A DSGE model on Agricultural choice

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Outline

Summary

The target is to have a simple GE framework to model behavior of farmers in village economies. With this I pretend to:

- Have a GE framework that can explain facts and "puzzles" observed in developing countries.
- Have a GE framework to evaluate the effects of introducing a rainfall index-based insurance policy.
- Disentangle income smoothing vs consumption smoothing.

The model:

- the model takes the form of ABHI models but adds 2 idiosyncratic shocks and a fixed-agent productivity (TFP analysis).
- Agents obtain their income from 2 production functions: a risky high-productive function (subject to 2 shocks) and a low-productive function (subject to only one shock). Agents can also (borrow) and save assets at interest rate (r).

Facts and Puzzles of the Agricultural Sector in Developing countries.

Presenting evidence from literature and data facts from the UNPS.

- Low agricultural productivity in developing countries.
- Low intermediate input usage.
- The importance of Risk in Agricultural production.
- The importance of rainfall shocks.

Low agricultural productivity in developing countries

In developing countries around 70% of the population work in the agricultural sector even though its low productivity: *Differences in agricultural labor productivity between the richest and poorest countries are twice as large as differences in aggregate labor productivity.* (Donovan, 2018)

Low intermediate inputs usage

- the value of intermediate inputs used on farms ranges from 4 percent in Uganda to 40 percent in the United States.
- In the 2013-14 UNPS, only 4.6% of all the plots received organic fertilizer and only 2.1% received inorganic/chemical fertilizer. Only 4.8% of the plots had received pesticides. (similar numbers for other UNPS waves).

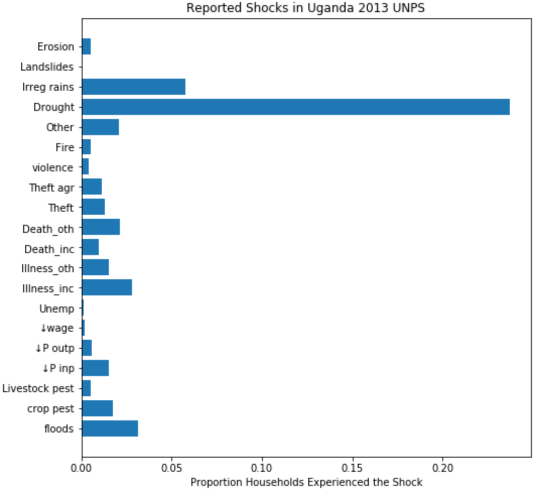
Why do so few farmers in sub-Saharan Africa use fertilizer? (Duflo, Kremer and Robinson, 2011), (Donovan, 2018).

the importance of risk in agricultural production

- **Income smoothing**: farmers farmers engage in costly ex-ante "income smoothing," shifting production behavior to reduce rainfall risk exposure, at the cost of lower average profits farmers(Rosenzweig and Binswanger, 1992), Morduch (1995).
- in Uganda farmers seem to diversify across crops. 25% of households plant 2 type of crops, 22% plant 3 varieties, 18% one variety and the rest more than 3. UNPS 2013-14.
- **Consumption smoothing**: High-degree of consumption smoothing but imperfect. Results from my master thesis. Thesis

Rainfall Shocks

- In 2013-14 UNPS, 98% of the plots have rainfall as the main water source. 1.3% on swamps/wetland and 0.6% irrigation.
- Rainfall variation is the more reported shock in Uganda.



Heterogeneity in Rainfall Shocks

Table 1: approximate Values of Seasonal Crop Water Needs: Source FAO

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Crops	Crop water need (mm/total growing period)
Beans	300 - 500
Citrus	900 - 1200
Cotton	700 - 1300
Groundnut	500 - 700
Maize	500 - 800
Sorghum/millet	450 - 650
Soybean	450 - 700
Sunflower	600 - 1000

- (Mobarak & Rosenzweig, 2012) Rainfall insured households plant riskier varieties of rice.

