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Agricultural Productivity and Non-Farm Employment

Evidence from Bangladesh

Forhad Shilpi
Shahe Emran

World Bank Group
Development Research Group
Environment and Energy Team
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Abstract

This paper provides evidence on the impacts of agricultural productivity on employment growth and structural transformation of non-farm activities. To guide the empirical work, this paper develops a general equilibrium model that emphasizes distinctions among non-farm activities in terms of tradable-non-tradable and the formal-informal characteristics. The model shows that when a significant portion of village income is spent on town/urban goods, restricting empirical analysis to the village sample leads to underestimation of agriculture's role in employment growth and transformation of non-farm activities. Using rainfall as an instrument for agricultural productivity, empirical analysis finds a significant positive effect of agricultural productivity growth on growth of informal (small-scale) manufacturing and skilled services employment, mainly in education and health services. For formal employment, the effect of agricultural productivity growth on employment is found to be largest in the samples that include urban areas and rural towns compared with rural areas alone. Agricultural productivity growth is found to induce structural transformation within the services sector with employment in formal/skilled services growing at a faster pace than that of low skilled services.

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Agricultural Productivity and Non-Farm Employment: Evidence from Bangladesh

Forhad Shilpi

World Bank

Shahe Emran

IPD, Columbia University

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1. Introduction

The classic model of structural change in the tradition of Lewis (1954), Kuznets (1973), Chenery and Elkington (1979), Chenery et al (1982) and Laitner(2000) deals with the process of industrialization and the long-term decline of agriculture, both in terms of employment and output share in an economy. With more than half of the population still residing in villages in many developing countries, the transition from agriculture to non-farm within the rural economy is now widely recognized as an important aspect of the overall structural transformation.[1] In contrast to the classic structural change literature, the recent analysis has two distinguishing features. First, there is a recognition that structural change is multidimensional and a serious attempt should be made to incorporate many faces of dualism and their interactions: home production-market exchange, formal-informal, tradable-nontradable, skilled-unskilled, low productivity-high productivity etc. as part of the process of structural change (Buera and Kaboski (2012)). Second, it emphasizes the importance of identifying the relevant causal forces at work, so that the analysis may eventually lead to better design of policies.[2] This paper is a contribution in this emerging literature: it analyzes the causal role played by agricultural productivity shock in the structural change in a village economy: from farm to nonfarm, from informal to formal, and from low to high skilled economic activities.[3]

A central theme in structural change has been the potential role played by productivity improvements in agriculture (Lewis (1954), Gollin et al (2002), Matsuyama (2005)). The traditional view was that policies should aim at accelerating the decline of agriculture so that low wage labor could fuel the growth of manufacturing; but the later literature emphasized the role of productivity growth in circumventing the 'wage goods constraint', and domestic demand constraint.[4] Similarly, an increase in agricultural productivity can have conflicting effects on growth of non-agricultural activities in a village, through the demand and supply sides. Since much of the rural population are engaged in agricultural activities, a rise in agricultural productivity increases rural income and thus can have a positive demand effect on non-

[1] Recent empirical evidence indicates that growth in non-farm sector is important for both poverty reduction and employment transformation (Christaensen, De Weerdt, and Todo (2013), Foster and Rosenzweig (2004), Haggblade, Hazell and Reardon (2006), Lanjouw and Lanjouw (2001)).

[2] For example, in an analysis of structural change within the agricultural sector, Emran and Shilpi (2012) uses data from rural Nepal and shows that the pattern of crop specialization is affected by the extent of the relevant urban market in a non-linear way.They use heteroskedasticity based identification for establishing causality.

[3] The transition from low skilled and informal activities to formal skill-intensive activities has been an integral part of the development policy discourse from early literature (Lewis(1954), Hymer and Resnick(1969), Ranis and Stewart (1973), Ghani and Kanbur (2013) for a survey).

[4] ADLI of Adelman etc.

farm activities (Mellor (1976), Ranis and Stewart (1973), Haggblade, Hazell and Reardon (2006), Johnson (2000)). On the other hand, a higher agricultural productivity is likely to push up wages and thus make labor more expensive to the non-farm sector, impeding its growth (Lewis(1954), Hymer and Resnick (1969), Foster and Rosenzweig (2004)).[5]

While a considerable volume of literature reports a positive correlation between agricultural productivity and non-farm employment (see, for example, Lanjouw and Lanjouw (2001)), causal evidence on the role of agriculture in structural change within the rural economy is rare with the exception of Foster and Rosenzweig (2004). Using household and village level panel data from India, Foster and Rosenzweig (2004) find that a positive casual link between agricultural productivity and non-farm employment holds only for non-traded local services activities. They report that factory (tradeable) employment grew at a faster rate in villages where agricultural productivity growth was slower, which is consistent with a wage effect discussed above.

The theoretical model developed in this paper considers a broader spectrum of rural non-farm activities ranging from internationally traded formal activities (e.g. importable/exportable) to goods and services traded in wider domestic markets to locally produced and consumed informal activities. This broader specification of the economic activities captures the fact that not all manufacturing goods produced in a typical developing country are internationally traded, and not all services are locally consumed within the village. Evidence from developing countries shows that informal activities account for the major share of non-farm activities (both manufacturing and services), and that the share of informal activities has remained unchanged during the post liberalization period in many developing countries.[6] Moreover, the services activities run the entire gamut of unskilled domestic workers (maids) to skilled professionals (e.g. doctors, teachers). The distinction between formal and informal activities, while widely noted in the descriptive and theoretical literature on non-farm activities in rural areas and towns (Ranis and Stewart (1973), Hag-

[5] One might argue that capital intensive technological change such as mechanization would reduce the demand for labor and wages, even though agricultural productivity will be higher. This argument is, however, misleading, because mechanization occurs in a village economy only when wages are higher.

[6] Recent estimates for India shows that the informal manufacturing plants employing 10 or less workers account for nearly 99 percent of enterprises and 81 percent of manufacturing employment (Kanbur and Ghani, 2013). The employment share of informal service activities ranges between 74 to 90 percent depending on the definition. Ghani et al. (2012) also find no change in the share of informal sector in total manufacturing employment between 1989 (pre-liberalization) and 2005 (post-liberalization). Ghani et al (2012) also finds that formal manufacturing firms are increasingly moving into rural areas. The share of informal activities in total manufacturing employment has remained stable around 22 percent between 2000 and 2009 in Bangladesh – a country where labor regulations are weak, and enforcement is virtually non-existent.

gblade, Hazell and Reardon (2006), Lanjouw and Lanjouw (2001)), has, to the best of our knowledge, not been examined in the context of empirical analysis of farm-non-farm linkages. The theoretical model shows that by focusing on the coarser distinction of tradeable manufacturing vs. non-tradeable services, one may miss important implications of agricultural growth for both employment growth and structural transformation (informal to formal) within the non-farm sector. A more complete analysis needs to take into account both the tradable-nontradable and the formal-informal characteristics of economic activities. Second, the theoretical model highlights the importance of appropriate units of analysis; we focus on a larger geographical area (sub-district) instead of villages alone as is done in the extant literature. The motivation for this comes from the observation that many manufacturing and services activities located in rural towns cater to demand from surrounding villages – a fact which is widely recognized in the literature on non-farm activities.

We test the predictions of the model using panel data compiled from the population and enterprise censuses from Bangladesh. Our dataset covers the period between 2000 and 2010. Between 2000 and 2010, Bangladesh experienced substantial reduction in the incidence of poverty, from 48.9 percent to 31.5 percent. This decade also witnessed substantial expansion in non-farm employment as a result of which its share in total employment increased from 47 percent to 52 percent. On an average, income from non-farm activities is much higher than that from agriculture, with the result that more than 60 percent of rural household income now comes from non-farm activities. Agricultural GDP has grown at an annual rate of 3.7 percent during the same period. The rice yield, which is taken as a measure of agricultural productivity, has grown at an annual rate of 3.6 percent.[7]

To understand the implications of agricultural productivity, we exploit variations in rainfall across upazilas and over time, and implement a procedure that focuses on the effects of rainfall shocks in reduced form regressions on the outcome variables (employment in different types of non-farm activities) and also on the measure of agricultural productivity (crop yield). The evidence from the reduced form regressions is sufficient to test the predictions of the theoretical analysis, which relies on the fact that rainfall variations can be interpreted as shifts in the production function, because rainfall is a major determinant of crop yield in Bangladesh (Sarkar et. al. (2012), Bhowmik and Costa (2012)). We also provide an instrumental

[7]Rice is the predominant crop in Bangladesh.

variables interpretation of our estimates, using rainfall deviations (from long term average) across upazilas and over time as an instrument for crop yield (rice yield). The regressions include upazila fixed effects to remove the influences of time invariant unobserved area characteristics, and year fixed effects to wipe out the common price (international) and other macroeconomic shocks. We included an extensive set of control variables to account for time varying direct effects of infrastructure and other area characteristics. Empirical estimation issues and strategy to deal with them are discussed in detail in Section 3. It is worth emphasizing that while rainfall shocks have been used for identification in a variety of contexts, agricultural productivity is probably among the most natural contexts where rainfall can provide reasonable identifying variations ((Foster and Rosenzweig (2004), Adhvaryu, Chari and Sharma (2013), Bruckner and Ciccone (2011)).

