Why is Agricultural Productivity So Low in Poor Countries? – The Case of India

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Abstract

It is well known that poor countries exhibit a large labor productivity gap between urban and agricultural sectors. Furthermore, development economists have pointed out that the low agricultural productivity stems from the persistence of small non-mechanized farms. We propose and quantify one potential explanation for these phenomena. If residing in a village provides access to a network that effectively insures against income fluctuations, then households are less willing to live in cities where labor income risk is uninsured. As a result, labor stays cheap in agriculture, and the incentives for switching to capital-intensive methods of farming remain weak. In order to understand the quantitative importance of this mechanism, we calibrate the model to Indian data and study an abstract policy intervention – a provision of complete insurance against earnings risk in the city. The policy intervention increases labor productivity in agricultural sector by 37 percent and reduces the urban-rural productivity gap by 30 percent. This effect comes about because of the 7 percent drop in agricultural share of employment, which encourages an inflow of capital in agricultural sector and raises the average farm size by 12 percent.

Key words: Labor Productivity in Agriculture, Structural Transformation, Labor Earnings Risk, Social Insurance.
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It is well known that low agricultural labor productivity is a major impediment to development. In India, labor productivity in agriculture is only a fifth of the level of urban productivity. In other words, agriculture seems to be one sector of the economy where ways of production lag particularly far behind the frontier technology, with small non-mechanized farms persisting through time (e.g. Foster and Rosenzweig (2011)). More generally speaking, the gap in agricultural labor productivity between the rich and poor countries is so large that it accounts for most of the observed income gap. Our main goal is to understand why poor countries fail to mechanize their ways of farming.

We begin with the premise that residing in a rural area provides access to a network that effectively insures its residents against income fluctuations. This premise has a solid foundation in a large body of literature and survey data.[1] If households indeed value their agricultural land beyond its productive value because it provides them with access to a network that effectively insures against labor income risk, then they are less willing to migrate to the city where labor earnings risk is uninsured. As a result, labor remains cheap in agriculture, and the incentives for switching to capital-intensive methods of farming stay weak. This description captures the main essence of our mechanism.

We capture this mechanism in a dynamic general equilibrium model that features uninsured labor income risk in the city. We allow for a very general production technology in agriculture that allows us to endogenize labor productivity through the choice of farm size and capital intensity. We assume that capital can substitute for labor, but land is a complementary input to both. There are economies of scale in production, so reducing the number of farms in favor of larger farms raises productivity. As has become standard in literature

[1] Townsend (1994) has drawn attention to risk sharing feature in rural areas by empirically documenting that household consumption co-moves with village average consumption in India and shows little dependence on own income. Appendix D shows that risk sharing is much higher in rural areas compare to in urban areas in India. Santaeulàlia-Llopis and Zheng (2018) have found higher levels of consumption insurance in rural areas than in urban areas in China. De Magalhães and Santaeulàlia-Llopis (2018) have found more consumption insurance in rural areas than in urban areas in poor African countries.

on structural transformation, our framework features non-homothetic preference. Risk is completely insured away in rural areas. In urban areas, individuals self-insure against labor income risk through savings. Finally, newborns optimally choose whether to live in the rural or urban area.

The direct effect of the location choice is that an increase in the relative supply of urban labor will result in the fall of the urban-rural wage gap, mechanization of rural production, an increase in the average farm size and therefore labor productivity. The presence of non-insurable risk in urban labor income creates the urban-rural wage gap and consumption gap. In the scenario of no risk in urban areas, there is a spatial equilibrium with no consumption gap.

In order to understand the quantitative importance of our mechanism, we calibrate the model (under the assumption of a stationary steady state) to data for India for the period around 2000. We use wage data to discipline the labor market risk in the city. We rely heavily on the agriculture census of India to discipline the technology parameters. Our model successfully replicates the urban-rural wage gap (a factor of 1.3). To assess the importance of differential insurance access across locations, we study an abstract policy intervention. To be more precise, we employ the calibrated model to quantify the effect of introducing complete insurance in the city on migration and labor productivity in agriculture. As a result, the urban-rural consumption gap disappears and the share of workers in the agricultural area declines from 0.59 to 0.55, implying increased labor movement to urban areas. Our mechanism working through migration is consistent with Munshi and Rosenzweig (2016) which shows that informal insurance in rural areas decreases low-skilled labor migration in India. While this effect on labor reallocation is far from dramatic, the impact on agricultural productivity is very large. In the agricultural sector, capital input per farm rises by 120 percent as farm size expands and capital inflows to substitute for the lost labor. In fact, we find that the average farm size increases by 12 percent. The labor productivity gap between the two sectors decreases by 30 percent.

One clear implication of our benchmark model with uninsured labor risk in the city is the presence of the urban-rural consumption and wage gap. Because workers have differential access to social insurance across the two locations, they must be compensated with greater levels of consumption in the city. In India, the urban-rural wage gap declines from 1.7 to 1.3 and the consumption gap declines from 1.3 to 1.2 from 1983 to 2008 (Hnatkovska and Lahiri, 2016).[2] But these gaps are still large, and they cannot be explained by differences in observed worker characteristics or justified by worse amenities in the cities. Hnatkovska and Lahiri (2016) have examined the urban-rural both wage and consumption expenditure gaps in India by incorporating differential sectoral productivity shocks.Young (2013) has examined the urban-rural consumption expenditure gaps in 65 countries. Young (2013) and Hnatkovska and Lahiri (2016) have found the gaps cannot be accounted for by differences in observed characteristics of urban-rural workers, such as schooling levels. Gollin et al. (2017) have emphasized that spatial models require that amenities (or something else) must be worse in the urban areas to justify the presence of the observed urban-rural consumption inequality as an equilibrium outcome. Contrary to this implication, they show (using African data) that cities tend to offer not only higher consumption but also better quality amenities along all dimensions. Our framework based on differential access to insurance across the two locations provides one alternative explanation for the presence of the consumption gap that is consistent with spatial models. Another alternative explanation is of course the difference in unobserved worker characteristics across the two locations.