Evidence on rainfall index-based Insurance policies

Rainfall index-based insurance seem a promising policy to cope with risk in developing countries. In the last decade, Governments and NGOs started to implement them with low success. begin

- Most studies (RCTs) on rainfall Insurance found very low take-up rates: (Gine et al., 2009) in Malawi. Mobarak, Rosenzweig, 2012) in India, (Cole et al., 2013) in India.
- (Karlan, et al., 2012) found in Ghana that demand for rainfall insurance is strong (high take-up), and insurance lead to significantly larger investments on agriculture and riskier production choices.
- In my master thesis I reject 2 possible explanations of low take-up: Rainfall not being a main income shock and that farmers are already insured against rainfall shocks trough informal networks. Thesis

Testing Cobb-Douglas Form per Crop Production

- **Data**: Appended waves of the UNPS (2010-11, 2011-12, 2013-14). Each observation (p) is a plot. Plots that were cultivated by more than one crop are removed from the data. Total observations: 22896. y is output value in \$, A is area in acres, L is total labour hours (household + hired), m is value of inputs in \$ (fertilizers +insecticides+seeds) k is capital value in \$ (farm assets not including livestock) in the plot. distributions
- Production function to test per each crop:

$$y_{crop} = zk^{\alpha} A^{\beta} m^{\gamma} L^{\kappa}$$

- Equation to test under OLS:

$$lny_{crop,p} = lnz + \alpha lnk_p + \beta lnA_p + \gamma lnm_p + \kappa lnL_p + u_p$$

- Non-rejection of Cobb-Douglas form if F-test on $H_0 : \alpha + \beta + \gamma + \kappa = 1$ is not significant.

OLS results:

Table 2: Logarithm of agricultural output: UNPS 2010-2014

	Sw Potatoes	Beans	Maize	Groundnuts	Sorghum	Millet
Inter	3.3686***	2.0207***	2.6564***	3.1306***	1.8785***	2.9475***
	(0.4967)	(0.2303)	(0.2239)	(0.3177)	(0.3636)	(0.5387)
lnk	0.0818	0.1613***	0.0916**	0.0245	0.2738***	0.1518*
	(0.0707)	(0.0387)	(0.0393)	(0.0525)	(0.0631)	(0.0872)
lnA	0.3781***	0.2449***	0.4744***	0.5677***	0.2425**	0.2080
	(0.1382)	(0.0579)	(0.0589)	(0.0813)	(0.0969)	(0.1410)
lnm	0.0709	0.2725***	0.2857***	0.2420***	0.1910**	0.2958***
	(0.0865)	(0.0423)	(0.0356)	(0.0465)	(0.0783)	(0.1094)
lnl	0.0891	0.2283***	0.1755***	0.0325	0.1589	0.0265
	(0.1138)	(0.0550)	(0.0527)	(0.0687)	(0.0975)	(0.1297)
Obs	181	651	581	410	203	122
F	5.66**	11.85	0.15	1.81	1.46	2.67
P-val	0.01	0.17	0.69	0.17	0.22	0.10

OLS results

Table 3: Logarithm of agricultural output: UNPS 2010-2014

	Simsim	Potatoes	Rice	Sugarcane	Sunflower	Soya Beans
Inter	2.2329***	1.9859***	4.7809***	2.7009***	3.1379***	0.7031
	(0.2826)	(0.4586)	(0.5642)	(0.2879)	(0.6030)	(0.8612)
lnk	0.1173**	0.1816**	0.0162	0.0693	-0.0941	0.0556
	(0.0471)	(0.0886)	(0.1104)	(0.0594)	(0.0814)	(0.1110)
lnA	0.3212***	0.3812***	0.9143***	0.2932**	0.6812***	-0.3562*
	(0.0874)	(0.1281)	(0.1790)	(0.1141)	(0.1488)	(0.2139)
lnm	0.2297***	0.4043***	0.0734	0.4111***	0.4295***	0.5885***
	(0.0706)	(0.0705)	(0.1181)	(0.0814)	(0.1192)	(0.1282)
lnL	0.3639***	0.1611*	0.0577	0.1871***	0.0601	0.4439**
	(0.0699)	(0.0956)	(0.1241)	(0.0689)	(0.1522)	(0.1909)
Obs	240	154	80	113	75	83
F	0.11	0.72	0.08	0.10	0.28	1.42
P-val	0.73	0.39	0.77	0.75	0.597	0.235

Do I find differences of different productivity levels across crops?