The empirical results establishes the positive effect of rainfall on rice yields, expansion of irrigated areas and agricultural wages. Several substantive conclusions can be drawn from the empirical results discussed later. The empirical results show clearly that much of the impacts of a positive rainfall shock and hence agricultural productivity growth on employment diversification and growth will go undetected if we restrict our analysis only to rural areas. For the rural sample, the only statistically and numerically significant effects are found for informal manufacturing and services, and for transport, construction and education services. We find more substantial impacts of a positive rainfall shock on both formal and informal employment in the samples that included rural towns and non-metropolitan urban areas. Second, the transformative effect of agricultural productivity shocks will remain unnoticed if we ignore the distinction between formal and informal non-farm activities. For manufacturing employment, the effect of a positive rainfall shock is at best weak for formal employment (firms employing more than 10 workers), felt mostly in transport, construction and utilities, but is significant for informal employment. For services employment, the pattern is opposite: the effect is numerically large and statistically significant for formal/skilled services such as education, health and other services. While the effect is positive and statistically significant for informal services as well, the magnitude of the effect is much smaller compared with skilled services. The empirical results for Bangladesh suggests that a positive shock to agricultural productivity in terms of better rainfall does induce structural transformation in the non-farm sector: from unskilled to skilled services. As predicted by the model, the positive impact on manufacturing is limited to informal and small firms that tend to serve local and domestic markets. The negative impact on growth of agricultural employment is on the other hand consistent with the presence of substantial subsistence constraint as shown in the theoretical model.

The rest of the paper is organized as follows. Section 2 provides a simple general equilibrium model to highlight the different channels of interactions between farm and non-farm sectors located in rural areas and towns. Section 3 describes the econometric strategy followed by a description of data used in empirical analysis in section 4. Section 5 organized in different sub-sections presents the main empirical results. Section 6 concludes the paper.

2. The Model

To derive testable hypotheses regarding the effects of agricultural productivity growth on non-farm employment, we develop a general equilibrium model with two locations: a village and a rural town. Households in the village are engaged in the production of food and a composite village good (informal manufacturing or services). Households in towns are engaged in the production of a continuum of goods and services where the continuum is defined in terms of their trading status. Specifically we make distinction among three types: traded manufacturing (price internationally given), informal manufacturing catering to domestic demand, and internationally non-tradeable skilled services. We assume food to be internationally traded and take its price as the numeraire. The utility functions for households in the village and rural town are defined as the following:

$$U_v = u^v(c_f, c_s, c_T); \quad U_T = u^T(c_f, c_T)$$

where super/subscript v refers to village and T to town, c_f is consumption of food, c_s consumption of composite village good produced and consumed within the village, c_T is the composite of goods and services produced in town. This formulation of utility function allows village household to consume skilled services produced in towns. To provide an example, a service available within the village (c_s) could be an untrained village doctor whereas skilled service in towns could be a professionally trained doctor. For simplicity we assume that utility function in village takes the form of a Stone-Geary utility function:

$$U_v = \sum \upsilon_i \ln(c_i - \gamma_i), \ \sum \upsilon_i = 1, \text{and } i = f, s, T$$

where γ_i is the subsistence or minimum level of consumption of i. We assume that consumption of non-farm goods (s and T) does not need to meet a minimum subsistence requirement and thus $\gamma_s = \gamma_T = 0$. For simplicity, we assume that utility in town takes the Cobb-Douglas form with τ_i as the share of good/service i in town. The budget constraint for the households can be stated as:

$$Y^v = c_f + P_s c_s + P_T C_T; \quad Y^T = c_f + P_T C_T$$

where P_s and P_T are prices of village and town goods respectively. Y^v and Y^T are total household incomes in village and town respectively. Given the assumptions of Stone-Geary utility function in village and Cobb-Douglas utility function in town, demand for goods and services in each location can be expressed as:

$$\text{Village:} \qquad c_i = \frac{\upsilon_i[Y^v - \sum_j \gamma_j P_j]}{P_i} + \gamma_i, \text{ with } \sum \upsilon_i = 1,\ \gamma_s = \gamma_T = 0, P_f = 1, \text{ and } i = f, s, T$$

$$\text{Town:} \qquad c_k = \frac{\tau_k Y^T}{P_k}, \text{ with } \sum \tau_k = 1,\ P_f = 1 \text{ and } k = f, T$$

Instead of taking labor supply in each location as fixed, we consider the case where labor supply responds to wage changes.

(2.1) Labor Supply

Households in each location are assumed to engage in the production and consumption of home good (d). The production functions for the home goods are of the following form:

$$Q_{di} = l_{di}^{\delta i} \quad \text{for } i = v, T \text{ and } 0 < \delta_i < 1$$

The curvature of the home goods production function differs between village and town. The relevant opportunity cost of home production is the market wage rate w in respective locations. The marginal condition determining the optimal use of labor in home production can be expressed as:

$$\delta_i l_{di}^{\delta i-1} = w_i \text{ for } i = v, T$$

Since labor allocated to home production varies inversely with wage (equation 1), the supply of labor can be written as:

$$L_i(w_i) = L_i^0 - l_{di}^* = L_i^0 - \left(\frac{\delta_i}{w_i}\right)^{(1-\delta_i)^{-1}}, \text{ with } L_i^w = \frac{\partial L_i}{\partial w_i} > 0 \text{ for } i = v, T \tag{1}$$

The model set up above generates a positive sloping labor supply function, and is general enough where the home good can also be interpreted as leisure. A labor supply function increasing in wage is however more consistent with the employment situation in villages in developing countries where a large fraction of the labor force remains underemployed in family farms. An alternative model is where there is unemployment, and labor supply responses occur primarily at the extensive margin. The formulation adopted here is attractive, because explicit unemployment is not high in rural areas of developing countries, and poor people are poor not because they are unemployed (consuming leisure), but because they work long hours in extremely low productivity activities. Those low productivity non-market economic activities are modeled as home production in our model.

Household incomes in village and town are determined by labor market equilibrium. First we consider the case where there is no labor migration between village and town.

(2.2) Segmented Labor Markets: Labor Immobile

All production functions are assumed to display CRS. Since there is no labor mobility between village and town, we can consider the labor market equilibrium in each location separately.

(2.2.1) Income and Employment Determination in the Village

Households in village produce food using land and labor under CRS technology. The income from food production net of labor cost can be defined as:

$$y_f = \theta F(A, l_f) - w_v l_f$$

where θ represents total factor productivity in food production, A is the endowment of land which is assumed to be fixed and l_f is the labor used in food production and w_v is the wage rate in village. To keep things simple, we assume that locally consumed village good (s) is produced under CRS technology using only labor, giving income as:

$$y_s = P_s \phi l_s - w_v l_s$$

where ϕ is the technology in the production of non-traded village good. The production function assumes that village good uses only labor for its production which is consistent with village economy where informal enterprises use little capital or land. While this form of the production function simplifies the general equilibrium model considered here, the main implications of the model will hold if we use more general CRS production function using other factors (e.g. capital) as well. Assuming α as the share of land in food production function, the demand for labor in agriculture and village good can be derived as:

$$l_f = \theta^{\frac{1}{\alpha}} A[\frac{(1-\alpha)}{w_v}]^{\frac{1}{\alpha}},\, l_s = \frac{\upsilon_s}{w_v}[Y^v - \gamma_f]$$

