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Population Pressure and Livelihood Dynamics

Panel Evidence from Bangladesh

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Contents

Abstract	v
Acknowledgements	vi
1. Introduction	1
2. Overview of Land Policy Evolution	3
3. Data and Methods	4
4. Results	6
5. Conclusion	17
Appendix: Supplementary Tables	18
References	20

Tables

4.1 Real prices, population density, and farm sizes, 1980–2010	7
4.2 Changes in the composition of income sources, 1988–2008	9
4.3 Distribution of land and households by farm size, 1988–2000	10
4.4 Land and farming practices by population density quintile, 1988–2008	11
4.5 Indicators of agricultural commercialization by population density quintile	12
4.6 First-stage correlated random effects model estimates of population density	13
4.7 Determinants of landholding and input costs from the second-stage regression	14
4.8 Population density and other determinants of income, the second-stage regression	15
A.1 Second-stage correlated random effects model estimates on landholding and farming practices	18
A.2 Second-stage correlated random effects model estimates on various income indicators	19

Figures

4.1 Trends in real rural and urban wages at December 2010 prices	8
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ABSTRACT

Since the publication of the World Development Report 2008, two related strands of research have emerged—one on the validity of smallholder-led development strategy and the other on agricultural intensification under population pressure. The former casts doubt about the role of agriculture in economic development in smallholders dominated countries and the later provides evidence that are contrary to earlier findings on induced innovation theory.

Using a unique panel dataset, we examine whether these arguments are valid for Bangladesh--a densely populated country that has experienced significant growth in recent decades. The results suggest that (1) agriculture as a source of income declined significantly over the past two decades; (2) the operated farm size stopped declining in the late 1980s; and (3) that population density relates positively with a host of agricultural intensifications indicators with no evidence of threshold. Historical data on real prices, domestic surpluses, and other macroeconomic variables lend further support to these results. Thus, the paper concludes that small-holding was not a deterrent to structural changes in Bangladesh thus far and that agricultural intensification continued amid intense population pressure.

Keywords: theories of agriculture-led development and induced innovation; panel data estimations, rural economy, Bangladesh

JEL Classification: Q12, C23, D1, and Q12

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1. INTRODUCTION

When the first agricultural census report of Bangladesh (then East Pakistan) was published in July 1960, the future of the country looked bleak. The average farm size was 3.7 acres (1.49 hectares), an average rural household had eight members, the rice yield was just about one metric ton¹ per hectare, the population (then about 50 million) was growing at an annual rate of 3.5 percent, and wages were declining in real terms.² Projecting those numbers 40 years into the future, one would have predicted the population to reach 200 million, average farm size to decline to less than one-third of a hectare, and the food gap to widen considerably. Indeed, this dreadful projection dominated the development community's thinking in the 1960s, with many experts writing off the country in line with Malthusian views. While Henry Kissinger described Bangladesh as a "basket case" (Jahan 1973), other countries in the region were commonly labeled by terms such as "famine 1975" (Paddock and Paddock 1967), "triage" (Ehrlich 1971), and "lifeboat ethics" (Hardin 1978).

Even though more than a third of the country's population lived below the poverty line at the turn of the century, Bangladesh (and other countries in the region) did not live out the gloomy predications spouted by those development experts. Instead, quite the opposite had happened. The economy grew at 5 percent per year in the 1990s and overall well-being improved significantly. By 2000, population growth had slowed, farm sizes had stabilized at around 1.4 acres, rice (milled) yields had more than tripled, and the country was close to food self-sufficiency.³ The overall growth continued into the 2000s, averaging roughly 6 percent per year, with an accelerated rate of poverty reduction. The head count measure of poverty dropped from 49 percent in 2000 to 31.5 percent in 2010—about a 1.74 percentage point decline per year (World Bank 2013). To put these numbers in perspective, almost 1.6 million people escaped poverty every year between 2000 and 2010.

These broad trends suggest that Bangladesh can serve as an important case study to inform two important strands of inter-related literature emerged after the publication of the World Development Report by the World Bank in 2008. In their commentary on the World Development Report (2008), Collier and Dercon (2009) argued that the success of a smallholder-led development strategy is based on weaker evidence than commonly perceived. In particular, they challenge the existing evidence on the inverse size–productivity relationship, the poverty reduction effects and the linkage and multiplier effects of agricultural development, and agriculture's role in overall growth. On the other hand, using panel survey data from Kenya, Jayne and Muyanga (2012) demonstrate that although household well-being (measured by net farm income, input use, adult-equivalent income, and so on) improves initially with population density, it declines rapidly when the population density reaches around 650 persons per square kilometer.

From a development theory perspective, the arguments of these studies boil down to this: casting doubts about the theories of agriculture-led development (Johnston and Mellor 1961) and that the theory of induced innovation under population pressure (Boserup 1965; Hayami and Ruttan 1971) does not hold at all levels of populations. The central premise of the agriculture-led development theory is that the government, as well as the private sector, can use the domestic surplus generated by agricultural growth to finance the development of the industries and services sectors. On the other hand, the induced innovation theory implies that agricultural intensifications should positively relate to the population density. Given decades of agricultural productivity growth amid intense population pressure, and subsequent growth in the industrial and service sectors, Bangladesh's experiences appear to be in line with predictions of these theories. However, deeper analysis is need to understand the structural changes,

¹ Ton refers to metric ton. All the mentions of ton(s) henceforth refers to metric ton(s)

² The census results were published by the Pakistan Institute of Development Economics (1960) and are available at <http://www.jstor.org/stable/41243218>. Farm size and per acre rice production estimates are from Bose (1968), and the declining real wage argument is from Khan (1984) and Boyce and Ravallion, 1991.

³ All these estimates are based on the latest versions of the World Development Indicators of the World Bank and the FAOSTAT database Food and Agriculture Organization of the United Nations (FAO).

the nature of the relationships between population density and indicators of agricultural intensifications, as well as whether or not there exists a population density threshold beyond which household well-being declines (Jayne, Chamberlin, and Muyanga 2012; Jayne and Muyanga 2012). Using a unique panel of household surveys, and a large volume of secondary data, this paper explores these issues for Bangladesh. The rest of the paper is organized as follows: Section 2 provides a historical overview of land policies; a discussion on data and methods follows in Section 3; Section 4 presents the research findings; and Section 5 concludes with a summary and implications.

2. OVERVIEW OF LAND POLICY EVOLUTION

Rulers of Bengal recognized very early that land could be a major source of revenue.⁴ The Mughal emperors refined centuries-old revenue collection systems by introducing more accurate land measurement methods in order to increase revenue. A clear example is the *mansabdari* system, introduced by the emperor Akbar, which made state officials responsible for revenue collection. At the end of Mughal rule in the early 18th century, state officials and other influential elites became landlords, wherever possible. Thus, when British rule was firmly established in India, it was hard to determine the original land revenue systems of India. Consequently, as Banerjee and Iyer (2005) argue, different British administrators formulated different revenue collection systems in different parts of India, which fell under one of three alternative systems: a landlord-based system (also known as *zamindari*), an individual cultivator-based system (*raiyatwari*), and a village-based system (*mahalwari*).