- Beans: $2k^{0.16}A^{0.24}m^{0.27}l^{0.22}$
- Maize: $2.65k^{0.09}A^{0.47}m^{0.28}l^{0.17}$
- Sorghum: $1.87k^{0.27}A^{0.24}m^{0.19}l^{0.15}$
- Irish Potatoes: $1.98k^{0.18}A^{0.38}m^{0.4}l^{0.16}$
- Sugarcane: $2.7k^{0.06}A^{0.29}m^{0.41}l^{0.18}$

Model without Insurance: Household's Problem Set up

- Utility takes CRRA form.
- 2 idiosyncratic shocks: θ, ε
- Household specific productivity level: z
- Household borrowing constraint: -b
- 2 production functions: $y_t^1 = \theta \varepsilon z A(m_1)^\alpha$
  $y_t^2 = \varepsilon z B(m_2)^\gamma$
- Where:
  $\mathcal{E}_\theta(y_t^1 \mid \varepsilon) > \mathcal{E}_\theta(y_t^2 \mid \varepsilon)$
  $\mathcal{E}_\theta(\frac{\delta y^1}{\delta m_1} \mid \varepsilon) > \mathcal{E}_\theta(\frac{\delta y^2}{\delta m_2} \mid \varepsilon)$
- Do I need 2 production functions? Can differences in crops be integrated as different inputs (m)?

$$\underset{\{a(s^t)_{t+1},m_1(s^t)_{t+1},m_2(s^t)_{t+1}\}_{t=0}^{\infty}}{\text{Max}} \quad U = \sum_{t=0}^{\infty} \sum_{i_\theta=0}^{\Theta} \sum_{i_\varepsilon:0}^{\varepsilon} \beta^t \pi(\theta_t \mid \theta_{t-1}) \pi(\varepsilon_t \mid \varepsilon_{t-1}) u(c(s^t))$$

subject to:

$$\mathrm{c}_t(s^t) + a_{t+1}(s^t) + p\{m1_{t+1}(s^t) + m2_{t+1}(s^t)\}\} \leq y_t^1(s^t) + y_t^2(s^t)_t + (1+r)a_t(s^t)$$

$$\mathrm{y}_t^1(s^t) = \theta \varepsilon z A(m_{1t})^\alpha$$

$$\mathrm{y}_t^2(s^t) = \varepsilon z B(m_{2t})^\gamma$$

$$\mathrm{a}_{t+1}(s^t) \geq -b$$

Model without Insurance: Recursive Formulation of the Household Problem

Let $S = \{a, m_1, m_2, \theta, \varepsilon\}$

$$\mathrm{V}_t(S) = \underset{a', m_1', m_2' \in \Gamma(S)}{\mathrm{Max}} u(c) + \beta \sum_{i_\theta=0}^{\Theta} \sum_{i_\varepsilon=0}^{\varepsilon} \pi(\theta_t \mid \theta_{t-1}) \pi(\varepsilon_t \mid \varepsilon_{t-1}) V_{t+1}(S')$$

$$\Gamma(S) = \begin{cases} c \geq 0, a \geq -b, a_0 given, \\ c + a' + p(m_1 + m_2) = y^1 + y^2 + (1+r)a \\ y^1 = \theta \varepsilon z A(m_1)^\alpha \\ y_t^2 = \varepsilon z B(m_2)^\gamma \end{cases} \tag{1}$$

Model without Insurance: HH problem First Order Conditions

$$[\text{a'}]\text{: } u'(c) \geq \beta(1+r) \sum_{i_\theta=0}^{\Theta} \sum_{i_\varepsilon=0}^{\varepsilon} \pi(\theta' \mid \theta)\pi(\varepsilon' \mid \varepsilon)u'(c')$$

$$[m_1']\text{: } pu'(c) = \beta \sum_{i_\theta=0}^{\Theta} \sum_{i_\varepsilon=0}^{\varepsilon} \pi(\theta' \mid \theta)\pi(\varepsilon' \mid \varepsilon)u'(c')\theta'\varepsilon' zA\alpha(m_1')^{\alpha-1}$$

$$[m_2']\text{: } pu'(c) = \beta \sum_{i_\theta=0}^{\Theta} \sum_{i_\varepsilon=0}^{\varepsilon} \pi(\theta' \mid \theta)\pi(\varepsilon' \mid \varepsilon)u'(c')\varepsilon' zB\gamma(m_2')^{\gamma-1}$$

