Volatility and the Gains from Trade

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- For farmers in developing countries second moment effects of trade may have large welfare implications.
- Goal of this paper: develop a quantitative framework that incorporates volatility, use it to estimate welfare effects of trade in India.

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   - First moment gains dominate second moment effects on average.
   - Highways + banks $\rightarrow$ farmers take advantage of higher-risk higher-return allocations.

Related literature

- Pareto inferior trade literature: Helpman and Razin (1978), Newbery and Stiglitz (1982, 1984), Eaton and Grossman (1985), Dixit (1987, 1989)
- Macro literature exploring openness and volatility: Easterly, Islam, and Stiglitz (2000), di Giovanni and Levchenko (2009), Caselli, Koren, Lisicky, and Tenreyro (2014), Garetto and Fillat (2014)
- Reduced form evidence on volatility: Burgess and Donaldson (2013)
- Quantitative trade literature: Eaton and Kortum (2002), Arkolakis, Costinot, and Rodriguez-Claire (2008), Donaldson (2012), Costinot and Rodriguez-Claire (2013), Allen, Arkolakis, and Takahashi (2014)
- Agricultural decisions as portfolio allocation problem: Fafchamps (1992), Rosenzweig and Binswanger (1993), Kurosaki and Fafchamps (2002)

Outline of Talk

Introduction

Trade and Volatility: Stylized Facts

Modeling trade and volatility

Quantifying the welfare effects of trade and volatility

Conclusion

Rural India over the past forty years

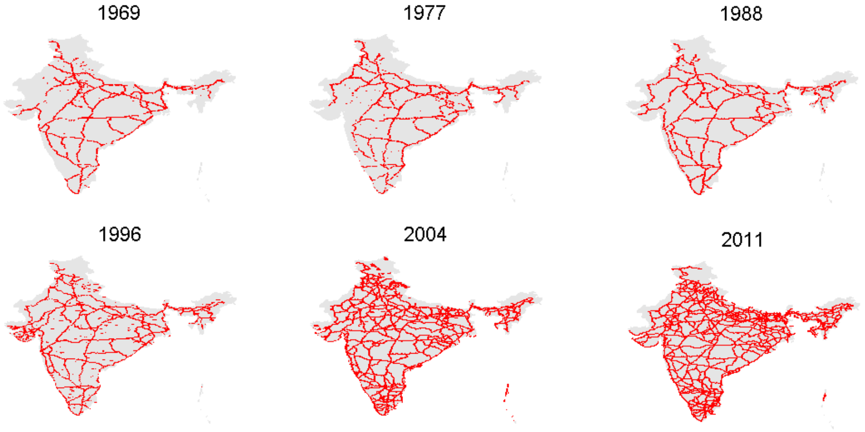
- Fundamentally risky production: even today, $\sim$60% agriculture depends on rainfall.
- Substantial reduction in international and intranational trade costs.
- Concern that these changes worsened plight of farmers:

  "When market reforms were introduced in 1991, ...import barriers fell, thrusting small farmers into an unforgiving global market. Farmers took on new risks, switching to commercial crops ... They found themselves locked in a whiteknuckle gamble, juggling everlarger loans at exorbitant interest rates ... This pattern has left a trail of human wreckage." **NYT "After Farmers Commit Suicide, Debts Fall on Families in India" (02/22/2014)**
- ...but a lot of other things changed too:
  - Introduction of irrigation, genetically modified crops (HYVs).
  - Expansion of rural banking helped farmers smooth income shocks.

Data

- **Crop Choices:** Area planted, yields, and prices covering 15 major crops across 311 districts from 1970-2009 (source: ICRISAT VDSA).
- **Trade Costs:** Highway network data from digitizing *Road Map of India* 1962, 1969, 1977, 1988, 1996, 2004, 2011.
- **Insurance:** Rural bank data from RBI bank openings (Fulford 2013).
- **Rainfall:** Gridded weather data (Willmott and Matsuura).
- **Consumer Preferences:** Household consumption surveys (NSSO).

Indian highway network over time



- Generate a Market Access measure $MA_d = \sum_{d'} \frac{\omega_{d'}}{road\ \ distance^{\phi}_{dd'}}$ using revenue weighted inverse travel times (fast marching method). ▸ Details
- Major goal was to connect cities (cf Asturias et al. 2015), mitigates endogeneity concerns.

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- Traders at the *mandis* sell the produce to the largest traders in the state who then transport the goods across state borders
- Downstream trade follows this network in reverse
    - Interstate traders sell the goods to intrastate traders in the state, who then sell to smaller traders in the districts

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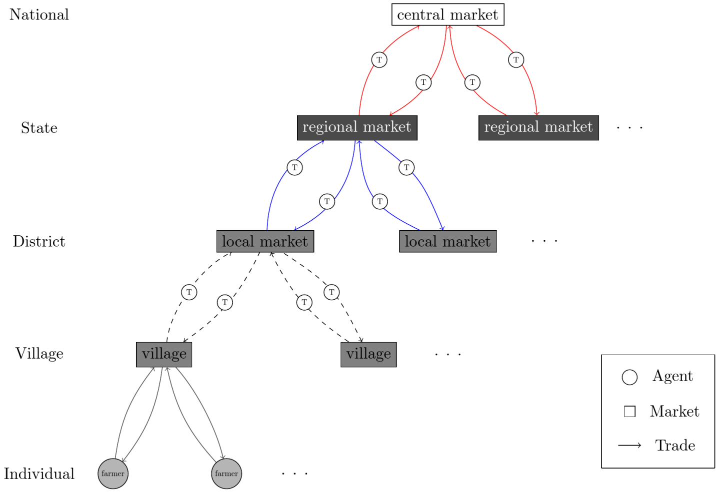
Figure: Hierarchical Trading Network



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  (3) As trade costs fall, farmers' revenue volatility increases...and the volatility of their price index declines...with the volatility of real income rising on net.

