Missing Markets and Comparative Advantage

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(*work in progress*)

Gains from trade - Adverse consequences

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  1. Extended consumption possibilities (Ricardo, H-O).
  2. Love for variety (**Krugman**; **1979**).
  3. Increased average productivity (**Melitz**; **2003**).

- Potential adverse consequences
  1. Factors' displacement (**Topalova**; **2010**).
  2. Unemployment & inequality (**Goldberg et al**; **2007**).
  3. Volatility of earnings (**Allen**; **Atkin**; **2022**).

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- Trade-induced volatility:

Newbery Stiglitz 1984

Trade liberalization

Specialization in production

Higher exposure to external fluctuations

Externally induced volatility

Trade-induced volatility meets limited insurance

Trade-induced volatility is especially consequential where formal insurance is absent.

- No formal credit, savings, or insurance markets in rural villages.
- Instead: informal, voluntary transfers gifts, in-kind support governed by custom.
- Crop diversification: a complementary means of insurance.

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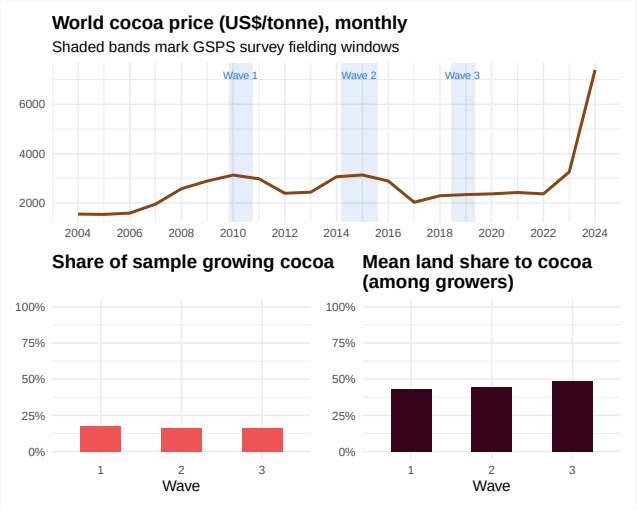
Trade-induced volatility

Missing formal insurance, informal mutual insurance instead

Crop diversification as a means to insure

Incomplete specialization
(cf. strawberries v wheat)

Motivation: comparative advantage, incompletely realized



- Ghana: **2nd largest cocoa exporter** globally (clear comparative advantage).
- Cocoa is a pure cash/marketable crop.
- Substantial price variation even within the sample period.
- Yet **no response** in land allocated to cocoa or in the share of households growing it.

Puzzle: incomplete specialization, despite a clear comparative advantage and real price variation.

National data | Anecdotal evidence

Research question

Trade lowers costs and raises returns to specialization – but where insurance is missing, diversification retains value.

How does market access affect the joint choice of crop specialization and informal insurance?

If trade creates comparative advantage, why do households not fully specialize?

- **Empirically**: study MCC feeder-road rehabilitation in rural Ghana as a opening-up to trade episode.
- **Quantitatively**: model crop choice (specialization), trade and insurance under limited commitment.

Descriptive statistics on agriculture and trade from rural Ghana

Data: Ghana Socioeconomic Panel Survey (EGC and ISSER)

- Three waves: 2009, 2014 and 2019.
- 5,009 HHs from 334 enumeration areas.
- 517 communities with community survey data.
- GPS coordinates for all HHs.
- GPS coordinates for local goods' markets (-expected-)

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- Single-crop cultivation at the plot level ($\sim$ 45% of plots). Diversification at the HH level (Avg # of dif. crops per HH = 2.8). Figures
- Crop cultivation is mostly concentrated on food/staple crops. Single-cropping more pronounced in cash crops. Figures

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- "Market traders" dominate crop sales at the intensive margin. Figures

Empirical Analysis

MCC Feeder Roads Rehabilitation Program

- 357 km rehabilitated feeder roads
- 8 districts, 4 regions
- between 2007-2013 (wave 1 - wave 2)

Objective

Reduce transportation costs and improve market access for rural producers.

This paper

Exploit variation in proximity to rehabilitated roads to study the effects of market integration on:

- crop specialization
- consumption smoothing

Measuring exposure to rehabilitated roads

- Merge the GSPS with GIS information on all rehabilitated MCC feeder roads.

$$Treat_h^5 = \mathbb{1}\{d_h \leq 5 \text{ km}\}$$

$$d_h = \min_{r \in \mathcal{R}} Distance(h, r)$$

where d_h is the distance between household h and the nearest rehabilitated road.

Alternative thresholds:

$$Treat_h^{10} = \mathbb{1}\{d_h \leq 10 \text{ km}\}, \qquad Treat_h^{20} = \mathbb{1}\{d_h \leq 20 \text{ km}\}.$$

- Baseline treatment group (5 km): 107 households in 10 villages.

Treatment exposure and baseline characteristics

	Control	Treated 5 km
Households	2,206	107
Villages	188	10
Number of crops	3.27	2.69
Farmland (ha)	6.48	6.71
Household size	4.42	4.41
Income	1,712	1,660
Distance to regional capital (km)	50.6	31.9

Notes: baseline values from Wave 1. Treatment defined as household distance to nearest rehabilitated road $\leq$ 5 km.