Model without Insurance: Market Clearing Conditions

Endogenous input market:

$$\sum a = \sum k$$

$$\sum (m_1^i + m_2^i) = M = f(K)$$

$$\underset{k}{\text{Max}} \Pi = pm - rk, \text{ subject to: } m = f(k), \text{ (Input Producers Problem)}$$

Alternatively, Village network System:

$$\sum a = 0$$

Model without Insurance: Transition Funcitons

$$\lambda(a', m_1', m_2', \theta', \varepsilon') = \sum_{a} \sum_{m_1}^{M} \sum_{m_2 : m_2' = g^{m_2}}^{M} \sum_{i_\theta = 0}^{\Theta} \sum_{i_\varepsilon : 0}^{\varepsilon} Q(a', m_1', m_2', \theta', \varepsilon' \mid a, m_1, m_2, \theta, \varepsilon)$$

$\lambda(a, m_1, m_2, \theta, \varepsilon)$

$$\lambda(a', m_1', m_2', \theta', \varepsilon') = \sum_{a : a' = g^{a(s)}}^{A} \sum_{m_1 : m_1' = g^{m_1}}^{M} \sum_{m_2 : m_2' = g^{m_2}}^{M} \sum_{i_\theta = 0}^{\Theta} \sum_{i_\varepsilon : 0}^{\varepsilon} \pi(\theta_t \mid \theta_{t-1}) \pi(\varepsilon_t \mid \varepsilon_{t-1})$$

$\lambda(a, m_1, m_2, \theta, \varepsilon)$

Model with Insurance: Household's Problem Set up

- Now households can insure x against shock θ at price q.
- I consider x as a quantity not as a proportion of household crop income.

Model with Insurance: Recursive Formulation of the Household Problem

Let $S = \{a, m_1, m_2, x, \theta, \varepsilon\}$

$$\mathrm{V}_t(S) = \underset{a', m_1', m_2', x' \in \Gamma(S)}{\mathrm{Max}} u(c) + \beta \sum_{i_\theta=0}^{\Theta} \sum_{i_\varepsilon=0}^{\varepsilon} \pi(\theta' \mid \theta)\pi(\varepsilon' \mid \varepsilon) V_{t+1}(S')$$

$$\Gamma(S) = \begin{cases} c \geq 0, a \geq -b, a_0 given, \\ c + qx' + a' + p(m_1' + m_2') = y^1 + y^2 + (1+r)a + \mathcal{I}_{\theta_L} x \\ y^1 = \theta \varepsilon z A(m_1)^\alpha \\ y_t^2 = \varepsilon z B(m_2)^\gamma \end{cases} \tag{2}$$

Model with Insurance: HH problem First Order Conditions

$$[a']:\ u'(c) \geq \beta(1+r)\sum_{i_\theta=0}^{\Theta}\sum_{i_\varepsilon=0}^{\varepsilon}\pi(\theta' \mid \theta)\pi(\varepsilon' \mid \varepsilon)u'(c')$$

$$[m_1']:\ pu'(c) = \beta\sum_{i_\theta=0}^{\Theta}\sum_{i_\varepsilon=0}^{\varepsilon}\pi(\theta' \mid \theta)\pi(\varepsilon' \mid \varepsilon)u'(c')\theta'\varepsilon' zA\alpha(m_1')^{\alpha-1}$$

