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Effects of Population Growth on Smallholder Farmers' Productivity and Consumption in Rwanda: A Long-term Analysis

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The study investigates the impact of population growth on agricultural change, particularly on agricultural intensification, farm productivity and household welfare. We use a unique panel dataset that spans a 26 year-period, constructed from two waves of household surveys conducted in the northwest district of Rwanda (Nyabihu). The study finds much support for Boserupian land intensification hypothesis in the sample area. The results suggest that, demographic variables (such as household size) are highly associated with input intensity and agricultural productivity. However, the inverse correlation between family size and annual expenditure per capita warns for a sound population policy in the near future. In the long run, over intensive cultivation resulting from population pressure is likely to have decreasing effects on land productivity.

Keywords: Population growth; agricultural change; farm productivity; household welfare; smallholder farmers; Rwanda; Africa.

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1. INTRODUCTION

Over the past two and a half decades Rwanda has faced a number of economic shocks including the genocide which left over 800 thousand inhabitants dead in late 1994 [1-4]. As an agricultural based country, this has had a significant impact on agricultural production and economic growth in general. Today, the overall image of Rwandan post-war economic recovery is judged to be quite positive [5]. Nevertheless, despite considerable efforts by the government of Rwanda and the ongoing economic and political recovery from the devastating war and genocide, the rate of poverty is still high [6]. Little is known on the household responses to adverse income and demographic shocks stemming from the conflict in Rwanda [4]. But in order to paint an overall picture of household economic change, one must consider the households' behavior before and after the shock. McKay and Loveridge [7] found that the struggle to income recovery during the period 1995-2000 was accompanied by an increase in population, and has resulted in a decrease in land per capita, increase in inequality, and rural poverty.

The population of Rwanda has increased progressively from 6.3 million in 1986 to 10.5 million inhabitants in 2012 with a growth rate of 2.6 percent [8]. The rapid population growth in Rwanda has brought considerable changes in the agricultural systems such as a decrease and fragmentation in land holding, cultivation pushed on lands previously under pastures and forests, increased cultivation on rented land, and shortened periods of fallow [9]. This is likely to increase soil erosion and lower agricultural productivity. Farmers living in the areas subject to growing pressure on available land as a result of population growth (such as in Rwanda) need to adopt new appropriate land use and institutional arrangements that aim at economizing the scarce resources [10]. The 1993 sample from Rwanda showed that very few inputs were used, and that most farmers were relying on traditional techniques of cultivation and soil conservation, with simple tools like hoes and machetes [10,11].

Against this background, the purpose of this paper is to assess the mechanisms by which demographic changes in rural Rwanda affect agricultural practices and household welfare over time. The next sections are sequentially devoted to the theoretical background, conceptual framework, empirical strategy, data description, empirical results, and discussion.

2. LITERATURE REVIEW

From a macroeconomic point of view, the neoclassical growth theory [12] finds a negative correlation between population growth and per capita income. The model is built on fixed assumptions such that the rate of population growth, the rate of saving, and the rate of technological progress are constant and exogenously determined. Even though this was rejected by the endogenous growth theory which shows a strong positive correlation between population growth rate and per capita income [13], the evidence from 105 countries supported the neoclassical growth theory, and it is believed that a high growth rate in population leads to lower levels of income per capita in the long run [14].

Since the time of Malthus, there has been a long debate on how population growth affects land scarcity as well as the well-being of agrarian societies. The opposite arguments showed that the high population growth will, in the long run, give rise to higher standards of living through agricultural intensification and improved productivity [15,16], also referred to as "demographically induced change." Under the Boserupian optimistic view on the impact of population growth, a beneficial density-intensity development is expected regardless of possible diminishing well-being and environmental deterioration [17]. von Braun, de Haen [18] tested for Boserup effects in Rwanda and found significant support for it: productivity in agriculture increased with population growth. Similarly, evidence showed that farmers adapted to population growth by adoption of agricultural technologies such as fertilizer use and new crops in Nigeria [19]. Population growth was also found to increase the intensity of agricultural land use in Kenya and stimulate non-farm enterprises [20], and hence increase well-being.

However, the adoption of agricultural technology is also influenced by both a farm or a farmer's characteristics [21] and the institutional environment the farmers operates. These are also referred to as monetary incentives, physical incentives, wealth, and human capital incentives to invest in agricultural technology adoption and land conservation [9,11,22]. Literature also recognizes the role of institutional factors [23] and farmers organizations [24] to influence adoption of fertilizer and pesticides.

