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

Oksana Leukhina* Raghav Paul † Md Mahbubur Rahman‡

February 16, 2018

Abstract

It is well known that the gap in agricultural labor productivity accounts for most of the output gap between rich and poor countries. Furthermore, development economists have pointed out that the low agricultural productivity in poor countries stems from the persistence of small non-mechanized farms. We propose and quantify a novel explanation for this phenomenon. We begin with a premise that residing in a rural area provides access to a network that effectively insures its residents against income fluctuations. If living in the rural area provides access to "insurance", households 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 are weak. In order to understand the quantitative importance of this mechanism, we calibrate the model to Indian data and study an abstract policy intervention – provision of complete insurance against earnings risk in the city. Our framework successfully accounts for the urban-rural consumption gap. The policy intervention decreases the share of workers in agriculture from 0.59 to 0.52, increases capital demand per firm by 79 percent, the average farm size increases by 9 percent and the labor productivity gap between the two sectors decreases by 32 percent.

Key words: Labor Productivity in Agriculture, Structural Transformation, Labor Earnings Risk, Social Insurance.
JEL: O1, O4, J2.

*Federal Reserve Bank of St. Louis, Email:oksana.m.leukhina@gmail.com
†University of Washington, Email: rpaul@uw.edu
‡McMaster University, Email: rahmanmm@mcmaster.ca

It is well known that low agricultural labor productivity is a major impediment to development. Mechanically speaking, the gap in agricultural labor productivity accounts for most of the output gap between rich and poor countries. Development economists have pointed out that the low agricultural productivity in poor countries stems from the persistence of small non-mechanized farms (e.g. Rosenzweig and Foster, 2012).[1] Our main goal is to understand why farmers in poor countries fail to mechanize their ways of farming.

We begin with a 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 the large body of literature and survey data. If households indeed value their land beyond its rental value (or its marginal product) simply because it also provides them access to "insurance", 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 are weak. This description captures the main essence of our mechanism.

In order to understand the quantitative importance of this mechanism, we calibrate the model to Indian data and study an abstract policy intervention. Precisely, we employ the calibrated model to quantify the effect of introducing complete insurance against labor earnings risk 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 agricultural area declines from 0.59 to 0.52, implying increased labor movement to urban areas. While this effect on labor reallocation is far from dramatic, the impact on agricultural productivity is very large. In agricultural sector, capital demand per firm increases by 79 percent due to substitutability between labor and capital inputs. We also see the average firm size increases by 9 percent. The labor productivity gap between the two sectors decreases by 32 percent.

[1] Townsend [1994] has drawn attention to risk sharing feature in rural areas by empirically noticing that household consumption co-moves with village average consumption in India and shows little dependence on own income.

Our mechanism working on migration is consistent with Munshi and Rosenzweig [2016] which show that informal insurance in rural areas decrease low-skilled labor migration in India and which affect rural-urban wage gaps. That paper does not consider implications for agricultural labor productivity.

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 rural-urban 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. Young [2013] has examined the rural-urban consumption expenditure gaps in 65 countries. Hnatkovska and Lahiri [2016] have examined the rural-urban both wage and consumption expenditure gaps in India by incorporating differential sectoral productivity shocks. Young [2013] and Hnatkovska and Lahiri [2016] have found the gaps cannot be accounted for by differences in observed characteristics of rural of urban workers, such as schooling levels. Gollin et al. [2017] have emphasized that spacial models require that amenities (or something else) must be worse in the urban areas to justify the presence of the observed rural-urban consumption inequality as an equilibrium outcome. Contrary to this conclusion, they show in African data that cities across the board 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's consistent with spatial models. Another alternative explanation is of course the difference in unobserved worker characteristics across the two locations.

[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 (log) consumption expenditures on a rural dummy.

We now provide more details on our framework. We use an overlapping generation model with endogenous spatial choice. There are four main features in our model. First, the location choice is explicit. Second, non-homotheticity preference as is typical in structural transformation literature (Herrendorf, Rogerson, Valentinyi 2018). Third, farm size is endogenous and so is labor productivity in agriculture. Fourth, there is non-insurable labor income risk in urban areas. 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 area, there is a spatial equilibrium with no consumption gap. In Hnatkovska and Lahiri [2016] location choice is costly and sectoral TFPs differ across areas whereas in our model location choice is not costly and sectoral TFPs are same. Our work is related to Adamopoulos and Restuccia [2014] and Chen et al. [2017]. These literatures focus on misallocation in factor production and firm size distribution. Our work is not focused on this area.