The Bengal (Bangladesh and West Bengal of India) was one of the few states that came under the *zamindari* system—where a single landlord held the tax collection responsibility, on behalf of the British treasury, for a village or a group of villages. These lords were free to set the rental rates for the peasants within their jurisdiction. The British law also allowed them to bequeath, sell, or buy the revenue collection rights to or from others, implying that they were practically granted secured property rights of the lands. Furthermore, by proclamation of the Permanent Settlement Act in 1793, the British approved that the landlords' revenue commitments to the government be fixed in perpetuity. Thus, for more than 150 years, agricultural surpluses from Bengal largely went to the *zamindars* and their offspring, which allowed them to enjoy a lavish life, leaving the peasants at subsistence levels.

There were many protests against the system, but the major challenge to the *zamindari* system was the *tebhaga* movement in 1946, initiated by the peasant wing of the communist party of Bengal, known as *Kishan Shaba*. The movement demanded that instead of giving half their harvest, peasants would give only one-third to the *zamindars* and keep the rest for their own consumption. In many parts of East Bengal (current Bangladesh), the agitations turned violent and landlords fled the villages. Thus, after independence, when East Bengal became part of Pakistan, the government passed the East Bengal Estate Acquisition Act of 1950 abolishing the *zamindari* system. The act stipulated that a family could not own more than 33 acres of land; however, although it provided momentum for land reform, landownership in East Pakistan did not change much in the following decade. In fact, Pakistan retreated from the original act, when in 1961, the then-president of Pakistan Ayub Khan increased the landownership ceiling to 125 acres and land reform remained a central issue for the leftist political parties until the liberation. After gaining independence from Pakistan in December 1971, the new government passed a revised Estate and Tenancy Act in 1972.

This brief history highlights an important fact: until the 1970s smallholders in Bangladesh had little incentive to strengthen the production. In fact, sharecropping did not receive legal recognition until the passing of the 1984 Land Reform Ordinance, which also coincided with the growth of nongovernmental organizations in Bangladesh. Thus, an assessment of agricultural intensification is perhaps relevant only from 1980s.⁵

⁴ The land revenue system began in the third century B.C. after the decline of the Maurya Empire.

⁵ This is somewhat similar to Banerjee and Iyer's (2005) conclusion that Indian states that had landlord systems had significantly lowered agricultural investments and productivity in the post-independence period than areas in which these rights were given to the cultivators.

3. DATA AND METHODS

Data

The analysis of this paper primarily relies on a panel survey of rural households conducted between 1988 and 2008 by the Bangladesh Institute of Development Studies (BIDS) and the International Rice Research Institute (IRRI). The first round of the survey included a sample of 1,240 rural households in 64 unions (lowest administrative unit consisted of a few villages), which covered 57 out of 64 districts in the country. Household samples were drawn using a multistage random sampling method, which began by fixing the size of union samples at 64 (that is, one union per district). Those 64 unions were randomly selected from a list of all unions in each of the 64 districts in the country; then one village was selected from each union based on its representation of the union with respect to the size of landholding, population density, and literacy rates. Following the village selection, a census of all the households in each village was conducted to stratify the households by the size of landownership and land tenure. A random sample of 20 households was drawn from each village using probability-proportional-to-size sampling. The survey was repeated in 2000, 2004, and 2008. In each subsequent round, additional households, mainly offspring, were added to account for attrition. Therefore, the sample size increased from 1,240 in 1988 to 1,880 in 2000, 1,930 in 2004, and 2,010 in 2008. The survey collected information on multiple aspects of the rural economy and livelihoods that can be used for the analysis of a wide range of issues related to household dynamics. However, a potential problem of this dataset is that the survey rounds are unequally spaced, as there is a 12-year gap between the first and the second round of survey. A brief discussion is presented under the next section on how we address this problem in our actual estimation.

In addition to the panel dataset, we also use a large volume of data from the Bangladesh Bureau of Statistics (BBS), the Ministry of Agriculture's Directorate of Agricultural Marketing, and the Bangladesh Bank. The BBS data include the Household Income Expenditure Survey and agricultural census data, which we used to construct variables on population density and changes in farm size, and to triangulate the results generated from the BIDS-IRRI panel survey. Monthly cereal prices and remittance data are from the Ministry of Agriculture's Directorate of Agricultural Marketing and Bangladesh Bank, respectively. District-level monthly agricultural wage data as well as two types of urban wages (construction helpers and casual manufacturing workers) in seven major cities in the country are compiled from the monthly statistical bulletin of the BBS.

Methods

We use both descriptive and econometric analyses in this paper, with econometric analysis primarily focusing on the theory of induced innovation. Our remarks on the relevance of the theory of agriculture-led transformation rely on analysis of historical data. In particular, we focus on the theory's predictions about food price and wages, domestic surplus generation and industrialization, and rural-urban labor dynamics. For econometric analysis on population density and induced innovation, we adopt the same method as Jayne and Muyanga (2012). To formally describe the method, suppose a well-being indicator of given household i at time t is represented by W_{it} , which is hypothesized to be a function of population density along with host-village-specific and household-specific variables, such as education, market access, agro climatic condition, and so on. Formally, this relationship can be written as follows:

$$W_{it} = f(X_{it}, V_{it}, V_i^c; D_t, \alpha_i, \varepsilon_{it}); i = 1, 2, 3, \dots, N; t = 1, 2, 3, \dots, T, \quad (1)$$

where X_{it} represents a vector of household-specific time-varying variables (variables such as markets, availability of hospital, electricity, and so forth) and V_{it} represents village-specific time-varying variables

(such as village-level population density, rainfall variability, and so on); V_i^c is a vector of village-level time-constant variables (for example, soil quality and other agro-ecological conditions); D_t is a survey year dummy; ε_{it} is an error term; and α_i represents the unobserved heterogeneity.

We encounter three potential problems in estimating the model as specified. First, as already indicated, the four survey rounds are not equally spaced (a larger gap exists between the first and the second round). As Baltagi and Wu (1999) point out, that is a common problem with financial data (for example, the stock market is closed on weekends and other holidays and hence an equally spaced panel cannot be constructed with such data), especially if the disturbance term follows an AR (1) process, which we believe is unlikely for a household survey panel. Another problem with an unequally spaced panel is that one cannot use the lag. In our estimation, all lagged explanatory variables (for example, population density, market access, rainfall) are constructed using the secondary data, but all other variables are kept in levels.