10km / 20km

A naive specialization measure: no effect

Number of distinct crops cultivated (household-level count) as indicative of specialization.

$$\#Crops_{ht} = \beta_2 \left(Treat_h^5 \times Wave2_t\right) + \beta_3 \left(Treat_h^5 \times Wave3_t\right) + \alpha_h + \mu_t + \varepsilon_{ht}$$

	# Crops, corrected
$Treat_h^5 \times Wave2_t$	-0.12
	(0.49)
$Treat_h^5 \times Wave3_t$	-0.34
	(0.60)
Household FE	Yes
Wave FE	Yes
Observations	4,545

Market access and crop reallocation

Not fewer crops – a shift in *which* crops generate revenue. Sample: households with no marketable-crop sales at baseline (wave 1).

$$Share_{ht} = \beta_2 \left(Treat_h^5 \times Wave2_t \right) + \beta_3 \left(Treat_h^5 \times Wave3_t \right) + \alpha_h + \mu_t + \varepsilon_{ht}$$

	Hybrid-crop revenue share	Marketable-crop revenue share
$Treat_h^5 \times Wave2_t$	0.066	-0.080**
	(0.066)	(0.024)
$Treat_h^5 \times Wave3_t$	0.281***	-0.119***
	(0.061)	(0.025)
Household FE	Yes	Yes
Wave FE	Yes	Yes
Observations	1,179	1,179

- Revenue shifts toward **hybrid/dual-purpose crops**, away from **marketable/industrial crops**.

Crop taxonomy

Market access and mutual insurance

$$\log(c_{ht}) = \beta_1 \log(y_{ht}) + \beta_2 \left[\log(y_{ht}) \times Treat_h^5\right] + \gamma \log(\bar{c}_{vt}) + \alpha_h + \mu_t + \varepsilon_{ht}$$

- $\log(\bar{c}_{vt})$: village consumption controls for aggregate village shocks.

	$\log(c_{ht})$
$\log(y_{ht})$	0.055***
	(0.007)
$\log(y_{ht}) \times Treat_h^5$	-0.077**
	(0.029)
$\log(\bar{c}_{vt})$	0.883***
	(0.029)
Household FE	Yes
Wave FE	Yes
Observations	4,612

Consumption smoothing: effects decay with distance

$$\log(c_{ht}) = \beta_1 \log(y_{ht}) + \beta_2 \left[\log(y_{ht}) \times Treat_h^r\right] + \gamma \log(\bar{c}_{vt}) + \alpha_h + \mu_t + \varepsilon_{ht}, \qquad r \in \{5, 10, 20\}$$

	$Treat_h^5$	$Treat_h^{10}$	$Treat_h^{20}$
$\log(y_{ht}) \times Treat_h^r$	-0.077**	-0.040*	-0.023
	(0.029)	(0.020)	(0.018)
Household FE	Yes	Yes	Yes
Wave FE	Yes	Yes	Yes
Village controls	Yes	Yes	Yes
Observations	4,612	4,612	4,612

- Effects are strongest in close proximity to rehabilitated roads.
- Consistent with roads operating through local market access.

The joint puzzle

Market access

- Crop-sales composition shifts toward hybrid crops, away from marketable/industrial crops.

$$Treat_h^5$$

$$\Longrightarrow$$

Reallocation, not full specialization

Mutual insurance

- Consumption smoothing improves.

$$Treat_h^5$$

$$\Longrightarrow$$

Lower consumption-income elasticity

Market access induces reallocation *and* improves consumption smoothing simultaneously — can a single limited-commitment mechanism generate both?

A benchmark model of mutual insurance with limited commitment

A benchmark model of mutual insurance with limited commitment

- Environment
  1. Two ex-ante identical, risk-averse households: $i \in 1, 2$.
  2. Infinite horizon.
  3. Stochastic agricultural income: $y_i(s)$, where the aggregate state $s \in S$ follows a Markov process with transition probabilities $\pi(s'|s)$.

- Limited commitment
  1. Households can walk away to autarky in any state.
  2. A social planner allocates consumption and future utility to sustain risk sharing.

Resource constraint

$$c_1 + c_2 = y_1(s) + y_2(s)$$

Participation constraints

$$u(c_i) + \beta E[V_i^{in}(s')] \geq V_i^{out}(s), \qquad i = 1, 2.$$

- Insurance is constrained by voluntary participation.