Our work is also related to Adamopoulos and Restuccia (2014) and Chen et al. (2017). These papers focus on misallocation of inputs across farms of varying productivity. Adamopoulos and Restuccia (2014) have emphasized that resource misallocation across farms have the

[2] Wage gaps are obtained from a regression of (log) wages on a rural dummy, age, and age squared. Consumption gaps are obtained from a regression of (log) consumption expenditures on a rural dummy.

potential to account for differences in farm size and productivity between rich and poor countries. In contrast, we focus on trying to understand why the average farm size is small in India.

The rest of the paper is structured as follows. Section 1 presents the model while Section 2 discusses the calibration of model parameters. Section 3 presents quantitative results from the benchmark calibration as well as some sensitivity analysis. Concluding remarks are followed by an appendix that outlines model solution used in our paper.

1 The Model

Consider a model economy where time is discrete and indexed by $t = 0, 1, 2...$ N new households are born every period and live for exactly 2 periods (young and old). There are two spatially separated locations: rural and urban. We associate these locations with agricultural production and the "rest of the economy". Newborns decide once and for all on their location. The location determines the sector of employment and access to insurance. We denote by χ_t the fraction of generation t choosing to live in the rural area.

The timing of decision-making within each period is given as follows:

1. the new generation chooses their location of residence;
2. labor endowment shocks are realized;
3. in urban areas, identical CRS firms hire labor and rent capital to produce non-agricultural goods. In rural areas, households choose between running their own farms or working for wages, and farm managers hire labor and rent capital;
4. agricultural farms hire workers, rent land and capital to produce agricultural goods;
5. households receive proceeds for their factors of production and make consumption/savings decisions.

While we assume that people work where they live, we allow for capital to freely flow across locations. This means that rental rates of capital will equalize across locations, and this will be reflected in our notation from the start.

1.1 Urban Area

1.1.1 Urban Firms

The urban sector produces the non-agricultural good. It is comprised of a large number of identical firms endowed with a constant returns to scale technology. This allows us to restrict attention to a single aggregate firm that exhibits competitive behavior. The aggregate output of the non-agricultural good is given by $Y_{n,t} = A_n K_{n,t}^{\alpha} N_{n,t}^{1-\alpha}$, where $K_{n,t}$ and $N_{n,t}$ denote aggregate employment of capital and effective units of labor. A_n denotes total factor productivity. We set the non-agricultural good to be the numeraire so that all time t prices are quoted in the units of this good. Taking factor rental rates $w_{n,t}$ and the rental price of capital r_t as given, the aggregate firm hires inputs to maximize profit:

$$\max_{K_{n,t},\, N_{n,t}} \left\{ Y_{n,t} - w_{n,t} N_{n,t} - r_t K_{n,t} \right\}. \tag{1}$$

1.1.2 Urban Households

Households that choose to live in urban areas face idiosyncratic labor market risk. We follow the standard approach to model this risk as a stochastic endowment of effective labor units. The effective labor endowment when young and old are given by $\kappa \exp(\zeta^y)$ and $\kappa \exp(\zeta^o)$ where ζ^y is drawn from the set $[-\zeta, \zeta]$ with probabilities π^y and $1 - \pi^y$, while ζ^o is drawn from the same set with probabilities depending on the previous realization. We assume the transition probability matrix of the form

$$\begin{bmatrix} \pi & 1-\pi \\ 1-\pi & \pi \end{bmatrix},$$

We also assume the initial probability distribution $[\pi^y, 1-\pi^y]$ is stationary with respect to the above transition probability matrix, i.e. $\pi^y = 0.5$. This approach of modeling labor endowment shocks allows us to approximate the AR(1) log earnings process estimated from the data. Because there is a continuum of young and old households, the probabilities also correspond to the overall measures of households experiencing a given shock. The measure of the young households with $\exp(-\zeta)$ endowment is always 0.5, and the measure of the old households with $\exp(-\zeta)$ is also 0.5 (due to the stationarity assumption). This immediately implies that the average labor endowment per young and per old household in each period is given by $\kappa\,(0.5)\,[\exp(-\zeta)+\exp(\zeta)]$ and we normalize $\kappa = \frac{1}{(0.5)[\exp(-\zeta)+\exp(\zeta)]}$ as to make the average labor endowment equal to 1.

Expected utility, prior to the initial shock realization, of the cohort born in t choosing the urban location, is given by

$$\begin{aligned} (2) \qquad EU_n &= E_{\zeta^y}\left\{\phi\frac{(a^y_{n,t}(\zeta^y)-\bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi)\frac{c^y_{n,t}(\zeta^y)^{1-\sigma}}{1-\sigma} + \right. \\ &\left. \beta E_{\zeta^o|\zeta^y}\left(\phi\frac{(a^o_{n,t+1}(\zeta^y,\zeta^o)-\bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi)\frac{c^o_{n,t+1}(\zeta^y,\zeta^o)^{1-\sigma}}{1-\sigma}\right)\right\}, \end{aligned}$$

where $a^y_{n,t}(\zeta^y)$ and $c^y_{n,t}(\zeta^y)$ denote the initial state-contingent consumption of the agricultural and non-agricultural goods when young, $a^o_{n,t+1}(\zeta^y,\zeta^o)$ and $c^o_{n,t+1}(\zeta^y,\zeta^o)$ denote the state history-contingent consumption of agricultural and non-agricultural good when old, ϕ denotes the preference weight on agricultural goods, and β is the discount factor. We follow the large literature on structural transformation in assuming non-homothetic preferences stemming from the subsistence consumption level $\bar{a} > 0$.

We now describe the state-contingent budget constraints. The household is born with no capital. There is no leisure in utility, so the household inelastically supplies the available endowment of effective labor units to the urban firm. In period t, the young agent earns wage income $w_{n,t}\exp(\zeta^y)$ and allocates it between consumption and savings, $k^n_{t+1}(\zeta^y)$. In period $t+1$, the old agent earns labor and capital income, all of which he consumes at this point. The following constraints must hold for all t and all possible realization histories (ζ^y, ζ^o):

$$p_{a,t}a^y_{n,t}(\zeta^y) + c^y_{n,t}(\zeta^y) + k^n_{t+1}(\zeta^y) = w_{n,t}\kappa\exp(\zeta^y), \tag{3}$$

$$p_{a,t+1}a^o_{n,t+1}(\zeta^y,\zeta^o) + c^o_{n,t+1}(\zeta^y,\zeta^o) = w_{n,t+1}\kappa\exp(\zeta^o) + r_{t+1}k^n_{t+1}(\zeta^y), \tag{4}$$

where $p_{a,t}$ denotes the price of agricultural goods in time t. Note we assume capital fully depreciates upon use which is reasonable given that the model period length is half the length of one's working years.