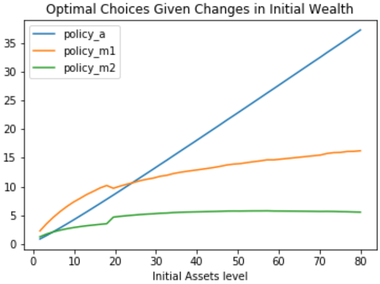
$$[m_2']:\ pu'(c) = \beta\sum_{i_\theta=0}^{\Theta}\sum_{i_\varepsilon=0}^{\varepsilon}\pi(\theta' \mid \theta)\pi(\varepsilon' \mid \varepsilon)u'(c')\varepsilon' zB\gamma(m_2')^{\gamma-1}$$

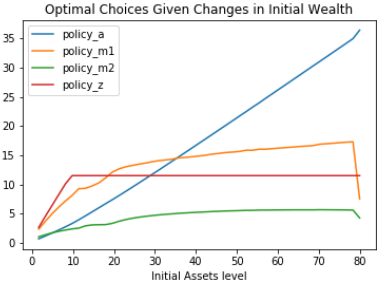
$$[x']:\ qu'(c) = \pi(\theta' = \theta_L \mid \theta)\beta\sum_{i_\varepsilon=0}^{\varepsilon}\pi(\varepsilon' \mid \varepsilon)u'(c')$$

2 period model

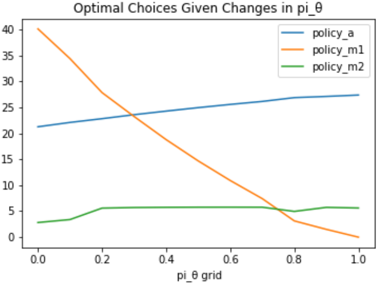
I present statics comparative of PE solutions under the 2-period model for changes in relevant parameters and prices.
Set-up parameters:
$\rho = 1$, $\beta = 0.95$, $\alpha = 0.4$, $\gamma = 0.2$, $A = B = 2$, $r = 0.05$, $p = 0.05$, $q = 0.07$, $\theta = \{0, 1\}$, $\varepsilon = \{0, 1\}$, $pi_\theta = [0.2, 0.8]$, $pi_\varepsilon = [0.5, 0.5]$, $a_0 = 10$

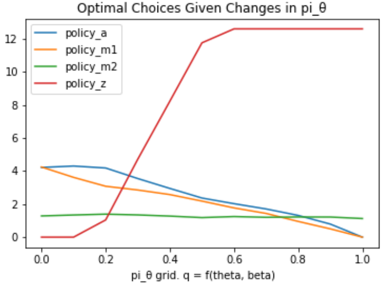
2 period model solutions: Optimal choices given different inital wealth