Recursive contract

Let $V_s(w)$ denote the value delivered to household 2 when household 1 is promised utility w in state s.

$$V_s(w) = \max_{c,\{w'(s')\}_{s'}} \left\{ u(Y_s - c) + \beta \sum_{s'} \pi(s'|s) V_{s'}(w'(s')) \right\}$$

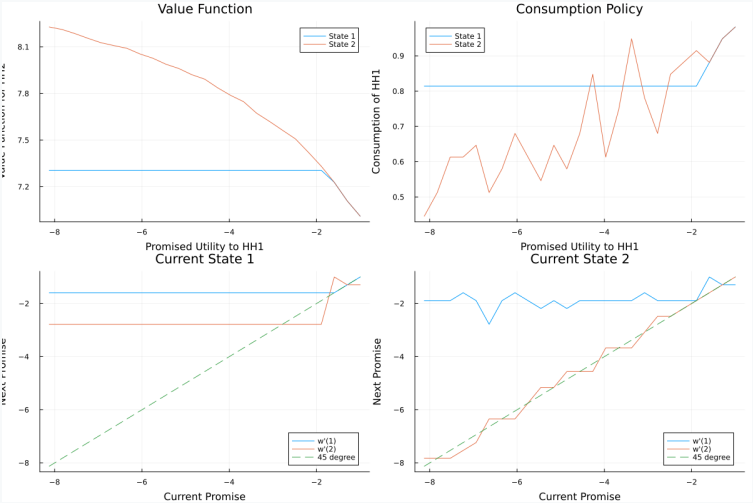
subject to

$$u(c) + \beta \sum_{s'} \pi(s'|s) w'(s') \geq w \qquad \text{Promise keeping}$$

$$u(c) + \beta \sum_{s'} \pi(s'|s) w'(s') \geq V_1^{out}(s) \qquad \text{HH1 participation}$$

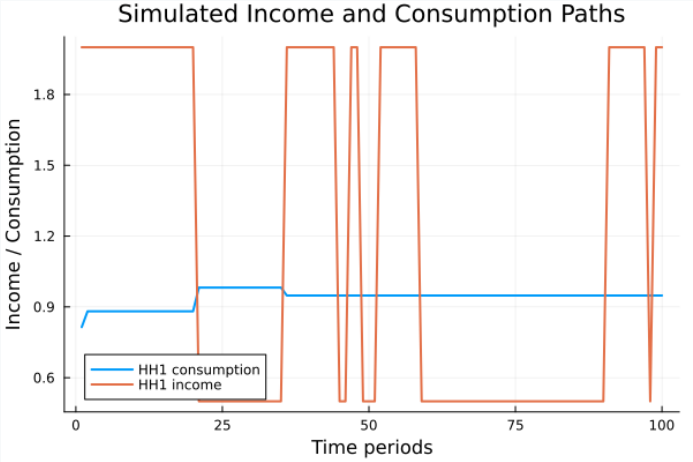
$$u(Y_s - c) + \beta \sum_{s'} \pi(s'|s) V_{s'}(w'(s')) \geq V_2^{out}(s) \qquad \text{HH2 participation}$$

Benchmark numerical solution



- The contract uses state-contingent continuation promises.
- Insurance is sustained through current transfers and future promised utility.
- Participation constraints shape the allocation across states.

Simulated income and consumption paths



- Household income fluctuates substantially across states.
- Consumption remains considerably smoother than income.

What the benchmark model explains

	Benchmark model
Consumption smoothing	✓
Limited commitment	✓
Specialization choice	×
Trade participation	×

The benchmark captures the insurance mechanism, but takes production decisions as exogenous.

To explain the empirical evidence, specialization must be determined jointly with insurance.

Extension: trade, specialization and insurance

What changes relative to the benchmark

	Benchmark	Extension
Income	$y_i(s)$, exogenous	$y_i(\theta_i, s, p, \tau)$, endogenous
Land allocation θ_i	fixed	planner's choice variable
Cash-crop price p	—	stochastic, p_t
Trade cost τ	—	enters return to cash crops
Outside option	$V_i^{out}(s)$	$V_i^{out}(s, p, \theta_i)$

Production is no longer exogenous: the planner now jointly chooses consumption, land allocation, *and* continuation promises.

Crucially, the household's outside option now depends on θ_i — crop choice feeds back into insurance sustainability.

Extended Model: The Village Chief's Problem

The village chief maximizes HH 2's utility, given HH 1's promised utility w:

$$V_x(w;\theta) \;=\; \max_{c,\,\theta,\,\{w_{x'}\}} \left\{ u(Y_x(\theta) - c) + \beta \sum_{x'} \pi(x'|x)\; V_{x'}(w_{x'};\theta) \right\}$$

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$$c + (Y_x(\theta)-c) \;\leq\; Y_x^1(\theta) + Y_x^2(\theta) \qquad \text{[FC]}$$

Price process $\{p_x\}$ exogenously given, $\qquad Y_x^i(\theta) = \theta \cdot y^{i,f}(s) + (1-\theta)\cdot p_x \cdot (1-\tau_c)\cdot y^{i,c}(s)$

Extended Model: Autarky

Due to limited commitment, households can walk away to autarky — where they make/receive no transfers and consume their own income.