The total household income in the village thus becomes:

$$Y^v = y_f + w_v L_v(w_v) = \alpha A \theta^{\frac{1}{\alpha}} [\frac{(1-\alpha)}{w_v}]^{\frac{1-\alpha}{\alpha}} + w_v L_v(w_v)$$

where $L_v(w_v)$ is the total labor supply function which is increasing in w_v. Note that $L_v(w_v)$ =constant would imply a fixed labor endowment in which case any shift in labor demand will be reflected only in wage and perhaps reallocation of labor across activities. Imposing the labor market equilibrium condition that labor supply ($L_v(w_v)$) is equal to labor demand ($l_f + l_s$), and simplifying provides the following condition determining equilibrium wage rate:

$$(1-\upsilon_s) w_v L_v = \Delta_1 \theta^{\frac{1}{\alpha}} [w_v]^{-\frac{1}{\alpha}+1} - \upsilon_s \gamma_f \quad (2)$$

where $\Delta_1 = A[1-\alpha(1-\upsilon_s)](1-\alpha)^{\frac{1-\alpha}{\alpha}}$. The effect of agricultural productivity increase can be derived from equation (2) as:

$$\frac{\partial w_v}{\partial \theta} = \frac{\Delta_1 (1-\alpha)^{\frac{1-\alpha}{\alpha}} \theta^{\frac{1-a}{\alpha}} w_v^{-\frac{1}{\alpha}}}{[\alpha(1-\upsilon_s)\{w_v L_v^w + L_v\} + \Delta_1 (1-\alpha)\theta^{\frac{1}{\alpha}} w_v^{-\frac{1}{\alpha}}]} > 0 \tag{3}$$

where $L_v^w = \frac{\partial L_v}{\partial w_v}$.The terms in the denominator are all positive. The first term is positive because labor supply increases with an increase wage ($\frac{\partial L^v}{\partial w^v} > 0$) (equation 1). An increase in agricultural productivity thus increases village wage and since labor supply responds positively to wage, it increases labor supply also. If labor supply did not respond to wage and was assumed to be fixed, then increase in wage due to an increase in agricultural productivity would have been much higher. The more elastic labor supply is to wage, the smaller (larger) is the extent of increase in wage (employment).

The equilibrium labor allocation in agriculture and village good are:

$$l_f^* = (1-\alpha)\Delta_2[(1-\upsilon_s)L_v + \frac{\upsilon_s \gamma_f}{w_v}]; \quad l_s^* = \Delta_2[\upsilon_s L_v - \frac{(1-\alpha)\upsilon_s \gamma_f}{w_v}] \tag{4}$$

where $\Delta_2 = 1/[1-\alpha(1-\upsilon_s)]$.

Proposition 1: Under the assumption that village good is produced and consumed locally, and agriculture is internationally traded, labor supply increases with an increase in wage and labor is immobile between town and village, an increase agricultural productivity increases employment, wage and income in the village. A positive shock in agricultural productivity increases employment in village non-farm activities whereas its effect on agricultural employment depends on the subsistence requirement for food (γ_f) and demand parameter for village good relative to labor supply response.

Proof: The impact of agricultural productivity shock on total employment and wages follow directly from equations (1) and (3). Substituting from the labor market equilibrium condition in equation (2), village income can be expressed as:

$$Y^v = \alpha A \theta^{\frac{1}{\alpha}} [\frac{(1-\alpha)}{w_v}]^{\frac{1-\alpha}{\alpha}} + w_v L_v = \frac{w_v L_v + \alpha \upsilon_s \gamma_f}{[1-\alpha(1-\upsilon_s)]}$$

The impact of agricultural productivity shock on village income is:

$$\frac{\partial Y^v}{\partial \theta} = \frac{[L_v + w_v L_v^W]}{[1-\alpha(1-\upsilon_s)]}] \frac{\partial w_v}{\partial \theta} > 0$$

The impact on agricultural employment can be derived as:

$$\frac{\partial l_f^*}{\partial \theta} = [1-\alpha)\Delta_2[(1-\upsilon_s)L_v^w - \frac{\upsilon_s \gamma_f}{w^2}]\frac{\partial w^\upsilon}{\partial \theta}$$

If there is no subsistence requirement for food ($\gamma_f = 0$), then $\frac{\partial l_f^*}{\partial \theta} > 0$ since $L^w = \frac{\partial L^\upsilon}{\partial w^\upsilon} > 0$. On the other hand, if labor supply is fixed ($L^w = 0$), then $\frac{\partial l_f^*}{\partial \theta} < 0$. The larger is γ_f ceteris paribus, the greater is the possibility that $\frac{\partial l_f^*}{\partial \theta} < 0$. Similarly, the larger the income share (υ_s) of village good while other things being equal, the greater is the possibility that $\frac{\partial l_f^*}{\partial \theta} < 0$. On the other hand, a larger labor supply response to wage (L_v^w) improves the odds of a positive effect of agricultural productivity on employment in agriculture. The unambiguous positive effect of agricultural productivity increase on village non-farm employment follows directly from equation (4).

(2.2.2) Income and Employment Determination in the Town

We adopt a broader definition of C_T. It could be manufacturing good such as processed food, textile and garments produced for domestic consumption or export, and equipment needed for agriculture. It could also be relatively skilled services such as better trained doctors in hospitals, better teachers in schools and other professionals. Since implication of agricultural productivity growth will run in the same direction for all of them, we treat them under a single category C_T. In order to provide more precise definition of trading status of town goods, we assume that its demand comes three sources: village (C_T^v), town itself (C_T^T) and outside areas (e.g. urban or other countries) (C_T^O) .[8] For simplicity, we assume that demand coming from outside (village or town) is exogenously given in the model. Depending on the relative influence of village or outside demand in total demand for town goods, we define three different trading regimes: (i) *Locally traded*: if demand for town goods depend only on village demand ($C_T^v > 0, C_T^O = 0$);(ii) domestically traded: if demand is determined by both village and other urban areas ($C_T^v > 0, C_T^O > 0$); (iii) internationally traded: if demand is determined by outside areas only ($C_T^O > 0, C_T^v = 0$).[9]

For simplicity, we assume that C_T is produced under CRS technology using labor and capital.

[8] For simplicity, C_T^O is assumed to be nominal expenditure on town good by consumers residing outside the village and town economies described here.

[9] In conventional literature, our case (i) (locally traded) corresponds to what is termed as "nontraded" and case (ii) to "traded".

$$Q_T = G(K, L_T) = K^{\beta} L_T^{1-\beta}$$

We assume that urban segment of the economy is populated by a single representative agent who invests $K > 0$ amounts of capital in the production of town good at an interest rate r which is determined outside the model. The total profit from town good net of labor and capital cost is:

$$\pi_T = P_T K^{\beta} L_T^{1-\beta} - w_T l_T - rK$$

where w^T is real wage (nominal wage normalized by food price).As shown before, labor supply (L_T) is an increasing function of w^T. The profit maximization condition implies that:

$$\begin{aligned}\beta P_T K^{\beta-1} L_T^{1-\beta} &= r \\ (1-\beta) P_T K^{\beta} L_T^{-\beta} &= w_T\end{aligned}$$

Using the above two first order conditions and noting that $Y_T = P_T Q_T = w_T l_T + rK$, town income can be defined as $Y_T = \frac{w_T L_T}{(1-\beta)}$. Setting output supply (Q_T) equal to demand ($C_T^v + C_T^T + C_T^O$) and utilizing the optimization conditions, the labor market equilibrium condition can be written as:

$$w_T L_T = \frac{(1-\beta)[\upsilon_T (Y^v - \gamma_f) + C_T^O]}{(1-\tau_T)}$$

where τ_T is the share of C_T in the Cobb-Douglas utility function for town. The change in town wage in response to agricultural productivity is derived as:

$$\frac{\partial w_T}{\partial \theta} = \frac{(1-\beta)\upsilon_T \frac{\partial Y^v}{\partial \theta}}{(1-\tau_T)[L_T + w_T L_T^w]} > 0 \tag{5}$$

An increase in agricultural productivity thus increases demand for town good which in turn increases wage and employment in town.

Proposition 2: Under the assumption that town good is domestically traded, labor supply is a positive *function of wage and labor is immobile between town and village, (i) an increase in agricultural productivity increases demand for town good raising its equilibrium wage and employment; (ii) The more elastic the labor supply curve is, the smaller (larger) is the rise in wage (employment); (iii) The higher is the share of village income spent on town good (υ_T), the larger are the magnitudes of effects of agricultural productivity increase on town's employment and wage (equation 5); (iv) Agricultural productivity growth has a multiplier effect when a part of demand for town good comes from its own income.*

The proof of proposition 2 follows directly from equation (5). The intuition for (iv) comes from the fact that $(1-\tau_T) < 1$, thus $\frac{\partial w^{\upsilon}}{\partial \theta}|_{\tau_T=0} < \frac{\partial w^{\upsilon}}{\partial \theta}|_{\tau_T>0}$.Proposition 3(iii) implies that a substantial part of the positive impact of agricultural productivity will go undetected if we focus only on village economy. This can be particularly important when consumption share of town good (υ_T) is large.

