Misallocation and Product Choice

Stepan Gordeev
Texas Christian University

Sudhir Singh
University of Rochester

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how does heterogeneous product choice affect
aggregate misallocation cost?

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  - $\rightarrow$ understate total cost of misallocation

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  - ▶ *why*
  - but mechanisms apply equally to other sectors

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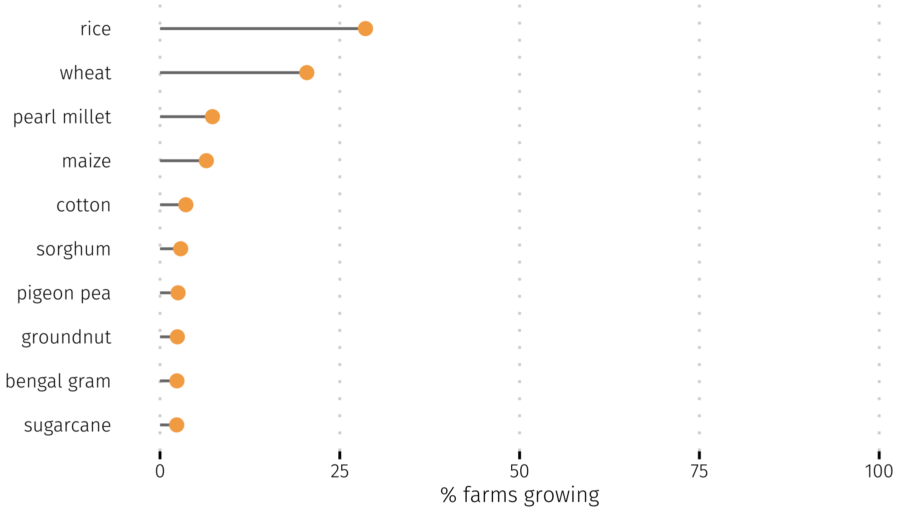
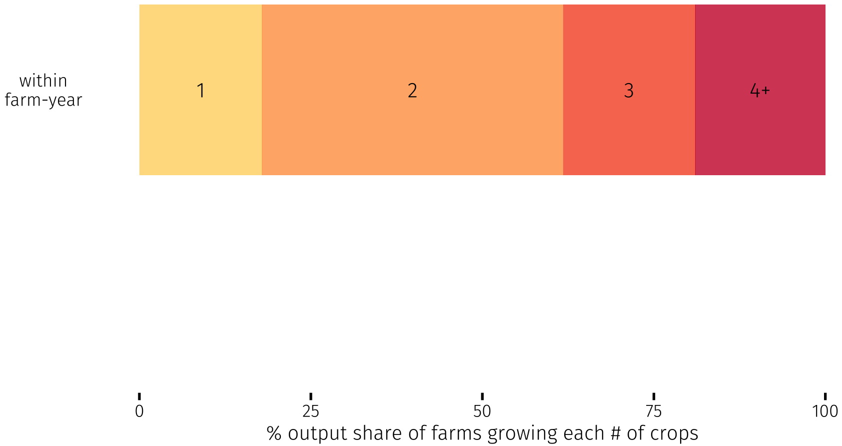
Multi-Product Farms in India