Budget constraint under autarky (trade still allowed):

$$c_x^i \;=\; Y_x^i(\theta) \;=\; \theta \cdot y^{i,f}(s) + (1-\theta)\cdot p_x \cdot (1-\tau_c)\cdot y^{i,c}(s)$$

The autarky value is defined:

$$V_x^{i,\text{aut}} \;=\; \max_{\theta} \left\{ u\Big(Y_x^i(\theta)\Big) + \beta \sum_{x'} \pi(x'|x)\, V_{x'}^{i,\text{aut}} \right\}$$

Key property: road rehabilitation raises the outside option:

$$\frac{\partial V_x^{i,\text{aut}}}{\partial \tau_c} \;<\; 0$$

Proof

Insurance and Specialization: The Trade-off

The contract may support more specialization than autarky:

$$1 - \theta^{in,*} > 1 - \theta^{out,*}$$

$\rightarrow$ farmers feel more secure to take on higher-risk, higher-return crops

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But specialization tightens participation constraints in good states:

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The sign of the wedge is ambiguous:

$$\text{sign}\left(\theta^{in,*} - \theta^{out,*}\right) = ?$$

$\rightarrow$ whether insurance and comparative advantage are complements or substitutes is a quantitative question

The Wedge

The planner's optimality condition for θ:

$$\mu \cdot \Delta_x(\tau_c) \;=\; \lambda_1 \cdot \frac{\partial V_x^{1,\text{aut}}}{\partial \theta} + \lambda_2 \cdot \frac{\partial V_x^{2,\text{aut}}}{\partial \theta} - \beta \sum_{x'} \pi(x'|x) \, \frac{\partial V_{x'}^{2}}{\partial \theta}$$

where the *comparative advantage gap* is:

$$\Delta_x(\tau_c) \;\equiv\; y^{i,f}(s) - p_x \, (1 - \tau_c) \, y^{i,c}(s)$$

Key result: whenever participation constraints bind ($\lambda_i > 0$), the planner is distorted away from the autarky optimum:

$$\theta^{in,*} \;\neq\; \theta^{out,*}$$

$\rightarrow$ the λ_i terms force the planner to account for how θ affects the outside option — a distortion that vanishes only when PCs never bind.

Comparative Statics: Road Rehabilitation as $\tau_c \downarrow$

Ricardo effect: lower trade costs raise the return to cash crops, shifting the autarky optimum toward specialization:

$$\frac{d\theta^{out,*}}{d(1-\tau_c)} < 0$$

$\rightarrow$ comparative advantage is more fully realized when markets are better integrated

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Wedge dynamics:

$$\text{sign}\left(\frac{dW}{d(1-\tau_c)}\right) = ? \qquad W \equiv \theta^{out,*} - \theta^{in,*}$$

$\rightarrow$ roads may widen the missing-markets distortion precisely where market access improves most

Theory: What to Expect

Interior solution: the contract predicts incomplete specialization:

$$\theta^{in,*} \in (0, 1)$$

$\rightarrow$ e.g. even with rising cash-crop prices, farmers never move to full specialization

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The data resolves the ambiguity (for now ; but quantitative solution is needed):

$$0 < \theta^{in,*} < \theta^{out,*} < 1$$

- Shift to hybrid crops.
- Consumption smoothing improves alongside this shift.

Next Steps

Empirics

- Construct a comparative advantage index using GAEZ attainable yield data — compare potential vs. realized yields to directly measure suppressed specialization
- Obtain market GPS coordinates to refine treatment definition: whether the route to the closest market passes through a rehabilitated road segment

Model

- Quantitative solution of the extended model — pin down the sign and magnitude of the wedge $\theta^{in,*} - \theta^{out,*}$ and simulate the effect of road rehabilitation
- SMM estimation of structural parameters using GSPS moments

Conclusion

- **Empirically**: road rehabilitation shifts households toward hybrid, dual-purpose crops.

  → reallocation rather than specialization

- Consumption smoothing improves at the same time.

- **Theoretically**: under limited commitment, crop choice shapes each household's outside option, generating an interior θ

  → that persists even as market access improves.

Comparative advantage is real, but market access alone does not realize it – market access and informal insurance are jointly determined.

Thank you

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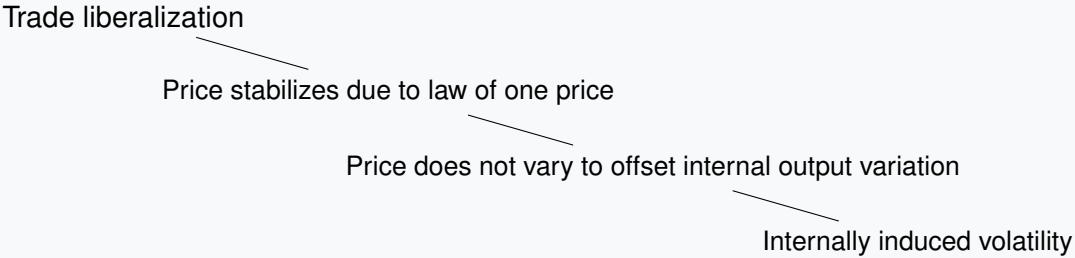
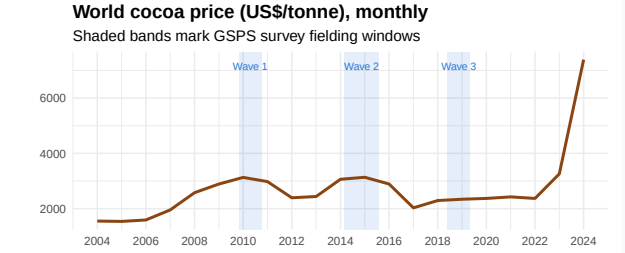
Newbery Stiglitz 1984 - mechanism

- Trade induced volatility in the **newbery1984pareto** context.