A maintained assumption of the model described so far is that labor is immobile between locations. In the following subsection, we relax this assumption and explore its implication for employment and wages in both village and town.

2.3 Interlinked Labor Markets: Perfect Labor Mobility

We assume that labor is perfectly mobile and migration cost is equal to zero, so that equilibrium wage (w) are the same regardless of location. The demand for labor in town can be described as:

$$l_T = \frac{\Delta_3(Y^{\upsilon} - \gamma_f)}{w} + \frac{(1-\beta)C_T^O}{w}$$

where $\Delta_3 = \frac{(1-\beta)\upsilon_T}{(1-\tau_T)}$. For an interior solution, we assume that $(1-\beta) < (1-\tau_T)$.The labor market equilibrium condition can be solved as:

$$L_T + (1 - \upsilon_s - \Delta_3)L^{\upsilon} = \Delta_4 \theta^{\frac{1}{\alpha}} [w^{\upsilon}]^{-\frac{1}{\alpha}} - \frac{(\upsilon_s + \Delta_3)\gamma_f - (1-\beta)C_T^O}{w^{\upsilon}} \tag{6}$$

where $\Delta_4 = A[1 - \alpha(1 - \upsilon_s - \Delta_3)](1-\alpha)^{\frac{1-\alpha}{\alpha}}$.Note that $1 > (1 - \upsilon_s - \Delta_3) > 0$, since $\Delta_3 < \upsilon_T$.

Proposition 3: Under the assumption that labor is perfectly mobile between locations and that demand for town goods depends only on town and village income ("locally traded"), an increase in agricultural productivity increases wage and employment in both village and town goods' production while its impact on *agricultural employment is ambiguous. The larger is the share of town good in village consumption, the larger is the increase in its employment.*

Proof: The assumption that demand for town goods depends only on town and village income implies that $C_T^O = 0$. Utilizing the equilibrium condition in equation (6), the impact of a change in agricultural productivity on wage can be derived as:

$$\frac{\partial w}{\partial \theta} = \frac{\Delta_4(1-\alpha)^{\frac{1-\alpha}{\alpha}}\theta^{\frac{1-a}{\alpha}}w^{-\frac{1}{\alpha}}}{[\alpha w\{L_T^w + (1-\upsilon_s-\Delta_3)L_v^w\} + \{L_T + (1-\upsilon_s-\Delta_3)L_v\} + \Delta_4(1-\alpha)\theta^{\frac{1}{\alpha}}w^{-\frac{1}{\alpha}}]} > 0 \qquad (7)$$

Using the equilibrium wage (equation 6) and labor demand functions, the equilibrium allocation of labor among three activities can be described as follows:

$$l_T^* = \frac{\Delta_3[(\alpha L_T + L_v) - \frac{(1-\alpha)\gamma_f}{w}]}{[1-\alpha(1-\upsilon_s-\Delta_3)]}; \quad l_s^* = \frac{\upsilon_s[(\alpha L_T + L_v) - \frac{(1-\alpha)\gamma_f}{w}]}{[1-\alpha(1-\upsilon_s-\Delta_3)]}$$

$$l_f^* = \frac{(1-\alpha)[L_T + (1-\upsilon_s-\Delta_3)L_v + \frac{(\upsilon_s+\Delta_3)\gamma_f}{w^{\upsilon}}]}{[1-\alpha(1-\upsilon_s-\Delta_3)]}$$

The impacts of agricultural productivity shock on employment in farm and non-farm activities are:

$$\frac{\partial l_T^*}{\partial \theta} = \frac{\Delta_3[(\alpha L_T^W + L_v^W) + \frac{(1-\alpha)\gamma_f}{w^2}]}{[1-\alpha(1-\upsilon_s-\Delta_3)]}\frac{\partial w}{\partial \theta} > 0; \quad \frac{\partial l_s^*}{\partial \theta} = \frac{\upsilon_s[(\alpha L_T^W + L_v^W) + \frac{(1-\alpha)\gamma_f}{w^2}]}{[1-\alpha(1-\upsilon_s-\Delta_3)]}\frac{\partial w}{\partial \theta} > 0$$

$$\frac{\partial l_f^*}{\partial \theta} = \frac{(1-\alpha)[L_T^w + (1-\upsilon_s-\Delta_3)L_v^w - \frac{(\upsilon_s+\Delta_3)\gamma_f}{w^2}]}{[1-\alpha(1-\upsilon_s-\Delta_3)]}\frac{\partial w}{\partial \theta} \gtreqless 0$$

The larger is consumption share of $C_T^v(\upsilon_T)$, the larger is Δ_3, and thus larger is the impact of agricultural productivity on employment in the production of town good. Note that $\frac{\partial l_T^*}{\partial \theta}/\frac{\partial l_s^*}{\partial \theta} = \frac{\Delta_3}{\upsilon_s}$. The larger is the Δ_3 relative to υ_s, the larger is the impact on employment in town good's production relative to village services.

Proposition 4:Under the assumption that labor is perfectly mobile between locations and that demand for town goods does not depends on village income (nationally/internationally traded"), an increase in agricultural productivity increases wage and employment in village good's production and but decreases *employment in town good's production while its impact on agricultural employment remains ambiguous.*

Proof: Under the assumption that demand for town good does not depend on village income, the demand for labor in the production of town good becomes:

$$l_T = \frac{(1-\beta)C_T^O}{w}$$

The labor market equilibrium condition can be solved as:

$$L_T + (1-\upsilon_s)L^\upsilon = \Delta_4 \theta^{\frac{1}{\alpha}}[w^\upsilon]^{-\frac{1}{\alpha}} - \frac{\upsilon_s \gamma_f - (1-\beta)C_T^O}{w^\upsilon}$$

The impact of agricultural productivity on wage and labor allocation can be derived as:

$$\begin{aligned}
\frac{\partial w}{\partial \theta} &= \frac{\Delta_1 (1-\alpha)^{\frac{1-\alpha}{\alpha}} \theta^{\frac{1-a}{\alpha}} w_v^{-\frac{1}{\alpha}}}{[\alpha w\{L_T^w + (1-\upsilon_s)L_v^w\} + \{L_T + (1-\upsilon_s)L_v\} + \Delta_1(1-\alpha)\theta^{\frac{1}{\alpha}} w_v^{-\frac{1}{\alpha}}]} > 0 \\
\frac{\partial l_T^*}{\partial \theta} &= -\frac{(1-\beta)C_T^O}{w^2}\frac{\partial w}{\partial \theta} < 0; \ \frac{\partial l_s^*}{\partial \theta} = \frac{\upsilon_s[(\alpha L_T^W + L_v^W) + \frac{(1-\alpha)\gamma_f}{w^2}]}{[1-\alpha(1-\upsilon_s)]}\frac{\partial w}{\partial \theta} > 0
\end{aligned}$$

where $\Delta_1 = A[1-\alpha(1-\upsilon_s)](1-\alpha)^{\frac{1-\alpha}{\alpha}}$.When agricultural productivity growth has no demand effect on town good, a rise in agricultural productivity makes labor more expensive leading to a decrease in employment in its production. This prediction is also reported in Foster and Rosenzweig (2004). To the extent village workers commute to avail jobs in the production of internationally traded goods, agricultural productivity will reduce such commuting.

Proposition 5:Under the assumption that labor is perfectly mobile between locations and that demand for town goods depends on both outside and village income ("domestically traded"), an increase in agricultural productivity increases wage and employment in village services while its impacts on employment in agriculture and town good production are ambiguous.