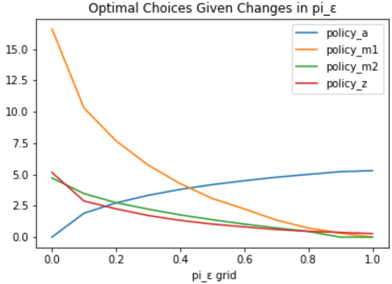


2 period model solutions: Optimal choices given rainfall risk variation

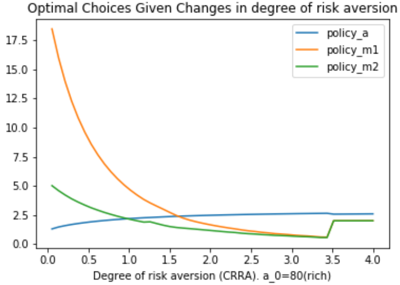


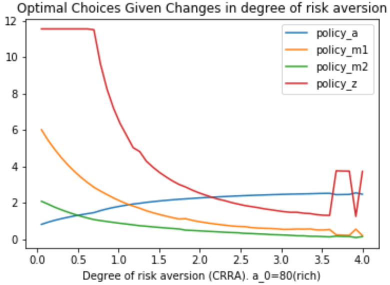


2 period model solutions: Optimal choices given basis risk variation

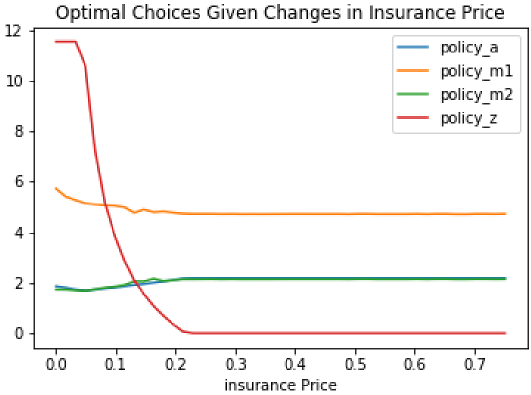


2 period model solutions: Optimal choices under risk aversion variation

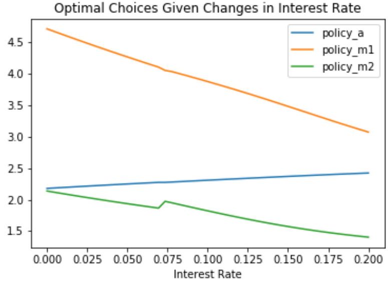


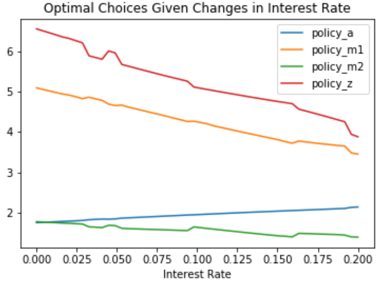


2 period model solutions: Optimal choices given interest rate variation



2 period model solutions: Optimal choices given interest rate variation





Related literature to take into account:

The Impact of Climate Change on Rice Yields: Heterogeneity and Uncertainty, Tazhibayeva & Townsend (2012).

- 3 stages CES production function: seedling, growing, and harvesting.
- Though weather is an aggregate shock, realized and expected weather varies across plots due to variation in stage timing (source of household heterogeneity). The effect of rain also depends on temperature and quality of soil.

Risk, Insurance and Wages in General Equilibrium, Mobarak & Rosenzweig (2014).

- Estimate the general-equilibrium labor market effects of a rainfall index insurance product.
- Introducing a rainfall insurance makes both labour demand and equilibrium wages more rainfall sensitive. Insurance on only those who own land makes wage laborers worse-off than scenario without insurance.

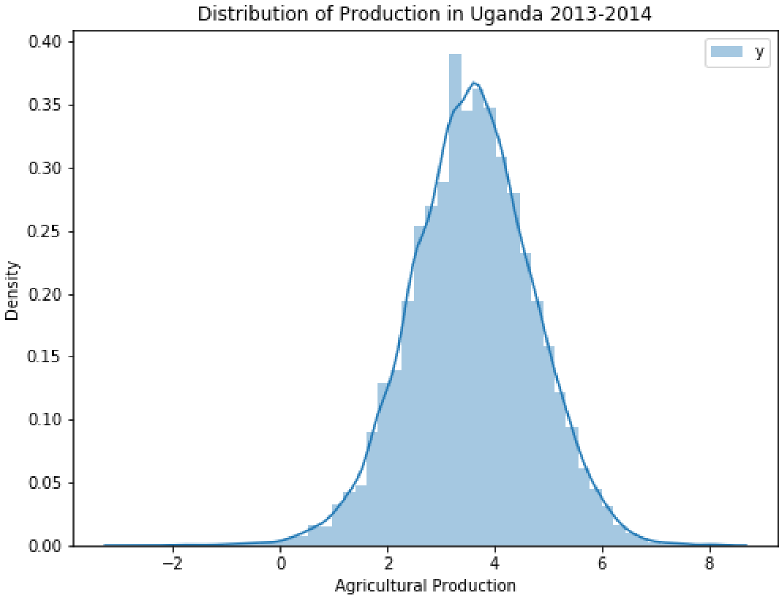
Further Steps & Suggestions

- Explore more results with the 2 part model. Output and welfare analysis of no insurance vs insurance in the 2-period model.
- Can the 2-period model explain facts-puzzles of agriculture in developing countries and rainfall insurance?
- Solve the HH problem in infinite horizon. Set up algorithm for GE solving.