Back

Backup: comparative advantage, national-aggregate view



Same pattern at the national level, using FAO aggregate statistics rather than our own household sample:

- Ghana's total land area harvested to cocoa has grown only gradually, showing no sharp response to the price swings above
- Consistent with the sample-level finding on the main slide – this is not an artifact of our particular household sample

Source: FAOSTAT, Ghana, Cocoa beans, Area harvested.

Back

Backup: anecdotal evidence – response, and its cost

Farmers do respond to rising cocoa prices

- Cocoa prices surged in 2023–24. A Cameroonian high-school teacher bought a 3-hectare plot to plant cocoa, timed to bear fruit at retirement: *"If the price of cocoa keeps rising, the crop will give me more money than teaching."* A farmer who had abandoned cocoa three years earlier switched back, hiring two extra workers to expand. (Bloomberg, via GhanaWeb, 2024)

And pay the price when that same volatility reverses

- By early 2026, the world price had fallen over 75% from its 2024 peak. Ghanaian cocoa farmer Emmanuel Nojor, waiting months for payment from middlemen, lacked funds to pay harvest workers, so "the harvest has gone bad." (Fröhlich, *Deutsche Welle*, 1 Jul 2026)

Households that lean into the price incentive are the ones directly exposed when the same volatility turns – the mechanism this paper's model formalizes.

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Agriculture in rural Ghana - Appendix

* Small-scale agriculture in rural Ghana.

Table: Rural land

	Plot size (ha)		Num of plots per hh		HH land (ha)	
	mean	st.dev.	mean	st.dev.	mean	st.dev.
Wave 1	1.35	1.54	2.10	1.19	2.85	3.41
Wave 2	1.85	2.43	1.79	0.90	3.32	3.94
Wave 3	1.58	1.99	1.86	1.12	2.94	4.14
All waves	**1.59**	**2.02**	**1.91**	**1.08**	**3.04**	**3.86**

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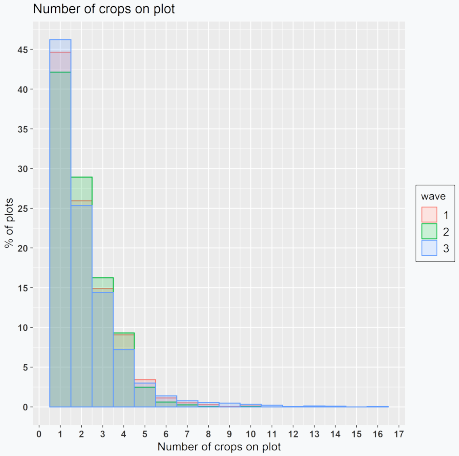
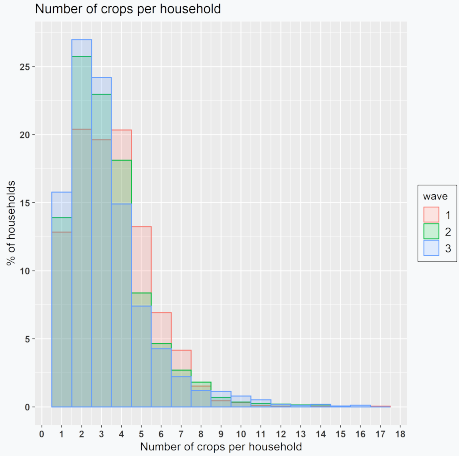
Agriculture in rural Ghana - Appendix

* Single-crop cultivation at the plot level. Diversification at the hh level.





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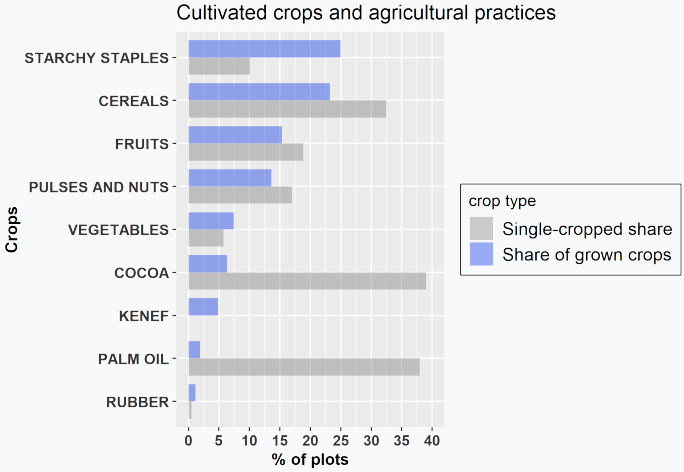
Agriculture in rural Ghana - Appendix