Most research presented above on this issue presents one important limitation of relying on one year "snapshots" of rural livelihoods [25] even though the socio-economic household characteristics are controlled for. Little was done to assess the relationship between population growth, and agriculture technical change with longitudinal data, which provide a great foundation for an assessment of economic changes over time. Doss [26] criticized researchers in agricultural technology adoption to use cross-sectional data to address issues that are fundamentally dynamic, and they are unable to account for the role of institutions, policy and infrastructure on technology adoption.

Recent findings also highlighted the positive impact of population density on input demand in Sub-Saharan Africa using panel data. For example Muyanga and Jayne [27] assessed the impact of rural population density on Kenyan smallholder agriculture and they found negative correlations between rising population densities and farm sizes and cultivated areas, but the same rising population densities contribute to land intensification and increased crop production per unit of land at least up to 550-600 persons per square kilometers. On the other hand the rural population density has a positive effect on fertilizer with a declining income effect in in Ethiopia [28], and it is associated with reduced farm size, lower agricultural wage rates, and high maize prices in Malawi [29].

In this study, we analyze the role of demographic composition among others factors affecting land intensification and agricultural productivity with evidence from Rwanda. We use panel micro data to assess the impact of family size on (1) agricultural intensification, (2) labor use per hectare, (3) net farm income per capita, and (4) per capita expenditure per capita as a measure of household welfare.

3. MATERIALS AND METHODS

3.1 The Framework

It is hypothesized that farmers adapt to population growth in order to avoid food shortages in the future [15,16,30,31]. The possible options include labor intensification in traditional agriculture (technology change) and labor migration. With little mechanization in developing countries, cultivators increase their productive capacities through larger inputs of labor in different farming activities. Traditionally, the increased labor force and intensity of land use and husbandry was the major channel of adaptation to population growth. Today, the traditional techniques are supplemented by industrial inputs (such as chemical fertilizers, pesticides and insecticides), improved seeds, tractors, irrigation, extension services, etc. [30]. The latter allow the use of all types of available land and higher yields to be obtained from the population-constrained agriculture.

According to Galor and Weil [32], the level of human capital of children of members of generation *t*, h_{t+1}, is an increasing, strict concave function of their education e_{t+1}, and a decreasing strictly convex function of the rate of technology progress from period *t* to period *t+1*, $g_{t+1} \equiv (A_{t+1} - A_t)/A_t$. This implies that, the higher the quality of children, the lower the adverse effect of technological progress.

$$h_{t+1} = h(e_{t+1}, g_{t+1}) \qquad (1)$$

Where $h(e_{t+1}, g_{t+1}$, $h_e(e_{t+1}, g_{t+1}) > 0$, $h_{ee}(e_{t+1}, g_{t+1}) < 0$, $h_g(e_{t+1}, g_{t+1}) > 0$, and $h_{gg}(e_{t+1}, g_{t+1}) < 0$. If the rate of technological progress between the two periods depends on the education per capita e_t of the working generation in period *t*, L_t , then

$$g_{t+1} \equiv \frac{A_{t+1} - A_t}{A_t} = g(e_t, L_t) \qquad (2)$$

Where for $e_t \geq 0$ and $L_t > 0$, $g(0, L_t) > 0$, $g_i(e_{t,}L_t) > 0$, $g_{ii}(e_{t,}L_t) < 0$, $i = e_t, L_t$

Hence, for large population size, the rate of technological progress between two times *t* and *t+1* is a positive and increasing function of the size of working generation and its level of education. The rate of technological progress remains positive even if the quality of labor is zero.

Smallholder farmers like any other human being are driven by rational behavior in adoption of new agricultural technologies. Being so, farmers drop traditional technology and adopt a new one if they expect additional output from it or anticipate the possibility of making gain [33]. Both farmers' attributes and access to financial, social and biophysical capital enhance farmers' perception about new agricultural technology. Guided by the rational behavior of profit maximization, the farmer decides to invest or not in one or more available agricultural technologies, subject to cost constraints. The expected outcomes from any adoption are principally increase in crop yields, hence increase in agricultural returns, and capital and labor savings when the adopted technology is capital-saving and labor-saving respectively.