Stylized fact #1

As trade costs fall, prices respond less to local yields and more to yields elsewhere within the state

- Methodology: Regress local price on local yield (IV with local rainfall shocks), allow the elasticity to vary with market access:

$$\ln p_{igtd} = \beta_1 \ln A_{igtd} + \beta_2 \ln A_{igtd} \times MA_{id}^{instate} + \gamma_{gtd} + \gamma_{igd} + \gamma_{it} + \nu_{igdt},$$

Figure: Price-Yield Elasticities and Roads

Dependent variable:					Log Price					
	(1) OLS	(2) IV	(3) IV	(4) IV	(5) RF	(6) RF	(7) RF	(8) IV	(9) IV	(10) IV
Ln(Yield)	-0.032***	-0.071***	-0.072***	-0.069***				-0.085***	-0.071***	-0.087***
	(0.004)	(0.010)	(0.013)	(0.011)				(0.015)	(0.019)	(0.022)
Ln(Yield)XStateMA	0.033*	0.155***						0.135***	0.257***	0.245***
	(0.019)	(0.041)						(0.042)	(0.075)	(0.075)
Ln(Yield)XStateMA (phi=1)			0.065***							
			(0.024)							
Ln(Yield)XStateMA (alt. speed)				0.116***						
				(0.035)						
Ln($\widehat{\text{Yield}}$)XStateMA					0.063*	0.253***	0.030			
					(0.034)	(0.061)	(0.079)			
Ln(Yield)XNationalMA								0.039		0.045
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Ln(StateYield)									-0.004	0.005
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Crop-district-decade FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Crop-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Crop-decade Yield Interactions	No	No	No	No	Yes	No	Yes	No	No	No
Crop-district Yield Interactions	No	No	No	No	No	Yes	Yes	No	No	No
R-squared	0.946	0.000	0.001	0.001	0.946	0.950	0.951	-0.000	0.000	-0.000
Observations	86,811	86,811	86,811	86,811	86,811	86,811	86,811	86,811	86,172	86,172
First-Stage F Stat	.	2421.183	2479.071	2423.527	.	.	.	1603.735	569.530	376.069

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Stylized fact #2

As trade costs fall, farmers reallocate their land toward crops for which they have a comparative advantage and away from crops that are more risky, with the riskiness of yields mattering more in locations with worse access to banks.

- Methodology:
  - Regress "log" crop choice (θ_{igd}) on mean and variance of log yields (μ_{igd}^{A} and $\sigma_{igd}^{2,A}$), allow the coefficients to vary with market access:

$$\begin{aligned}\text{arcsinh}\theta_{igd} =& \beta_1 \mu_{igd}^{A} + \beta_2 \sigma_{igd}^{2,A} + \beta_3 \mu_{igd}^{A} \times MA_{id}^{instate} + \beta_4 \sigma_{igd}^{2,A} \times MA_{id}^{instate} \\ &+ \gamma_{gd} + \gamma_{id} + \gamma_{ig} + \varepsilon_{igd}\end{aligned}$$

  - Instrument for mean and variance of log yields with mean and variance of rainfall predicted log yields.

Figure: Crop Choice and Openness

Dependent variable:			IHS fraction of land planted by crop				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	IV	IV	IV	IV	IV	IV
Mean(lnYield)	0.001	0.004	0.005*	-0.006**	0.002	0.002	-0.007**
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)
Var(lnYield)	0.008*	0.028**	0.006	0.038**	0.080***	0.004	0.066**
	(0.004)	(0.012)	(0.012)	(0.016)	(0.023)	(0.026)	(0.027)
MeanXStateMA	0.012***	0.010***	0.010**	0.001	0.012***	0.012***	0.003
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
VarXStateMA	-0.034**	-0.125***	-0.074**	-0.080***	-0.224***	-0.083	-0.174***
	(0.016)	(0.031)	(0.034)	(0.028)	(0.062)	(0.075)	(0.058)
Covar(lnYield)			0.028***			0.066***	
			(0.009)			(0.020)	
CovarXStateMA			-0.076**			-0.133**	
			(0.030)			(0.060)	
MeanXNatMA				0.021***			0.022***
				(0.005)			(0.005)
VarXNatMA				-0.044*			0.002
				(0.026)			(0.044)
VarXBank					-13.319***	-3.019	-10.835**
					(3.665)	(4.025)	(5.053)
VarXStateMAXBank					22.719***	7.370	16.277**
					(8.327)	(9.956)	(7.709)
CovarXBank						-8.646***	
						(3.013)	
CovarXStateMAXBank						13.646*	
						(8.045)	
VarXNatMAXBank							-1.066
							(4.820)
Crop-decade FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District-decade FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District-crop FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.972	-0.001	-0.015	0.005	-0.006	-0.034	0.001
Observations	18639	18626	18626	18626	18626	18626	18626
First-Stage F Stat	.	117.050	37.676	84.341	78.623	14.800	22.865

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				(0.005)			(0.005)
VarXNatMA				-0.044*			0.002
				(0.026)			(0.044)
VarXBank					-13.319***	-3.019	-10.835**
					(3.665)	(4.025)	(5.053)
VarXStateMAXBank					22.719***	7.370	16.277**
					(8.327)	(9.956)	(7.709)
CovarXBank						-8.646***	
						(3.013)	
CovarXStateMAXBank						13.646*	
						(8.045)	
VarXNatMAXBank							-1.066
							(4.820)
Crop-decade FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District-decade FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District-crop FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.972	-0.001	-0.015	0.005	-0.006	-0.034	0.001
Observations	18639	18626	18626	18626	18626	18626	18626
First-Stage F Stat	.	117.050	37.676	84.341	78.623	14.800	22.865

Figure: Crop Choice and Openness

Dependent variable:	IHS fraction of land planted by crop						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	IV	IV	IV	IV	IV	IV
Mean(lnYield)	0.001	0.004	0.005*	-0.006**	0.002	0.002	-0.007**
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.003)
Var(lnYield)	0.008*	0.028**	0.006	0.038**	0.080***	0.004	0.066**
	(0.004)	(0.012)	(0.012)	(0.016)	(0.023)	(0.026)	(0.027)
MeanXStateMA	0.012***	0.010***	0.010**	0.001	0.012***	0.012***	0.003
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
VarXStateMA	-0.034**	-0.125***	-0.074**	-0.080***	-0.224***	-0.083	-0.174***
	(0.016)	(0.031)	(0.034)	(0.028)	(0.062)	(0.075)	(0.058)
Covar(lnYield)			0.028***			0.066***	
			(0.009)			(0.020)	
CovarXStateMA			-0.076**			-0.133**	
			(0.030)			(0.060)	
MeanXNatMA				0.021***			0.022***
				(0.005)			(0.005)
VarXNatMA				-0.044*			0.002
				(0.026)			(0.044)
VarXBank					-13.319***	-3.019	-10.835**
					(3.665)	(4.025)	(5.053)
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Stylized fact #3

As trade costs fall, farmers' revenue volatility increases and the volatility of their price index declines with the volatility of real income rising on net.