* Categories of crops and cultivation practices



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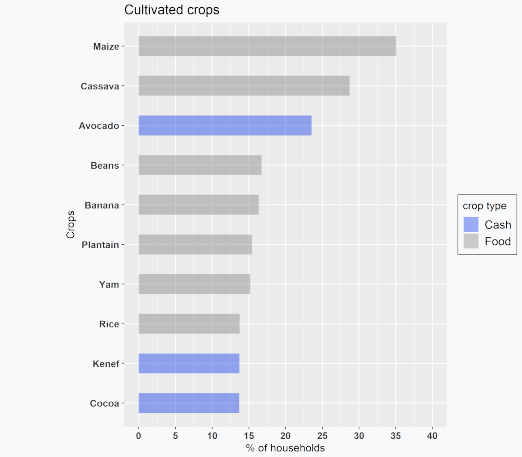
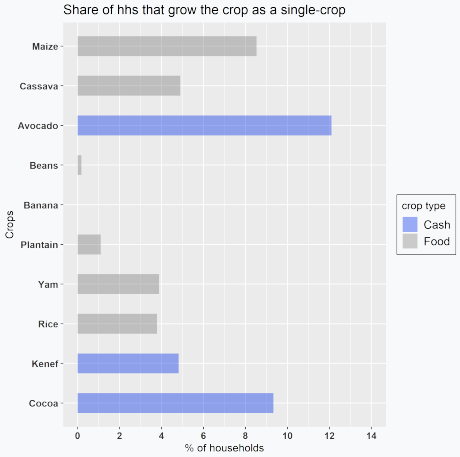
Agriculture in rural Ghana - Appendix

* Certain crops and cultivation practices





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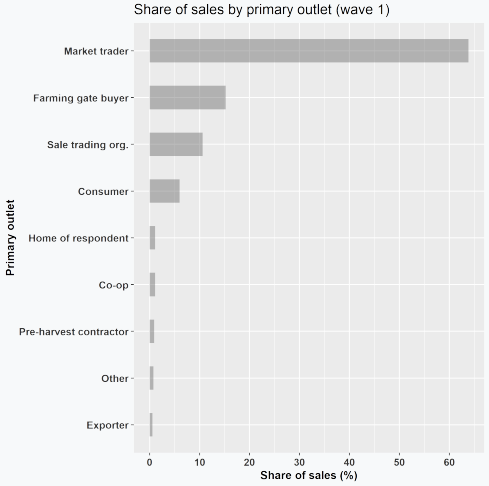
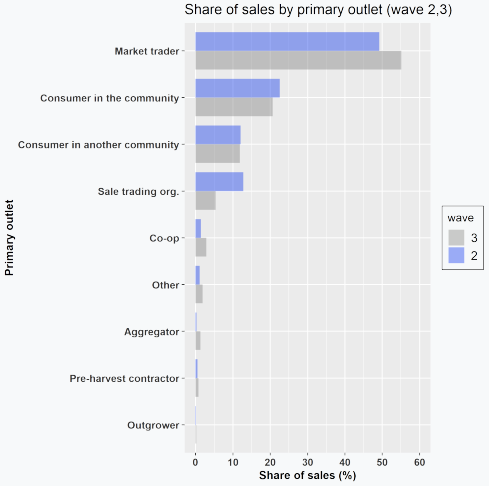
Trade structure in rural Ghana - Appendix

* “Market traders” are a dominant outlet channel in the intensive margin.





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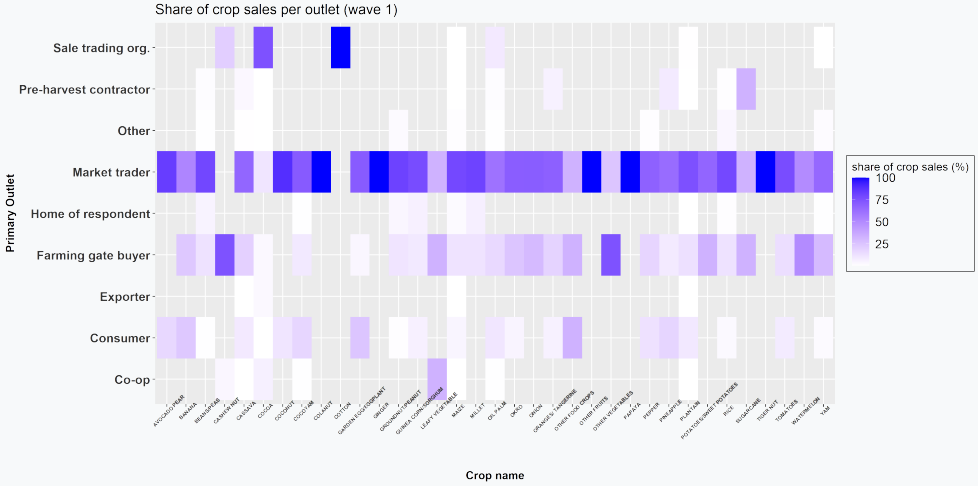
Trade structure in rural Ghana - Appendix

* “Market traders” are trading almost all crops.