In our model, there are two cohort in each period and they live only two period. Each cohort choose the location to live and work at young age and stay that location in old age. Cohort living in nonagricultural area faces non-insurable risks to labor income through endowment. This shock process could be estimated by calculating standard deviation of (log of) wage income. There are two areas: non-agricultural (or urban) and agricultural (or rural) and two sectors: non-agricultural and agricultural. We calibrate out benchmark model to Indian experience and incorporate the stochastic labor earnings process.

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 the analytical calibration used in our paper.

1 The Model

Consider a model economy where time is discrete and indexed by $t = 0, 1, 2, \ldots$. There are two spatially separated locations: non-agricultural and agricultural. In each location, there are two generations of households live for two periods (i.e., young and old). We assume no mortality at young age and no population growth. We also assume the total measure of each generation is N_t. Measure χ_t of each generation lives in non-agricultural area.

We also consider two sectors: non-agricultural and agricultural. In each period, non-agricultural good is produced in non-agricultural area and agricultural good is produced in agricultural area. Each generation enjoys utility from consuming of both agricultural and non-agricultural good, according to non-homothetic preferences.

Timing: Within each period t, i) a new generation of young people is born, ii) the new generation chooses a area i.e., nonagricultural or agricultural to live, iii) a standalone non-agricultural firm hires workers and rents capital to produce non-agricultural good, iv) agricultural firms hire workers, rent land and capital to produce agricultural goods, v) the households receive proceeds from their factor of production, and the young generation in agricultural area save the proceeds as capital and purchase land and the young generation in non-agricultural area save their proceeds as capital for the next period, vi) the old generation dies, while the young generation ages and becomes old in the next period.

1.1 Non-agricultural Area

1.1.1 Non-agricultural Firm

The non-agricultural good is produced by a standalone firm in period t. This firm behaves competitively and has a constant returns to scale technology that requires labor and capital as inputs.

$$Y_{n,t} = A_n K_{n,t}^{\alpha} N_{n,t}^{1-\alpha} \tag{1}$$

where $Y_{n,t}$ is total amount of non-agricultural good produced, $K_{n,t}$ is total amounts of capital and $N_{n,t}$ is effective unit of labor employed in non-agricultural sector. A_n is total factor productivity (TFP) parameter.

The non-agricultural firm takes the wage rate $w_{n,t}$ and the rental price of capital $r_{n,t}$ as given and chooses its demand for capital $K_{n,t}$ and effective unit of labor services $N_{n,t}$ to maximize profits,

$$\max_{K_{n,t},N_{n,t}} \left\{ Y_{n,t} - w_{n,t}N_{n,t} - r_{n,t}K_{n,t} \right\}. \tag{2}$$

It hires capital and effective unit of labor until their market prices $r_{n,t}$ and $w_{n,t}$ are equal to their marginal products, as following:

$$w_{n,t} = (1-\alpha)A_n K_{n,t}^{\alpha} N_{n,t}^{-\alpha}, \tag{3}$$

$$r_{n,t} = \alpha A_n K_{n,t}^{\alpha-1} N_{n,t}^{1-\alpha} \tag{4}$$

We assume the firm rents capital from both agricultural and non-agricultural areas but employs labor from non-agricultural area.

1.1.2 Non-agricultural: household

In period t, measure $1 - \chi_t$ of each cohort lives in non-agricultural area. The cohort living in non-agricultural area is endowed with one unit of time at both young and old age; and that is supplied inelastically to labor market. At young age, each cohort faces idiosyncratic shocks to effective labor endowment $\zeta^y \in \{\zeta^H, \zeta^L\}$ drawn with probability π^H and $1-\pi^H$. At old age, they also face idiosyncratic shocks to effective labor endowment $\zeta^o \in \{\zeta^H, \zeta^L\}$ with probability $\begin{bmatrix} \pi^{HH} & 1-\pi^{HH} \\ \pi^{LH} & 1-\pi^{LH} \end{bmatrix}$. There is no aggregate uncertainty, so the fraction of the young agents living in non-agricultural area that receive a high realization is exactly equal to π^H. We assume $\pi^{LH} = 1-\pi^{HH}$.