Back

Table 4: Insurance tests under Heterogeneous Shocks

	Δlnc				
	Intercept	$\Delta\overline{lnc}$	ΔlnY	*shock*	$\Delta lny \times shock$
Shock	0.1793***	0.2697**	0.1077***	-0.0274***	0.0248**
	(0.0369)	(0.1149)	(0.0414)	(0.0077)	(0.0122)
Aggreg	0.1401***	0.2587**	0.1121***	-0.0187*	0.0447
	(0.0368)	(0.1157)	(0.0372)	(0.0113)	(0.0178)
Idosyn	0.1543***	0.2754**	0.1751***	-0.0582***	0.0026
	(0.0329)	(0.1151)	(0.0330)	(0.0142)	(0.0216)
Clima	0.1381***	0.2707**	0.1031***	-0.0204*	0.0556***
	(0.0366)	(0.1157)	(0.0378)	(0.0124)	(0.0200)
Prices	0.1195***	0.22877**	0.1794***	-0.0435	0.0188
	(0.0323)	(0.1163)	(0.0267)	(0.0467)	(0.0676)
Health	0.1382***	0.2447**	0.1735***	-0.0557***	0.0185
	(0.0328)	(0.1152)	(0.0304)	(0.0211)	(0.0352)
Job	0.1094***	0.2663**	0.1742***	-0.1319	0.3034**
	(0.0314)	(0.1158)	(0.0255)	(0.0943)	(0.1305)
Pests	0.1299***	0.2460**	0.1828***	-0.2040***	-0.0644
	(0.0316)	(0.1149)	(0.0269)	(0.0502)	(0.0602)


Distribution of Production in Uganda 2013-2014
y
Density
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−2
0
2
4
6
8
Agricultural Production