Crop Choice is Heterogeneous



Many Farms Grow Multiple Crops, Mainly Across Seasons



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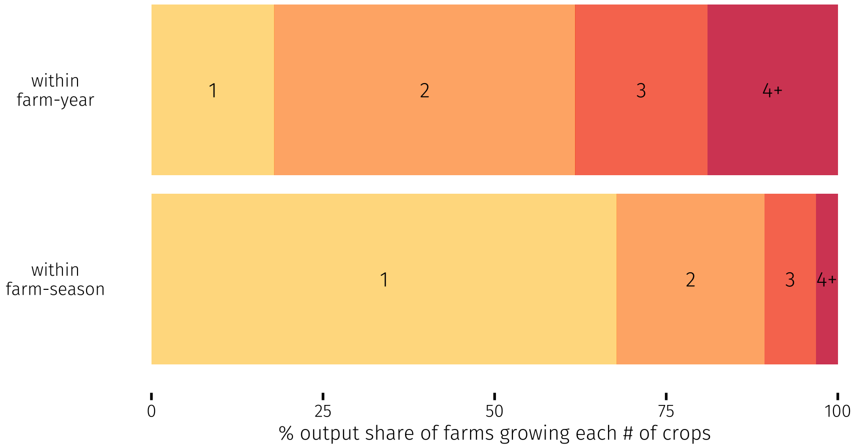

- 3 agricultural seasons: Kharif (monsoon), Rabi (winter/spring), Zaid (summer/dry)

Production Functions

Estimate Crop-Specific Production Functions

- production function:

$$y_{f,i,t} = z_{f,i,t} l_{f,i,t}^{\gamma_i} x_{labor,f,i,t}^{\alpha_{labor,i}} x_{inter,f,i,t}^{\alpha_{inter,i}}$$

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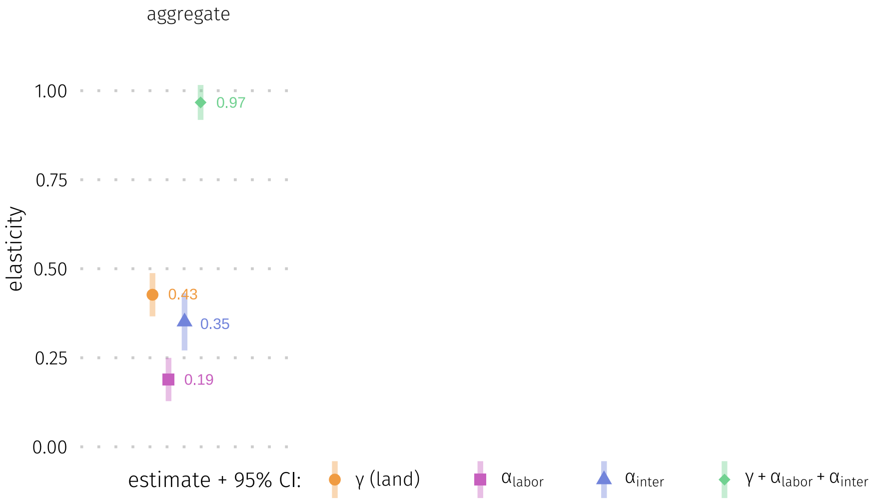

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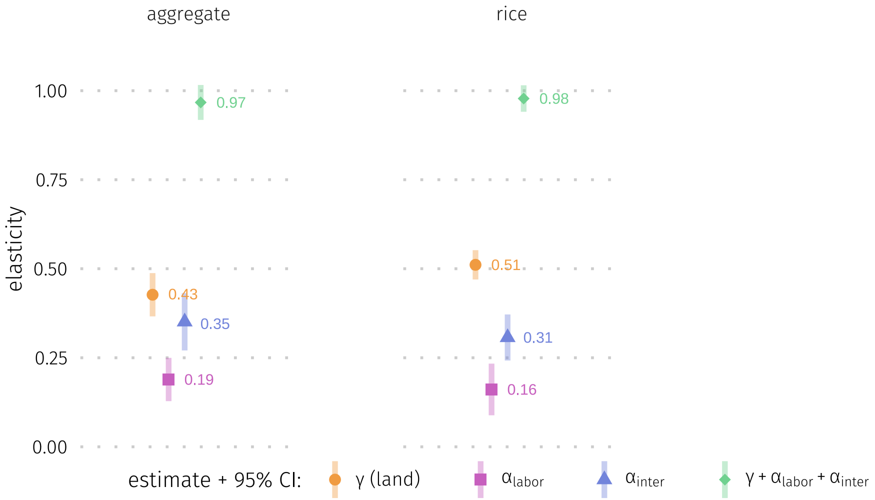