Each cohort gets expected lifetime utility $\mathcal{U}^n$ over the two states: H and L:

$$\mathcal{U}^n = \pi^H \mathcal{U}^n_H + (1-\pi^H)\mathcal{U}^n_L. \tag{5}$$

The cohort faced ζ^H idiosyncratic shocks at young age gets lifetime utility $\mathcal{U}^n_H$ over agricultural and non-agricultural goods as following:

$$\begin{aligned} \mathcal{U}^n_H =& \phi \, \frac{(a^n_t(y,H)-\bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi)\, \frac{c^n_t(y,H)^{1-\sigma}}{1-\sigma} \\ &+ \beta\Big[\pi^{HH}\{\phi\frac{(a^n_{t+1}(o,HH)-\bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi)\frac{c^n_{t+1}(o,HH)^{1-\sigma}}{1-\sigma}\} \\ &+ (1-\pi^{HH})\{\phi\frac{(a^n_{t+1}(o,HL)-\bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi)\frac{c^n_{t+1}(o,HL)^{1-\sigma}}{1-\sigma}\}\Big] \end{aligned} \tag{6}$$

, where $a^n_t(y,H)$ is consumption of agricultural good at young age in period t, $c^n_t(y,H)$ is consumption of non-agricultural good at young age in period t, $a^n_{t+1}(o,HL)$ and $a^n_{t+1}(o,HH)$ are consumption of agricultural good at old age in period $t+1$, $c^n_{t+1}(o,HL)$ and $c^n_{t+1}(o,HH)$ are consumption of non-agricultural good at old age in period $t+1$. And $\bar{a} > 0$ is a subsistence constraint for agricultural good, ϕ is a preference weight for the agricultural good and β is time discounting factor.

The cohort faced ζ^L idiosyncratic shocks at young age gets lifetime utility $\mathcal{U}^n_L$ over agricultural and non-agricultural goods as following:

$$
\begin{aligned}
\mathcal{U}_L^n = & \phi \frac{(a_t^n(y,L)-\bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi)\frac{c_t^n(y,L)^{1-\sigma}}{1-\sigma} \\
& + \beta \Big[\pi^{LH} \{ \phi \frac{(a_{t+1}^n(o,LH)-\bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi)\frac{c_{t+1}^n(o,LH)^{1-\sigma}}{1-\sigma} \} \\
& + (1-\pi^{LH}) \{ \phi \frac{(a_{t+1}^n(o,LL)-\bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi)\frac{c_{t+1}^n(o,LL)^{1-\sigma}}{1-\sigma} \} \Big]
\end{aligned} \tag{7}
$$

where $a_t^n(y,L)$ is consumption of agricultural good at young age in period t, $c_t^n(y,L)$ is consumption of non-agricultural good at young age in period t, $a_{t+1}^n(o,LL)$ and $a_{t+1}^n(o,LH)$ are consumption of agricultural good at old age in period $t+1$, $c_{t+1}^n(o,LL)$ and $c_{t+1}^n(o,LH)$ are consumption of non-agricultural good at old age in period $t+1$. ϕ, $\bar{a} > 0$ and β are same as before.

In period t, the young agent earns only wage income $w_{n,t}\zeta^y$ and purchases $c_t^n(y)$ amount of non-agricultural good from non-agricultural good producer at price 1 (numeraire), $a_t^n(y)$ amount of agricultural good from non-agricultural good producer at price $p_{a,t}$ and $k_{t+1}^n(y)$ amount of consumption good to save as capital for old age.

In period $t+1$, the agent at old age earns wage income $w_{n,t+1}\zeta^o$ and capital rent $r_{n,t+1}k_{t+1}^n(y)$ and purchases $c_{t+1}^n(o)$ amount of non-agricultural good from non-agricultural good producer at price 1 (numeraire), $a_{t+1}^n(o)$ amount of agricultural good from non-agricultural good producer at price $p_{a,t+1}$.

The budget constraints for the cohort faced ζ^H idiosyncratic shocks at young age are following:

$$p_{a,t}a_t^n(y,H) + c_t^n(y,H) + k_{t+1}^n(y,H) = w_{n,t}\zeta_t^H, \tag{8}$$

$$p_{a,t+1}a_{t+1}^n(o,HH) + c_{t+1}^n(o,HH) = w_{n,t+1}\zeta^H + r_{n,t+1}k_{t+1}^n(y,H), \tag{9}$$

$$p_{a,t+1}a^n_{t+1}(o,HL) + c^n_{t+1}(o,HL) = w_{n,t+1}\zeta^L + r_{n,t+1}k^n_{t+1}(y,H). \tag{10}$$

This cohort chooses $c^n_t(y,H)$, $a^n_t(y,H)$, $c^n_{t+1}(o,HH)$, $c^n_{t+1}(o,HL)$, $a^n_{t+1}(o,HH)$,$a^n_{t+1}(o,HL)$ and $k^n_{t+1}(y,H)$ to maximize (6) subject to (8), (9) and (10), which yields following first order conditions:

$c^n_t(y,H)$:

$$(1-\phi)c^n_t(y,H)^{-\sigma} = \lambda^H_{n,t} \tag{11}$$

, $a^n_t(y,H)$:

$$a^n_t(y,H) =(\frac{1-\phi}{\phi}p_{a,t})^{-\frac{1}{\sigma}}c^n_t(y,H) + \bar{a} \tag{12}$$

, $c^n_{t+1}(o,HH)$:

$$\beta\pi^H H(1-\phi)c^n_{t+1}(o,HH)^{-\sigma} = \lambda^{HH}_{n,t} \tag{13}$$

$c^n_{t+1}(o,HL)$:

$$\beta(1-\pi^{HH})(1-\phi)c^n_{t+1}(o,HL)^{-\sigma} = \lambda^{HL}_{n,t} \tag{14}$$

$a^n_{t+1}(o,HH)$:

$$a^o_{t+1}(o,HH) = (\frac{1-\phi}{\phi}p_{a,t+1})^{-\frac{1}{\sigma}}c^n_{t+1}(o,HH) + \bar{a} \tag{15}$$

$a^n_{t+1}(o, HL)$:

$$a^n_{t+1}(o, HL) = (\frac{1-\phi}{\phi} p_{a,t+1})^{-\frac{1}{\sigma}} c^n_{t+1}(o, HL) + \bar{a} \tag{16}$$

$k^n_{t+1}(y, H)$:

$$c^n_{t+1}(y, H) = (\beta r_{n,t+1}(\pi^{HH} c^n_{t+1}(o, HH)^{-\sigma} + (1-\pi^{HH}) c^n_{t+1}(o, HH)^{-\sigma})^{-\frac{1}{\sigma}} \tag{17}$$

where $\lambda^H_{n,t}$, $\lambda^{HH}_{n,t}$ and $\lambda^{HL}_{n,t}$ are Lagrange multipliers for (8), (9) and (10) respectively.

The budget constraints for the cohort faced ζ^L idiosyncratic shocks at young age are following:

$$p_{a,t} a^n_t(y, L) + c^n_t(y, L) + k^n_{t+1}(y, L) = w_{n,t} \zeta^L_t, \tag{18}$$

$$p_{a,t+1} a^n_{t+1}(o, LH) + c^n_{t+1}(o, LH) = w_{n,t+1} \zeta^H + r_{n,t+1} k^n_{t+1}(y, H), \tag{19}$$

$$p_{a,t+1} a^n_{t+1}(o, LL) + c^n_{t+1}(o, LL) = w_{n,t+1} \zeta^L + r_{n,t+1} k^n_{t+1}(y, H). \tag{20}$$

This cohort chooses $c^n_t(y, L)$, $a^n_t(y, L)$, $c^n_{t+1}(o, LH)$, $c^n_{t+1}(o, LL)$, $a^n_{t+1}(o, LH)$,$a^n_{t+1}(o, LL)$ and $k^n_{t+1}(y, L)$ to maximize (7) subject to (18), (19) and (20), which yields following first order conditions:

$a^n_t(y, L)$:

$$a^n_t(y, L) = (\frac{1-\phi}{\phi} p_{a,t})^{-\frac{1}{\sigma}} c^n_t(y, L) + \bar{a}, \tag{21}$$

$a^n_{t+1}(o, LH)$:

$$a^o_{t+1}(o, LH) = (\frac{1-\phi}{\phi} p_{a,t+1})^{-\frac{1}{\sigma}} c^n_{t+1}(o, LH) + \bar{a}, \tag{22}$$

$a^n_{t+1}(o, LL)$:

$$a^n_{t+1}(o, LL) = (\frac{1-\phi}{\phi} p_{a,t+1})^{-\frac{1}{\sigma}} c^n_{t+1}(o, LL) + \bar{a}, \tag{23}$$

$k^n_{t+1}(y, L)$:

$$c^n_{t+1}(y, L) = (\beta r_{n,t+1}(\pi^{LH} c^n_{t+1}(o, LH)^{-\sigma} + (1-\pi^{LH}) c^n_{t+1}(o, LH)^{-\sigma})^{-\frac{1}{\sigma}}, \tag{24}$$

