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How does population density influence agricultural intensification and productivity? Evidence from Malawi

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ABSTRACT

This article uses nationally representative household-level panel data from Malawi to estimate how rural population density impacts agricultural intensification and household well-being. We find that areas of higher population density are associated with smaller farm sizes, lower real agricultural wage rates, and higher real maize prices. Any input intensification that occurs seems to be going to increasing maize yields, as we find no evidence that increases in population density enable farmers to increase gross value of crop output per hectare. We also find evidence that households in more densely populated areas increasingly rely on off-farm income to earn a living, but there appears to be a rural population density threshold beyond which households can no longer increase off-farm income per capita.

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Introduction

Boosting agricultural production in the face of a growing population is one of the major challenges facing Sub-Saharan Africa (SSA) at the start of the 21st century. However, to date few empirical studies attempt to estimate the extent to which population density affects agricultural intensification and household well-being. This is a critical issue because current population estimates in SSA stand at 856 million people, and the United Nations projects that the region's population could increase to 2 billion by 2050 under their medium growth scenario (United Nations, 2011; Bremner, 2012). While cereal yields increased by 1.8% per year on average across the continent between 2000 and 2010 (FAOSTAT, 2012), in most SSA countries population growth averages above 2% per year, and tops 3% per year in a number of countries (World Bank, 2013). The disparity between yield increases and population growth raises doubt about how millions of smallholder farm households will feed themselves, and how the food system in SSA can generate enough surplus to feed the non-agricultural population. This is particularly the case as the amount of additional arable land that can be brought into cultivation continues to decline and is already non-existent in some areas.

It is against this background that this study was conducted using household-level panel data from Malawi with the objective to estimate how rural population density affects both agricultural intensification, and household well-being. Other important studies have discussed agricultural intensification in SSA in the context of rising population density (Boserup, 1965; Binswanger and McIntire, 1987; Pingali and Binswanger, 1988; Pender, 1998; Pender et al., 2006). In particular, Pender et al. (2006) use household-level panel data for Ethiopia, Kenya, and Uganda to compare how agricultural intensification and well-being are affected along the gradient of agricultural potential, market access and population density.

In this article, we define agricultural intensification at the household-level in terms of input usage and productivity. Specifically, we estimate (1) demand for inorganic fertilizer per hectare of land cultivated, (2) maize yield, and (3) gross value of crop output per hectare of land cultivated. Well-being is measured as (1) off-farm income per adult equivalent, (2) total household income per adult equivalent.[1] We measure population density in this study

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[1] Adult equivalents are created to normalize the nutritional needs of different family members in a household based on age and gender. The conversion calculations for adult equivalents in this study come from the World Health Organization (1985), and are available from the author upon request.

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as persons per square kilometer of land using population estimates from the Global Rural Urban Mapping Project (GRUMP), available from the International Food Policy Research Institute (IFPRI) website (http://www.ifpri.org/dataset/global-rural-urban-mapping-project-grump).[2]

Malawi is an ideal case study because it is a densely populated country with an estimated 15 million people, whereby 85% of the population lives in rural areas and derives its livelihood from agriculture. There is a substantial regional variation in population density, with the majority of the population concentrated in the central and southern regions, while the north remains sparsely populated. It is estimated that Malawi's population will reach 20.8 million by 2020 (NSO, 2008). As Malawi has little room for expanding area under cultivation, agricultural production must intensify in order to produce enough food for the growing population.[3,4]

In this study we empirically test Boserup's (1965) hypothesis that increasing population density leads to increased input use per unit of land, and increased production per unit of land as farmers move successively from long fallow to short fallow, to annual cropping, and finally to multiple cropping cycles per year. The related *induced innovation* hypothesis predicts that as population grows, farmers will substitute away from labor saving practices like slash and burn agriculture and long follow, and adopt labor and capital intensive practices such as inorganic fertilizer and hybrid seed which maximize output per unit of land (Hayami and Ruttan, 1971).

Critically, this article also tests whether or not there is a population density threshold beyond which the Boserupian and *induced innovation* hypotheses do not apply, as farmers are no longer able to intensify production through using modern inputs. Intensification will not proceed beyond the point at which its marginal cost exceeds the marginal returns. Even in high density areas, marginal returns to purchased inputs may be insufficient to rationalize their use. This may be especially true in high-density areas of longstanding continuous cultivation where soil degradation (particularly diminished soil organic matter) may have given rise to poor responsiveness to inorganic fertilizer applications (Drechsel et al., 2001). Given limited access to technology and capital faced by many smallholders, such limits may be further accentuated by high fixed costs of new technology discovery and adoption. Inability to intensify will lead to lower incomes, assets and lack of credit availability, which makes it difficult for farmers to purchase modern inputs and increase yields and farm output. The existence of thresholds raises the question of whether or not structural transformation in Africa may decelerate, or break down altogether, as rural densities approach critical levels.