Note there are no social insurance arrangements in the city. Households can self-insure against labor market risk, which gives rise to precautionary savings. This assumption is consistent with the lack of social insurance institutions typically observed in developing countries.

1.2 Agricultural Area

One defining characteristic of rural residence that we aim to capture is that it provides access to a network of friends and family that effectively insures against idiosyncratic labor income risk. The straightforward way to model this is to introduce idiosyncratic labor endowment risk as in the urban households' problem described above, but allow for households to enter risk-sharing contracts which are perfectly enforceable. If we assume that households are born identical, this would yield identical allocations for all households regardless of idiosyncratic realization. To simplify the exposition, we go directly to modeling a representative household that faces no uncertainty. Each household has 1 unit of time endowment when young and when old. We assume that young households work for wages, while old households either work for wages or manage farms.

Land is in fixed supply denoted by L. It is initially in the hands of the initial old residents of the agricultural areas. The old households sell land to the young at the end of the period.

1.2.1 Agricultural Farms

Suppose an endogenous fraction ε_t of old households use their entire time endowment to manage farms while the remaining households work for wages. Given the rental price of capital, land and labor $(r_t, q_t, w_{a,t})$, each manager hires capital, labor and land $(k^f_{a,t}, n^f_{a,t}\, l^f_{a,t})$ to maximize profit, denoted by d_t:

$$\max_{k^f_{a,t}, n^f_{a,t}, l^f_{a,t}} d_t = p_{a,t} y_{a,t} - w_{a,t} n^f_{a,t} - r_t k^f_{a,t} - q_t l^f_t, \tag{5}$$

where $y_{a,t}$ is the amount of non-agricultural good produced. We modify the Lucas (1978) span of control approach to endogenize the farm size and assume

$$y_{a,t} = A_a \left[(1-\theta) \left(l^f_t \right)^{\rho} + \theta \left(\nu \left(k^f_{a,t} \right)^{\mu} + (1-\nu) \left(n^f_{a,t} \right)^{\mu} \right)^{\frac{\rho}{\mu}} \right]^{\frac{\eta}{\rho}},$$

where $\eta \in (0,1)$ represents the span of managerial control parameter, μ governs the elasticity of substitution between capital and labor, and ρ governing the elasticity of substitution between land and the capital-labor composite, $\theta \in (0,1)$ captures the relative importance of land and $\nu \in (0,1)$ determines the relative importance of capital and labor. To be consistent with well-documented empirical facts regarding the elasticity of substitution between factors of production in agriculture in developing countries, we assume $\mu > 0$ and $\rho < 0$, i.e. capital and labor are gross substitutes whereas land is a complementary factor (e.g. Salhofer (2000)).

We require that managers are indifferent between working for wages and running farms, which yields the no-arbitrage condition:

$$d_t = w_{a,t}. \tag{6}$$

1.2.2 Agricultural Households

Households that choose to live in agricultural areas have the same preferences as households residing in the urban area, except they face no uncertainty. Again, this is a shortcut to modeling fully enforceable risk-sharing contracts. The lifetime utility of a cohort born in t that chose the agricultural location is given by

$$U_a = \phi \frac{(a^y_{a,t} - \bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi) \frac{\left(c^y_{a,t}\right)^{1-\sigma}}{1-\sigma} + \beta \left\{ \phi \frac{(a^o_{a,t+1} - \bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi) \frac{\left(c^o_{a,t+1}\right)^{1-\sigma}}{1-\sigma} \right\}, \tag{7}$$

where $a^y_{a,t}$ denotes consumption of the agricultural good at young age in period t, $c^y_{a,t}$ denotes consumption of the non-agricultural good at young age in period t, $a^o_{a,t+1}$ denotes consumption of the agricultural good at old age in period $t+1$, $c^o_{a,t+1}$ is consumption of the non-agricultural good at old age in period $t+1$.

The household is born with no capital and no land. Therefore, the only source of income for the young agents is labor income. The young purchase agricultural and non-agricultural goods for consumption and save in the form of capital and land. They purchase $k_{a,t+1}$ units of capital from the non-agricultural good producer at price 1 and l_{t+1} units of land from the old households at price $p_{l,t}$. The time t budget constraint for the young agents is summarized as follows:

$$p_{a,t} a^y_{a,t} + c^y_{a,t} + p_{l,t} l_{t+1} + k_{a,t+1} = w_{a,t}. \tag{8}$$

In period $t+1$, the old agents either work for wages or manage firms, in either case earning $w_{a,t+1}$. They also get rental income from capital $r_{a,t+1}k_{a,t+1}$, rental income from land $q_{t+1}l_{t+1}$ and income from land sale $p_{l,t+1}l_{t+1}$. The old agents consume all of their income. The time $t+1$ budget constraint of the old agents is given by

$$p_{a,t+1}a^o_{a,t+1} + c^o_{a,t+1} = w_{a,t+1} + r_{a,t+1}\,k_{a,t+1} + q_{t+1}l_{t+1} + p_{l,t+1}l_{t+1}. \tag{9}$$

1.2.3 Equilibrium

Measure χ_t of each cohort decides to locate in agricultural areas. This measure is determined by equalization of lifetime utility across areas:

$$EU_n = U_a. \tag{10}$$

Before we can define our market clearing conditions, we need to establish additional notation. Recall that N denotes the size of each cohort. The measure of young households living in urban locations is then given by $N^y_{n,t} = \chi_t N$. Because all young households survive to adulthood and the location choice is permanent, this is also the measure of the urban old agents in time $t+1$:

$$N^y_{n,t} = N^o_{n,t+1} = \chi_t N.$$

Likewise, the measure of the rural young and old households in time t and $t+1$ is given by

$$N^y_{a,t} = N^o_{a,t+1} = (1-\chi_t)\,N.$$

The measure of farm managers in time t is given by $\varepsilon_t N^o_{a,t}$.