The allocation for $a^n_t(y)$, $c^n_t(y)$, $a^n_t(o)$, $c^n_t(o)$, and $k^n_t(y)$ in non-agricultural area are following:

$$a^n_t(y) = \pi^H a^n_t(y, H) + (1-\pi^H) a^n_t(y, L), \tag{25}$$

$$c^n_t(y) = \pi^H c^n_t(y, H) + (1-\pi^H) c^n_t(y, L), \tag{26}$$

$$\begin{aligned} a^n_t(o) =& \pi^H \left\{ \pi^{HH} a^n_t(o, HH) + (1-\pi^{HH}) a^n_t(o, HL) \right\} \\ &+ (1-\pi^H) \left\{ \pi^{LH} a^n_t(o, LH) + (1-\pi^{LH}) a^n_t(o, LH) \right\} \end{aligned} \tag{27}$$

$$\begin{aligned} c^n_t(o) =& \pi^H \left\{ \pi^{HH} c^n_t(o, HH) + (1-\pi^{HH}) c^n_t(o, HL) \right\} \\ &+ (1-\pi^H) \left\{ \pi^{LH} c^n_t(o, LH) + (1-\pi^{LH}) c^n_t(o, LH) \right\} \end{aligned} \tag{28}$$

$$k^n_t(y) = \pi^H k^n_t(y, H) + (1 - \pi^H)k^n_t(y, L) \tag{29}$$

1.2 Agricultural Area

1.2.1 Agricultural Firm

Each old agent living in agricultural area owns an agricultural firm. The old agent decides what ε_t fraction of her 1 unit her time spends for managing her firm and remaining $1 - \varepsilon_t$ unit of her time spends as a worker. We assume no labor endowment risk due to social insurance among people living in agricultural areas.

In period t, given the rental price of capital, land and labor $(r_{a,t}, q_t, w_{a,t})$ and the relative price of agricultural good $p_{a,t}$, each manager maximizes its profits that requires land, labor and capital as inputs.

$$\max_{k_{a,t}, n_{a,t}\, l_{a,t}} d_t = p_{a,t}y_{a,t} - w_{a,t}n_{a,t} - r_{a,t}k_{a,t} - q_t l_{a,t} \tag{30}$$

where d_t is profit. The production technology of non-agricultural good is a constant elasticity of substitutions (CES) as following:

$$y_{a,t} = A_a \left[(1 - \theta)l^\rho_{a,t} + \theta(\nu k^\mu_{a,t} + (1 - \nu)n^\mu_{a,t})^{\frac{\rho}{\mu}}\right]^{\frac{\eta}{\rho}} \tag{31}$$

where $y_{a,t}$ is amount of non-agricultural good produced, and $k_{a,t}$, $n_{a,t}$, and $l_{a,t}$ are amounts of capital, effective unit of labor employed and land demanded respectively. $l_{a,t}$ is also a measure of firm size. A_a is total factor productivity (TFP) parameter. ρ determines the elasticity of substitution between land and composite of capital and labor, μ determines the elasticity of substitution between capital and labor, $\theta \in (0, 1)$ is relative importance of land to composite of capital and labor, ν determines relative important of capital and labor, $\eta \in (0, 1)$ determines returns to scale at each firm level, is also called as "span-of-control" parameter.

To maximize profit, each manager rents land, capital and effective unit of labor until their marginal products equal to their market prices q_t, $r_{a,t}$ and $w_{a,t}$ respectively,

(32)

$$w_{a,t} = \theta p_{a,t}\, \eta\, A_a \left[(1-\theta)l_{a,t}^{\rho} + \theta(\nu k_{a,t}^{\mu} + (1-\nu)n_{a,t}^{\mu})^{\frac{\rho}{\mu}}\right]^{\frac{\eta}{\rho}-1} (\nu k_{a,t}^{\mu} + (1-\nu)n_{a,t}^{\mu})^{\frac{\rho}{\mu}-1}(1-\nu)n_{a,t}^{\mu-1}$$

(33) $$r_{a,t} = \theta p_{a,t}\, \eta\, A_a \left[(1-\theta)l_{a,t}^{\rho} + \theta(\nu k_{a,t}^{\mu} + (1-\nu)n_{a,t}^{\mu})^{\frac{\rho}{\mu}}\right]^{\frac{\eta}{\rho}-1} (\nu k_{a,t}^{\mu} + (1-\nu)n_{a,t}^{\mu})^{\frac{\rho}{\mu}-1}\, \nu k_{a,t}^{\mu-1}$$

(34) $$q_t = p_{a,t}\, \eta\, A_a \left[(1-\theta)l_{a,t}^{\rho} + \theta(\nu k_{a,t}^{\mu} + (1-\nu)n_{a,t}^{\mu})^{\frac{\rho}{\mu}}\right]^{\frac{\eta}{\rho}-1} (1-\theta)l_{a,t}^{\rho-1}$$

Same as non-agricultural sector, we assume the firm rents capital from both agricultural and non-agricultural area but employs labor from agricultural area.

The profit d_t of each firm is

(35) $$d_t = (1-\eta)p_{a,t}y_{a,t}$$

In equilibrium, ε_t is determined from a no-arbitrage condition that states each manger allocates it time across manager and worker jobs until her profit is equal to wage rate.