- Methodology:
  - Step #1: Calculate (log) nominal income, price index, and real income for each district-year.
  - Step #2: Regress their respective variance over the district-decade on market access, e.g.:

$$var(\ln nominal\ \ income)_{id} = \beta_1 MA_{id} + \gamma_i + \gamma_{sd} + \varepsilon_{id}.$$

Figure: Real Income and Roads

Dependent variable:	Components of Real Income					
	(1)	(2)	(3)	(4)	(5)	(6)
	Var Nominal Y	Var P Index	Var Real Y	Var Nominal Y	Var P Index	Var Real Y
State Market Access	1.656**	-0.500*	1.049***	1.873**	-0.527*	1.142***
	(0.706)	(0.292)	(0.376)	(0.744)	(0.308)	(0.396)
National Market Access				-0.750	0.094	-0.322
				(0.814)	(0.336)	(0.434)
District FE	Yes	Yes	Yes	Yes	Yes	Yes
State Decade FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.541	0.754	0.484	0.541	0.754	0.484
Observations	1169	1199	1169	1169	1199	1169

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Outline of Talk

Goals of the model

1. Match the empirical setting
2. Incorporate volatility
3. Tractable
    - Explain the stylized facts.
    - Estimate model parameters.
    - Quantify the welfare gains from trade.

Goals of the model

1. Match the empirical setting: *Hierarchical trading network.*

2. Incorporate volatility: *Embed a portfolio choice model.*

3. Tractable: *Heterogeneous traders.*
    - Explain the stylized facts.
    - Estimate model parameters.
    - Quantify the welfare gains from trade.

Model setup: Production

- N locations ("villages") and one central market.

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- L_i individuals ("farmers") in village $i \in \{1, ..., N\}$, each with unit of land.
- Quantity produced of good g in village i in state s is:

$$Q_{ig}(s) = \theta_{ig} A_{ig}(s) L_i$$

  - $A_{ig}(s) > 0$ is the productivity.
  - $\{\theta_{ig}\}_g \in \Delta^G$ is the pattern of specialization ("crop choice").

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- Note: Pattern of specialization chosen before state realized (plant before you know the rainfall).

Model setup: Consumption

- Farmers have CRRA utility with Cobb Douglas preferences across crops:

$$U_i^f(s) \equiv \frac{1}{1-\rho_i}\left(\left(Z_i^f(s)\right)^{1-\rho_i} - 1\right)$$

  where $Z_i^f(s) \equiv \prod_{g \in \mathcal{G}} c_{ig}^f(s)^{\alpha_{ig}}$

  - $\rho_i > 0$ is the *effective risk aversion* (capturing innate risk aversion + ability to ex post consumption smooth) Microfoundation
  - $\{\alpha_{ig}\} \in \Delta^G$ good specific preferences.
  - $C_{ig}(s)$ is the total quantity consumed.

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  - **For farmer wishing to buy good g:** trader decides whether to source locally or import.
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- Arbitrage behavior implies:

$$C_{ig}(s) = \left(\frac{p_{ig}(s)}{\bar{p}_g(s)}\right)^{\varepsilon_i} Q_{ig}(s)$$

Prices

- Combining demand and market clearing condition yields the pricing equation:

$$\ln p_{ig}(s) = -\left(\frac{1}{1+\varepsilon_i}\right)\ln Q_{ig}(s) + \frac{\varepsilon_i}{1+\varepsilon_i}\ln \bar{p}_g(s) + \frac{1}{1+\varepsilon_i}\ln\left(\alpha_{ig} Y_i(s)\right). \quad (1)$$

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- **Matches Stylized fact #1**:

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- Central market prices determined by trader arbitrage income, demand.

▸ Details

Optimal crop choice: No volatility

- Farmers must be indifferent across producing all goods:

$$p_{ig} A_{ig} = \lambda_i. \tag{2}$$

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- Combining with the price equation (1) and applying the land constraint $\sum_{g \in \mathcal{G}} \theta_{ig} = 1$ yields:

$$\theta_{ig} = \frac{\left(A_{ig} \bar{p}_g\right)^{\varepsilon_i} \alpha_{ig}}{\sum_{h \in \mathcal{G}} \left(A_{ih} \bar{p}_h\right)^{\varepsilon_i} \alpha_{ih}} \tag{3}$$

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- Greater allocation to crops with higher consumption (α_{ig}) higher market return ($A_{ig} \bar{p}_g$).
  - As village becomes more open ($\epsilon_i \uparrow$), production shifts toward good with higher market returns.

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$$\max_{\theta \in \Delta^G} \underbrace{\mu_i^Z + \frac{1}{2}\sigma_i^2}_{\text{log of mean real returns}} - \rho_i \underbrace{\sigma_i^2}_{\text{variance of log real returns}}$$

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- First order conditions generalize (2):

$$\mu_{ig}^Z - \rho_i \left(\frac{\varepsilon_i}{1+\varepsilon_i}\right) \sum_{h \in \mathcal{G}} \left(\left(\frac{\varepsilon_i}{1+\varepsilon_i}\right)\theta_{i,h} + \left(\frac{1}{1+\varepsilon_i}\right)\alpha_{ih}\right)\Sigma_{gh}^{A,i} = \lambda_i \qquad (4)$$

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- Crop choice generalizes (3), **matches Stylized Fact #2**.

$$\theta_{ig} = \frac{\alpha_{ig} \left(\bar{p}_g B_{ig}\right)^{\varepsilon_i}}{\sum_{h \in \mathcal{G}} \alpha_{ih} \left(\bar{p}_h B_{ih}\right)^{\varepsilon_i}}$$

  - B_{ig} *is risk-adjusted* productivity (B_{ig} is decreasing in $\rho_i \sum_{h=1} \theta_{ih}^f \Sigma_{gh}^{z,i}$ and simplifies to A_{ig} if $\boldsymbol{\Sigma}^{A,i} = \mathbf{0}$).

Explaining Stylized fact 3

Proposition

(3) Trade increases the volatility of nominal income and reduces the volatility of nominal price, but it's effect on real income volatility is ambiguous:

$$\frac{\partial \sigma_i^{2,Y}}{\partial \varepsilon_i} > 0, \frac{\partial \sigma_i^{2,P}}{\partial \varepsilon_i} < 0, \ \textit{and} \ \frac{\partial \sigma_i^{2,Z}}{\partial \varepsilon_i} \lesseqgtr 0.$$

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- Farmers always (weakly) gain from trade.
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  - By decoupling production from consumption, trade offers technology for farmers to reduce risk through crop choice.

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  - Volatility creates GFT in each state of the world even if average yields are the same.
  - By decoupling production from consumption, trade offers technology for farmers to reduce risk through crop choice.

- Volatility can *attenuate* gains from trade:
  - Intuition: if comparative advantage goods are also relatively more risky, farmers will specialize less in them, eroding traditional first moment gains from trade.

Outline of Talk

Introduction

Trade and Volatility: Stylized Facts

Modeling trade and volatility

Quantifying the welfare effects of trade and volatility

Conclusion

Quantifying the welfare effects of trade and volatility

- Goal:
  - Quantify the impact of the Indian highway expansion on farmer welfare...
  - ...and how the expansion of rural bank access affected that impact.