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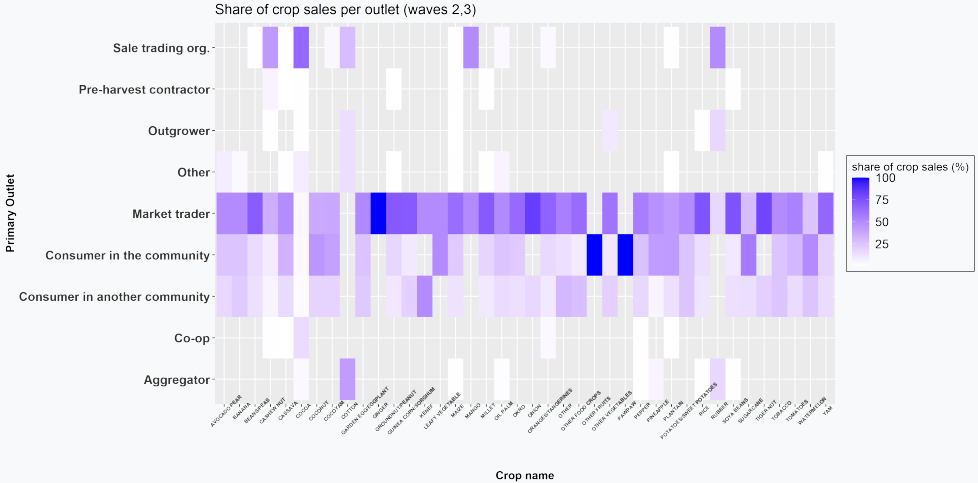
Trade structure in rural Ghana - Appendix

* “Market traders” are trading almost all crops.



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Treatment exposure and baseline characteristics

	Control	5 km	10 km	20 km
Households	2206	107	204	375
Villages	188	10	19	33
Number of crops	3.27	2.69	2.38	2.58
Farmland (ha)	6.48	6.71	5.41	5.06
Household size	4.42	4.41	4.14	4.05
Income	1712	1660	1491	1717
Distance to regional capital (km)	50.6	31.9	36.6	39.8

Wave 1 averages. Treatment defined as household distance to the nearest rehabilitated road.

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Backup: crop taxonomy

Crops classified into three revenue-orientation categories, based on typical market vs. own-consumption use in Ghanaian smallholder agriculture:

- **Staple/subsistence**: cassava, maize, yam, plantain, cocoyam, rice, millet, sorghum.
- **Hybrid/dual-purpose**: groundnut, pepper, tomatoes, okro, onion, pineapple.
- **Marketable/industrial**: cocoa, oil palm, cashew, rubber, cotton.

Classification reflects typical cultivation purpose and gestation length (staple and hybrid crops: annual/near-annual; marketable crops: perennial, multi-year to first harvest).

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Backup: distance decay and independent confirmation

	$Treat_h^5$	$Treat_h^{10}$	$Treat_h^{20}$
Hybrid-crop revenue share ($Wave3_t$)	0.281^{***}	0.224^{***}	0.195^{***}
	(0.061)	(0.060)	(0.050)
Distinct hybrid crops sold, count ($Wave3_t$)	0.427^{***}	0.337^{*}	0.227^{*}
	(0.092)	(0.129)	(0.111)

- Effect strongest and most significant closest to the road; monotonic decay through 20 km.
- Confirmed on an **independent outcome** – number of distinct hybrid crop types sold, not just revenue share – same pattern.
- **Robust to excluding the N1 trunk highway** from the road network defining treatment (feeder roads only): coefficients unchanged to three decimal places.
- Passes standard placebo checks: no effect on farmland (log ha, $\beta \approx 0.09$, n.s.) or non-agricultural income ($\beta \approx 0.64$, n.s.) – rules out land consolidation and labor reallocation as alternative explanations.

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Backup: market engagement does not change

Same sample and specification. Road access changes *what* households sell (previous slides), but not *how* they engage with the market.

	$Treat_h^5 \times Wave3_t$
Sold to any outside-community outlet	-0.005 (0.093)
Sold at home / farm-gate (passive)	-0.035 (0.029)
Incurred any crop transport cost	-0.020 (0.139)

- No shift toward outside-community outlets or away from passive (buyer-comes-to-you) sales.
- No change in whether households incur transport costs at all.
- All estimated on the full analysis sample (n = 1,188); precisely estimated nulls, not underpowered non-results.
- Consistent with a **production-side** response (crop choice) rather than a change in market-engagement behavior.