(36) $$d_t = w_{a,t}$$

1.2.2 Agricultural: Household

In period t, measure χ_t of each cohort living in agricultural area gets life time utility, $\mathcal{U}^a$ over the two goods according to following:

$$
\begin{aligned}
\mathcal{U}^a = \max_{\substack{a_t^n(y), c_t^a(y),\\ k_{t+1}^a(y),\\ a_{t+1}^a(o),\, c_{t+1}^a(o)}} \;& \phi \,\frac{(a_t^a(y)-\bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi)\,\frac{c_t^a(y)^{1-\sigma}}{1-\sigma} \\
&+\beta\left\{\phi\frac{(a_{t+1}^a(o)-\bar{a})^{1-\sigma}}{1-\sigma} + (1-\phi)\frac{c_{t+1}^a(o)^{1-\sigma}}{1-\sigma}\right\}
\end{aligned} \tag{37}
$$

where $a_t^a(y)$ is consumption of agricultural good at young age in period t, $c_t^a(y)$ is consumption of non-agricultural good at young age in period t, $a_{t+1}^a(o)$ is consumption of agricultural good at old age in period $t+1$, $c_{t+1}^a(o)$ is consumption of non-agricultural good at old age in period $t+1$. ϕ, $\bar{a} > 0$ and β are same as before.

In period t, the young agent earns only wage income $w_{a,t}$ and purchases $c_t^a(y)$ amount of non-agricultural good from non-agricultural good producer at price 1, purchases $a_t^a(y)$ amount of agricultural good from non-agricultural good producer at price $p_{a,t}$, purchases l_{t+1} amount of land from current old age cohort at price $p_{l,t}$ and purchases $k_{t+1}^a(y)$ amount of consumption good to save as capital for old age.[3]

$$
p_{a,t}a_t^a(y) + c_t^a(y) + p_{l,t}l_{t+1} + k_{t+1}^a = w_{a,t} \tag{38}
$$

In period $t+1$, the agent at old age earns wage income $(1-\varepsilon_t)w_{a,t+1}$, profits $\varepsilon_t d_{t+1}$, land rent $q_{t+1}l_{t+1}$ and capital rent $r_{a,t+1}k_{t+1}^a(y)$, and purchases $c_{t+1}^a(o)$ amount of non-agricultural good from non-agricultural good producer at price 1, $a_{t+1}^a(o)$ amount of agricultural good from non-agricultural good producer at price $p_{a,t+1}$, and at the end of the period sales the

[3] l_{t+1} is land supply, k_{t+1}^a is capital supply.

land to young cohort.

$$p_{a,t+1}a^a_{t+1}(o) + c^a_{t+1}(o) = (1-\varepsilon_t)w_{a,t+1} + \varepsilon_t d_{t+1} + r_{a,t+1}\, k^a_{t+1} + q_{t+1}l_{t+1} + p_{l,t+1}l_{t+1} \tag{39}$$

By combining equation (38) and equation (39), we get:

(40)

$$p_{a,t}a^a_t(y) + c^a_t(y) + p_{l,t}l_{t+1} + \frac{p_{a,t+1}a^a_{t+1}(o) + c^a_{t+1}(o) - w_{a,t+1} - q_{t+1}l_{t+1} - p_{l,t+1}l_{t+1}}{r_{t+1}} = w_{a,t}.$$

This cohort chooses $a^a_t(y)$, $c^a_t(y)$, $a^a_{t+1}(o)$, $c^a_{t+1}(o)$, l_{t+1} to maximize (37) subject to (40), which yields following first order conditions:

c^a_t:

$$(1-\phi)c^a_t(y)^{-\sigma} = \lambda^a_t \tag{41}$$

$a^a_t(y)$:

$$a^a_t(y) = (\frac{1-\phi}{\phi}p_{a,t})^{-\frac{1}{\sigma}}c^a_t(y) + \bar{a} \tag{42}$$

a^a_{t+1}:

$$a^a_{t+1}(o) = (\frac{1-\phi}{\beta\phi}\frac{p_{a,t+1}}{r_{t+1}})^{-\frac{1}{\sigma}}c^a_t(y) + \bar{a} \tag{43}$$