Quantifying the welfare effects of trade and volatility

- Goal:
  - Quantify the impact of the Indian highway expansion on farmer welfare...
  - ...and how the expansion of rural bank access affected that impact.

- Three step strategy:
  1. Beef up the model.
  2. Estimate structural parameters:
     - Recover *trade costs* from relationship between local prices, own yields and regional market price.
     - Recover *effective risk aversion* from location of crop choice on mean-variance frontier.
  3. Perform counterfactuals, lowering trade costs to match highway expansion, with:
     - Bank access constant at 1970s levels.
     - Bank access at actual levels.
     - Bank access at improved levels.

A quantitative version of the model

- We add:
  - Generalized (CES) preferences.
  - Costlessly traded manufacturing good.
  - A multi-tiered hierarchical trading network (districts $\rightarrow$ state markets $\rightarrow$ central market).
  - Arbitrary variance-covariance matrix of yields across districts$\times$crops.
- Details in the paper.

Estimating trade costs

- Structural price equation between districts i and their regional markets (state markets) $m(i)$:

$$\ln p_{ig}(s) = -\frac{1}{\sigma+\varepsilon_i} \ln A_{ig}(s) + \frac{\varepsilon_i}{\sigma+\varepsilon_i} \ln \bar{p}_{m(i)g}(s) + \delta_{ig} + \delta_i(s)$$

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- Empirical analog:

$$\ln p_{igtd} = -\frac{1}{\sigma + \varepsilon_{id}} \ln A_{igtd} + \frac{\varepsilon_{id}}{\sigma + \varepsilon_{id}} \ln \bar{p}_{m(i)gtd} + \delta_{igd} + \delta_{itd} + \nu_{igtd}$$

  - Allow trade costs ε_{id} to vary with market access $MA_{id}^{instate}$.

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  - Allow trade costs ε_{id} to vary with market access $MA_{id}^{instate}$.

- Hierarchical nature of the trading network implies a similar expression between regional market prices and central market:

$$\ln \bar{p}_{mg}(s) = -\frac{1}{\bar{\sigma} + \varepsilon_m} \ln \bar{Q}_{mg}(s) + \frac{\varepsilon_m}{\bar{\sigma} + \varepsilon_m} \ln p_g^*(s) + \delta_{mg} + \delta_m(s)$$

Interstate trade costs

Figure: Estimated openness to trade: District level openness (ϵ_i)

	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) GMM	(6) GMM
Log yield	-0.034***	-0.120***	-0.040***	-0.151***		
	(0.002)	(0.006)	(0.004)	(0.010)		
State MA × Log yield			0.322*	1.576***		
			(0.178)	(0.420)		
Log state price	0.385***	0.256***	0.382***	0.227***		
	(0.009)	(0.014)	(0.013)	(0.021)		
State MA × Log state price			0.142	1.375**		
			(0.438)	(0.616)		
District trade openness (ϵ_i)	11.315***	2.134***			2.134***	1.705***
	(0.913)	(0.190)			(0.190)	(0.240)
District trade openness (ϵ_i) × State MA						16.860**
						(7.215)
District elasticity of substitution (σ)	18.084***	6.196***			6.196***	5.969***
	(1.309)	(0.307)			(0.307)	(0.284)
Observations	85918	85918	85918	85918	85918	85918
First Stage F-statistic		7293.04		3095.02	291.99	150.50
Crop-District-Decade FE	Yes	Yes	Yes	Yes	Yes	Yes
District-Year-Decade FE	Yes	Yes	Yes	Yes	Yes	Yes

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Crop-District-Decade FE	Yes	Yes	Yes	Yes	Yes	Yes
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Estimating effective risk aversion

- Recall first order conditions of farmer's crop choice:

$$\mu_{ig}^{Z} - \rho_i \left(\frac{\varepsilon_i}{1+\varepsilon_i}\right) \sum_{h \in \mathcal{G}} \left(\left(\frac{\varepsilon_i}{1+\varepsilon_i}\right) \theta_{i,h} + \left(\frac{1}{1+\varepsilon_i}\right) \alpha_{ih} \right) \Sigma_{gh}^{A,i} = \lambda_i$$

  - *Intuition*: farmers growing more risky crops must be compensated by higher real returns, with trade-off governed by ρ_i.

Estimating effective risk aversion

- Recall first order conditions of farmer's crop choice:

$$\mu_{ig}^{Z} - \rho_i \left(\frac{\varepsilon_i}{1+\varepsilon_i}\right) \sum_{h \in \mathcal{G}} \left(\left(\frac{\varepsilon_i}{1+\varepsilon_i}\right) \theta_{i,h} + \left(\frac{1}{1+\varepsilon_i}\right) \alpha_{ih} \right) \Sigma_{gh}^{A,i} = \lambda_i$$

  - *Intuition*: farmers growing more risky crops must be compensated by higher real returns, with trade-off governed by ρ_i.

- Empirical analog:

$$\mu_g^{Z,id} = \rho_{id} \sigma_g^{Z,id} + \delta_{id} + \delta_{ig} + \delta_{gd} + \nu_{gid},$$

  - Allow ρ_{id} to vary with bank access.
  - Unobserved crop costs identified (calibrated) by $\delta_{ig} + \delta_{gd} + \nu_{gid}$.

▸ Crop cost correlations

Figure: Estimated effective risk aversion

Dependent variable:	Mean real returns (μ_{ig}^{Z})			
	(1) OLS	(2) IV	(3) OLS	(4) IV
Variance of real returns (σ_{ig}^{Z})	0.554**	1.324***	1.710***	3.265***
	(0.224)	(0.429)	(0.443)	(1.111)
Variance of real returns (σ_{ig}^{Z}) $\times$ Banks			-0.310***	-0.454**
			(0.098)	(0.217)
District-decade FE	Yes	Yes	Yes	Yes
District-crop FE	Yes	Yes	Yes	Yes
Crop-decade FE	Yes	Yes	Yes	Yes
First stage F-stat		421.491		76.946
R-squared	0.969	-0.004	0.969	-0.005
Observations	14916	14916	14916	14916

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Quantifying the welfare effects of volatility: Overview

- Hold structural parameters (yield distribution, preferences) constant at 1970s level.
    1. **Counterfactual 1:** Only trade costs evolve.
    2. **Counterfactual 2:** Trade costs & effective risk aversion evolve.
    3. **Counterfactual 3:** Trade costs evolve, effective risk aversion is improved ($\min\left\{\rho_{id}, \{\rho_i\}_{p25}\right\}$).
- Calculate optimal crop choice, and then (log of) mean real returns, variance (of log) real returns, and expected welfare.
- Report average welfare change (certainty equivalent variation) across districts relative to 1970s baseline. Spatial Heterogeneity in GFT