Proof: Assuming $\bar{C}_T$ is the subset of town good (C_T^O) whose demand is generated outside village/town economy, labor allocation among activities is described by:

$$l_T = \frac{[\Delta_3\{(\alpha L_T + L^\upsilon) - \frac{(1-\alpha)\gamma_f}{w}\}] + \frac{(1-\beta)\bar{C}_T[1-\alpha(1-\upsilon_s)]}{w}]}{[1-\alpha(1-\upsilon_s-\Delta_3)]};\ l_s = \frac{\upsilon_s[(\alpha L_T + L^\upsilon) - \frac{(1-\alpha)\gamma_f}{w} - \frac{\alpha(1-\beta)\bar{C}_T}{w}]}{[1-\alpha(1-\upsilon_s-\Delta_3)]}$$

$$l_f = \frac{(1-\alpha)[L_T + (1-\upsilon_s-\Delta_3)L_\upsilon + \frac{(\upsilon_s+\Delta_3)\gamma_f}{w^\upsilon} - \frac{(1-\beta)\bar{C}_T}{w}]}{[1-\alpha(1-\upsilon_s-\Delta_3)]}$$

Simple differentiation of equilibrium employment levels with respect to wage establishes the predictions of proposition 5 since $\frac{\partial w}{\partial \theta} > 0$. The impact of agricultural productivity shock on employment in town good is now indeterminate because part of its demand is generated outside village/town economy. The larger is the demand for town goods coming from outside world, the greater is the possibility that employment in town good decline in response to agricultural productivity shock due to negative wage effect.

3. Empirical Strategy

To estimate the effects of agricultural productivity growth on non-farm employment, we construct and utilize a subdistrict (upazila) level panel dataset. The theoretical model presented above implies a regression specification as:

$$O_{ijt} = \rho_j + \rho_t + \pi\theta_{jt} + \Pi Z_{jt} + \varepsilon_{ijt} \tag{8}$$

where i indexes the outcome variables (e.g. employment, wage etc), and j upazila. O_{ijt} is the outcome variable i. ρ_j and ρ_t denote upazila and year fixed effects respectively. θ_{jt} is the measure of agricultural productivity, Z_{jt} is a vector of upazila characteristics and ε_{ijt} is an iid error term. Estimation of the impact of agricultural productivity on non-farm employment however presents challenges. Unobserved upazila characteristics (e.g. proximity to river) may attract firms into an upazila (due to ease of transport) and also affect agricultural productivity (due to availability of water for irrigation) positively. The upazila fixed effects ρ_j remove any time invariant but unobserved regional effects. The year fixed effects (ρ_t) control for any macro economic and international shocks (including commodity price shocks) that may have affected both agricultural productivity and outcomes of our interest.[10]

For the actual estimation of equation (8), the upazila level unmeasured fixed factors are removed by de-

[10] The year fixed effects will control for any general equilibirum effect common to all households (e.g. prices) also.

meaning all variables in the regression. Such de-meaning however leads to attenuation bias as it magnifies any measurement error in agricultural productivity (Griliches, 1967). To remedy this potential source of bias, we utilize an instrumental variable approach. Following standard practice in literature (Foster and Rosenzweig (2004), Adhvaryu, Chari and Sharma (2013)), agricultural productivity is measured by crop yield. For our specific case, it is proxied by rice yield as rice is the predominant subsistence and cash crop in Bangladesh. We use rainfall as an instrument for rice yield. To be precise, we use deviation of current rainfall from its long term average as an instrument. The long term average rainfall is defined as average rainfall during a 30 year period from 1960 to 1990. Rainfall is found to affect agricultural yields in both developed and developing countries and hence used widely as an instrument for agricultural yields (Foster and Rosenzweig (2004), Adhvaryu, Chari and Sharma (2013), Rajan and Ramcharan (2010), Bruckner(2012)).

In the empirical analysis, we follow a two step procedure: first, a reduced form regression of an outcome variable (for example, formal non-farm employment) on the instrument, and second, a reduced form regression of the productivity measure (yield per acre) on rainfall deviation. This two-step procedure has some important advantages in our application. First, the reduced form estimates of the effects of rainfall on the outcome variables such as non-farm employment are of interest on their own; for example, they provide us evidence on the potential benefits of increased irrigation investment on the rural non-farm economy. Second, when the focus is on the effects of productivity increase in agriculture, one can interpret the variations in rainfall as variations in the parameter θ in the model. Finally, with a focus on the standard measures of agricultural productivity such as crop yield, and rainfall as an instrument, the reduced form estimates of rainfall on employment are still useful. This is because they provide evidence on the *existence* of a causal effect of higher crop yield, which is not subject to weak instrument bias (Chernozhukov and Hansen(2008)).[11] We estimate the following reduced form regressions:

$$O_{ijt} = \rho_j + \rho_t + \pi_1 R_{jt} + \Pi_1 Z_{jt} + \varepsilon_{ijt} \tag{9}$$

$$V_{jt} = \eta_j + \eta_t + \pi_2 R_{jt} + \Pi_2 Z_{jt} + \upsilon_{jt} \tag{10}$$

[11] We, however, emphasize that the main results of this paper do not depend on the exclusion restriction on rainfall; what we need is that rainfall affects productivity significantly.

where R_{jt} is the deviation of annual rainfall from its long term average in upazila j and V_{jt} is the measure of productivity. The deviation is defined as the difference between log of current rainfall from log of its long term average. Thus our empirical model with upazila and year fixed effects provides estimates of the impact of rainfall shock on the growth of outcome variables. A positive coefficient of rainfall ($\pi_2 > 0$) for instance in the yield regression means that an increase in rainfall over its long term average level (a positive rain shock) increases rice yield.

To ensure that rainfall primarily captures variation in agricultural productivity, we include an appropriate set of controls in Z_{jt}. A potential concern in our context is that rainfall may be directly correlated with growth in non-farm employment and hence may not be reflecting the impact of agricultural productivity. Firms in developing countries are observed to locate near large urban centers (Fafchamps and Shilpi (2003) and (2005), Deichmann et al (2008)). These areas may happen to have higher rainfall as well. To address this concern, travel time from the upazila center to the nearest of two main metropolitan cities (Dhaka and Chittagong) is added as a control in the regression. Third, some non-farm activities may be susceptible to rainfall directly. For instance, construction employment may rise with higher rainfall if rainfall leads to flooding and destruction. Flooding and destruction may also lead to a negative correlation between rainfall and non-farm employment growth if it disrupts production activities of firms. As flooding may affect some types of non-farm activities directly, we include a dummy for floodplain in the regression. Both travel time and the floodplain dummy are time-invariant, and would be taken care of by upazila fixed effects. To allow for time varying effects of these variables, we interacted them with time trend. Third, both nonfarm and farming activities may have been affected positively by availability of new infrastructure. The travel time variable already partly controls for this. In addition, we included proportion of household with electricity as a control. To capture changes in labor endowment, we control for upazila population, total active labor force, and proportion of active labor force with secondary or above education (human capital). To account for any agglomeration externalities that may affect firm location, we control for upazila population in 1991 interacted with time trend (initial condition) and share of urban households in total households in the upazila (urbanization economy). [12] A final issue for the empirical specification is that rainfall is expected to have significant effect on rice yield only if a upazila is predominantly rural in its economic activity.

[12] Our empirical results are robust to more finer controls of agglomeration economies such as area share in total industry employment in 1991.

We thus exclude upazilas located in two main metropolitan areas from our sample. The theoretical model suggests that effects of agricultural productivity may vary across areas. Accordingly we carry out empirical analysis for three different samples whose definitions are given below in the data section.

4. Data

To test the hypotheses regarding the impacts of agricultural productivity growth on non-farm employment and household expenditure, we combine different data sources to define an upazila (subdistrict) level panel data set covering the period 2000 to 2009/2010. Data on employment in formal non-farm activities are drawn from three rounds of economic censuses (2000, 2006 and 2009). The economic census provides a detailed list of all firms engaged in industrial and services activities (at 4-digit level) with number of employees more than 10. These relatively larger firms are mostly registered and tend to serve larger markets. Following standard practice in the literature on formal and informal firms (see Ghani and Kanbur (2013) for a discussion on this), we take employment in these firms as "formal" employment. Arguably a large fraction of these firms serves only domestic market. However, the larger is the firm size, the greater is the possibility that it produces internationally traded goods or serves wider geographical area domestically.[13]

A second source employment data is the population censuses (1990, 2000 and 2010). The census unit records are publicly available for 10 percent of population in 1990 and 2000, and 5 percent in 2010.[14] The unit record data contain employment records of all household members.[15] We define total employment level in each activity from these unit records using appropriate weights. The total employment defined from census data includes employment in both formal and informal activities. Unlike economic census, population census used a much more aggregated industrial classification in coding employment (top level). Specifically, 2010 census distinguishes only between agriculture, manufacturing and services activities. The comparison of formal and informal employment growth are done at this aggregate level (manufacturing vs. services). The economic census data are then used to conduct more disaggregated analysis within the formal activities.