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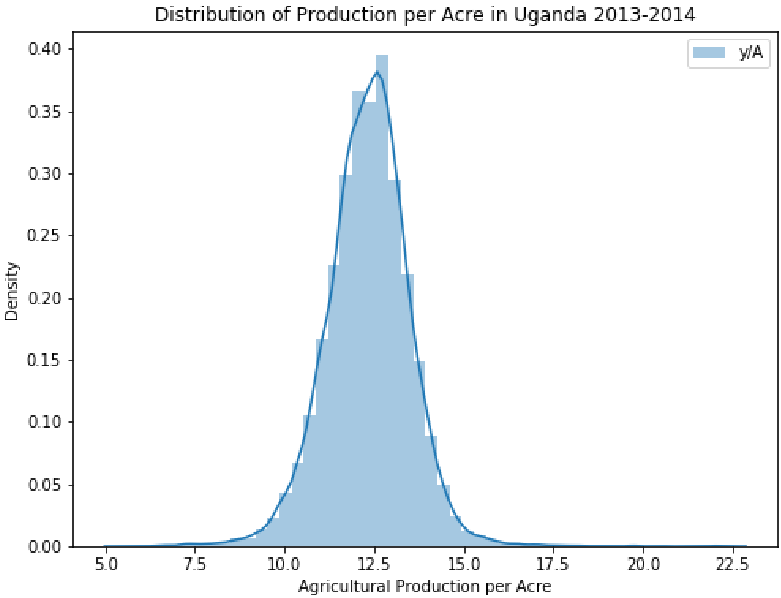
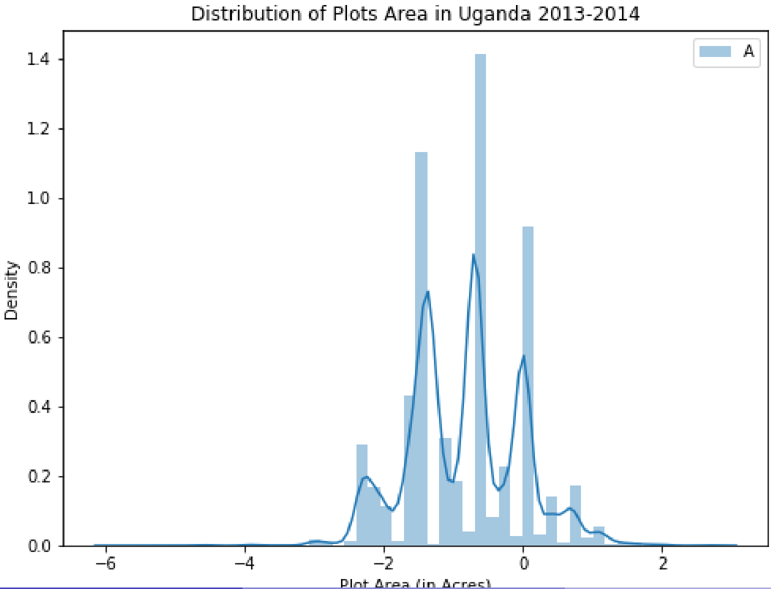
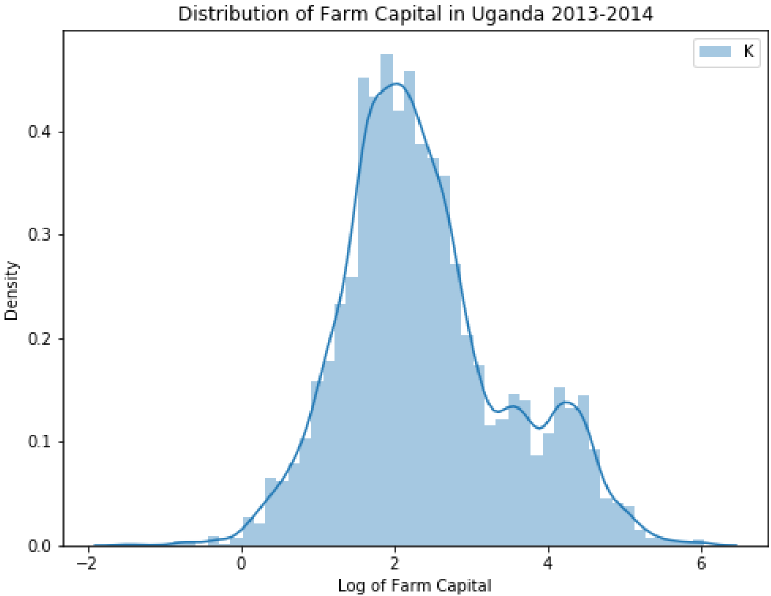
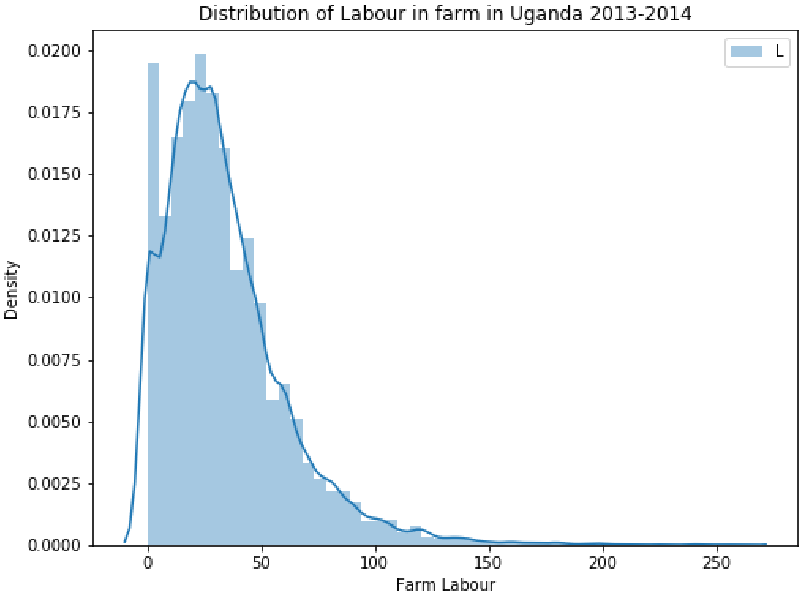


Distribution of Production per Acre in Uganda 2013-2014
y/A
Density
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
Agricultural Production per Acre

Distribution of Land




Distribution of Farm Capital in Uganda 2013-2014
K
Density
0.0
0.1
0.2
0.3
0.4
−2
0
2
4
6
Log of Farm Capital


Distribution of Labour in farm in Uganda 2013-2014
L
Density
0.0200
0.0175
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
0
50
100
150
200
250
Farm Labour