3.2 Econometric Strategy

To assess the population effects on rural economic change over time, the following panel fixed effect model was selected to account for unobserved household heterogeneity:

$$Y_{it} = D_{it}\beta + X_{it}\delta + a_i + \mu_{it} \qquad (3)$$

Where Y_{it} is a vector of dependent variables, D_{it} a vector of household demographic composition, X_{it} is a vector of other socio-economic household characteristics, whereas β and δ , are parameters to be estimated, respectively. The term a_i is the household fixed effect, and μ_{it} is the idiosyncratic error term. The robustness check is carried out distinctively on intensification, farm productivity, and household welfare models, respectively.

3.3 Data Description

The data used in this paper comes from the two-wave household survey conducted in the northwestern and densely populated area of Rwanda. The first wave of data was collected in 1986 by the International Food Policy Research Institute during the study on agricultural commercialization under population pressure [18] and targeted 190 respondents randomly selected across five sectors [1]. The simple random sampling technique was used, based on a list of the farm households. This particular area was selected due to its high population density, and its proximity to Gishwati forest that constituted the major source of agricultural commercial-lization in that time. The second wave of data was collected by the author in 2012 and targeted the same households and their offspring which makes 364 respondents.

The tracing of original households and their offspring was easy using the household roster information from the 1986 survey. The roster contained necessary information about the household including the names of all members, their gender, age, and relationship with the household head. The identification code was useful to locate administrative sectors and cells inhabited. Once an original household was found, the existing head helped to locate individuals (on roster) who moved from the parent household to form their own since the previous survey. All split-off households residing in the study area and neighboring areas were traced and interviewed. In case the targeted households were not found (when destroyed, or completely moved of the area), we contacted their neighbors to help us locating them. The latter also informed us whether all members died, migrated to an unknown area, or exiled outside the country. 26 households (14% of the original sample) could not be traced. The annual attrition rate is 0.6[2] percent which is far below the attrition rates reviewed by Alderman, Behrman [34] among developing countries household surveys and proved not to be a problem to obtain consistent estimates.

Table 1. Number of original and split-off households

Interviewed households	1986	2012
Original sample	190	164
Split-off (offspring)	-	200
Total sample	190	364

Source: Author conception based on survey data.

The unique feature of the study dataset is that it followed both the original and split-off households during the second wave. This allowed constructing an extended families dataset, made of both original and split-off households. Therefore, the extended family (dynasty) is considered in this study, as the unit of analysis in panel regressions. The purpose is to analyze the household evolution and observe how a nuclear family in 1986 came up in terms of production, income, and population in 2012. The motivation of this procedure comes from a current debate on how much the economic decisions are made at the levels of families or extended dynasties. Cox and Fafchamps [35] argued that, due to several reasons, including the lack of economic/financial safety nets in developing countries, households may rely on parents, friends, and other relatives for their livelihoods and their survivals. This social arrangement may also originate from the

[1] *A sector is hereby referred to as the administrative sub-unit under the District in Rwanda. The study was conducted in the Western Province, Nyabihu District, in Jomba, Mulinga, Rambura, Rurembo, and Shyira sectors.*

[2] *Annual attrition rate=1-(1-q)$^{1/T}$ where q is the overall attrition rate, and T is the number of years covered by the panel (Alderman et.al., 2001)*

absence or shortage of financial and insurance markets in rural areas [36]. Therefore extended families play a key role in risk sharing by pooling their income and other resources to support their relatives, especially in agricultural-depending societies where production and income variations are very frequent. If this is the case, it would be inappropriate to drop split-off households and base the analyses only on original households' panel.

In his study on risk sharing within the extended family in Indonesia, Witoelar [37] suggested that researchers should consider extended families as the unit of analysis while analyzing consumption growth and decisions. Even though the extended family does not fully act as a unitary household, some important allocations are made at extended family level. Therefore, when analyzing households' production, income, and consumption over time, using a panel of extended families is preferable to using a panel of original households only. In this view, our study links the split-off households (offspring) to their original parent households and takes advantage of this featured dataset to assess the determinants of long-term growth in agricultural production in rural Rwanda.