The productivity growth in agriculture is measured by growth in crop yields. The predominant crop in

[13] For instance, larger garment factories in Bangladesh produce almost exclusively for export market whereas smaller ones (e.g. tailoring shops) meet domestic demand.

[14] The sample sizes are 10.6, 12.4 and 7.2 million individuals in 1990, 2000 and 2010 censuses respectively.

[15] Total numbers of employment records in census data are 3.1, 3.5 and 2.1 million for 1990, 2000 and 2010 censuses respectively.

Bangladesh is rice/paddy, of which three different types (Boro, Aman and Aus) are grown.[16] The official source of agricultural statistics provides yield data at district level.[17] Another source of yield data is the community part of the Household Income and Expenditure Surveys (HIES) (2000, 2005, 2010). We defined rice yield per acre as the average of yields of boro, aman and aus rice reported in the village/community part of HIES. The upazila (subdistrict) level yields are the average over villages surveyed within a upazila. Since number of villages within upazila are small, these data arguably involve large measurement errors and available for only a restricted sample of upazilas. We compared yield growth from both sources of data and both show considerable and comparable growth during the decade of 2000.

Rainfall data – used as an instrument for agricultural productivity – are drawn from Bandyopadhyay and Skoufias (2012). The original data on rainfall come from the Climate Research Unit (CRU) of the University of East Anglia. The CRU reported estimated monthly rainfall for most of the world at the half degree resolution from 1902 to 2009. The CRU estimation combines weather station data with other information to arrive at the estimates.[18] To estimate the sub-district (upazila/thana) level rainfall from the CRU data, Bandyopadhyay and Skoufias (2012) uses area weighted averages.[19] Travel times to different destinations were computed using GIS software and road network from mid-1990s. Data on agro-ecological zones are drawn from the Bangladesh Water Board database.

Over the years, a number of larger upazilas were split to form new upazilas, thus increasing the total number of upazilas from 486 in 1990 to 507 in 2000 to 543 in 2010. We use upazila maps to identify the borders of upazilas overtime and matched all upazilas in 2000 and 2010 to 1990 upazilas. The upazila level panel is defined using 1990 upazila boundaries. The theoretical model in section 2 suggests that the impact of agricultural productivity growth may be felt in smaller towns and peri-urban areas as well. Accordingly we carry out estimation in three samples. The full sample consists of all upazilas except for those in two main metropolitan cities. The size of full sample is 355. The second sample is defined to include all rural

[16] High yielding variety of Boro rice now accounts for more than half of rice production (56%). Aman is the next important crop accounting for 44% of rice production. Yields of both of these varieties are much higher than Aus.

[17] These data are actually reported at old (and much larger) district level – there are about 20 old districts. With newly created districts, there are now 64 districts in Bangladesh.

[18] Previous versions of the CRU data were homogenized to reduce variability and provide more accurate estimation of mean rain at the cost of variability estimation. The version 3.1 data is not homogenized and thus allows for better variability estimates. The estimates of rainfall near international boundaries are not less reliable as compared with those in the interior of the country, as the CRU estimation utilizes data from all the weather stations in the region.

[19] For example if an Upazila/thana covers two half degree grid cells for which CRU has rainfall estimates, then upzila/thana rainfall is estimated as the average rainfall of the two grid-cells, where the weights are the proportion of the area of the upazila/thana in each grid-cell. For details, please see Bandyopadhyay and Skoufias(2012).

areas and towns where less than half of the households are classified as urban (320 upazilas). Finally, the rural sample is defined to include all upazilas – 217 of them – where less than 15 percent of households are classified as urban. As firms with larger sizes are expected to serve larger markets, firms/activities located in rural villages can be argued to be of informal nature serving mostly local demand.

Table 1 provides the summary statistics for upazilas over the years. The population censuses indicate strong employment growth in overall non-farm sector including both formal and informal activities.[20] Total employment in non-farm activities grew at an annual rate of 8.9 percent between 2000 and 2010. Total manufacturing employment (formal plus informal) posted an annual growth of 15.4 percent during this period. Services employment grew by 7 percent. Between 2000 and 2009, employment in firms with more than 10 employees (formal) has grown at an annual rate of 8.4 percent. Within formal sector, growth in manufacturing employment has been quite robust at 6.9 percent compared with 2.1 percent growth in services employment. The comparison of employment composition shows that more than three-quarters of total employment in non-farm sector are in the informal sector where firms are smaller in size (10 or fewer employees). Interestingly, the share of formal sector in total non-farm employment declined from 0.268 in 2000 to 0.238 in 2010. Another important difference between compositions in formal vs. total employment is that while about 29 percent of all employment is in manufacturing in 2010, the share of manufacturing in formal employment is much higher (39 percent in 2009). This is expected as few services enterprises are large in size. Larger services enterprises appear to be more concentrated in the provision of health (hospitals, clinics etc) and education (schools) (Table 1).

The summary statistics in Table 1 indicate substantial growth in rice yield between 2000 and 2010. Average rice yield per acre has grown by an annual rate of 3.6 percent. This rate is consistent with about 3.7 percent growth in agricultural GDP during the same time.[21] There has been substantial expansion of irrigation during the decade as well -from 61 percent in 2000 to 67 percent in 2010. The standard deviation estimate (Table 1) shows that there are considerable variations in rice yields across upazilas. Among other variables, access to electricity by households improved considerably during the decade (4.9 percent annual growth rate).

[20] According to census data, share of non-farm employment in total employment increased from 0.475 in 2000 to 0.53 percent in 2010. The total labor force during this period increased by an annual rate of 2.05 percent from 35 million to 42.5 million.

[21] Crop agriculture accounts for 56 percent of agricultural GDP and rice is the single most important crop in Bangladesh not only as a subsistence but also as a cash crop.

5. Empirical Results

In this section, the main empirical results along with robustness tests are presented sequentially. All outcome variables as well as rainfall are expressed in logarithms. All regressions include upazila and year fixed effects. All standard errors are corrected for correlation in the error term within upazila.

5.1 Rainfall, Agricultural Productivity, and Agricultural Wage

We begin by presenting evidence on rainfall shock's impact on agricultural productivity. Table 2 reports the results from regressions where log of rice yield is regressed on deviation of rainfall after controlling for upazila and year fixed effects. Column (1) shows the result when no other explanatory variable is included in the regression. Regression in column (2) includes full set of upazila level controls as discussed in empirical strategy section (section 3) whereas column (3) adds control for proportion of area irrigated. The first panel reports results for the full sample, second from rural and town sample and third rural sample. All three regressions in each of the panels show statistically and numerically significant impact of rainfall shock on rice yield. The estimated coefficients imply an increase in yield growth due to a positive shock in rainfall over its mean level. This result is consistent with findings from a rich body of evidence accumulated by the agronomists and crop scientists that shows that rainfall is a major determinant of yield growth in rice in Bangladesh in last few decades (see, for example, Sarkar et. al. (2012)).

While positive rainfall shock increases rice yield, does it increase farming income? We do not have reliable data on total farming income. We utilize HIES data on agricultural wage to examine the effect of rainfall shock on farming income. Note that the sample size for the wage regression shown in column (4) of Table 2 is somewhat smaller due to the fact that HIES – though nationally representative – did not cover all of the upazilas in our sample. The results in column (4) show statistically significant and positive impact of rainfall on agricultural wage in all three of our samples – the impact being largest in the full sample followed by the rural sample. This result confirms that farming incomes particularly of the poorest farm workers do increase with an increase in agricultural productivity induced by positive rainfall shock.

While positive rainfall shock increases rice yield, for appropriate interpretation of the results, it is useful to understand whether this reflects only the impact of transitory weather shock on farming. While the rainfall variations across upazilas and over time are expected to affect the yield directly, they are also likely to affect long-term productivity differences by influencing investment in irrigation. The third column reports estimated effect of rainfall variations on the area irrigated in a specification with upazila fixed effects and other controls used in our main regressions. Thus the estimated coefficient shows the determinant of irrigation *expansion* over time. A positive and statistically significant coefficient on the rainfall variable in this regression indicates that irrigation expansion over our sample period has happened increasingly in areas with relatively higher rainfall.[22] Thus rainfall variable in our panel regressions captures not only transitory shock in agriculture but also the diffusion of modern technology in farming over time. Note also that modern farming technology such as irrigation may also reduce risk by decreasing variability of yield even without increasing yields. The expansion of irrigation in Bangladesh allowed adoption of boro rice whose yields are significantly higher than other rice types (aman and aus). This is confirmed in the results in Table 2 which shows that higher rainfall does increase yield significantly.