Given the nature of our study, it suffices to focus on a stationary equilibrium, i.e. a decentralized competitive equilibrium characterized by stationary allocations, prices and location choice.

Definition A stationary equilibrium is defined as state-contingent allocations for the urban young households $\{a_n^y(\zeta^y), c_n^y(\zeta^y), k_n(\zeta^y)\}_{\zeta^y}$ and for the urban old households $\{a_n^o(\zeta^y, \zeta^o), c_n^o(\zeta^y, \zeta^o)\}_{(\zeta^y, \zeta^o)}$, for the rural area households $\{a_a^y,\ c_a^y,\ k_a,\ l,\ a_a^o, a_a^o\}$, for the urban firm $\{Y_n, K_n, N_n\}$ and for the rural farms $\{y_a, k_a^f,\ n_a^f,\ l^f, d\}$, prices $\{w_n,\ w_a,\ r,\ q,\ p_l\ ,\ p_a\}$, the measure of each cohort choosing to live in the urban area (χ) and the measure of the rural young managing farms (ε) such that:

1. given the equilibrium prices, the allocations for the urban households maximize utility (2) subject to the budget constraints (3) and (4);

2. given the equilibrium prices, the allocations for the rural households maximize utility (7) subject to the budget constraints (8) and (9);

3. given the equilibrium prices, the allocation for the urban firm maximizes profit given in (1);

4. given the equilibrium prices, the allocation for the rural firm maximizes profit given in (5);

5. lifetime utility equalizes across the two locations: equation (10) holds;

6. farm managers are indifferent between managing a farm and working for wages, i.e. (6) holds;

7. all markets clear:

    - labor market in agriculture:

$$\varepsilon N_a^o n_a^f = N_a^y + N_a^o(1-\varepsilon), \tag{11}$$

- labor market in the urban area:

$$N_n = N_n^y + N_n^o, \tag{12}$$

- capital market:

$$K_n + \varepsilon N_a^o k_a^f = N_n^o k_n + N_a^o k_a, \tag{13}$$

- land market in agriculture:

$$\varepsilon N_a^o l^f = N_a^o l = L, \tag{14}$$

- agricultural goods market:

$$\varepsilon N_a^o y_a = N_n^y a_n^y + N_n^o a_n^o + N_a^y a_a^y + N_a^o a_a^o, \tag{15}$$

- non-agricultural goods market:

$$Y_n = N_n^y c_n^y + N_n^o c_n^o + N_n^y k_n + N_a^y c_a^y + N_a^o c_a^o + N_a^y k_a, \tag{16}$$

where $N_n^y = N_n^o = \chi N$ denote the population size of young and old residing in the urban area, and $N_a^y = N_a^o = (1-\chi) N$ denote the population size of young and old residing in the agricultural area, and where $k_n = 0.5 \left[k_n \left(\zeta^y = -\zeta\right) + k_n \left(\zeta^y = \zeta\right)\right]$ is investment per urban young household (and capital holdings per urban old household), $a_n^y = 0.5 \left[a_n^y \left(-\zeta\right) + a_n^y \left(\zeta\right)\right]$ is the average consumption of the agricultural good for the urban young household, $c_n^y = 0.5 \left[c_n^y \left(-\zeta\right) + c_n^y \left(\zeta\right)\right]$ is the average consumption of the non-agricultural good for the urban young household, $a_n^o =$

$0.5[\pi a_n^o(-\zeta,-\zeta)+(1-\pi)\,a_n^o(-\zeta,\zeta)+\pi a_n^o(\zeta,\zeta)+(1-\pi)\,a_n^o(\zeta,-\zeta)]$ is the average consumption of the agricultural good for the urban old household, and $c_n^o = 0.5[\pi c_n^o(-\zeta,-\zeta)+(1-\pi)\,c_n^o(-\zeta,\zeta)+\pi c_n^o(\zeta,\zeta)+(1-\pi)\,c_n^o(\zeta,-\zeta)]$ is the average consumption of the non-agricultural good for the urban old household.

A few clarifications are in order. Note that the demand for labor appearing on the left hand side of (11) comes from the number of individual farms ($=\varepsilon N_a^o$), each of which demands n_a^f units of labor. While the young supply their labor inelastically, only a measure $1-\varepsilon$ of the old households work for wages – the rest manage farms. The demand for capital on the left hand side of equation (13) comes from the aggregate firm in the urban area (K_n) and measure εN_a^o of individual farms each demanding k_a^f. The supply of capital is from urban and agricultural households. Taking expectations over shock realizations gives the average savings by the young. These are last period savings of the current old. Just like the capital market, there is a single market for each of the consumption goods. Expectations are used to get the appropriate averages. It should be noted that capital investment comprises a part of the demand for the non-agricultural good.

The characterization of equilibrium is provided in Appendix A. Here we focus on the key conditions of the model. Performing the optimization yields to the following first-order conditions describing households intratemporal and intertemporal trade-offs in urban area,

$$\begin{aligned}\frac{\phi}{1-\phi}\left(\frac{c_n^y(\zeta^y)}{a_n^y(\zeta^y)-\bar{a}}\right)^{\sigma} &= p_a,\ \text{for } \zeta^y=-\zeta,\zeta \\ \frac{\phi}{1-\phi}\left(\frac{c_n^o(\zeta^y,\zeta^o)}{a_n^o(\zeta^y,\zeta^o)-\bar{a}}\right)^{\sigma} &= p_a,\ \text{for } (\zeta^y,\zeta^o)=(-\zeta,-\zeta)\,,(-\zeta,\zeta)\,,(\zeta,\zeta)\,,(\zeta,-\zeta)\end{aligned}$$

$$\begin{aligned}\frac{c_n^y(-\zeta)^{-\sigma}}{\pi c_n^o(-\zeta,-\zeta)^{-\sigma}+(1-\pi)\,c_n^o(-\zeta,\zeta)^{-\sigma}} &= \beta r, \\ \frac{c_n^y(\zeta)^{-\sigma}}{\pi c_n^o(\zeta,\zeta)^{-\sigma}+(1-\pi)\,c_n^o(\zeta,-\zeta)^{-\sigma}} &= \beta r,\end{aligned}$$