In the subsequent analyses that involve panel data regression, a comparison is made between different specifications and datasets. An extended family is hereby defined as a set of households that originate from the same 1986 nuclear household. An *extended family dataset* (or *balanced panel*) is therefore constructed, consisting of 164 original households (stayers) for the first wave, and 164 extended families (that is 164 stayers merged with their respective 200 offspring households) in the second wave. On the other hand, a *full sample* (or *unbalanced panel*) is referred to as a panel dataset made of 164 original households for the 1986 wave, and 364 households for the 2012 wave (164 stayers and 200 split-offs considered individually). Despite the possible shortcomings associated to each specification, it is assumed that the true parameters lay in between.

4. EMPIRICAL RESULTS AND DISCUSSION

4.1 Population Growth and Intensification Impacts

The impact of population growth on agricultural intensification, farm productivity, and rural economic change has been assessed with data collected in both surveys. Significant changes occurred in the input intensity, net returns per hectare, and the value of household assets and expenditure. The role of population at micro-level is principally measured by the family size (or the number of household members), and other demographic characteristics that are susceptible to impact agricultural practices [38]. Table 2 indicates definitions and summary statistics of key variables by year.

Table 3 reports panel fixed effects results on agricultural intensification. For robustness check, two dependent variables are selected to measure intensification: inputs intensity per hectare (models 1-2) and labor units per hectare (models 3-4). The results suggest positive correlation between population variables (household size, and the proportion of adult males) on input use intensity and labor unit per hectare. Over time, the population pressure has motivated agricultural intensification in the study area, which is consistent with Boserupian intensification theory. One additional member to the family results in 9 percent increase in input intensity per hectare. However, all other things being equal, the overall units of labor used per hectare decreased over the last 26 years. The latter may due to the decrease in land holdings observed in 2012, as result of population pressure.

The negative effect on farm size and head age is also as expected. All other things being equal, a ten percent increase in the size of available land will have a subsequent decrease of at least 3.5 and 5.5 in input intensity and labor units per hectare, respectively. Agricultural intensification is found to be an affair of young farmers, who are more motivated, more innovative, and less risk averse than their counterpart old farmers. This is indicated by a negative correlation between head age and input intensity. It is also evident that input intensity increases the household's assets. The correlation is highly significant; this may also reveal the positive impact of household income on land intensification. The 2012 year dummy coefficient suggests substantial positive changes in the study area over time with respect to input use intensity.

Changes in agricultural intensification may also be attributed to agricultural reforms introduced by the government of Rwanda during the past one and a half decades like the Crop Intensification

Table 2. Variables definition and summary statistics by year

Variable	Description	1986		2012	
		Mean	**Std. dev.**	**Mean**	**Std. dev.**
Input intensity	The total cost of agricultural inputs per hectare in RWF: fertilizers, seeds, hired labor, and land preparation	5,427	11,340	27,508	34,124
Fertilizers/ha	Value (in Rwf) of fertilizers used per hectare,	1,878	7,109	10,767	20,963
Labor units /ha	The total person-days per hectare	941	642	438	1,368
Net farm income/ ha	Total net farm returns per unit of land	24,099	18,814	67,595	168,913
Household expenditure /ca	Value of household expenditure per capita in Rwf	11,421	5,522	17,767	14,632
Household size	The family size (number of persons)	5.7	2.14	5.3	2.09
Women share	Share of adult females within a household	0.27	0.13	0.29	0.17
Male share	Share of adult males in a household	0.26	0.16	0.23	0.16
Head education	Average education level of the head in years	2.28	2.68	3.86	3.36
Head age	Age of the household's head in years	42.37	13.61	44.38	16.28
Farm size	The size of landholding in hectares	0.76	0.46	0.43	0.61
Land quality	The subjective land quality measure: Percentage households with good quality land	96%	-	60%	-
Extension services	Access to extension services: percentage of households visited by extension agent in a year	6%	23%	62%	49%

Note: All monetary values are expressed in constant prices, base: 1986

Table 3. Population growth and agricultural intensification: Fixed effects results