Another issue in the IV interpretation of rainfall is that it may be capturing not only agricultural productivity shock but also resulting price changes. In a completely segmented rice market at the upazila level, a rainfall shock would affect the equilibrium rice price through income effect. However the rice market is the most developed and spatially integrated market in Bangladesh (see, for example, Golleti, Ahmed and Farid (1995), Hossain and Verbeke (2010)). In addition, we already control for the distances to the main city markets, which would capture spatial price dispersion due to transport costs. The theoretical model assumes that rice price is pinned down by the international market, and available evidence on rice markets in Bangladesh clearly supports this assumption.

5.2 Rainfall, Formal and Informal Employment in Non-farm Sector

With the evidence that a positive rainfall shock increases agricultural productivity and wage, we now turn to non-farm employment. The theoretical model predicts a positive effect of agricultural productivity growth on non-farm employment if it works mainly through increase in demand due to increased farming income and if labor supply is relatively elastic to wage. On the other hand, if labor supply is fixed, increased agricultural productivity may lead to a reallocation of labor across sectors: from internationally traded formal activities to domestically traded informal activities and non-traded services activities, and to agriculture. Even when labor supply is quite responsive to wages, the employment effects of agricultural

[22] Historically, irrigation is adopted first in drier regions in Bangladesh resulting in a negative correlation bewteen area irrigated and rainfall in the cross-section data. However, expansion of irrigated areas happened increasingly in high rainfall areas – as confirmed by our panel regression result.

productivity growth will depend on the income share of domestically traded and non-traded non-farm activities. To test these hypotheses, we make a distinction between formal and informal activities in terms of sizes of the firms. The dependent variables in the employment regressions are all expressed in logarithms. All regressions include full set of regressors and upazila and year fixed effects.

The first three columns of Table 3 report the fixed effects regression results for formal activities and last three for all employment including informal activities. In order to facilitate comparison between economic census data on formal activities and population census data on all activities, employment categories are kept at a fairly aggregate level distinguishing only between manufacturing and services.[23] The top panel reports results for the full sample, middle for rural and town sample and bottom for rural only sample. For formal manufacturing employment, the results suggest a weak effect of rainfall: the effect is statistically significant at the 10 percent level only for the full sample. For the rural sample, the effect is numerically small as well (coefficient=0.41 with t-statistic=0.39). This is consistent with the theoretical prediction in section 2 that if a considerable proportion of rural income is spent on goods manufactured outside rural areas, then one would seriously underestimate the effect of agricultural productivity growth on non-farm employment by focusing on rural areas alone. In contrast to manufacturing, the results in column 2 show a positive, numerically large and statistically significant effect of rainfall on employment in services. While the coefficient of rainfall is statistically significant in all three samples, its magnitude is much larger in the rural and town, and full samples compared with the rural sample. The pattern of these estimates across samples again highlights the possibility that effects of agricultural productivity growth may extend much beyond the immediate vicinity of rural areas. The results for total formal employment are consistent with those for manufacturing and services employment: the effect is positive but somewhat weaker in the rural sample compared with the other two samples.

The FE regression results for all employment including formal and informal employment are reported in columns 4-6 in Table 3. The sample sizes are smaller in this case as 2006 is a non-census year. In contrast to formal manufacturing employment, the effect of rainfall on total manufacturing employment is statistically significant in all three samples. The estimated coefficients imply large and positive effect of rainfall on total manufacturing employment. The magnitude of the coefficient is largest in the rural sample. The results

[23] Census data do not provide employment information at disaggregate level for 2010.

for formal and total manufacturing employment imply that agricultural productivity has significant and positive effect on employment in smaller and informal manufacturing firms. The results for all services employment (in column 5) are also quite opposite to what we found for formal services employment. The estimated coefficient of rainfall is positive and statistically significant in all three samples but the magnitude is largest in the rural sample. The magnitude of estimated coefficient is smaller for all services compared with formal services in all three samples. The effect of rainfall on total employment is largest in rural areas followed by rural and towns. The results in Table 3 show a complete opposite pattern for total formal employment with effect in rural sample being the smallest in magnitude. The final column in Table 3 reports the results for employment in the agricultural sector. The effect of rainfall on agricultural employment is small, negative and statistically insignificant in the full sample. The effect is statistically significant and negative for the rural, and rural and town samples. The results for all three samples are consistent with the case where subsistence requirement for food is substantial.

The results in Table 3 show clearly that the effects of agricultural productivity differ across areas and across types of activities. Consistent with the predictions of the model in section 2, employment in formal manufacturing firms which serve larger markets at home and abroad is less responsive to agricultural productivity shock. Employment in smaller informal manufacturing firms serving mostly domestic and local markets is on the other hand quite sensitive to agricultural productivity shock. The positive impact of rainfall on informal manufacturing employment is consistent with demand shift induced by agricultural productivity change.

The results for services employment indicate a relatively small effect of agricultural productivity growth on informal services but a large and positive impact on formal services. The effect is larger in magnitude in the towns and full samples. Both of these results are consistent with predictions in propositions 2, 3 and 5). The results suggest lower income elasticity for informal services compared with formal services. With income growth resulting from agricultural productivity shift, households appear to be spending more on better services which are often located in towns and cities.

Our results on manufacturing and services employment are in contrast with findings from Foster and Rosenzweig (2004) for India. Using village level data, Foster and Rosenzweig (2004) find that agricultural productivity growth has negative effect on number of factory workers and positive effect on employment in services. Using district and state level data from India, Adhvaryu, Chari and Sharma (2013) on the other hand find factory employment to be affected negatively by negative productivity (rainfall) shock. Our results for total services in the rural sample are consistent with the Foster and Rosenzweig (2004) results. Our results for total manufacturing employment are consistent with evidence in Adhvaryu, Chari and Sharma (2013). The results in Table 3 also highlight the need for making a distinction between formal and informal employment, and focusing on geographical areas beyond the villages.

5.3 Rainfall and Formal Employment in Non-farm Sector

The results above imply important differences in the way agricultural productivity shock affects different types of formal and informal activities. In this section, we explore whether these differences are observed at more disaggregated levels of formal employment for which we have data. Within the manufacturing sector, we make a distinction between food processing and beverages, and other manufacturing. Among services activities, we distinguish between trade, education, health and other services. We also examine employment in transport, construction, and utility as a separate category. The FE regression results are reported in Table 4. As before, all regressions include a full set of controls along with upazila and time fixed effects.

For the manufacturing employment in food and beverages, results in columns 1 in Table 4 indicate no significant effect of rainfall in any of the three samples. For all other manufacturing, the coefficient of rainfall is statistically significant only at 10 percent level for the full sample. For transport, construction and utilities, rainfall has statistically significant effect in all three samples, though effects are larger in magnitude in full and rural town samples. In the case of services, rainfall has significant positive effects in all three samples in the case of education. For health and other services, significant impacts are found for full and rural town samples. In the case of employment in formal trading firms, the effects of rainfall are small in both numerically and statistically. The patterns of magnitudes of effects for all these sub-categories are consistent: largest effect in full sample followed by rural town sample. For rural areas, we find significant effect only on education and on construction, transport and utilities (both at 10 percent level).

The results in Tables 3 and 4 show that increased agricultural productivity and rural income leads to employment transformation within the services sector: households appear to substitute away from informal and perhaps traditional services, and into skilled and formal services. The effect of agricultural productivity is most pronounced in the employment growth in skilled/formal education services and in construction, transport etc services. Employments in health and other services in rural areas and towns, and in our full sample also grows significantly in response to a positive rainfall shock.

6. Conclusions

There is now ample evidence from developing and developed countries that a shift of workers from agriculture to non-agriculture contributes significantly to economic growth and poverty reduction. How to stimulate the growth and transformation of the non-farm activities particularly in rural areas and towns has become an important policy concern in developing countries. There is an on-going debate on what policies a country should pursue for non-farm development. An influential view in this policy debate is that since non-farm activities in rural areas and smaller towns cater mainly to rural demand, growth in agricultural productivity is the primary driver of growth in this sector (Mellor,1976; Ranis and Stewart, 1973, Haggblade, Hazell and Reardon, 2006; Johnson, 2000). Thus policies that promote agricultural growth are argued to be the policies that can stimulate non-farm growth. The empirical evidence from India reported in Foster and Rosenzweig (2004) however casts doubt on this view. Foster and Rosenzweig (2004) find that the positive causal link between agricultural productivity and non-farm employment holds only for local (and non-traded) services activities. The link is found to be negative for factory employment, suggesting that a better policy to promote non-farm growth particularly for poverty reduction is perhaps to attract manufacturing in villages rather than focusing on agriculture productivity growth. This paper revisits the issue of agriculture's role in non-farm growth and transformation using a broader theoretical and empirical framework.