The second potential problem is that the popular panel estimation methods—that is, fixed and random effects models—can result in inconsistent parameter estimates if there is correlation between the unobserved heterogeneity (α_i) and the independent variables. To overcome this, Mundlak (1978) and Chamberlain (1984) proposed an estimation technique called the correlated random effects (CRE) estimator that models α_i as follows:

$$\alpha_i = \delta + \beta \bar{C}_i + \zeta_i, \quad \zeta_i | C_i \sim N(0, \sigma_{\zeta_i}^2), \quad (2)$$

where $\bar{C}_i$ represents the mean values of all time-varying variables over various survey rounds.⁶

The final issue in estimating equation (1) is that the population density variable is potentially endogenous in the equation, as some unobservable variables that influence agricultural production and household welfare are likely to influence population growth as well. If an appropriate instrument is unavailable, which clearly is the case for population density, an alternative is to use the control function (CF) approach. As Wooldridge (2010) suggests, although both the instrumental variables method and the CF method give the same results, the CF approach is superior as it allows for a straightforward endogeneity test. We therefore apply the CF approach, which involves a two-step estimation procedure. In the first step, we estimate the following and save the residuals:

$$d = z\pi + \mu, \quad \mu | z \sim N(0, \sigma_{\mu}^2), \quad (3)$$

where, d is the population density in a given village at time t , and z is a vector of exogenous variables, π 's are the coefficients to be estimated, and μ is a random error term. For identification purposes, vector z has to have one variable that is not in equation (1). In carrying out our estimation, we use population census figures from 1974. In the second step, we estimate equation (1) using the CRE method with the estimated residuals from equation (3) included as explanatory variables to account for endogeneity.

⁶For a discussion on the superiority of CRE over other panel estimation methods, see Wooldridge (2010).

4. RESULTS

Smallholder Agriculture-Led Transformation

According to the theories of economic transformation, agricultural productivity growth generally predates structural changes in the economy. The underlying idea is simple: agricultural productivity growth (1) helps generate the surplus needed for investment in other sectors, and (2) helps keep food prices and nominal wages low, so that the industrial or the urban sector can continue to generate surpluses and reinvest until rural wages begin to increase and equalize with urban wages. Case studies from Taiwan and South Korea demonstrate this fact, finding that increased agricultural productivity was fundamental to generating surpluses, which helped finance the development of other industries (Lee and Chen 1979; Johnston and Kilby 1975; and Timmer 1988).

To examine the relevance of the agriculture-led transformation theory, we consider three broad indicators:

1. Wages and food prices
2. Trends in domestic savings and industrialization
3. Patterns of rural–urban wage dynamics

For the analysis of wages and food prices, we use monthly food (rice and wheat) prices and rural wages from 64 districts, as well as urban wages from seven major cities in the country. The rural wage represents the average daily wage of agricultural laborers, and the urban wage is the average wage rates of two types of workers, namely construction helpers and casual unskilled workers in the manufacturing sector. The nominal values of both wages and food prices are deflated by the Consumer Price Index at 2000 prices before calculating the annualized means and growth rates.

Table 4.1 presents the estimates of the means and growth rates generated from monthly data, by decade. The numbers in the table support two important predictions of agriculture-led transformation—that is, an increase in agricultural productivity leads to low food prices and wages. The real price of rice has declined consistently since the Green Revolution took hold, at annualized rates of -2.4 percent in the 1980s, -1.08 percent in the 1990s, and -0.50 percent during the period 2001–2011. The same is true for the price of wheat, except that in the current decade the price increased by 0.06 percent due to import dependence and the 2007–2008 global food crisis.

On the other hand, although rural wage rates grew slightly (0.08 percent), they remained relatively low compared with urban wages during the 1980s. The growth in rural wages in the 1980s, albeit modest, is in sharp contrast with findings of earlier studies. Boyce and Ravallion concluded that “the implicit long-run real wage rate has been on an alarming downward trend since the mid-1960s to early 1980s, a period which witnessed a positive trend in overall agricultural productivity” (1991, 373). This finding was consistent with studies based on data from the 1960s and 1970s as well (Khan 1984 and Bose 1968). One explanation of this trend was that rapid population growth from 1951 through 1981 might have outweighed the induced innovation (Boyce 1988).

Table 4.1 Real prices, population density, and farm sizes, 1980–2010

Variables	Statistics	1980s	1990s	2000s
<i>Real wage and price (at 2,000 taka)</i>				
Rural wage (taka/day)	Mean	61	63	68
	Growth rate (%)	0.08	1.08	0.72
Urban wage (taka/day)	Mean	78.3	84.1	80.2
	Growth rate (%)	2.52	-0.48	-0.01
Rice (taka/kilogram)	Mean	20.6	15.0	11.6
	Growth rate (%)	-2.4	-1.2	-0.5
Wheat (taka/kilogram)	Mean	12.9	10.6	9.9
	Growth rate (%)	-2.4	-0.84	0.06
<i>Population density (person/square kilometer) and land (in acres)</i>				
Population density	Districts' mean	831	1,036	1,258
Farm size	Mean	2.40	1.40	1.40
Per capita cultivable land	Mean	0.36	0.31	0.28

Source: Nominal wage and the Consumer Price Index are compiled from the monthly statistical bulletin of the BBS; rice and wheat prices are from the Directorate of Agricultural Marketing, Ministry of Agriculture. Population and cultivable land data are from the World Bank and FAO, respectively. Farm size for the 1980s is from Osmani and Quasem (1985) based on a 1982 survey. The remainders are authors' calculations based on the BIDS-IRRI panel survey, with the 1990s representing averages of the 1988 and 2000 rounds and the 2000s representing averages of the 2004 and 2008 rounds.

Next, both domestic saving and the pace of industrialization accelerated after the Green Revolution took hold in the 1980s. Domestic savings, a key determinant of investment, experienced negative growth of -1.4 percent per year from 1960 to 1979 but grew at 11.63 percent during 1980–2000 and at 8.23 percent in 2001.⁷ Industrial growth, largely driven by garments and textiles, also began in the 1980s. In the mid-1980s, the garment sector employed only 120,000 people and exported about US\$31 million⁸ worth of merchandise. By the mid-1990s, the sector employed 1.3 million people and the export value had soared to about \$2.2 billion, equivalent to about 60 percent of the country's total exports. The sector grew further in the 2000s—with exports reaching \$19 billion (79 percent of the country's total exports) and the sector providing direct employment to about 4.0 million people in 2012.⁹ These employment figures are likely to be much higher if the calculation factors in employment in allied and linkage industries.