In this study we hypothesize that population density affects agricultural intensification and household well-being through both *direct* and *indirect* channels. The *direct* effects come through supply and demand forces such as increased information flow, development of markets and institutions, and reductions in transaction costs that may occur as a result of increased population density. McMillan et al. (2011) show that communities with high population density in Burkina Faso have more developed formal and informal institutions than areas of low population density. Pender (1998) introduces a neo-classical growth model to the issue of population density, and finds that increasing population leads to the development of markets, and institutions, along with the substitution of natural capital for man-made capital.

The *indirect* channels through which population density affects agriculture and household well-being come from its effect on landholding, agricultural wage rates, and output prices. Landholding, wage rates and prices then in turn directly affect agricultural intensification, and household well-being. Since land markets are very thin and underdeveloped in Malawi and in most of SSA, we would expect to see the impact of population growth reflected in household landholding, rather than through land prices.[5] *Ex ante*, population growth should lead to smaller farm sizes, as land gets divided over time and as households move from long fallow, to short fallow, to annual cropping, to multiple cropping cycles per year, as hypothesized by Boserup. We would also expect that agricultural wage rates will decline in areas of high population density, as the number of workers increases relative to the amount of land, as predicted by the *induced innovation* hypothesis. The relationship between declining wage rates and rising population density will certainly depend on the extent to which rural agricultural markets are integrated with local non-farm markets and urban labor markets. In addition, in a closed economy with limited land we would expect to see rising population lead to rising prices for staple crops like maize, as more and more people compete for food. Conversely, in a small open economy higher population density may not affect food prices (other than perhaps in the short run), as food can be brought in from elsewhere to meet demand, other things being equal.

Data used to measure the effect of population density on agricultural production and household well-being in this analysis come from three main sources. First, we use three waves of nationally representative household-level panel data collected between 2003 and 2009 by Malawi's National Statistical Office. Second, we use Geographic Information Systems (GIS) data to construct village-level estimates of population density, elevation and agricultural productivity factors in Malawi. Third, we compliment the quantitative data with qualitative information on population growth and its impact on agriculture and livelihoods, from focus group discussions conducted across Malawi during October 2011.

In this study we recognize that population density may be endogenous in our models of agricultural intensification and household well-being. We deal with the potential endogeneity of population density by first including a rich set of explanatory variables that control for household characteristics, market access, and agro-ecological potential. Second we use the correlated random effects estimator (CRE) to control for potential correlation between population density and the unobserved time-constant factors that affect our outcomes of interest. Nevertheless, as with any study using observational data on household behaviour, assuming direct causality from our results must be treated with caution.

Results from our analysis demonstrate that in Malawi areas of high rural population density are associated with a reduction in farm sizes, lower real agricultural wage rates, and higher real

[2] We use GRUMP rather than AfriPop data (as used by other case studies in this special issue) because in the case of Malawi, the spatial resolution of the input data is much better for GRUMP. GRUMP uses population data from 9219 Enumeration Areas (about 3 km^2 on average), whereas AfriPop uses input data from just 253 Traditional Authorities. While the input data for GRUMP are from 1998 and the input data for AfriPop are from 2008, we felt that the benefits of increased spatial resolution of input statistics were greater than having more recent input data. In addition, since the first year of our data was collected in 2003 it makes sense to have population estimated based on an *ex ante* rather than *ex post* estimate. In practice, however, this probably matters little, since the 2010 projections vary little between the AfriPop and GRUMP datasets for the villages in our study.

[3] For nearly a decade, the Government of Malawi has been implementing the farm input support program (FISP) to mainly boost maize and tobacco production. The presence of a large-scale input subsidy program is an example of an important institutional reform that can impact intensification, and well-being. Fortunately with our data, we are able to control for the input subsidy program's possible effect of the outcomes of interest in this article.

[4] Malawi's annual population growth rate is estimated to be 2.9% (World Bank, 2013).

[5] The vast majority of land in Malawi is held under customary tenure, with only a very small percentage being leased or owned by farmers (National Statistical Office, 2011). While antecdotal evidence suggests that land sale transactions are rare, there is evidence to suggest that land rental markets in Malawi are fairly active. For example, the data used in this analysis indicate that in the 2008/09 rainy season 24% of respondents either rented out or rented in land.

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