The theoretical model developed in this paper distinguishes among rural non-farm activities in terms of trading status where tradeability is allowed to range from internationally traded formal activities (e.g. importable/exportable) to goods and services traded in wider domestic markets to locally produced and consumed informal activities. The model shows that this distinction is important for understanding the impact of an agricultural productivity shock on structural transformation within the non-farm sector. More importantly, the model shows that when a significant part of farming income is spent on goods and services produced outside villages, one would seriously underestimate the positive impact of agricultural productivity growth by focusing on village level analysis.

Following a large literature on the importance of rainfall shocks in agricultural productivity variations in Bangladesh, we exploit rainfall shocks (relative to the mean level) across upazilas and over time to understand the effects of productivity increase on employment growth and diversification. We use a two step empirical approach that focuses on the reduced form regressions of rainfall on the measure of productivity (rice yield per acre) and on the set of outcome variables noted above. The evidence from the reduced form regressions shows that a higher rainfall shock increases informal (small-scale) manufacturing and skilled services employment (mainly in education and health services). For formal employment, we find the effect of a positive rainfall shock on employment is largest in the samples that include urban areas and rural towns compared with rural areas alone. When interpreted as instrumental variables estimates of the effects of productivity increase, the empirical results suggest that agricultural productivity induces structural transformation within the services sector with formal/skilled services employment growing at a much faster pace compared with informal services. When distinction between formal and informal activities is recognized and leakage of village income to goods and services produced outside the village is incorporated into theoretical and empirical analysis, we reach strikingly different conclusions about the role of agriculture in non-farm growth and transformation compared with the case which looks at the rural sample alone. The estimates show that an agricultural productivity shock has a significant positive impact on both non-farm employment growth and transformation. These results suggest that policies promoting agriculture would be beneficial to non-farm growth as well in Bangladesh.

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Table 1: Summary Statistics: Sub-district level Employment, Yield and other indicators (Full Sample)

	Mean	SD	Mean	SD	Mean	SD
Economic Census	**2000**		**2006**		**2009**	
Employment (Formal)	6749	15379	10022	31015	13967	43504
Manufacturing	3673	11198	6383	25250	6692	23514
Services	1868	3770	2130	3705	2249	4296
of which						
Trade	180	657	127	384	144	485
Education	941	968	1350	2045	1333	2016
Health	306	1038	294	577	323	736
Other (construction, transport, utility etc.)	3065	5585	3629	6852	7265	22136
Population Census	**2000**				**2010**	
Employment (Total)	25128	15379			58680	101408
Manufacturing	4093	27769			17172	46679
Services	21035	9442			41507	60724
Proportion urban	0.24	0.30			0.20	0.22
Population	271754	117707			353587	239267
Proportion with Secondary or higher Education	0.14	0.08			0.15	0.07
Proportion of households with electricity	0.32	0.32	0.40	0.31	0.51	0.31
Household Income and Expenditure Survey	**2000**		**2005**		**2010**	
Rice Yield (mt/acre)	0.95	0.11	1.01	0.13	1.35	0.46
% of land irrigated	61	30	60	31	67	24
Real Per Capita Expenditure	813	350	890	317	1143	360
Real Daily Wage	82	46	84	53	101	45
Annual Rainfall (mm)	1391	423	1636	382	1457	362

Table 2: Rainfall Shocks and Agricultural Yields

	Log (Rice Yield/acre)		Log(agricultural wage)	% of Area Irrigated
	(1)	(2)	(3)	(4)
Full Sample				
Rainfall Deviation	0.376***	0.492***	0.688***	24.35**
	(6.382)	(9.062)	(3.769)	(2.125)
Observations	922	922	830	909
Number of Upazilas	355	355	346	355
Rural and Towns Sample				
Rainfall Deviation	0.386***	0.520***	0.573***	26.26**
	(5.643)	(8.559)	(3.088)	(2.065)
Observations	828	828	782	816
Number of Upazilas	320	320	318	320
Rural Sample				
Rainfall Deviation	0.429***	0.554***	0.614**	40.12**
	(5.383)	(7.912)	(2.596)	(2.489)
Observations	559	559	530	552
Number of Upazilas	217	217	215	217
Year & Upazila Fixed Effects	Yes	Yes	Yes	Yes
Area Characteristics	No	Yes	Yes	Yes

Note: Rainfall Deviation is defined as the difference between log(current rainfall) and log(30 year average rainfall). The regressions in even numbered columns include a number of controls (log of travel time to Capital and/or Port cities interacted with time trend, flood prone dummy interacted with time trend, proportion of household with electricity, log of 1991 population interacted with trend, log of total active labor force, and proportion of labor force with above secondary education, share of urban households. All regressions include year and upazila fixed effects. Standard errors are clustered at upazila level.
Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Rainfall Shocks, Agricultural Productivity and Non-farm Employment

	Log (Non-farm Employment)						Log(Agri. Employm.)
	Formal Activities			Total (formal + informal)			
	Manufact.	Services	Total	Manufact.	Services	Total	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full sample							
Rainfall Deviation	1.818*	2.287**	2.236**	1.043***	0.244***	0.363***	-0.0789
	(1.876)	(2.584)	(2.377)	(3.511)	(3.173)	(4.399)	(-0.456)
Observations	922	922	922	601	601	601	601
Number of Upazilas	355	355	355	355	355	355	355
Rural and Towns Sample							
Rainfall Deviation	1.108	2.073***	1.809**	1.059***	0.262***	0.366***	-0.170**
	(1.260)	(2.619)	(2.194)	(3.469)	(3.135)	(4.182)	(-2.535)
Observations	828	828	828	536	536	536	536
Number of Upazilas	320	320	320	320	320	320	320
Rural Sample							
Rainfall Deviation	0.410	1.772*	1.259	1.301***	0.341***	0.452***	-0.134*
	(0.392)	(1.856)	(1.309)	(3.362)	(3.250)	(4.053)	(-1.825)
Observations	559	559	559	364	364	364	364
Number of Upazilas	217	217	217	217	217	217	217
Year & Upazila Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Rainfall Deviation is defined as the difference between log(current rainfall) and log(30 year average rainfall). The regressions include a number of controls (log of travel time to Capital and/or Port cities interacted with time trend, flood prone dummy interacted with time trend, proportion of household with electricity, log of 1991 population interacted with trend, log of total active labor force, and proportion of labor force with above secondary education, share of urban households. All regressions include year and upazila fixed effects. Standard errors are clustered at upazila level.

Robust t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4: Rainfall Shocks, Agricultural Productivity and Formal Sector Employment

	Log (employment in manufacturing)			Log(employment in services)			
	Food & Beverages	Other Manfact.	Transport Const. & other	Trade	Education	Health	Other Services
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Full Sample							
Rainfall Deviation	0.753	1.572*	2.137**	1.074	1.913***	1.720**	1.580**
	(0.911)	(1.650)	(2.529)	(1.584)	(2.691)	(2.537)	(2.161)
Observations	922	922	922	922	922	922	922
Number of Upazilas	355	355	355	355	355	355	355
Rural and Towns Sample							
Rainfall Deviation	0.353	0.687	1.958***	0.713	1.649**	1.429**	1.355**
	(0.413)	(0.859)	(2.598)	(1.248)	(2.524)	(2.327)	(2.077)
Observations	828	828	828	828	828	828	828
Number of Upazilas	320	320	320	320	320	320	320
Rural Sample							
Rainfall Deviation	-0.243	0.0551	1.670*	0.0703	1.459*	1.150	0.951
	(-0.232)	(0.0556)	(1.838)	(0.103)	(1.867)	(1.512)	(1.154)
Observations	559	559	559	559	559	559	559
Number of Upazilas	217	217	217	217	217	217	217
Year & Upazila FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Area Characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Rainfall Deviation is defined as the difference between log (current rainfall) and log(30 year average rainfall). The regressions include a number of controls (log of travel time to Capital and/or Port cities interacted with time trend, flood prone dummy interacted with time trend, proportion of household with electricity, log of 1991 population interacted with trend, log of total active labor force, and proportion of labor force with above secondary education, share of urban households. All regressions include year and upazila fixed effects. Standard errors are clustered at upazila level.
Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1