Finally, the recent trend in rural and urban wage rates also supports Lewis's (1954) dual economy theory. Some simple calculations lend support to this statement. Consider the population numbers first. In the 1980s, 1990s, and 2000s, the country's population was growing at an annual rate of 2.6, 2.05, and 1.3 percent, respectively. By contrast, during the same three decades the population of the capital city, Dhaka was growing at much faster rates of 7.04, 6.1, and 3.5 percent respectively. Yet real agricultural wage rates grew modestly at one-eighth of one percent in the 1980s, but began rising at a faster rate in the 1990s. On the other hand, as Table 4.1 shows, real urban wages of unskilled workers, which had grown at more than 2.5 percentage points per year in the 1980s began experiencing small negative growth. This is consistent with the massive growth of the urban population. More important, there is a clear convergence between rural and urban wages, as shown in Figure 4.1, which is again in line with the prediction of Lewis's model. The convergence between rural and urban wages seems to be consistent across many data sources. For example, Zhang et al. (2012) find similar patterns in the Household Income Expenditure Survey of BBS, data from a selected set of factories, and district-level data published by BBS.¹⁰

⁷ These are authors' calculations based on the World Development Indicators data.

⁸ All dollars refer to US dollars.

⁹ Based on Bangladesh Garment Manufacturers and Exporters Association data.

¹⁰ However, the evidence is not yet fully conclusive. Since the new government came to power in 2008, there have been

Figure 4.1 Trends in real rural and urban wages at December 2010 prices

Source: Based on the BBS monthly statistical bulletin data

However, we note a striking difference between Bangladesh and other countries where agriculture-led development, induced innovation, or the dual economy (Lewis) model figured importantly in economic transformation—a massive international migration and an increasing flow of remittances. According to official statistics, total remittances to Bangladesh in 1980 were about \$300 million. That total grew at more than 10 percent per year to reach \$780 million by 1990. Since then, remittances have grown at 13.5 percent per year, reaching about \$12.0 billion in 2012, accounting for 44 percent of the total remittances to the least developed countries (UNCTAD 2013). At the national level, the share of remittances in GDP increased from 0.20 percent in 1976 to about 11 percent in 2012. In other words, as a share of GDP, remittances now account for more than half of total agricultural value added (18 percent) in the country. More importantly, a relatively higher proportion of remittances seem to be going to the rural areas (discussed later in the paper). It is very likely that remittances are an important determinant of rapid growth in non-farm income in the past two decades. If so, recent changes in the economic structure in Bangladesh are not comparable with Lewis's (1954) dual economy model or Johnston and Mellor's (1961) model of agriculture-led development, as those theories are based on the closed economy assumption.

Despite all these successes, Bangladesh is still a least developed country, and its success in the past 30 years is nowhere close to what Taiwan or South Korea accomplished in the early decades of their development. However, one can draw a number of parallels. Consider the following statistics from the early years of Korea's development. In 1949, right before the devastating Korean War, the Republic of Korea's per capita GDP was slightly lower than that of Haiti and Ethiopia and about 40 percent lower than that of India; and a typical household had no more than an acre of farmland (Kim 1985). Land distribution was highly unequal until a drastic land reform policy was implemented that forced the redistribution of land of landlords owning more than 3 *chongbo*, equal to about 3 hectares, to tenant farmers and landless farm laborers (Adelman and Robinson 1985). Finally, South Korea's industrial

many fold increases in transfer programs and subsidies. For instance, public distribution of food (mostly rice) has reached 950,000 tons more than the annual averages from 2003–04 to 2007–08; public transfers under safety net programs have reached \$3.0 billion (Ministry of Food 2010); and input subsidy bills have jumped from about \$17 million in 2001–02 to \$825 million in 2008–09 (Bangladesh Economic Survey 2010).

development started with massive growth in labor-intensive industries, such as plywood and garments and textiles in the late 1950s and continued until the mid-1970s when wages started rising. Even in the mid-1960s, domestic savings were financing only 25 percent of the investment that increased to 70 percent in the early 1980s.

To summarize, these statistics reinforce the fact that, except in the cities, the process of economic transformation follows similar paths and there are few countries, if any, in Africa now that have worse agricultural potential than what South Korea had in the early 1950s.

Descriptive Statistics from the BIDS-IRRI Panel Survey

We present three sets of descriptive statistics from the BIDS-IRRI panel survey: (1) distribution of incomes, (2) distribution of land by ownership and use pattern, and (3) various household well-being indicators by population density (at the village level). Note that our per capita estimates are lower than the national per capita income. For example, our estimate of per capita income in 2008 is \$303, which is about 16 percent lower than the official estimate of about \$355 calculated based on a nationally representative survey. Since the country grew about 5 percent annually in 2008, our estimates come pretty close to the official estimates, giving us more confidence in the data quality.

Rural Income Distribution

The income estimates by broad source presented in Table 4.2 reveal a couple of striking trends. First, the rural economy appears to have experienced a fundamental shift: agriculture is no longer the main means of livelihood in rural Bangladesh. In 2008, a typical rural household derived almost 60 percent of income from agriculture, which dropped to 45 percent in 2008. On the other hand, non-agricultural income jumped from 42 percent in 1988 to 55 percent in 2008. Second, important changes have also occurred within the sources of agricultural and nonagricultural incomes. In the 20 years since 1988, income from remittances and services has changed from being the second-most-important to the single-most-important source of income, accounting for 24 and 33 percent of total household income, respectively. Since the share of remittances in total GDP is about 12 percent, this implies that a larger share of remittances goes to the rural household, which is consistent with the fact that the majority of migrant workers are from rural Bangladesh.

Table 4.2 Changes in the composition of income sources, 1988–2008

Source of income (broad categories only)	Per capita income (in current \$US)		Share of total household Income (%)	
	1988	2008	1988	2008
Agriculture	103	137	58	45
Crop	56	86	32	28
Non-crop	20	32	11	11
Wages	27	20	15	6
Non-agriculture	76	166	42	55
Trade and business	15	37	8	12
Remittances and service	44	100	24	33
Wages	17	29	10	10
Total (Agriculture + Non-Agriculture)	179	303	100	100
Sample size	1236	2010	1236	2010

Source: Authors' calculations based on the BIDS-IRRI panel surveys (1988, 2000, 2004, and 2008).

These estimates are consistent with the national accounts data. The share of agriculture in the country's GDP fell from more than 50 percent at the country's independence in 1971 to about 18 percent in 2011; and employment in agriculture, which accounted for more than three quarters of total employment until the early 1970s (Chen and Chowdhury 1975), declined to less than 40 percent in 2011.¹¹

Distribution of Cultivable Land

Table 4.3 presents the results of the distribution of land and households by farm size categories. Two types of landholding are considered: operated land and owned land. *Operated land* is defined as the sum of owned land and net leased-in cultivable land (that is, owned land + leased-in – leased-out land). Leased-in and leased-out lands include all tenancy forms, such as sharecropping with cost sharing, cash payment for the lease period, and various other sharecropping arrangements. *Owned land* includes all land under a household's ownership except homestead land. In the distribution of operated land (top panel), we see clear changes in all categories except in the medium farm group. Whereas the share occupied by large farms declined from 37 percent in 1988 to only 18 percent in 2008, the share occupied by marginal farms increased from 8 percent in 1988 to 20 percent in 2008, and that of small farmers increased from 24 percent to 33 percent. Since the rate of intensification is higher for small farmers, this means that more than 82 percent of the agricultural production in 2008 came from farmers operating with less than 5 acres (slightly more than 2 hectares) of land, compared with 63 percent in 1988.