Figure: Welfare impact of the Indian highway expansion: Highway expansion only

	Districts				Regional Markets		Central Markets	
	(1) Mean	(2) Variance	(3) Welfare	(4) Welfare (70s ρ_i)	(5) Mean	(6) Variance	(7) Mean	(8) Variance
1980s	0.593***	-0.055***	0.659***	0.659***	-0.336**	-0.005**	0.119	-0.003
	(0.062)	(0.008)	(0.060)	(0.060)	(0.126)	(0.002)		
1990s	1.597***	-0.050***	1.660***	1.660***	-0.913***	-0.008**	0.391	-0.002
	(0.114)	(0.008)	(0.113)	(0.113)	(0.235)	(0.003)		
2000s	2.240***	-0.048***	2.300***	2.300***	-1.344**	-0.009***	0.702	-0.003
	(0.178)	(0.008)	(0.177)	(0.177)	(0.464)	(0.003)		
N	311	311	311	311	16	16	1	1

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Figure: Welfare impact of the Indian highway expansion: Highway and bank expansion

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	(1) Mean	(2) Variance	(3) Welfare	(4) Welfare (70s ρ_i)	(5) Mean	(6) Variance	(7) Mean	(8) Variance
1980s	1.137***	0.718***	2.917***	0.314**	-0.323*	0.011**	0.194	0.000
	(0.160)	(0.156)	(0.224)	(0.148)	(0.152)	(0.004)		
1990s	2.146***	0.891***	4.178***	1.118***	-0.899***	0.010**	0.506	0.002
	(0.190)	(0.188)	(0.255)	(0.206)	(0.245)	(0.004)		
2000s	2.733***	0.584***	4.285***	2.041***	-1.349**	0.005**	0.784	0.000
	(0.227)	(0.138)	(0.246)	(0.222)	(0.469)	(0.002)		
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	(1) Mean	(2) Variance	(3) Welfare	(4) Welfare (70s ρ_i)	(5) Mean	(6) Variance	(7) Mean	(8) Variance
1980s	1.353***	1.210***	4.197***	-0.073	-0.369*	0.024**	0.280	0.005
	(0.175)	(0.247)	(0.308)	(0.229)	(0.186)	(0.009)		
1990s	2.332***	1.264***	5.207***	0.848***	-0.952***	0.021**	0.570	0.006
	(0.198)	(0.253)	(0.317)	(0.261)	(0.268)	(0.008)		
2000s	3.021***	1.204***	5.823***	1.594***	-1.395**	0.020**	0.860	0.005
	(0.241)	(0.247)	(0.331)	(0.294)	(0.498)	(0.008)		
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Outline of Talk

Conclusion

- 40 years of crop price, yield and area; weather; banks; and roads data show that trade increased revenue volatility and farmers responded by reallocating to less risky crops.

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  - Analytical solutions for equilibrium prices and patterns of specialization, even in the presence of volatility.
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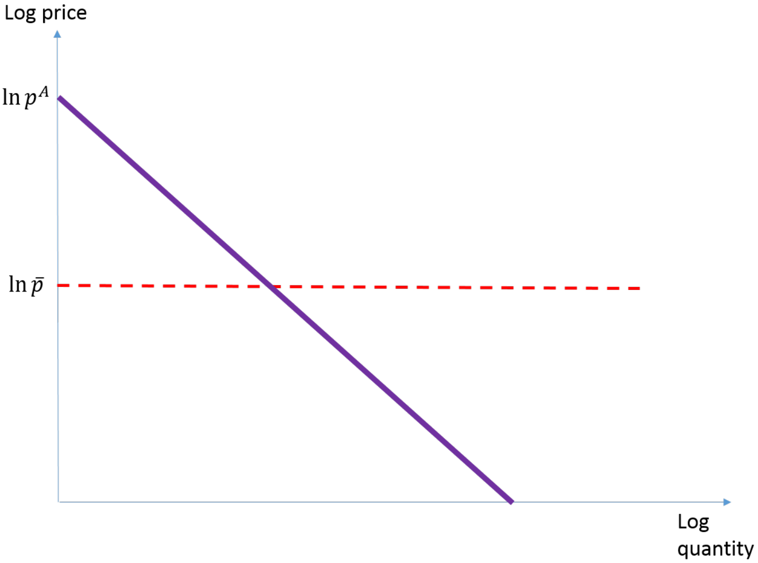
- Structural estimates suggest volatility had important impacts on gains from trade.
- Policy implication: policies improving insurance encourage producers to shift production toward higher-risk higher-return comparative advantage crops.

Intuition: Homogeneous trade costs



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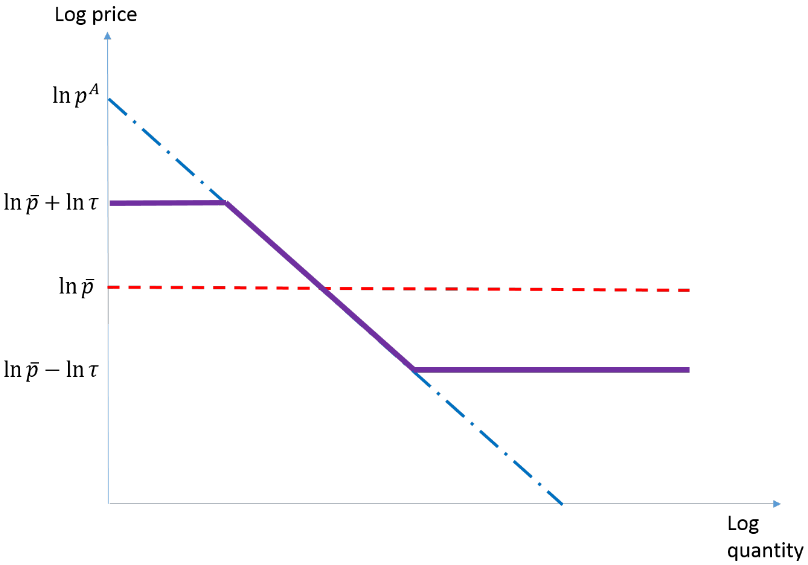