	Input intensity		Labor units/ha	
	Extended family (balanced) (1)	**Full sample (unbalanced)(2)**	**Extended family (balanced) (3)**	**Full sample (unbalanced)(4)**
Household size	**0.089***** **(0.021)**	**0.066*** (0.038)	**0.111***** **(0.015)**	**-0.002** (0.029)
Women share	-0.575 (0.497)	-1.094*** (0.417)	1.627*** (0.466)	0.680*** (0.252)
Males share	0.374 (0.474)	-0.046 (0.418)	1.899*** (0.509)	0.924*** (0.282)
Head education				
Primary: 4-6	-0.037 (0.190)	-0.431* (0.256)	-0.043 (0.156)	0.292** (0.144)
Post primary: 6-9	-0.421 (0.335)	-0.373 (0.352)	-0.048 (0.238)	0.325* (0.195)
Secondary: 10+	-0.457 (0.447)	-0.559 (0.515)	-0.163 (0.384)	1.131*** (0.303)
Head age	-0.014* (0.007)	-0.010 (0.007)	-0.012* (0.007)	0.006 (0.004)
Farm size (log)	-0.358** (0.138)	-0.550*** (0.116)	-0.551*** (0.100)	-0.799*** (0.063)
Land quality				
Medium	0.042 (0.263)	-0.123 (0.248)	-0.015 (0.212)	-0.109 (0.148)
Bad	-0.016 (0.323)	-0.071 (0.304)	0.022 (0.265)	-0.241 (0.190)
Asset value (log)	0.156** (0.069)	0.191*** (0.059)	0.074 (0.058)	0.058 (0.035)
Extension services	0.353 (0.256)	0.282 (0.242)	0.053 (0.198)	0.114 (0.132)
Year dummy 2012	1.695*** (0.296)	1.200*** (0.238)	-1.268*** (0.224)	-2.198*** (0.159)
Constant	6.564*** (0.832)	6.514*** (0.711)	4.655*** (0.694)	5.100*** (0.423)
Observations	303	473	321	492
F-statistic	62.27***	20.19***	17.29***	74.16***
R_squared	0.816	0.657	0.530	0.823

, **, and * denote a significance level at 10, 5 and 1 percent respectively. The reported are regression coefficients and the robust standard errors between brackets. All the dependent variables are expressed in log. The model also controls for land quality and community characteristics (extension services, distance to market, and distance to paved road)*

Program (CIP), the *Girinka* Program, the Information Gateway of Agriculture and Livestock Sector in Rwanda (AMIS), and numerous government projects and agricultural research-oriented institutions, which aim at transformation of agricultural sector from subsistence to professional agriculture, and self-sustained food security among households. They impacted in one way or another the intensity of adoption of agricultural technologies by rural smallholders. Besides, recent developments in the Information and Communication Technologies in Rwanda (particularly the expansion of mobile phones among rural farmers) are believed to be major factors to facilitate the flow of agricultural information on the existence and availability of new cultivars and fertilizers.

4.2 Productivity and Welfare Effect of Population Growth

Technical change is a precondition to productivity increases and household welfare. The relationships between population and farm productivity and household welfare are analyzed, and panel fixed effects regression results are reported in Table 4. Agricultural productivity is measured by net farm income per hectare (models 1-2) which includes, in addition to the net crop returns, the income from livestock (product) sales. The household welfare effect is captured by the annual household consumption expenditure per capita (models 3-4). For robustness check both results from balanced and unbalanced data are presented.

The results suggest that demographic variables are positively correlated with agricultural productivity, as would Boserup expect. A ceteris paribus one unit increase in household size is associated with a 10 percent increase in net farm income per hectare. Besides, farm productivity is inversely correlated with the landholding and the age of the household, which was also a priori expected. A ten percent increase in land size has a consequent decrease of 7.2 percent decrease in net farm return per hectare.

This inverse relationship is attributed to the labor market imperfection in rural area. Relatively small farms are likely to optimally absorb the amount of labor per hectare than large farms. In addition, there is reduced cost in labor supervision and organizational activities associated with small farms. This result seems to be controversial regarding the recent land consolidation policy that is against any landholdings subdivision as a means towards agricultural development and food security.

Table 4. Population growth, farm productivity and household welfare: Fixed effects results