Table 4.3 Distribution of land and households by farm size, 1988–2000

Farm size and type of landholding	Shares of households (HH) and landholding							
	1988		2000		2004		2008	
	HH	Land	HH	Land	HH	Land	HH	Land
	(.....Percent.....)							
Operated land^a								
Marginal farm (up to 1) ^b	53	8	63	15	63	17	67	20
Small farm (1–2.5 acres)	24	24	23	30	24	32	22	33
Medium farm (2.51–5 acres)	15	31	11	31	10	30	9	29
Large farm (> 5 acres)	8	37	3	24	3	20	2	18
Own land^c								
Marginal farm (up to 1)	59	10	66	13	66	15	68	15
Small farm (1–2.5 acres)	21	23	19	24	20	27	19	26
Medium farm (2.51– 5 acres)	11	26	10	27	9	25	9	26
Large farm (> 5 acres)	8	42	5	36	5	33	4	33

Source: Authors' calculations based on the BIDS-IRRI panel survey (1988, 2000, 2004, and 2008).

Notes: ^a Operated land is calculated as the sum of own land and net leased-in land. ^b Marginal farm includes landless households. ^c Own land excludes homestead land.

Looking at landownership, we see that it has changed for all farm size categories except medium farms. The large and medium farm size categories together, representing only 13 percent of households, owned 59 percent of the cultivable land in 2008, compared with 19 percent of households owning 68 percent of the land in 1988. This is clearly an indication of a highly skewed distribution. However, a comparison of these estimates with the recent estimates of the functionally landless can tell a different story. According to a recent study based on a nationally representative survey, Ahmed et al. (2013) report that about 57 percent of rural households in Bangladesh are functionally landless. Since the entire functionally landless are in the marginal farm category, one can adjust the distribution to exclude them. For example, if we subtract 57 from the marginal farm category, we would have the following landownership distribution in 2008: 26 percent (marginal); 44 percent (small); 21 percent (medium); and

¹¹ These statistics are from the World Bank's World Development Indicators database and the FAO's FAOSTAT.

9 percent (large). In the popular media, landlessness is portrayed as a social evil reflected through growing slum areas in major cities. However, although we do not deny the landlessness-related poverty and human suffering, it is a hard reality that landlessness accompanies economic transformation; and in countries with intense population pressure, it may be a necessary condition for sustainability of a nation. The challenge is replacing the land dependence with human capital so that being landless does not equate with poverty.

Population Density and Well-Being Indicators

We present two sets of descriptive statistics on population density and household well-being—one set focusing on farming practices and the other on income and some basic indicators of commercialization. These results are presented in Tables 4.4 and 4.5, respectively. Table 4.4 reinforces some of the results reported in Table 4.3, as well as the earlier discussion on farm size. Notice that although higher population density is negatively correlated with per capita operated land, there has been little to no change in the past 20 years in any of the density quintiles. This corresponds perfectly with the fact that although per capita owned land has declined, the size of operated land has stabilized since the late 1980s. A comparison of earlier and recent estimates of landownership inequality lends further support to this result. For instance, the Gini coefficient of landownership based on the 1960 census was 0.49. Based on a recent nationally representative rural household survey, Ahmed et al. (2013) reported that the Gini Coefficient estimates ranges from 0.55 to 0.80 depending on whether landless farmers are included in the calculation (estimates goes up if landless are included). More interestingly, the same study reports a Gini coefficient of 0.47 for operated land, which is very close to the 1960 estimate of 0.49. These numbers reveal the following fact: since rural livelihoods were predominantly dependent on agriculture in the 1960s, a major share of the land was owner-cultivated, but as families started moving out of agriculture, more and more lands are now being cultivated by the tenants.

Table 4.4 Land and farming practices by population density quintile, 1988–2008

Indicator	Pop. density quintile	Survey year				Average
		1988	2000	2004	2008	
Per capita operated land (in acres)	5 (highest)	0.26	0.27	0.27	0.25	0.26
	4	0.27	0.30	0.31	0.32	0.30
	3	0.34	0.33	0.34	0.32	0.33
	2	0.35	0.35	0.36	0.31	0.34
	1 (lowest)	0.32	0.39	0.38	0.37	0.37
Family labor per acre (man-days)	5 (highest)	7.08	9.08	8.58	7.96	8.32
	4	5.41	13.13	10.68	9.26	10.14
	3	4.76	12.95	7.70	7.53	8.88
	2	5.16	9.24	8.31	9.16	8.18
	1 (lowest)	5.03	10.43	8.19	9.76	8.47
Cost of input per acre (’000 taka)	5 (highest)	1.057	2.115	2.245	1.303	1.74
	4	3.101	1.343	1.596	1.280	1.74
	3	2.087	1.965	2.561	2.339	2.27
	2	2.058	1.450	1.754	1.386	1.64
	1 (lowest)	0.916	1.210	1.471	0.884	1.12
Wage rate (taka/day)	5 (highest)	72.53	59.02	79.64	134.30	88.84
	4	43.19	41.98	71.45	123.45	73.16
	3	47.80	41.94	65.45	112.92	69.70
	2	44.39	53.11	62.00	107.85	69.70
	1 (lowest)	45.48	45.96	61.41	105.20	64.51

Source: Authors’ calculations based on BIDS-IRRI survey data (1988, 2000, 2004, and 2008).

Table 4.5 Indicators of agricultural commercialization by population density quintile

Indicator (all are in '000 taka)	Population density quintile	Survey year				Average
		1988	2000	2004	2008	
Net crop income/acre	5 (highest)	3.8	9.1	11.0	27.0	12.72
	4	2.0	8.7	12.0	21.0	10.92
	3	3.0	10.0	13.0	23.0	12.26
	2	3.2	6.6	11.0	15.0	8.95
	1 (lowest)	4.0	7.1	9.9	17.0	9.49
Nonagricultural income per acre	5 (highest)	3.1	11.0	11.0	15.0	10.02
	4	2.0	5.8	7.2	7.5	5.66
	3	2.1	4.5	5.9	10.0	5.63
	2	2.3	5.4	6.1	9.2	5.73
	1 (lowest)	2.4	6.4	7.8	6.1	5.68
Per capita agricultural income	5 (highest)	3.3	5.0	5.6	7.7	5.40
	4	3.2	5.0	6.1	11.0	6.31
	3	3.4	5.2	7.0	8.3	5.99
	2	2.9	4.7	6.5	8.3	5.60
	1 (lowest)	3.2	5.3	6.4	11.0	6.47
Per capita capital assets	5 (highest)	1.8	1.4	7.4	8.2	4.73
	4	1.2	0.5	3.7	7.5	3.19
	3	1.4	0.5	4.8	7.2	3.50
	2	1.7	0.7	4.0	8.1	3.64
	1 (lowest)	1.9	0.8	4.3	8.7	3.91
Income per household	5 (highest)	6.4	16.0	17.0	25.0	16.09
	4	5.2	11.0	13.0	19.0	12.05
	3	5.4	10.0	13.0	20.0	12.11
	2	5.2	10.0	13.0	19.0	11.80
	1 (lowest)	5.2	12.0	14.0	19.0	12.54

Source: Authors' calculation based on the BIDS-IRRI panel dataset (1988, 2000, 2004, and 2008).