and in agricultural area,

$$\begin{aligned}\frac{\phi}{1-\phi}\left(\frac{c_a^y}{a_a^y-\bar{a}}\right)^{\sigma} &= p_a\\ \frac{\phi}{1-\phi}\left(\frac{c_a^o}{a_a^o-\bar{a}}\right)^{\sigma} &= p_a\end{aligned}$$

$$\left(\frac{c_a^y}{c_a^o}\right)^{-\sigma} = \beta r.$$

If we eliminate of risk in urban areas, i.e. by setting $\zeta = 0$ and $\pi = 1$, intratemporal and intertemporal tradeoffs become:

$$\frac{c_n^y(0)}{a_n^y(0)-\bar{a}} = \frac{c_n^o(0,0)}{a_a^o(0,0)-\bar{a}} \quad = \quad \frac{c_a^y}{a_a^y-\bar{a}} = \frac{c_a^o}{a_a^o-\bar{a}},$$

$$\frac{c_n^y(0)}{c_n^o(0,0)} = \frac{c_a^y}{c_a^o}.$$

So elimination of risk in urban areas eliminates consumption gaps across urban and agricultural areas.

In agricultural area, the optimal measure of manager (ε) depends on

$$d = w_a,$$

which implies managers must be indifferent between managing a farm and working. Then for a given value of ε, the average farm size (l_f) is determined by following land market clearing condition:

$$l_f = \frac{L}{\varepsilon}.$$

Since the average farm size is a ratio of land to measure of manager, the elimination of idiosyncratic risk in urban areas will drive a lower employment in agricultural area and also lower the measure of manager, that will increase the average farm size.

2 Calibration

Our objective is to investigate quantitatively the extend of an abstract policy intervention – a provision of complete insurance against earnings risk in urban area. The general strategy is to calibrate the benchmark model parameters by assuming steady state of our model adequately represents India's economic scenario during the period of 2000–2012, and by targeting several moments during this period.

Our strategy is to conduct the proposed quantitative analysis by choosing some parameters based on a priori information, by finding the rest as a part of solution in the benchmark model. We set values for ζ and π to match the estimated wage premium in non-agricultural sector and the estimation steps are detailed in Appendix C. In agricultural production technology, we use the value for ρ is -2.0 to maintain the elasticity of substitution of land with composite of capital and labor below 0.5.[3] We set $\theta = 0.5$ assuming equal the relative importance of land and capital-labor composite. We set $\mu = 0.6$ which governs the elasticity of substitution between capital and labor, $\nu = 0.5$ assuming equal the relative importance of capital and labor. We also set $\eta = 0.8$ assuming average profit is 20 percent of agricultural output. For preference, we use $\sigma = 2$ and for time discounting factor $\beta = 0.422$.[4] Maintaining values for ζ, π, μ, ν, θ, η, σ, β, we choose parameters $(\alpha,\ \bar{a},\ A_n,\ L,\ N)$ to match the following empirical moments: $[i]:\ \frac{rK_n}{Y_n} = 0.33$; $[ii]:\ 1-\chi = 0.59$; $[iii]:\ w_n/w_a = 1.35$; $[iv]:\ \frac{p_a(a_a^y + a_a^o)}{c_a^y + c_a^o + p_a(a_a^y + a_a^o)} = 0.50$; and $[v]:\ l_f = 1.33$. These moments refer to, in the order listed, capital income share in non-agriculture sector, population share in rural area, urban-rural wage gap, consumption expenditure share of agricultural good in rural area, and the average farm size. The resulting calibrated parameter values are in Table 1 and the data source of the targeted moments are detailed in the Appendix B. We normalize the value for A_a is 1.

[3] Salhofer (2000) reports that the empirical estimates of the elasticity of substitution in agriculture generally fall well below 0.5.

[4] Household's optimal decision in agricultural area is $\frac{c_a^y}{c_a^o} = \beta r$. Assuming in long run $\frac{c_a^y}{c_a^o} = 1$ and risk free annual interest rate is four percent, then $\beta = \frac{1}{1.04^{22}}$ with each period is 22 years long.

Table 2 shows the remaining parameters values used in the benchmark model.

Table 1: Calibrated Parameters

α	$\bar{a}$	A_n	L	N
0.33	0.001	2.0202	8.4296	20

Table 2: The Remaining Parameters

ϕ	β	σ	ρ	μ	ν	θ	η	A_a	N	ζ	π
0.4	0.422	2	-2	0.6	0.5	0.5	0.8	1	20	0.6596	0.5961

In Table 3, column 2 shows data moments, and column 3 shows model produced moments. This shows our model successfully match empirical moments. The model also matches well urban-rural consumption gap which is not targeted in calibration.

Table 3: Model: Moments

	(1)	(2) Data	(3) Benchmark Model	(4) Counter-factual
Targeted Moment				
[i] Capital income share	$\frac{rK_n}{Y_n}$	0.33	0.33	0.33
[ii] Employment share	$1-\chi$	0.59	0.59	0.55
[ii] wage gap	w_n/w_a	1.35	1.46	1.00
[iv] Consumption expenditure share of agricultural good in rural area	$\frac{p_a(a_a^y+a_a^o)}{c_a^y+c_a^o+p_a(a_a^y+a_a^o)}$	0.50	0.48	0.52
[v] Average farm size (Hectares)	l_f	1.33	1.34	1.50
Non-Targeted Moment				
[vi] Consumption gap	$\frac{c_n^y+c_n^o+p_a(a_n^y+a_n^o)}{c_a^y+c_a^o+p_a(a_a^y+a_a^o)}$	1.25	1.56	1.00

Notes: The data sources of above moments are detailed in Appendix B.