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Consumption measure

Consumption is the sum of the following components:

- Food consumption (reports on the last month)
- Fuel consumption
- Cloth consumption
- Fuel consumption

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Income measure

Income is the sum of the following components:

- Main occupation income
- Secondary occupation income
- Non-farm enterprise income
- Animal income
- Financial income (savings, credit, in-transfers, out-transfers, debt)
- Agricultural income

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Appendix: Proof of $\partial V_x^{i,\mathrm{aut}} / \partial \tau_c < 0$

Stacking the fixed point across all states $x \in \mathcal{X}$:

$$\mathbf{V}^{i,\mathrm{aut}}(\theta) \;=\; (I - \beta \Pi_x)^{-1}\, u\Big(\mathbf{Y}^i(\theta)\Big)$$

Differentiating with respect to τ_c:

$$\frac{\partial \mathbf{V}^{i,\mathrm{aut}}}{\partial \tau_c} \;=\; (I - \beta \Pi_x)^{-1} \left[u'\Big(\mathbf{Y}^i(\theta)\Big) \odot \frac{\partial \mathbf{Y}^i}{\partial \tau_c} \right]$$

Three observations establish the sign:

1. $(I - \beta \Pi_x)^{-1} = \sum_{k=0}^{\infty} (\beta \Pi_x)^k$ has all non-negative entries
2. $u'(Y_x^i) > 0$ for all x
3. $\dfrac{\partial Y_x^i}{\partial \tau_c} = -(1-\theta)\, p_x\, y^{i,c}(s) < 0$ for all x

Therefore every element of $u'(\mathbf{Y}^i) \odot \partial \mathbf{Y}^i / \partial \tau_c$ is strictly negative, and premultiplying by $(I - \beta \Pi_x)^{-1}$ preserves the sign. ■

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Appendix: Derivation of the θ FOC (1/2)

The Lagrangian of the village chief's problem:

$$\begin{aligned}\mathcal{L} &= u(Y_x(\theta) - c) + \beta \sum_{x'} \pi(x'|x)\, V_{x'}(w_{x'}; \theta) \\ &+ \mu \left[u(c) + \beta \sum_{x'} \pi(x'|x)\, w_{x'} - w \right] \\ &+ \lambda_1 \left[u(c) + \beta \sum_{x'} \pi(x'|x)\, w_{x'} - V_x^{1,\text{aut}}(\theta) \right] \\ &+ \lambda_2 \left[u(Y_x(\theta) - c) + \beta \sum_{x'} \pi(x'|x)\, V_{x'}(w_{x'}; \theta) - V_x^{2,\text{aut}}(\theta) \right]\end{aligned}$$

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Appendix: Derivation of the θ FOC (2/2)

Differentiating $\mathcal{L}$ with respect to θ and applying the envelope theorem on continuation values:

$$(1+\lambda_2)\,u'(Y_x(\theta)-c)\cdot\Delta_x(\tau_c) \;=\; \lambda_1\frac{\partial V_x^{1,\text{aut}}}{\partial\theta}+\lambda_2\frac{\partial V_x^{2,\text{aut}}}{\partial\theta}-\beta\sum_{x'}\pi(x'|x)\frac{\partial V_{x'}^{2}}{\partial\theta}$$

where:

- $\mu=-V_x'(w)$ by the envelope theorem on (PKC)
- $\Delta_x(\tau_c)\equiv y^{i,f}(s)-p_x(1-\tau_c)\,y^{i,c}(s)$ is the comparative advantage gap
- whenever $\lambda_i>0$, the planner is distorted away from the production optimum

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Appendix: Derivation of the Ricardo Effect (1/2)

Define the implicit function pinning down $\theta^{out,*}$:

$$H(\theta, \tau_c) \equiv \mathbb{E}_x^{pv}\left[\left[Y^i(\theta, \tau_c)\right]^{-\gamma} \cdot \Delta^i(\tau_c)\right] = 0$$

By the implicit function theorem:

$$\frac{d\theta^{out,*}}{d\tau_c} = -\frac{\partial H/\partial \tau_c}{\partial H/\partial \theta}$$

Sign of $\partial H/\partial\theta$:

$$\frac{\partial H}{\partial \theta} = \mathbb{E}_x^{pv}\left[(-\gamma)\left[Y^i\right]^{-\gamma-1} \cdot \left[\Delta^i\right]^2\right] < 0$$

since $\gamma > 0$ and $[\Delta^i]^2 \geq 0$.

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Appendix: Derivation of the Ricardo Effect (2/2)

Sign of $\partial H/\partial \tau_c$:
Using $\partial Y_x^i/\partial \tau_c = -(1-\theta)\, p_x\, y^{i,c}(s) < 0$ and $\partial \Delta_x^i/\partial \tau_c = p_x\, y^{i,c}(s) > 0$:

$$\frac{\partial H}{\partial \tau_c} \;=\; \mathbb{E}_x^{pv}\left[\left[Y^i\right]^{-\gamma-1} p\, y^{i,c} \cdot \left\{ f^i\left[\theta + \gamma(1-\theta)\right] + p(1-\tau_c)\, y^{i,c}(1-\theta)(1-\gamma)\right\}\right]$$

For $\gamma > 1$ and food income dominant at the optimum: $\partial H/\partial \tau_c > 0$. Therefore:

$$\frac{d\theta^{out,*}}{d\tau_c} > 0 \qquad \Longleftrightarrow \qquad \frac{d\theta^{out,*}}{d(1-\tau_c)} < 0$$

A fall in trade costs shifts $\theta^{out,*}$ toward cash-crop specialization. ■

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