Results of the other three indicators in Table 4.4 may be summarized as follows. There are no significant differences across population density quintiles with regard to family labor use, except that farmers in the second-highest density quintile appear to have the highest family labor use. Farmers operating in the top three population density quintiles appear to use higher cash inputs; and wage rates are significantly higher in the higher population density quintiles. These results imply that the population density is positively related with the key agricultural intensification indicators—namely labor use, cash input use, and wage rates.

The relationship between population density and household income show a similar pattern (Table 4.5). On average, farmers in the most densely populated villages have 25 percent higher crop income per acre than the farmers in the lowest density quintile. Similarly, compared with the lowest population density villages, the asset values and household incomes are higher in the most densely populated areas by 17 and 22 percent respectively. The most striking difference seems to be in the nonagricultural income category, where households in the most densely populated villages have 43 percent higher income than those in the least densely populated areas. Agricultural income is highest in the least densely populated areas, which may be attributed to the relatively larger farm size.

Econometric Results

Following the methods described in Section 2, we estimated the first-stage CRE model to examine the determinants of population density, as well as to control for endogeneity in the second-stage estimation. The results, presented in Table 4.6, suggest that except for distance to hospital, all market access and provision-of-public-services variables have the right signs and are statistically significant except 10 percent or above. With respect to agro ecology, the survey defines four different agroecological zones: coastal, flood prone, drought prone, and favorable. The results suggest that relative to coastal areas, population densities are higher in all other agro ecological zones.

Table 4.6 First-stage correlated random effects model estimates of population density

Dependent variable: Log village population density in 2008	Coefficient	Standard Error
Distance to bus station (in miles)	-0.001*	0.001
Distance to rail station (in miles)	-0.002***	0.000
Distance to market (in miles)	-0.013***	0.002
Distance to bank service (in miles)	-0.008***	0.002
Distance to hospital (in miles)	0.001	0.001
Population in 1974 census	0.00002***	0.000
Area in square kilometers	-0.00012***	0.000
Rainfall ('00 millimeters 6-year moving average)	0.00004***	0.000
Rainfall variability (cv)	0.725***	0.057
Agroecological zone (coastal region)		
Flood prone	0.160***	0.008
Drought prone	0.059***	0.011
Favorable	0.106***	0.007
Constant	6.658***	0.019
R ²	0.82	
N	4,963	

Source: Author's calculation.

Note: cv = coefficient of variation. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Since we have used the semi-log functional form, interpreting these numbers is straightforward. Consider the estimated coefficients on the market access variables. An estimated coefficient of 0.001 on distance to bus station suggests that a 0.1 mile decrease in the distance to the bus station leads to an increase in the population density by 100 people. The other estimates on market access can be interpreted in a similar manner. The results on the agroecology dummies and rainfall variability seem a bit counter-intuitive at first sight, as the favorable agroecology has a smaller coefficient than that of flood-prone areas, and there exists a large, positive association with rainfall variability. However, that is consistent with Dhaka having the highest population density despite being flood prone.

For the sake of clarity, we present only the key results from the second-stage regression and relegate the details to the appendix. In addition to estimated coefficients, we also calculate elasticity of the statistically significant variables at the respective sample mean values.¹² We ran seven different regressions with seven different indicators of household well-being results of which are presented under two broad groups: (1) landholding and input costs, and (2) household income and assets.

¹² Since we have used the semi-log functional form, the elasticity is simply $\varepsilon_i = \beta_i \overline{X_i}$.

Landholding and Input Costs

Table 4.7 presents the results of the logs of per capita landownership, per capita operated land and cash input costs per unit of land. A few broad conclusions can be drawn from these results. First, note that the square of the population density is statistically insignificant for all specifications, although population density appears to be significant for both landownership and input costs, but not for operated land. Given an elasticity estimate of -1.04, there appears to be an almost one-to-one relationship between per capita landholding and population density. These results are consistent with Binswanger's (2012) study on India, which demonstrated that although wages grew and poverty declined, farm size did not increase to an extent that would imply an economic transformation. Our results show the same pattern—even though wage rates increased and poverty declined, per capita landownership declined and the country has not seen an expansion in operated land since the late 1980s. This will remain a serious challenge for the country in the coming decades.

Table 4.7 Determinants of landholding and input costs from the second-stage regression

Explanatory variables	Mean value	Log of landholding (in ha) per capita		Log of operated land (in ha) per capita		Log of input cost per ha	
		β_i	ε_i	β_i	ε_i	β_i	ε_i
Village-level variables							
Population density/km ²	1040	-0.001**	-1.04	--	--	0.0026**	2.7
Distance to rail station	4.47	0.001*	0.004	--	--	0.005**	0.02
Distance to market	1.78	-0.001	-	-0.005*	-0.009	0.049**	0.09
Distance to bank	2.33	--	--	--	--	-0.059**	-0.14
Fertilizer price–village median	5.93	0.019**	0.113	--	--	0.015	0.09
Rainfall (6-year moving average)	206	--	--	0.000***	0.001	-0.002***	-0.41
Rainfall variability (cv)	0.94	--	--	--	--	-0.760**	-0.72
Household-level variables							
Mean of wage	75	--	--	-0.001***	-0.074	0.006***	0.45
Mean land rent	10176	--	--	0.00001**	0.102	--	--
Distance from train station	4.47	--	--	--	--	0.019***	0.09
Distance from marketplace	1.78	0.009***	0.016	0.005	0.009	0.073***	0.13
Distance from bank	2.33	0.003	0.007	-0.003	-0.007	-0.061***	-0.14
Distance from hospital	4.88	0.004***	0.02	-0.002	-0.01	0.023***	0.11
Average fertilizer price	8.39	-0.012**	-	-0.017**	-0.143	0.048***	0.401

Source: Authors' calculation based on Appendix Table A.1.