3 Result

To examine the quantitative effect of an abstract policy intervention, we shut down idiosyncratic labor endowment risk in the non-agricultural area by setting $\zeta = 0$ and $\pi = 1$. Then we solve the model by maintaining the same values for the remaining parameters. In Table 3, column 4 shows model generated moments of this counter-factual exercise. Before explaining result, we define some key variables: Aggregate Agricultural Output, $Y_a = \varepsilon(1-\chi)Ny_a$; Aggregate Labor in the Agricultural Area, $N_a = (1-\chi)2N$; Aggregate Capita in the Agricultural Sector, $K_a = \varepsilon(1-\chi)Nk_a^f$, real GDP $= Y_n + p_aY_a$, Labor Productivity Gap $= \frac{Y_n/N_n}{p_aYa/N_a}$; Labor Productivity in the Agricultural Sector $= \frac{p_aY_a}{N_a}$; Aggregate Productivity $= \frac{Y_n+p_aY_a}{2N}$. Due to full insurance, the consumption are equalized between two sectors and the wage premium disappears in urban areas, i.e. wages in two sectors are equalized. The population share in agricultural area decreases from 59 percent to 55 percent which means workers relocate to the urban area. The demand for capital per farm increases by 120 percent, whereas the demand for labor per farm increases by 3.6 percent due to substitutability between capital and labor inputs in agricultural good production technology. The average farm size increases by 12 percent. Capital flows to the urban sector so the ratio K_n/K_a decreases by 47 percent. Labor productivity in agricultural sector increases by 37 percent and aggregate labor productivity increases by 16 percent, the labor productivity gap between two sectors falls by 30 percent and GDP rises by 17 percent. Table 4 summarizes main results.

Table 4: Model: Main Results

	w_a	$\frac{Y_n/N_n}{p_aYa/N_a}$	$\frac{p_aY_a}{N_a}$	$\frac{Y_n+p_aY_a}{2N}$	$\frac{K_n}{K_a}$	GDP	k_a	l_f
% change in counter-factual relative to benchmark model	42	-30	37	16	-47	17	120	12

Notes: $Y_a = \varepsilon(1-\chi)Ny_a$, $N_a = (1-\chi)2N$, $K_a = \varepsilon(1-\chi)Nk_a^f$, GDP $= Y_n + p_aY_a$, Productivity Gap $= \frac{Y_n/N_n}{p_aYa/N_a}$, Productivity in agricultural sector $= \frac{p_aY_a}{N_a}$, Aggregate Productivity $= \frac{Y_n+p_aY_a}{2N}$.

To summarize: when a complete insurance is implemented in the urban area, capital mobilizes from rural to urban area, labor moves from rural to urban area, it generates higher labor productivity in agricultural sector through raising farm size. Given its parsimonious nature, we deem this quantitative result to be a considerable success of the model, and help to inquire further importance of social insurance policy in the city.

4 Conclusion

There is a large productivity gap between urban and agricultural sectors in India. Furthermore, agricultural production is characterized by small non-mechanized farms. We develop a tractable quantitative framework by incorporating one potential explanation. If residing in a village provides access to a network that effectively insures against income fluctuations, then households are less willing to live in the cities where labor income risk is uninsured. As a result, labor stays cheap in agriculture, and the incentives for switching to capital-intensive methods of farming remain weak. In order to understand the quantitative importance of this mechanism, we calibrate the model to Indian data and study an abstract policy intervention – a provision of complete insurance against earnings risk in the city. The policy intervention reduces the urban-rural labor productivity gap by 30 percent and raises aggregate labor productivity by 16 percent. This effect comes about because of the 7 percent drop in agricultural share of employment, which encourages an inflow of capital in agricultural sector and raises the average farm size by 12 percent.

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A Model Solution

The unknowns are:

- $\{a_n^y(-\zeta),\, c_n^y(-\zeta),\, k_n(-\zeta),\, a_n^y(\zeta),\, c_n^y(\zeta),\, k_n(\zeta)\}$ (6 variables)
- $\{a_n^o\,(-\zeta,-\zeta)\,, a_n^o\,(-\zeta,\zeta)\,, a_n^o\,(\zeta,-\zeta)\,, a_n^o\,(\zeta,\zeta)\,, c_n^o\,(-\zeta,-\zeta)\,, c_n^o\,(-\zeta,\zeta)\,, c_n^o\,(\zeta,-\zeta)\,, c_n^o\,(\zeta,\zeta)\}$ (8 variables)
- $\{a_a^y,\, c_a^y,\, k_a,\, l\}$ (4 variables)
- $\{a_a^o, a_a^o\}$ (2 variables)
- $\{Y_n,\, K_n,\, N_n\}$ (3 variables)
- $\{y_a,\, k_a^f,\, n_a^f,\, l^f,\, d\}$ (5 variables)
- $\{w_n,\, w_a,\, r,\, q,\, p_l\ ,\, p_a\}$ (6 variables)
- χ , ε (2 variables)

So we have 36 unknowns.

A.1 Urban Firm

Given r, w_n, we solve for $\{Y_n, K_n, N_n\}$.The aggregate urban firm profit maximization yields the following 3 conditions:

$$\begin{aligned} Y_n &= A_n K_n^{\alpha} N_n^{1-\alpha}, \\ w_n &= (1-\alpha) A_n K_n^{\alpha} N_n^{-\alpha}, \\ r &= \alpha A_n K_n^{\alpha-1} N_n^{1-\alpha}. \end{aligned}$$

A.2 Individual Farms

Given r, w_a, p_a, we solve for $\{y_a, k_a^f,\ n_a^f,\ l^f,\ d\}$. Individual farm profit maximization yields the following 5 conditions:

$$\begin{aligned}
y_a &= A_a\left[(1-\theta)\left(l^f\right)^\rho + \theta\left(\nu\left(k_a^f\right)^\mu + (1-\nu)\left(n_a^f\right)^\mu\right)^{\frac{\rho}{\mu}}\right]^{\frac{\eta}{\rho}}, \\
w_a &= \theta p_a \eta A_a\left[\cdot\right]^{\frac{\eta}{\rho}-1}\left(\nu\left(k_a^f\right)^\mu + (1-\nu)\left(n_a^f\right)^\mu\right)^{\frac{\rho}{\mu}-1}(1-\nu)\left(n_a^f\right)^{\mu-1}, \\
r &= \theta p_a \eta A_a\left[\cdot\right]^{\frac{\eta}{\rho}-1}\left(\nu\left(k_a^f\right)^\mu + (1-\nu)\left(n_a^f\right)^\mu\right)^{\frac{\rho}{\mu}-1}\nu\left(k_a^f\right)^{\mu-1}, \\
q &= p_a \eta A_a\left[\cdot\right]^{\frac{\eta}{\rho}-1}(1-\theta)\left(l^f\right)^{\rho-1}, \\
d &= (1-\eta)p_a y_a.
\end{aligned}$$