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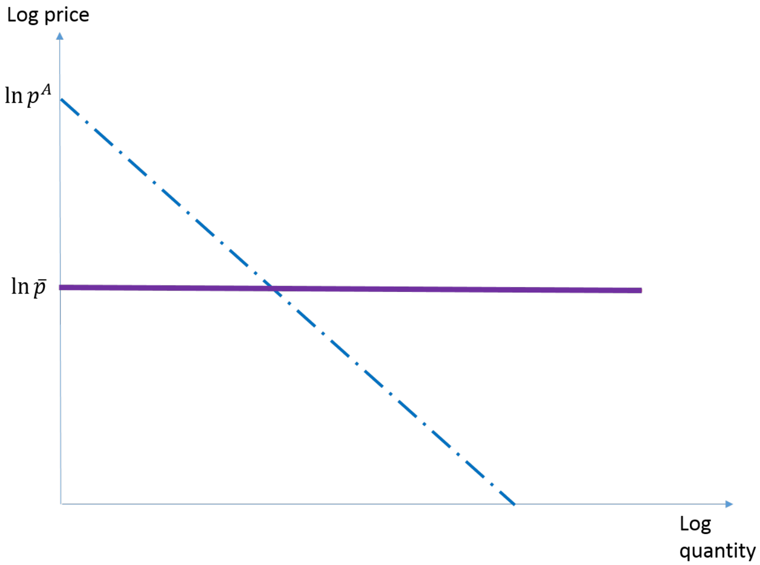

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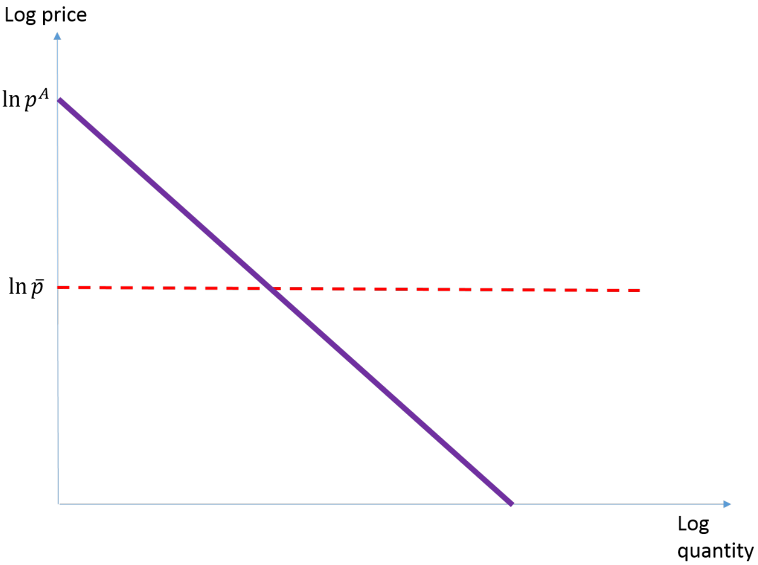

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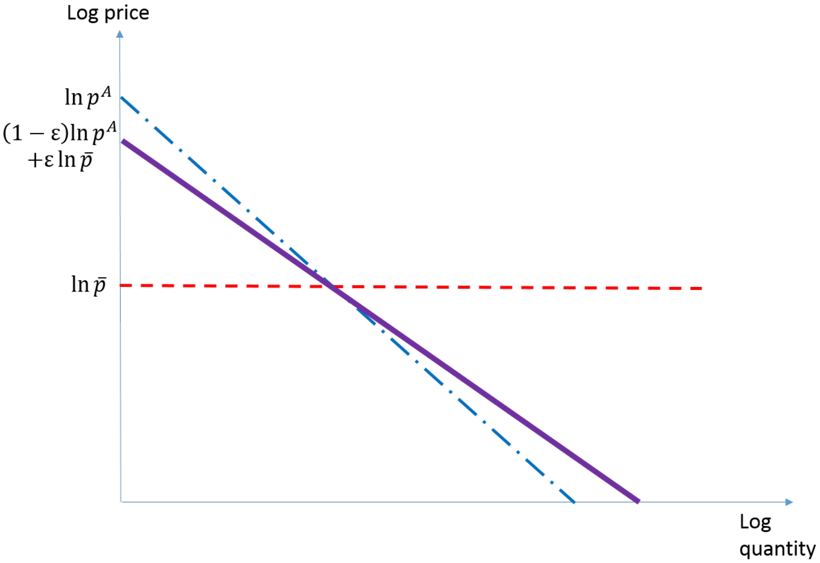

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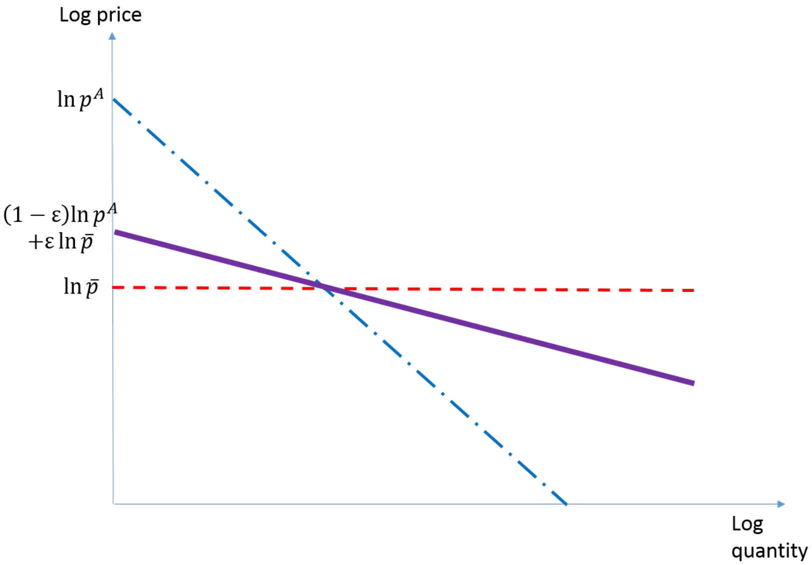
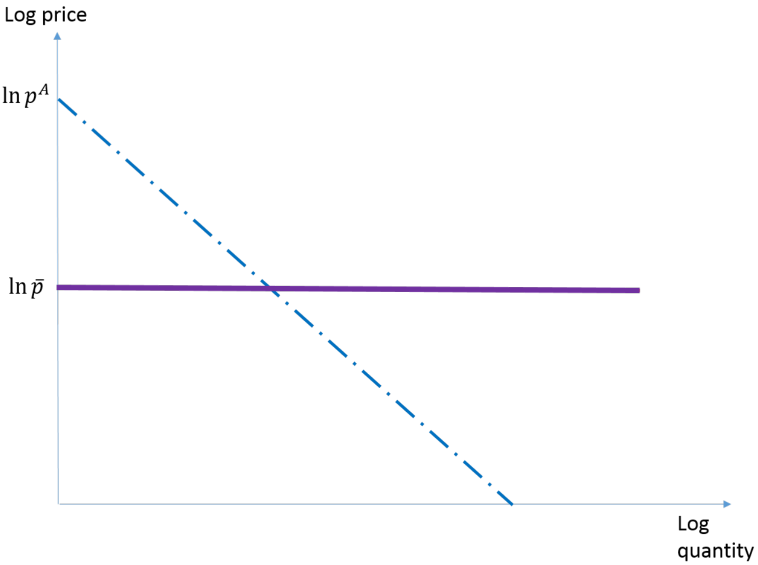
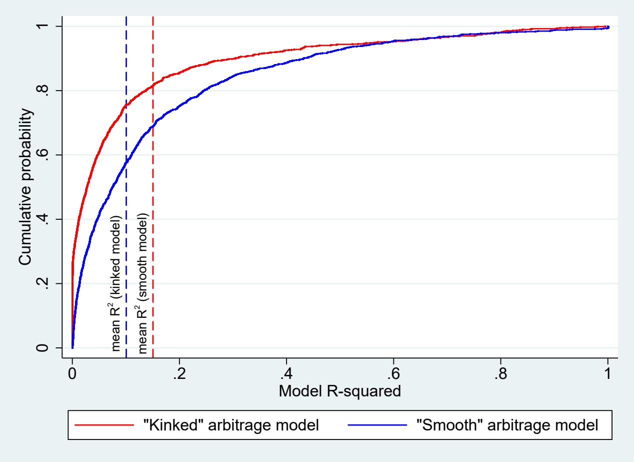