Notes: ha = hectares; km² = square kilometers; cv = coefficient of variation. All distances are measured in miles.

The results of the third specification (log of cash input costs) are consistent with the induced innovation theory. In particular, use of cash inputs, a measure of intensification, is positively related with population density with an estimated elasticity of 2.7. Furthermore, the results of this specification are consistent with Pingali and Binswanger's (1988) and Binswanger and Pingali's (1998) characterization of population and farming linkages, as most of the market access variables are significantly related with cash input use. All village-level market access variables, except distance to the nearest bank, have the right signs, and are statistically significant. In particular, a 10 percent increase in distance to the nearest railway station and distance to the nearest marketplace leads to an increase in cash input costs by 0.20 and 0.90 percent, respectively. Both rainfall (six-year moving average) and rainfall variability are negatively related with input costs.

When it comes to household-level variables, distance to market, distance to hospital, and fertilizer price are significant determinants of landownership. For operated land, on the other hand, significant determinants are wage rates, land rent and fertilizer price. The elasticity estimates suggest that a 10 percent increase in wage rates and land rent leads to a decrease in operated land by 0.74 percent and 1.02 percent, respectively. In the case of cash input costs, all variables except the mean land rental value are statistically significant. Wage rates and fertilizer price appear to be the strongest determinants of the cash input costs, with elasticity estimates of 0.45 and 0.40, respectively.

Household Income and Assets

In this set of regressions, we regress four well-being indicators—per capita farm income, household income, household assets, and per hectare farm income—on the same set of explanatory variables. Table 4.8 shows the summarized results, and the detailed regression results are shown in Appendix Table A.2. We discuss village-level and household-level results below.

Table 4.8 Population density and other determinants of income, the second-stage regression

Indicators	Log of net farm income/ha		Log of net farm income/capita		Log of household assets/capita		Log of per capita household income	
	β_i	ε_i	β_i	ε_i	β_i	ε_i	β_i	ε_i
<i>Village-level variables</i>								
Population density/km ²	--	--	--	--	--	--	0.0018**	1.87
Distance to bus station	-0.010**	-0.04	-.019***	-0.07	-0.013*	-0.05	-0.003*	-0.01
Distance to bank	-0.02	-0.04	--	--	0.045**	-0.10	0.00	-0.01
Distance to hospital	0.010*	0.05	--	--	--	--	--	--
Rainfall (6-year MA)	-0.002**	-0.41	-0.002***	-0.41	--	--	--	--
Rainfall variability (CV)	0.32	0.30	2.410***	2.28	--	--	--	--
<i>Household-level variables</i>								
Mean of wage (taka/day)	-0.003**	-0.22	-0.004**	-0.30	0.00	-0.15	0.003***	0.22
Mean land rent (taka/ha)			.00001**	0.10			0.000*	0.102
Distance to bus station	0.014***	0.05	--	--	-0.021**	-0.08		
Distance to train station	0.008*	0.04	--	--	--	--	-.007***	-0.03
Distance to marketplace	-0.060***	-0.11	--	--	--	--		
Distance from bank	-0.067***	-0.16	--	--	--	--	-0.073***	-0.17
Distance from hospital	0.033***	0.16	0.035***	0.17	--	--	--	--
Mean fertilizer price	-0.13***	-1.06	-0.125**	-1.05	-0.17***	-1.03	--	--

Source: Authors' calculations based on Appendix Table A.2.

Notes: ha = hectare; km² = square kilometers; MA = moving average; CV = coefficient of variation. All distances are measured in miles.

At the village level, population density does not seem to affect any of the indicators except per capita household income. One explanation of this result is that nonfarm income occupies a larger share in households living in densely populated areas. It also makes a larger point—that is, population density per se does not reduce household income; it is rather the unavailability of alternative employment opportunities that results in lower wages, per capita income and other well-being indicators. Among other village-level explanatory variables, distance to bus station is significant for all specifications, distance to the nearest bank is significant for asset ownership and rainfall variability is significant for both per capita and per hectare farm income.

The household-level explanatory variables exhibit a similar relationship. Average wage rates relate negatively with farm income but positively with per capita household income. Whereas most of the market access variables are significant for farm income per hectare and per capita household income, they are not so for per capita net farm income and asset holding. In terms of magnitude, the estimates suggest that a 10 percent increase in wage rates is associated with a 2.2 and 3.0 percent decline in per hectare and per capita farm income respectively, but a 2.2 percent increase in per capita household income. An increase in mean land rent has no significant effects on per hectare farm income, although it has a small negative effect on per capita farm income. Of the other market access variables, although they are all significant for farm income per hectare, only distance to bus station is significant for per capita assets; distance to the bank and distance to the train station are significant for per capita household income. Average fertilizer prices have negative and statistically significant coefficients under all specifications, except per capita household incomes. Since all dependent variables, except household income, are agriculture related, these results imply that fertilizer use, a key indicator of intensification, plays a dominant role in Bangladeshi agriculture.

5. CONCLUSION

Two important set of issues, both relating to the theories of agriculture-led development, have emerged since the publication of the World Development Report (2008) on agriculture. One of the issues questions the validity of the theory of agriculture led development in smallholders dominated economies and the other presents evidence that positive relationships between population density and agricultural intensification, as induced innovation theory predicts, do not hold true after population density reaches a certain threshold. Both of these arguments call for revisiting a vast body of literature on inverse size-productivity relationship in developing countries and this has clear implications for development strategies in countries where agriculture is the largest employer and farming is smallholder dominated. All emerging Asian countries tackled this challenge during their structural transformation and almost all developing countries confront this challenge today. This paper has presented evidence from such a country, Bangladesh, which has achieved impressive agricultural growth under intense population pressure.

Our results broadly support the basic tenets of agriculture-led and dual economy models of economic development. Rural and urban wages have begun converging in recent years; food prices have declined, non-farm activities have become the dominant source of rural income, and both domestic savings and the industrial sector grew. Furthermore, we find that from the panel regression that population density has no statistically significant effects on operated land per household, suggesting that farm sizes stopped declining since the late 1980s. Thus, we conclude that Bangladesh's experiences are in line with the predictions of the dual economy model. However, we note that the *closed economy* assumptions of these models are not applicable to Bangladesh, as the country has greatly benefited from the globalization. The structural changes observed in the past couple of decades would not probably have happened in the absence of rapid growth of garments and textile sector, flow of FDI, and massive flow of remittances from migrant workers.

The results of the relationship between population pressure and agricultural intensifications also appear to be consistent with induced innovation theory. In particular, population density is found to be positively related with a host of intensification and well-being indicators such as per hectare input costs, per hectare net crop income, wages, and income per household. Besides, since the square of population density has no statistically significant effect on the intensification and well-being indicators, our data (and methods) do not support a threshold in the relationship between population density and agricultural intensification. These results not only support the theory of induced innovation but also sharply contrast with recent results from Africa.