A.3 Urban Area Households

Given p_a, r, w_n, the urban household variables, $\{a_n^y(-\zeta),\ c_n^y(-\zeta),\ k_n(-\zeta),\ a_n^y(\zeta),\ c_n^y(\zeta),$ $k_n(\zeta)\}$ and $\{a_n^o(-\zeta,-\zeta), a_n^o(-\zeta,\zeta), a_n^o(\zeta,-\zeta), a_n^o(\zeta,\zeta), c_n^o(-\zeta,-\zeta), c_n^o(-\zeta,\zeta), c_n^o(\zeta,-\zeta),$ $c_n^o(\zeta,\zeta)\}$ (14 variables), must satisfy the following conditions:

– 6 budget constraints:

$$\begin{aligned}
p_a a_n^y(\zeta^y) + c_n^y(\zeta^y) + k_n(\zeta^y) &= w_n\kappa\exp(\zeta^y),\ \text{for } \zeta^y = -\zeta, \zeta \\
p_a a_n^o(\zeta^y,\zeta^o) + c_n^o(\zeta^y,\zeta^o) &= w_n\kappa\exp(\zeta^o) + r_n k_n(\zeta^y),\ \text{for } (\zeta^y,\zeta^o) = \{(-\zeta,-\zeta), (-\zeta,\zeta), (\zeta,\zeta), (\zeta,
\end{aligned}$$

– 6 conditions involving the marginal rate of substitution between c and a at each tree node:

$$\begin{aligned}
\frac{\phi}{1-\phi}\left(\frac{c_n^y(\zeta^y)}{a_n^y(\zeta^y)-\bar{a}}\right)^\sigma &= p_a,\ \text{for } \zeta^y = -\zeta, \zeta \\
\frac{\phi}{1-\phi}\left(\frac{c_n^o(\zeta^y,\zeta^o)}{a_n^o(\zeta^y,\zeta^o)-\bar{a}}\right)^\sigma &= p_a,\ \text{for } (\zeta^y,\zeta^o) = (-\zeta,-\zeta), (-\zeta,\zeta), (\zeta,\zeta), (\zeta,-\zeta)
\end{aligned}$$

– 2 conditions involving the intertemporal expected rate of substitution between c^y and c^o:

$$\begin{aligned}\frac{c_n^y(-\zeta)^{-\sigma}}{\pi c_n^o(-\zeta,-\zeta)^{-\sigma}+(1-\pi)\,c_n^o(-\zeta,\zeta)^{-\sigma}} &= \beta r \text{ for } \zeta^y=-\zeta \\ \frac{c_n^y(\zeta)^{-\sigma}}{\pi c_n^o(\zeta,\zeta)^{-\sigma}+(1-\pi)\,c_n^o(\zeta,-\zeta)^{-\sigma}} &= \beta r \text{ for } \zeta^y=\zeta\end{aligned}$$

A.4 Rural Area Households

Given p_a, r, w_a, q, p_l, the rural area household variables, $\{a_a^y,\ c_a^y,\ k_a,\ l\}$ and $\{a_a^o,\ a_a^o\}$ (6 variables), must satisfy the following conditions:

– 2 budget constraints:

$$\begin{aligned}p_a a_a^y + c_a^y + p_l l + k_a &= w_a, \\ p_a a_a^o + c_a^o &= w_a + r\,k_a + (q+p_l)\,l.\end{aligned}$$

– 2 conditions involving the marginal rate of substitution between c and a at each age:

$$\begin{aligned}\frac{\phi}{1-\phi}\left(\frac{c_a^y}{a_a^y-\bar{a}}\right)^{\sigma} &= p_a \\ \frac{\phi}{1-\phi}\left(\frac{c_a^o}{a_a^o-\bar{a}}\right)^{\sigma} &= p_a\end{aligned}$$

– 1 condition involving the intertemporal rate of substitution between c^y and c^o :

$$\left(\frac{c_a^y}{c_a^o}\right)^{-\sigma} = \beta r$$

– Note the household will save in terms of capital only if $r > \frac{q+p_l}{p_l}$, and in terms of land only otherwise. We will focus on the interior solution, which means that the rates of return equalize across the two assets, i.e.

$$r = \frac{q + p_l}{p_l},$$

we can solve the above equations to determine a_a^y, c_a^y, a_a^o, a_a^o and savings $s_a = p_l l + k_a$.

A.5 Market Clearing

To summarize what we have so far, for given prices, $\{w_n,\, w_a,\, r,\, q,\, p_l\ ,\, p_a\}$, we have solved for all household and firm variables (except l and k_a) and we have obtained 2 additional conditions:

$$\begin{aligned} r &= \frac{q + p_l}{p_l}, \\ s_a &= p_l l + k_a, \end{aligned}$$

where s_a is known.

It remains to find $\{w_n,\, w_a,\, r,\, q,\, p_l,\, p_a\}$, l, k_a, χ, ε (10 variables).

The remaining conditions are 6 market clearing where we substituted for the population size of the young and old in urban areas, $N_n^y = N_n^o = \chi N$, and for the population size of young and old in agricultural areas $N_a^y = N_a^o = (1-\chi)\, N$:

– Labor market in agriculture:

$$\varepsilon\,(1-\chi)\, N n_a^f = (1-\chi)\, N\,(2-\varepsilon)\,.$$

– Labor market in the urban area:

$$N_n = \chi 2N.$$

– Capital market:

$$K_n + \varepsilon (1-\chi) N k_a^f = \chi N k_n + (1-\chi) N k_a.$$

– Land market in agriculture:

$$\varepsilon (1-\chi) N l^f = (1-\chi) N l = L.$$

– Agricultural goods market:

$$\varepsilon (1-\chi) N y_a = \chi N (a_n^y + a_n^o) + (1-\chi) N (a_a^y + a_a^o).$$

– Non-agricultural goods market:

$$Y_n = \chi N (c_n^y + c_n^o + k_n) + (1-\chi) N (c_a^y + c_a^o + k_a).$$

$k_n = 0.5 [k_n (\zeta^y = -\zeta) + k_n (\zeta^y = \zeta)]$ is investment per urban young household (and capital holdings per urban old household),