$c^a_{t+1}(o)$:

$$c^a_{t+1}(o) = (\frac{1}{\beta r_{t+1}})^{-\frac{1}{\sigma}}c^a_t(y) \tag{44}$$

l_{t+1}:

$$p_{l,t} = \frac{q_{t+1} + p_{l,t+1}}{r_{t+1}} \tag{45}$$

1.2.3 Measure of Cohort and Population

Measure $\chi_t N$ living in agricultural area is determined by equalization of life time utility across areas. N is the measure of each cohort. In period t, $N^y_{n,t}$ is measure of young age who born in t living in non-agricultural area and $N^o_{n,t}$ is measure of old age who born in $t-1$ living in non-agricultural area. $N^y_{a,t}$ is young age who born in t living in agricultural area and $N^o_{a,t}$ is old age born in $t-1$ living in agricultural area. The measure of managers in agricultural area is $\varepsilon_t N^o_{a,t}$.

$$\text{Population in non-agricultural area} = N^y_{n,t} + N^o_{n,t}$$

$$\text{Population in agricultural area} = N^y_{a,t} + N^o_{a,t}$$

As no mortality, $N^y_{a,t} = N^o_{a,t+1}$ and $N^y_{n,t} = N^o_{n,t+1}$

1.2.4 Equilibrium

We are interested on the steady-state decentralized equilibrium of the economy in which allocations, prices and the measure of migration (χ) are stationary.

Definition A steady-state decentralized equilibrium is defined as for non-agricultural household $\{a^n(y),\ c^n(y),\ k^n(y),\ a^n(o),\ c^n(o)\}$, no-agricultural firm $\{K_n, N_n\}$ agricultural households $\{a^a(y)\ ,\ c^a(y),\ k(y),\ l,\ a^a(o),\ c^a(o)\}$, agricultural firm $\{k_a,\ n_a,\ l_a\}$ and prices $\{w_n,\ r_n,\ w_a,\ r_a,\ q,\ pl\ ,\ p_a\}$ such that

1. given prices, the allocation of non-agricultural household faced ζ^H idiosyncratic shocks at young age maximizes utility (6) subject to (8), (9) and (10); and given prices, the al-

location of non-agricultural household faced ζ^L idiosyncratic shocks at young age maximizes utility (7) subject to (18), (19) and (20); and using equations (26),(26),(28),(28),(29);

2. given prices, the allocation of non-agricultural firm maximizes profit in (2);
3. given prices, the allocation of agricultural household maximizes utility in (37) subject to budget constraints (38), (39);
4. given prices, the allocation of agricultural firm maximizes profit in (30);
5. capital is mobile across sector:

$$r_{a,t} = r_{n,t} \tag{46}$$

6. lifetime utility equalizes across two areas:

$$\mathcal{U}^n = \mathcal{U}^a \tag{47}$$

7. markets clear:

- for labor market:

$$\varepsilon_t N^o_{a,t} n_{a,t} = N^y_{a,t} + N^o_{a,t}(1-\varepsilon_t) \tag{48}$$

$$\begin{aligned} N^n_t =& N^y_{n,t}\left(\pi^H\zeta^H + (1-\pi^H)\zeta^L\right) \\ &+ N^o_{n,t}\left(\pi^H(\pi^{HH}\zeta^H + (1-\pi^{HH})\zeta^L) + (1-\pi^H)(\pi^{HH}\zeta^H + (1-\pi^{HH})\zeta^L\right) \end{aligned} \tag{49}$$

$$N^y_{a,t} = \chi_t N \tag{50}$$

$$N^{y}_{n,t} = (1-\chi_t)N \tag{51}$$

$$N^{o}_{a,t} = \chi_{t-1}N \tag{52}$$

$$N^{o}_{n,t} = (1-\chi_{t-1})N \tag{53}$$

- for capital market:

$$K_{n,t+1} + \varepsilon_t N^{o}_{a,t+1} k_{a,t+1} = N^{y}_{n,t} k^{n}_{t+1} + N^{y}_{a,t} k^{a}_{t+1} \tag{54}$$

- for land market: total amount of land in each period is L.

$$\varepsilon_t N^{o}_{a,t}\, l_{a,t} = L \tag{55}$$

$$N^{o}_{a,t} l_t = L \tag{56}$$

- for agricultural good market:

$$\varepsilon_t N^{o}_{a,t} y_{a,t} = N^{y}_{n,t} a^{n}_{t}(y) + N^{o}_{n,t} a^{n}_{t}(o) + N^{y}_{a,t} a^{a}_{t}(y) + N^{o}_{a,t} a^{a}_{a,t}(o) \tag{57}$$

- for non-agricultural good market:

(58)

$$Y_{n,t} = N^{y}_{n,t} c^{n}_{t}(y) + N^{o}_{n,t} c^{n}_{t}(o) + N^{y}_{n,t} k^{n}_{t+1}(y) + N^{y}_{a,t} c^{a}_{t}(y) + N^{o}_{a,t} c^{a}_{t}(o) + N^{y}_{a,t} k^{a}_{t+1}(y)$$