APPENDIX: SUPPLEMENTARY TABLES

Table A.1 Second-stage correlated random effects model estimates on landholding and farming practices

Dependent variable	Log of own land (in ha) per capita		Log of operated land (in ha) per capita		Log of input cost per ha (taka)	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Population density/km ²	-0.001***	0.000	-0.000	0.000	0.0026***	0.008
Population density squared					-0.000***	0.000
Distance to bus station (in miles)	-0.000	0.000	-0.001	0.001	0.003	0.003
Distance to rail station (in miles)	0.001*	0.000	-0.000	0.000	0.005***	0.002
Distance to market (in miles)	-0.001	0.001	-0.005*	0.002	0.049***	0.011
Distance to bank (in miles)	-0.000	0.001	0.004	0.003	-0.059***	0.012
Distance to hospital (in miles)	-0.000	0.001	0.001	0.001	-0.002	0.005
Access to electricity; 1 = yes	0.000	0.005	-0.002	0.007	0.005	0.034
Average wage rate: village median	0.000	0.000	0.000	0.000	0.001	0.001
Land rent: village median	0.000	0.000	-0.000	0.000	-0.000	0.000
Urea price: village median	0.019**	0.009	0.009	0.011	0.015	0.051
Rainfall (6-year moving average)	-0.000	0.000	0.000***	0.000	-0.002***	0.000
Rainfall variability (cv)	0.063	0.046	0.084	0.062	-0.761**	0.363
Agroecological zone (coastal region)						
Drought with flood prone	0.024***	0.009	0.002	0.011	0.156***	0.055
Drought prone	0.030***	0.011	0.020	0.014	0.600***	0.071
Favorable	-0.002	0.008	-0.018	0.011	0.431***	0.054
Survey year dummies (1988 is base)						
2000						
2004	-0.025*	0.014	-0.023	0.017	0.185**	0.074
2008	-0.034**	0.015	-0.018	0.019	-0.457***	0.087
Residuals from first-stage regression	-0.020	0.013	-0.051***	0.018	0.130	0.093
Residuals squared	0.055*	0.034	0.023	0.045	-0.737***	0.241
Mean values for all continuous variable						
Mean of wage	0.000	0.000	-0.001***	0.000	0.006***	0.001
Mean land rent	-0.000	0.000	0.000***	0.000	-0.000	0.000
Mean distance from bus station	0.000	0.001	0.000	0.001	0.016***	0.004
Mean distance from train station	-0.000	0.001	-0.000	0.001	0.019***	0.004
Mean distance from marketplace	0.009***	0.003	0.005	0.004	-0.073***	0.018
Mean distance from bank	0.003	0.003	-0.003	0.004	-0.061***	0.017
Mean distance from hospital	0.004***	0.001	-0.002	0.001	0.023***	0.007
Mean fertilizer price	-0.012**	0.005	-0.017**	0.006	0.048***	0.031
Constant	-0.024	0.103	0.107	0.151	6.436***	0.720
R-squared	0.04		0.03		0.30	
N	4,654		2,787		2,768	

Source: Author's calculation.

Note: CRE = ha = hectare; km² = square kilometers; CV = coefficient of variation. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A.2 Second-stage correlated random effects model estimates on various income indicators

Dependent variable	Net farm income per hector		Net farm income per capita		Household assets per capita		Household income per capita	
	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Population density/km ²	-0.016	0.011	-0.016	0.015	-0.003	0.017	0.018**	0.008
Population density squared	0.000	0.000	0.000	0.000	-0.000	0.000	-0.000	0.000
Distance to bus station (in miles)	-0.010**	0.005	-0.019***	0.007	-0.013*	0.007	-0.003	0.002
Distance to rail station (in miles)	-0.001	0.003	0.004	0.004	-0.003	0.004	-0.000	0.002
Distance to market (in miles)	-0.004	0.014	-0.011	0.019	0.027	0.020	0.006	0.008
Distance to bank (in miles)	-0.016	0.015	0.003	0.020	-0.045**	0.021	-0.004	0.009
Distance to hospital (in miles)	0.010*	0.006	-0.000	0.008	-0.009	0.009	-0.004	0.004
Access to electricity; 1 = yes	0.068*	0.041	0.005	0.063	-0.058	0.064	-0.012	0.029
Average wage rate: village median	0.001	0.001	-0.000	0.001	0.001	0.001	0.000	0.001
Land rent: village median	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Urea price: village median	-0.148**	0.067	0.048	0.098	0.054	0.101	0.128**	0.051
Rainfall (6-year moving average)	-0.002***	0.000	-0.002***	0.001	-0.000	0.001	-0.000	0.000
Rainfall variability (cv)	0.317	0.400	2.410***	0.601	0.884	0.600	0.137	0.261
Agroecological zone								
Drought with flood prone	-0.131*	0.067	0.207**	0.102	-0.038	0.105	-0.106**	0.043
Drought prone	-0.140*	0.076	0.360***	0.120	0.424***	0.116	0.078	0.048
Favorable	-0.099	0.064	0.085	0.099	-0.065	0.102	-0.062	0.042
Survey year dummies (1988 is base)								
2000								
2004	0.471***	0.094	0.110	0.142	1.510***	0.155	0.022	0.077
2008	0.810***	0.102	0.530***	0.160	2.074***	0.174	0.399***	0.082
Residuals from first-stage regression	0.076	0.124	0.213	0.192	-0.459**	0.195	-0.307***	0.088
Residuals squared	-0.620**	0.303	1.228***	0.467	-0.492	0.451	-0.307	0.199
Mean values for all continuous variable								
Mean of wage	-0.003**	-0.001	-0.004**	0.002	-0.002	0.002	0.003***	0.001
Mean land rent	0.000	0.000	0.000**	0.000	-0.000	0.000	-0.000*	0.000
Mean distance from bus station	0.014***	0.005	0.005	0.008	-0.021***	0.008	0.002	0.004
Mean distance from train station	0.008*	0.004	0.001	0.006	0.000	0.006	0.007***	0.003
Mean distance from marketplace	-0.060***	0.021	0.010	0.033	0.007	0.033	-0.015	0.015
Mean distance from bank	-0.067***	0.023	0.015	0.032	-0.028	0.030	-0.073**	0.014
Mean distance from hospital	0.033***	0.008	0.035***	0.012	0.005	0.012	-0.001	0.005
Mean fertilizer price	-0.126***	0.036	-0.125**	0.054	-0.173***	0.054	-0.008	0.024
Constant	16.211***	0.940	9.512***	1.343	8.905***	1.334	8.345***	0.589
R-squared	0.14		0.07		0.17		0.11	
N	2,750		4,073		4,143		4,766	

Source: Author's calculation.

Note: km² = square kilometers; cv = coefficient of variation. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

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