hold greater potential for poverty reduction (Renkow et al., 2004).

Although the results in this study are consistent with the idea that land use consolidation may not be a one-size-fits-all solution for poverty reduction, there are some data limitations that needs to be considered when interpreting the results concerning households' expenditure on improved inputs. As discussed, the analysis cannot control for the quality of the subsidized inputs, which could give rise to measurement errors. In the absence of data that could offer means to control for this, it is difficult to know if the results are reflective of low quality or lack of input supply in the local communities. In this respect, this study opens for further studies that attempts to disentangle these effects.

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Appendix A

Table A1. Summary statistics, raw data

	N	Mean	SD	Minimum	Maximum
Consumption	3840	362 157	631 676	10 951	18 594R
Consolidation	3840	0.41	1.08	0	12
Expenditure on inputs					
Irrigation	3840	35.19	544.40	0	20 000
Fertilizers	3840	6238	42 151	0	2 223R
Improved seeds	3840	1201	8298	0	192 000
(Total expenditure on inputs	3840	7671.0	27589	0	498000)
Household controls					
Share primary edu.	3840	0.09	0.18	0	1
Share secondary edu.	3840	0.04	0.11	0	1
Share higher edu.	3840	0.02	0.18	0	1
Size household	3840	4.70	2.22	1	22
Share adults (17-59)	3840	0.53	0.24	0	1
Assets	3840	41.73	30.34	5	560
Credit	3840	308.431	3 158R	0	150 000R
Remittances	3840	30 065	193 041	0	8 681R
Land	3840	0.91	2.95	0	132
Livestock	3840	141 068	621 809	0	28 851R
Lots protected against erosion	3840	2.49	2.61	0	22
Share non-farm income	3840	0.13	0.27	0	1
Distance all weather road	3840	6.68	9.34	0	99
Internet (phone)	3840	0.08	0.27	0	1
Internet (wireless)	3840	0.02	0.15	0	1
Locational controls					
Industry diversity	3840	2.26	0.37	1.58	2.87
Kigali City	3840	0.24	0.42	0	1
Northern province	3840	0.14	0.34	0	1
Eastern province	3840	0.19	0.39	0	1
Western province	3840	0.19	0.39	0	1
Southern province	3840	0.24	0.42	0	1
Instruments					
Altitude	3840	1683	265.45	1078	2393
Precipitation[a]	3840	0.36	1.35	-0.27	5.67
Temperature[b]	3840	25.17	2.76	15.56	27.87

Note: R denote in thousand Rwandan francs and January 2014 prices. [a] Calculated as the average annual change in precipitation in the district over the period 2000-2010. [b] Calculated as the average annual change in temperature in the district over the period 2000-2010.

Appendix B

Table B1. Summary statistics of transformed variables

	Mean	SD	Minimum	Maximum
Consumption (log)	12.36	0.819	9.30	16.73
Total expenditure on inputs (cube root)	4.13	5.13	0	26.56
Size household (log)	1.42	0.53	0	3.09
Assets (log)	3.56	0.57	1.60	6.32
Credit (cube root)	10.04	10.73	0	115.88
Remittances (cube root)	5.85	6.91	0	54.28
Livestock (cube root)	10.37	10.47	0	73.28
Industry diversity (log)	0.81	0.16	0.46	1.05

Appendix C

Table C1. Regression results; additional household controls

	FD (1)	FD-IV (2)	FD-IV (3)
Size household	– 0.57***	– 0.55***	– 0.55***
	(0.03)	(0.04)	(0.04)
Assets	0.38***	0.37***	0.37***
	(0.03)	(0.04)	(0.03)
Land	0.02**	0.03*	0.03*
	(0.00)	(0.02)	(0.02)
Livestock	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)
Share adults (17-59)	0.03	0.10	0.09
	(0.06)	(0.09)	(0.09)
Share non-farm income	0.31***	0.33***	0.33**
	(0.06)	(0.07)	(0.07)
Internet (phone)	0.48***	0.54***	0.53***
	(0.08)	(0.10)	(0.09)
Internet (wireless)	0.92***	0.79***	0.80***
	(0.22)	(0.26)	(0.26)
Province dummies			
Kigali City	– 0.49***	– 0.65***	– 0.63***
	(0.16)	(0.22)	(0.21)
Northern province	– 0.35***	– 0.38***	– 0.38***
	(0.11)	(0.12)	(0.12)
Eastern province	0.09	0.16	0.15
	(0.12)	(0.14)	(0.21)
Western province	– 0.08	– 0.08	– 0.08
	(0.08)	(0.08)	(0.08)
F value	47.87	-	-
R square	0.48	0.37	0.39
Observations	3069	3069	3069