	Net farm income/ha		**Household expenditure per capita**	
	Extended family (balanced)(1)	**Full sample (unbalanced)(2)**	**Extended family (balanced)(3)**	**Full sample (unbalance)(4)**
Household size	**0.101*** **	**0.009**	**-0.021** **	**-0.094*** **
	(0.023)	(0.038)	**(0.009)**	(0.021)
Women share	0.829	0.057	0.870***	0.626**
	(0.571)	(0.398)	(0.308)	(0.258)
Males share	0.437	0.104	0.650**	0.112
	(0.496)	(0.355)	(0.294)s	(0.256)
Head education				
Primary: 4-6	-0.236	-0.149	0.026	0.149
	(0.213)	(0.260)	(0.082)	(0.104)
Post primary: 6-9	-0.414	0.223	0.106	-0.012
	(0.345)	(0.299)	(0.127)	(0.163)
Secondary: 10+	0.194	1.956**	0.525**	0.692**
	(0.578)	(0.775)	(0.211)	(0.299)
Head age	-0.008	0.012*	-0.006*	-0.006*
	(0.007)	(0.006)	(0.003)	(0.003)
Farm size (log)	-0.728***	-0.809***	0.131**	0.078
	(0.128)	(0.099)	(0.064)	(0.064)
Land quality				
Medium quality	-0.103	-0.171	-0.139	-0.087
	(0.275)	(0.260)	(0.167)	(0.156)
Bad quality	-0.348	-0.443	-0.221	-0.119
	(0.328)	(0.324)	(0.206)	(0.192)
Asset value (log)	0.186**	0.238***	0.064**	0.062*
	(0.074)	(0.058)	(0.031)	(0.032)
Year dummy 2012	0.605***	-0.389*	0.436***	0.355***
	(0.218)	(0.220)	(0.125)	(0.115)
Constant	7.374***	6.923***	8.794***	9.320***
	(0.772)	(0.677)	(0.346)	(0.339)
Observations	304	452	321	493
F-statistic t	20.43***	8.95***	7.77***	5.75***
R_squared	0.57	0.456	0.39	0.314

, **, and * denote a significance level at 10, 5 and 1 percent respectively. The reported are regression coefficients, and all dependent variables are expressed in log. The community variables (access to market and road) are controlled for across all specifications, though they are not significant.*

On the other hand, the findings suggest a negative impact of population growth on household welfare. All other things being equal, one additional member in a family would result in 0.2 percent decrease in total expenditure per capita. Beyond the demographic component, welfare is also a function of head education, the size of landholding, and family assets. Compared to farmers without education, those with secondary education have at least 53 percent higher income (expenditure). This shows the dominant role of education in boosting household (family) income in the study area. Alternatively, one unit increase in family assets is associated with 6 percent increase in total expenditure per capita, other things being equal. The positive and statistically significant coefficient of the year dummy is again an indicator of positive change in household welfare over time.

5. CONCLUSION

The objective of this paper was to assess the impact of population change on agricultural intensification, productivity, and household welfare in Rwanda. Evidences show that the Boserupian land intensification hypothesis cannot be rejected in the study area. The results suggest that, demographic variables such as household size, proportion of adult females and adult males are highly associated with input intensity, labor units per hectare, and agricultural productivity (net farm income per hectare). Other things remaining constant, one additional household member will increase input intensity and net farm income per hectare by 9 and 10 percent respectively. These results are similar to those recently obtained in Ghana by Codjoe and Bilsborrow [38] while assessing the role of population and agricultural practices in the dry and derived savannah zones. Nevertheless, the inverse correlation between family size and annual expenditure per capita warns for a sound population policy in the near future, and it also consistent with the findings from Ethiopia [28], Malawi [29], and Kenya [27].

Finally, our results suggest an inverse relationship between farm size and input intensity and productivity in the study area. Ten percent increase in land size has a consequent decrease of 3.5 and 5.5 percent in net land intensification and net farm returns per hectare, respectively. This is in line with Ali and Deininger [39] who found a robust negative relationship between farm size and per hectare gross output in Rwanda, and consistent with many similar studies on farm size and productivity in India [40], China [41], Nepal [42], Bangladesh [43], and Malawi [44]. The intensive labor use by small farmers and high amount of fertilizers and other inputs required on large farms may be considered the main underlying reasons on the inverse relationship between farm size and productivity in Rwanda.

In this regard, policies for agricultural and rural development in Rwanda should tackle the problems of market imperfections that prevent optimal gains on large farms. In addition, though the Boserupian theory which is the basis of this study indicates that there is no need to worry about population, the population effect on land intensification and productivity may not hold in the long run if the pace of population keeps growing in Rwanda without possibility of land extension. The introduction of appropriate technologies will help but a sound population policy is urgently required. Apparently, it is clear that there has to be a cut-off point, beyond which the Boserupian hypothesis will no longer hold. Hence there is a need for a further study to determine this.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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