Intuition: Heterogeneous trade costs ▸ Back



Empirical comparison of kinked v.s smooth trade models



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Agricultural trade in India

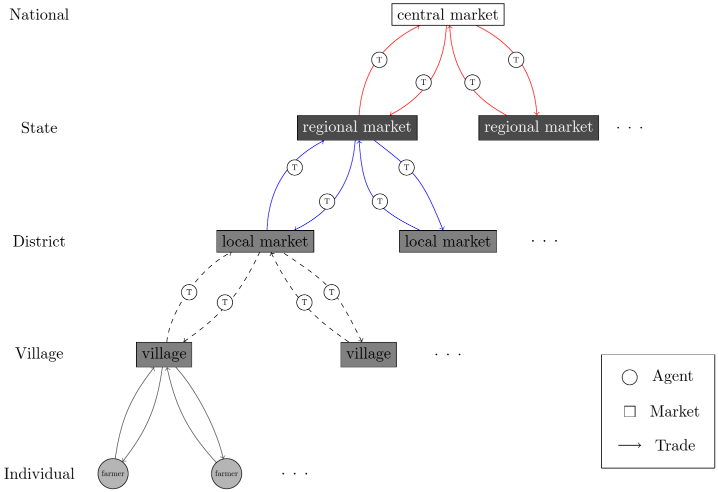

Figure: Hierarchical Trading Network

Trade Network Comparison

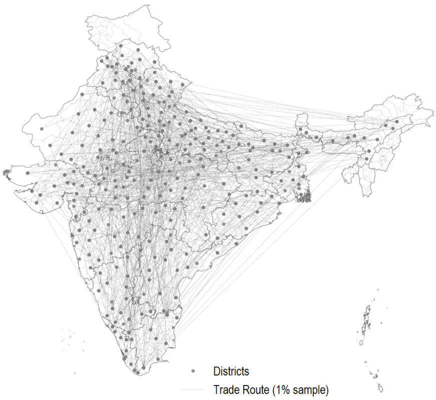

Figure: Horizontal trade network

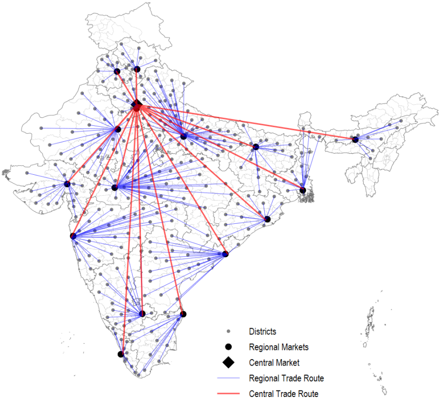

Figure: Hierarchical trade network

Back

Measuring Market Access

- From digitizing the Road Maps of India, we create a Market Access measure.
- We generate a Market Access measure using income weighted inverse road distance
  - $MA_d = \sum_{d'} \frac{\omega_{d'}}{road\ \ distance_{dd'}^{\phi}}$
  - where ϕ is the coefficient on distance from a gravity regression.
  - we take $\phi = 1.5$, the average coefficients for developing country samples in Disdier and Head's (2008) meta analysis of 103 papers.
  - (explore robustness to alternate ϕs and population not income weights)
- Explore how changes in MA_d relate to total revenue volatility and covariance of local price to local production.

Back

Microfoundation for insurance

- Farmers choose quantity of insurance q_s for each state of nature s at price p_s:

$$\max_{\{q_s\}} \sum_s \pi_s \frac{1}{1-\rho} \left(I_s + q_s - \sum_t p_t q_t \right)^{1-\rho}.$$

- Farmer's first order conditions:

$$\frac{\pi_s C_s^{-\rho}}{\sum_t \pi_t C_t^{-\rho}} = p_s$$

- Money-lenders offer insurance at price which equates their marginal utility cost and benefit of lending one unit income in s:

$$p_s = \frac{\pi_s I_s^{-\rho_{ML}}}{\sum_t \pi_t I_t^{-\rho_{ML}}}.$$

- Equating the two equations and using log normal distribution of I_s yields:

$$C_s = \kappa I_s^{\frac{\rho_{ML}}{\rho}} E\left[I_s\right]^{1-\frac{\rho_{ML}}{\rho}}$$

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Figure: Estimated openness to trade: State Market Access (ϵ_m)

	(1) OLS	(2) IV	(3) OLS	(4) IV	(5) GMM	(6) GMM
Log state quantity	-0.097***	-0.146***	-0.094***	-0.125		
	(0.021)	(0.048)	(0.036)	(0.082)		
Travel time to Delhi × Log state quantity			-0.000	-0.001		
			(0.001)	(0.004)		
Log India price	0.549***	0.287***	0.616***	0.299**		
	(0.064)	(0.058)	(0.134)	(0.127)		
Travel time to Delhi × Log India price			-0.003	-0.000		
			(0.004)	(0.004)		
State trade openness (ϵ_m)	5.643***	1.967**			1.967***	2.073
	(1.445)	(0.818)			(0.546)	(1.439)
State trade openness (ϵ_m) × Travel time to Delhi						-0.005
						(0.035)
State elasticity of substitution (σ)	4.645***	4.881***			4.881***	4.848***
	(1.147)	(1.602)			(1.181)	(1.607)
Observations	6870	6870	6870	6870	6870	6870
First Stage F-statistic		651.22		320.44	8.49	4.29
Crop-State-Decade FE	Yes	Yes	Yes	Yes	Yes	Yes
State-Year-Decade FE	Yes	Yes	Yes	Yes	Yes	Yes

