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Agricultural intensification: The status in six African countries

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ABSTRACT

Boserup and Ruthenberg (BR) provided the framework to analyze the impact of population growth and market access on the intensification of farming systems. Prior evidence in Africa is consistent with the framework. Over the past two decades, rapid population growth has put farming systems under stress, while rapid urbanization and economic growth have provided new market opportunities. New measures of agro-ecological potential and urban gravity are developed to analyze their impact on population density and market access. The descriptive and regression analyses show that the patterns of intensification across countries are only partially consistent with the BR predictions. Fallow areas have disappeared, but cropping intensities remain very low. The use of organic and chemical fertilizers is too low to maintain soil fertility. Investments in irrigation are inadequate. In light of the promising outcomes suggested by the Boserup-Ruthenberg framework, the process of intensification across these countries appears to have been weak.

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1. Introduction

Since independence in the 1960s, Sub-Saharan African countries (SSA) have undergone exceptionally fast population growth. They also have faced rapid urbanization and some economic growth, which would have tended to increase the demand for agricultural products. In more densely populated areas, the rising population has resulted in farm sizes now close to East and Southeast Asian levels (Headey and Jayne, 2014; Otsuka and Place, 2014).[1] This means that farmers now have to fend for their livelihood on a much reduced area, which requires rapid intensification and productivity growth. At the same time, the rising demand for agricultural commodities should be beneficial for them in terms of better market opportunities and higher prices for non-traded commodities. Both forces are leading to higher farming intensities, and possibly to higher investments and input use.

Under the theory of intensification of farming systems of Ester Boserup (1965) and Hans Ruthenberg (1980a,b), the BR model of intensification, both population growth and market access can lead to a virtuous cycle of intensification of agriculture: These forces lead to a reduction in fallow, higher use of organic manure and fertilizers to offset declining soil fertility, and investments in mechanization, land and irrigation. All of these have the potential to offset the negative impact of population growth on farm sizes, maintaining or increasing per capita food production, and even increase a farmer's income, which we call the BR predictions. Population growth provides the necessity for intensification, while market access provides the opportunity.[2] The increase in output, however, comes at the cost of an increase in labor and other inputs per hectare cultivated. The positive outcome has been realized in those tropical areas of the world where technical change has added impetus to productivity growth.

However, another outcome observed by Geertz (1963) in Java prior to the Green Revolution, was that the intensification triggered by population growth and market access was insufficient to lead to enough productivity growth to make today's farmers better off than their parents, and that instead, they became worse off. Geertz called this process agricultural involution.[3] Since the 1960s, biological technical change in SSA has been lagging behind the rest of the world, and so have fertilizer use, mechanization and investment in irrigation (World Bank, 2008). The question, therefore, is whether there has been agricultural involution in Africa, which was first addressed by Lele and Stone (1989), who found significant signs of involution. Have increases in farm profits per acre been sufficient to also lead to an increase in agricultural income per person,

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[1] In less densely populated countries and regions, it is still possible to maintain farm sizes as emphasized by Headey and Jayne (2014).

[2] In addition to intensification, farmers can diversify into cash crops and buy food, or they can migrate. These opportunities are better in an open economy than in a closed one.

[3] A study of agricultural intensification in Africa found signs of involution only in 2 of 10 locations they studied (Turner et al., 1993).

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more than offsetting the decline in land per person? This is the research question that needs to be evaluated in Africa, and towards which we make a modest contribution.

The literature on agricultural intensification in Africa developed significantly in the 1980s and has resumed over the past decade. As shown in the literature review below, it generally finds that in most areas studied, intensification has progressed along the lines predicted by Boserup and Ruthenberg, and that agricultural involution is confined to a few areas. These studies typically used case studies across locations. However, Headey and Jayne (2014), using cross country data, have shown that rises in population density have been associated with reduced fallow and more intensive use of fertilizer, but not in mechanization or irrigation. That would make involution very likely, as it is hard to see how yields and farm profits per acre could increase much under these circumstances. Testing whether involution is occurring or not would require access to micro-panel data that is not yet available in Africa over a sufficiently long period.

In this paper, we instead take initial steps towards analyzing the status of intensification processes using national representative household data. They are for six African countries that have been collected under the Integrated Surveys on Agriculture (ISA) that have been imbedded in broader Living Standard Measurement Studies (World Bank, 2009) (Ethiopia, Malawi, Niger, Nigeria, Uganda and Tanzania). These national household data contain the intensification and technology variables, as well as profits and household incomes. These will generate panels of five or more years of data which will have to be analyzed in the future. In this paper, we use the cross section data from the first year of the studies. We are therefore not able to rigorously test the BR predictions. However, rigorous tests of the BR framework micro-data has to wait until panel data of sufficient length become available in order to enable an analysis of changes in farming systems that may be quite slow. Instead, we are focusing on the description of the status of agricultural intensification in the six countries, including population density, cropping intensity, fallow, irrigation and use of inputs. We then check whether there is consistency of the predictions of the BR framework with respect to these variables, and among them.