2 Calibration

We calibrate a benchmark economy to Indian data. The parameters to be calibrated are: preference parameters ($\bar{a}$), technological parameters (α, ρ, μ), and endowment (L). In our calibration, we match following moments: capital income share in non-agricultural sector, land income share in agricultural sector, average land size, fraction of population in rural, capital-labor ratio in agricultural sector. We choose ϕ, σ, β based on a priori information. We normalized values for A_a, A_n, N. In the benchmark model, we set values for ζ^H, ζ^L, π^H, and π^{HH} for idiosyncratic risk case. Remaining θ, ν, η are possible to target to following empirical moments: capital income share agricultural sector, capital-land ratio in agricultural sector, labor income share agricultural sector.[4] Table 1 shows all parameters values used in benchmark model. Column 2 of Table 2 presents both endogenous and calibrated moments

Table 1: Parameters

Parameter		Value
Preferences	ϕ	0.376
	β	0.4220
	σ	2.00
Technology	A_n	1.00
	A_a	1.00
	ν	0.50
	$1-\theta$	0.70
	μ	0.50
	η	0.50
Endowment	N	20
	ζ^H	1.6487
	ζ^L	0.6065
	π^H	0.50
	π^{HH}	0.70

in benchmark economy.

[4]These moments have not targeted in this version.

Table 2: Model Output

Variable	Benchmark Value	Counter-factual Value
Population share in agriculture*	0.5900	0.5247
Value added share in agriculture	0.4674	0.4982
Productivity in agriculture	0.4666	0.6031
Firm size	1.3300	1.4542
Capital per firm	0.0532	0.0953
Labor per firm	0.5320	0.4896
Productivity nonagri	0.7649	0.6705
Productivity agri	0.4666	0.6031
Productivity gap	1.6395	1.116
Aggregate labor productivity	0.5889	0.6351
Relative wage w_n/w_a	1.2718	1.0000
Consumption gap c_n/c_a	1.7103	1.0000
Consumption gap : young	1.2873	1.0000
Consumption gap : old	2.4747	1.0000
Calibrated Parameter (Target)	Value	
α (capital income share in non-agriculture=0.33)	0.3300	
ρ (land income share in agriculture=0.18)	-0.8620	
L (average land size=1.33 Hectares)	20.4883	
$\bar{a}$ (fraction of Population in agriculture=0.59)	0.1796	
μ (capital-labor Ratio in agriculture=0.10)	0.6925	

Note: * It is targeted in benchmark case.

3 Result

In the counter-factual scenario, we introduce complete insurance against idiosyncratic risk in non-agricultural area. Column 3 of Table 2 presents model generated moments in counter-factual economy. It shows population share in agricultural area declines from 0.59 to 0.5247 which means migration in non-agricultural area increases. In agricultural sector, capital demand per firm in increases by 79 percent due substitutability between labor and capital inputs. We also see firm size increase by 9 percent. Productivity gap between two sectors decrease from 1.6395 to 1.116. Rural-urban gap in wage and agriculture disappears.

4 Conclusion

We use OLG model to quantify the effect of introducing complete insurance against labor earnings risk in the city on migration and labor productivity in agriculture. Our framework successfully accounts for the urban-rural consumption gap. The policy intervention decreases the share of workers in agriculture from 0.59 to 0.52, increases capital demand per firm by 79 percent, the average farm size increases by 9 percent and the labor productivity gap between the two sectors decreases by 32 percent.

References

Tasso Adamopoulos and Diego Restuccia. The size distribution of farms and international productivity differences. American Economic Review, 104(6):1667–97, 2014.

Chaoran Chen, Diego Restuccia, and Raül Santaeulàlia-Llopis. Land markets, resource allocation, and agricultural productivity. Unpublished Manuscript, University of Toronto, 2017.

Douglas Gollin, Martina Kirchberger, and David Lagakos. In search of a spatial equilibrium in the developing world. Technical report, National Bureau of Economic Research, 2017.

Viktoria Hnatkovska and Amartya Lahiri. Urbanization, structural transformation and rural-urban disparities. 2016.

Kaivan Munshi and Mark Rosenzweig. Networks and misallocation: Insurance, migration, and the rural-urban wage gap. American Economic Review, 106(1):46–98, 2016.

Robert M Townsend. Risk and insurance in village india. Econometrica: Journal of the Econometric Society, pages 539–591, 1994.

Alwyn Young. Inequality, the urban-rural gap, and migration. The Quarterly Journal of Economics, 128(4):1727–1785, 2013.