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Spatial heterogeneity in GFT

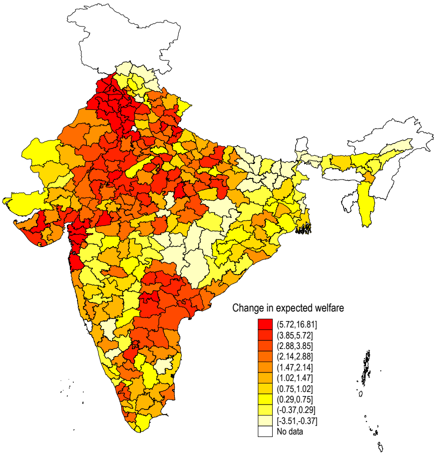

Figure: Expected Welfare (only evolving trade costs)

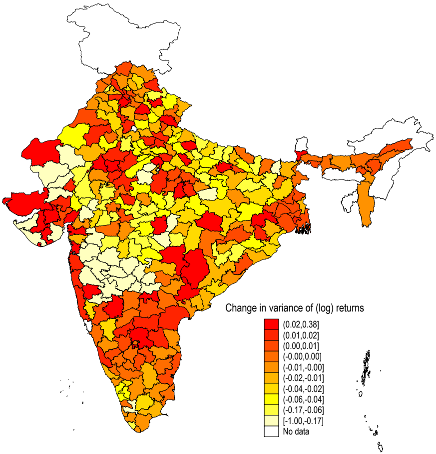

Figure: Variance of log returns (only evolving trade costs)

Back

Spatial Heterogeneity in GFT

Figure: Explaining the heterogeneity across districts in the gains from the expansion of the Indian highway network

	Mean		Variance		Welfare	
	(1)	(2)	(3)	(4)	(5)	(6)
1980s	0.593***	0.125**	-0.055***	-0.057***	0.659***	0.194***
	(0.062)	(0.050)	(0.008)	(0.009)	(0.060)	(0.048)
1990s	1.597***	0.091	-0.050***	-0.055***	1.660***	0.159
	(0.115)	(0.131)	(0.008)	(0.009)	(0.113)	(0.130)
2000s	2.240***	-0.001	-0.048***	-0.054***	2.300***	0.067
	(0.178)	(0.163)	(0.008)	(0.010)	(0.177)	(0.162)
Within-state Market		157.991***		0.483**		157.460***
Access		(15.008)		(0.204)		(14.968)
District FE	Yes	Yes	Yes	Yes	Yes	Yes
State-decade FE	0.307	0.851	0.109	0.112	0.319	0.856
R-squared (within)	1244.000	1244.000	1244.000	1244.000	1244.000	1244.000

Back

Central market prices

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$$\bar{C}_g(s) = \sum_i \left(1 - \left(\frac{p_{ig}(s)}{\bar{p}_g(s)}\right)^{\varepsilon_i}\right) Q_{ig}(s)$$

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- Total arbitrage income for central market agents (traders and drivers) can be similarly derived as

$$\bar{Y}(s) = \sum_{g \in \mathcal{G}} \sum_{i \in \mathcal{N}} \left(\bar{p}_g(s) - p_{ig}(s)\right) \left(1 - \left(\frac{p_{ig}(s)}{\bar{p}_g(s)}\right)^{\varepsilon_i}\right) Q_{ig}(s)$$

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- See paper for existence / uniqueness results. Back

Volatility, insurance, and the gains from trade

- Volatility can *amplify* gains from trade:
  - Example: $N = 2$, $G = 2$, $\sigma = 1$. $\mu_g^{A,1} = \mu_g^{A,2}$ for $g \in \{1, 2\}$.
  - Without volatility, no gains from trade.
  - Suppose crop 1 in village 1 is risky:
    - In autarky, $T_{ii} = 1 \implies$ cannot reduce risk through crop choice.
    - With trade, $T_{ii} < 1 \implies$ village 1 farmers can reduce risk by growing more crop 2.
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    - Village 2 farmers respond by growing more crop 1, everyone benefits.
- Volatility can *attenuate* gains from trade:
  - Example $N = 2$, $G = 2$, $\sigma = 1$. $\mu_1^{A,1} > \mu_1^{A,2}$, $\mu_2^{A,1} < \mu_2^{A,2}$.
  - Without volatility, standard gains from trade.
  - Suppose comparative advantage crops are risky and farmers sufficiently risk averse:
    - With trade, farmers specialize less in risky comparative advantage goods, eroding first moment gains.

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Crop Cost Calibration

Figure: Estimated crop costs and actual crop costs

Dependent variable:	Estimated Crop Costs (Log)	
	(1)	(2)
Observed Crop Costs (Log)	0.420**	0.420
	(0.197)	(0.359)
Decade FE	Yes	Yes
Crop FE	Yes	Yes
State-Decade-Crop Clustered SEs	No	Yes
R-squared	0.407	0.407
Observations	3030	3030

Back

Figure: Irrigation, HYVs and the mean and variance of yields

	(1) Mean Y	(2) Mean Y	(3) Mean Y	(4) Var Y	(5) Var Y	(6) Var Y
Proportion Irrigated	0.795***	0.361***	0.347***	-0.609***	-0.263***	-0.163***
	(0.030)	(0.025)	(0.026)	(0.050)	(0.048)	(0.045)
Crop-district FE	Yes	Yes	Yes	Yes	Yes	Yes
Crop-decade FE	No	Yes	Yes	No	Yes	Yes
District-decade FE	No	No	Yes	No	No	Yes
R-squared	0.920	0.946	0.955	0.589	0.630	0.705
Observations	14244	14244	14244	13518	13518	13518

	(1) Mean Y	(2) Mean Y	(3) Mean Y	(4) Var Y	(5) Var Y	(6) Var Y
Proportion HYV	0.470***	0.153***	0.155***	-0.333***	-0.054	-0.031
	(0.028)	(0.025)	(0.028)	(0.042)	(0.047)	(0.053)
Crop-district FE	Yes	Yes	Yes	Yes	Yes	Yes
Crop-decade FE	No	Yes	Yes	No	Yes	Yes
District-decade FE	No	No	Yes	No	No	Yes
R-squared	0.840	0.890	0.930	0.664	0.704	0.804
Observations	5163	5163	5163	4862	4862	4862

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