In the Boserup-Ruthenberg framework, the main drivers for agricultural intensification are population density and market access. These in turn are partly determined by the agro-ecological potential of a village, as people would have migrated more to high potential areas, such as tropical highlands, and have been able to support more children; and governments would have preferred to invest in roads and markets to take advantage of the food production potential and serve the dense population (Binswanger et al., 1993). Investments in roads and markets are likely to also depend on the strength of urban demand for food, and the distances of urban centers from the villages. In this paper, we also explore the relationship of the two drivers of intensification, population density and market access, to the agro-ecological endowment and the strength of urban demand impacting on the survey villages. In order to do so, we develop a single variable for the agro-ecological potential (AEP) of each enumeration area, and a second variable for urban gravity (UG) which reflects the economic size of the city in question and the travel time from the enumeration area to the city (see below). Clearly, these two variables are exogenous to the population density and government investments for market access, and we therefore can estimate a causal impact of these two variables on the BR drivers of intensification. The finding is that high AEP and UG have had a significant positive impact on population density of the enumeration areas and on better infrastructure and market access.

We can also estimate the total impact of AEP and UG on the various intensification variables, such as cropping intensity, fallow or the use of new seeds and fertilizers. The total impact includes the impacts via all pathways by which AEP and UG influence intensification, including via population density and market access. What we are not able to do, is to measure the components of the total impact that operates via population density and market access, and therefore the regression we present does not yet constitute a rigorous test of the BR framework.

The measure of a single agro-ecological potential (AEP) variable is based on the modeling of attainable crop yields across all agricultural areas of the globe, estimated by IAASA and FAO (Tóth et al., 2012). As a proxy for urban demand, we develop a measure of urban gravity (UG) that a particular location experiences with respect to all urban centers in the country with a current population of over 500,000 people.[4] We use an estimate of the light emitted at night by each city that is derived from exiting light intensity measures across all pixels of the city.[5] The light emitted by each city is assumed to be highly correlated with its overall GDP. We convert the light intensity to an urban gravity variable that is a negative exponential function of the distance of the urban area from the enumeration area (EA) in which the farmers live.

More specifically, this paper will

1. Develop internationally comparable measures of the overall agro-ecological crop potential (AEP) and of Urban Gravity (UG) in the farmers' location.
2. Describe the degree of agricultural intensification across the countries, and across the agro-ecological zones found in these countries.
3. Estimate the causal impact of agro-ecological potential and UG on population density, infrastructure and market access, and on a range of agricultural intensification variables.

As discussed, a rigorous test of the BR framework has to await panel data analysis. Nevertheless, some of the country data allow for consistency checks to be made of the observed values with the BR predictions, and these will also be signaled.

The plan of the paper is as follows: Section 2 reviews the theory and findings about agricultural intensification. Section 3 presents the analytical framework needed to test the BR framework rigorously and to estimate the impacts of AEP and UG on population density and market access, as well as their total impact via all routes they influence. Section 4 describes how the AEP and UG variables are constructed and defines the variables for all the intensification variables used in the paper. Section 5 presents the descriptive results while section six presents the regression results. Summary and conclusions follow in Section 7.

2. Agricultural intensification: Theory and findings

The general model of the evolution of farming systems originates in the work of Ester Boserup (1965) and Hans Ruthenberg (1980a,b) – henceforth referred to as the BR theory or framework. In the 1980s, these ideas were summarized, partially formalized, and tested for SSA in books by Pingali et al. (1987), Binswanger and McIntire (1987) and McIntire et al. (1992). All these authors

[4] We leave out the smaller cities, as their income as measured via light emissions could be affected by the agro-ecological potential of the zone in which they sit, making them endogenous to the system analyzed.

[5] As a proxy of light intensity, we used the sum of nighttime lights recorded in 2009. Input values ranging from 0 to 63 indicate average intensity of light observations, regardless of frequency of observation. Ephemeral events such as lightning strikes and fires have been discarded. The satellite source is DMSP F16, inter-calibrated for comparison between years. The range of 0–63 refers to the pixel-level value (the source data are gridded at 30 arc seconds). The variable we are using is aggregated at the 5 arc minute block level (resolution of SPAM, GAEZ and other harvest choice variables), which would include many pixels from the lights data.

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