***, **, and * denote statistical significance at the one, five and ten percent level respectively. Heteroskedasticity-robust standard errors in parentheses.

Appendix D

Table D1. Correlation matrix of transformed key variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Consumption	1.00													
2. Consolidation	-0.02	1.00												
3. Irrigation	0.02	0.07	1.00											
4. Chemical fertilizers	0.07	0.09	0.11	1.00										
5. Improved seeds	0.03	0.15	0.14	0.10	1.00									
6. Protection erosion	-0.15	0.29	0.03	0.11	0.08	1.00								
7. Share primary edu.	0.17	-0.00	0.01	0.01	-0.02	-0.08	1.00							
8. Share secondary edu.	0.19	-0.02	0.00	0.04	-0.01	-0.07	0.04	1.00						
9. Share higher edu.	0.46	-0.07	0.00	-0.01	-0.03	-0.18	0.03	0.06	1.00					
10. Dist. Road	-0.18	0.02	-0.01	0.01	0.06	0.13	-0.10	-0.07	-0.12	1.00				
11. Industry diversity	0.29	-0.20	-0.01	-0.04	-0.11	-0.39	0.23	0.16	0.27	-0.21	1.00			
12. Altitude	-0.17	0.18	0.01	0.11	0.12	0.27	-0.07	-0.05	-0.11	0.23	-0.18	1.00		
13. Precipitation	0.12	-0.25	-0.01	-0.09	-0.22	-0.27	0.06	0.06	0.11	-0.25	0.35	-0.72	1.00	
14. Temperature	-0.06	0.01	-0.02	-0.01	-0.01	0.02	-0.06	-0.03	-0.05	-0.05	-0.25	-0.18	0.19	1.00

Appendix E

Table E1. Variable definitions

Variable	Definition
Consumption	Average real consumption adjusted for poverty and spatial and temporal variations in prices (100=2014).
Consolidation	The number of land plots that are in consolidation.
Protection against erosion	The number of land plots that are protected against erosion.
Irrigation	Total real expenditure on irrigation (100=2014).
Chemical fertilizers	Total real expenditure on fertilizers (100=2014).
Improved seeds	Total real expenditure on improved seeds (100=2014).
Size household	Number of household members.
Share primary edu.	Share of household members that have completed primary education.
Share secondary edu.	Share of household members that have completed secondary education.
Share higher edu.	Share of household members above 17 years that have completed higher education (university or advanced secondary).
Share adults (17-59)	Share of household members that are in the age of 17-59.
Assets	Principal component calculated w.r.t. households' ownership of assets (e.g., motorized vehicles, bicycle, computer etc.).
Credit	The amount, cash value, of credit (100=2014).
Remittances	The amount, cash value, of remittances (100=2014).
Land	Number of hectares of land owned by the household divided by number of household members.
Livestock	The value of the livestock estimated by households using current market prices (100=2014).
Share nonfarm income	Amount of income from non-agricultural activities (e.g., service, manufacturing and public sector employment).
Distance all weather road	Distance in minutes from the house to the nearest all weather road, estimated by household.
Internet (phone)	The number of household members that have access to internet through mobile phone.
Internet (wireless)	Dummy equals 1 if the household has access to internet through wireless.
Industry diversity	The diversity of industries present in the district calculated using ISIC codes and wrt. number of employees (Equation 8).
Province dummies	Dummy variables indicating in which province the household is located.
Altitude	Number of meters above the sea level (district).
Precipitation	Average annual change in precipitation (2000-2010) in district.
Temperature	Average annual change in temperature (2000-2010) in district.