$a_n^y = 0.5 [a_n^y (-\zeta) + a_n^y (\zeta)]$ is the average consumption of the agricultural good for the urban young household,

$c_n^y = 0.5 [c_n^y (-\zeta) + c_n^y (\zeta)]$ is the average consumption of the non-agricultural good for the urban young household,

$a_n^o = 0.5[\pi a_n^o (-\zeta, -\zeta) + (1-\pi) a_n^o (-\zeta, \zeta) + \pi a_n^o (\zeta, \zeta) + (1-\pi) a_n^o (\zeta, -\zeta)]$ is the average consumption of the agricultural good for the urban old household,

$c_n^o = 0.5[\pi c_n^o (-\zeta, -\zeta) + (1-\pi) c_n^o (-\zeta, \zeta) + \pi c_n^o (\zeta, \zeta) + (1-\pi) c_n^o (\zeta, -\zeta)]$ is the average consumption of the non-agricultural good for the urban old household.

Measure χ of each cohort decides to locate in agricultural areas. This measure is determined by equalization of lifetime utility across areas:

$$EU_n = U_a.$$

We also know

$$d = w.$$

B Data Source

[*i*] *Capital Income Share in Non-agriculture Sector*: Standard in sectoral model.

[*ii*] *Population Share in Rural Area*: Figure 1.6 of State of Indian Agriculture 2015-16 reports workforce engaged in agricultural sector is 0.59.

[*iii*] *Urban-rural Wage Gap*: We estimate the value for rural-urban wage gap by using Indian Human Development Survey I and II. Estimation is detailed in Appendix C.

[*iv*] *Consumption Expenditure Share of Agricultural Good in Rural Area*: Anand and Prasad (2010) estimated minimum consumption requirement value to be 50 percent of food consumption for a sample of six emerging economies, including India.

[*v*] *The Average Farm Size*: Table 9.4 of State of Indian Agriculture 2015-16 reports the averages farm size is 1.33 Hectares,

[*vi*] *Consumption Gap per Capita*: Figure 2 in Hnatkovska and Lahiri (2016) reports the urban-rural consumption gap is 1.25 in 1999-2000.

C Wage Process

We use data from Indian Human Development Survey (IHDS), conducted by University of Maryland and the National Council of Applied Economic Research, which is a nationally representative multi-topic panel survey. The first round (IHDS-I) was completed in 2004-05 and the second round (IHDS-II) was completed in 2011-12. We estimate the persistence of wage for employed male worker living in urban area.

- Wage samples include only male, ages from 16 to 65, male household head, not enrolled in educational institution, full time employed. We convert hourly wage to daily wage in IHDS data.

- We estimate following equation for workers in urban area:

$$\log w_{i,t} = \beta_1 + \beta_2 \text{age}_{i,t} + \beta_3 \text{age}_{i,t}^2 + \varepsilon_{i,t}^w,$$

- then calculate residuals $r_{i,t}^w$:

$$r_{i,t}^w = \log w_{i,t} - \log \bar{w}_t,$$

- then estimate following equation, get ρ and calculate σ^2 (variance of $\varepsilon_{i,t}$)[5] ,

$$r_{i,t}^w = \alpha + \rho r_{i,t-1}^w + \varepsilon_{i,t}.$$

- Using estimated $\rho = 0.575^3$ and $\sigma^2 = 0.419$, we calculate ζ and π by following:

$$\zeta = \sqrt{\frac{\sigma^2}{1-\rho^2}},$$

[5]We need to use three exponents of ρ to get model equivalent.

$$\pi = \frac{1+\rho}{2}.$$

- We estimate wage gaps ($\exp(\beta_4) = 1.37$) in year 2012:

$$\log w_i = \beta_1 + \beta_2 \text{age}_i + \beta_3 \text{age}_i^2 + \beta_4 \text{sector} + \varepsilon_i^w.$$

D Measuring Consumption Insurance

We use consumption and income data from IHDS-I and IHDS-II, consumption and income are measured as follows:

- **Consumption**: The adult-equivalent consumption measures is computed by dividing the household consumption measure by the equivalence scales (KP) in Krueger and Perri (2006), defined as follows:

$$KP = [(\#\text{ of adults age} \geq 15) + 0.7 \times (\#\text{ of children age} < 15)]^{0.7}.$$

- **Income**: The adult-equivalent household income is obtained by dividing the benchmark income by the number of working age adults (age ≥ 15)

We estimate a partial insurance model by following steps[6]:

1. regress the (logged) adult-equivalent income Y_t on dummies of age, education level, province of residence, and ethnic minority separately by rural/urban status and by year,

$$Y_{i,t} = \beta_1 + \beta_2 age_{i,t} + \beta_4 education_{i,t} + \beta_4 state_{i,t} + \beta_5 minority_{i,t} + \varepsilon_{i,t}^Y,$$

[6] Estimation steps are similar to Santaeulàlia-Llopis and Zheng (2018), Storesletten et al. (2004).

2. regress the (logged) adult-equivalent consumption measure C_t on dummies of age, education level, province of residence, and ethnic minority separately by rural/urban status and by year,

$$C_{i,t} = \beta_1 + \beta_2 age_{i,t} + \beta_4 education_{i,t} + \beta_4 state_{i,t} + \beta_5 minority_{i,t} + \varepsilon^C_{i,t},$$

3. estimate residual of income y_t and consumption c_t ,

$$y_{i,t} = Y_{i,t} - \bar{Y}_{i,t},$$

$$c_{i,t} = C_{i,t} - \bar{C}_{i,t},$$

4. take the difference in the residuals; unexplained income growth Δy_t and unexplained consumption growth Δc_t ,

$$\Delta y_{i,t} = y_{i,t} - y_{i,t-1},$$

$$\Delta c_{i,t} = c_{i,t} - c_{i,t-1}$$

5. regress Δc_t on Δy_t, estimate shock transmission parameter ψ and estimate variance of the residuals (see Table A1).

Table A1: Regression Results, IHDS, 2005, 2012

Dependent variable: Δc		
	Rural	Urban
Independent variable: Δy		
ψ	0.102	0.194
	(0.008)	(0.011)
adjusted R^2	0.028	0.075
N	13540	5755