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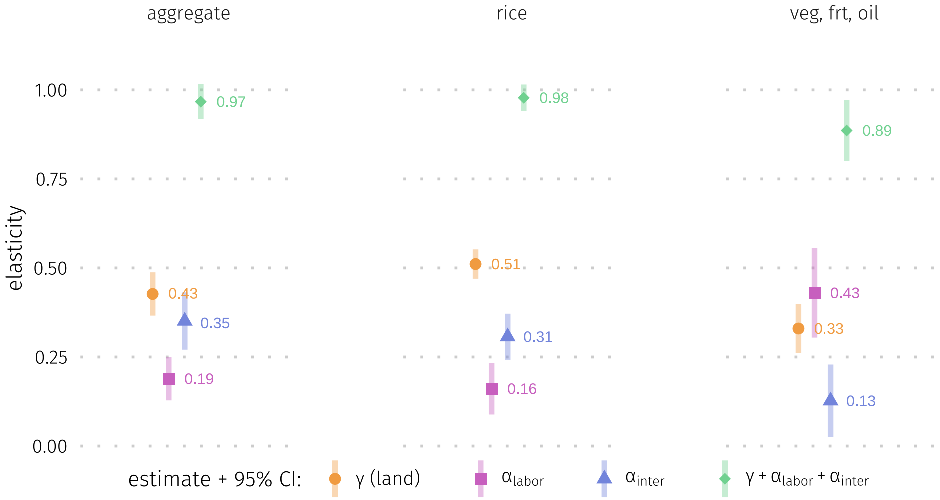

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- flexible inputs g: labor, intermediates
  - quantity $x_{f,g}$ rented at r_g

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- profit-maximizing farm f: sells output py_f, pays for inputs
- Cobb-Douglas production function with TFP z_f
- flexible inputs g: labor, intermediates
  - quantity $x_{f,g}$ rented at r_g
- land input l is in fixed supply L_f
  - almost no land market in India

Farm: Distortions

$$\max \quad \underbrace{p \overbrace{z_f \, l_f^{\ \gamma} \Pi_g \left(x_{f,g}^{\ \alpha_g}\right)}^{y_f}}_{\text{revenue}} - \underbrace{\sum_{g=1}^{G} r_g \tau_{f,g} \qquad x_{f,g}}_{\text{flex. input costs}}$$

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- L_f fixed $\rightarrow$ land is also distorted unless distributed to equalize λ_f
  - e.g. lacking property rights, communal land distribution
- distortions extracted from observed input, output choices
  - rationalize all heterogeneity in data ▶ *details*

Farm: Multiple Products

$$\max \underbrace{\sum_{i=1}^{N} p_i \overbrace{z_{f,i} {l_{f,i}}^{\gamma_i} \Pi_g \left({x_{f,g,i}}^{\alpha_{g,i}} \right)}^{y_{f,i}}}_{\text{revenue}} - \underbrace{\sum_{g=1}^{G} r_g \tau_{f,g} \sum_{i=1}^{N} \tau_{f,g,i} x_{f,g,i}}_{\text{flex. input costs}}$$

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- l in fixed supply $L_f \rightarrow$ interdependent crop production
  - params of crop i change $\rightarrow \lambda_f$ changes $\rightarrow$ inputs and outputs of crops $-i$ change
  - *Just, Zilberman, and Hochman (1983)*, *Shumway, Pope, Nash (1984)*
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- farm-input-crop distortions $\tau_{f,g,i}$, $\tau_{f,l,i}$

  $\rightarrow$ fit observed input ratio heterogeneity across crops within a farm

Farm: Fixed Cost

$$\max \underbrace{\sum_{i=1}^{N} p_i \overbrace{z_{f,i} {l_{f,i}}^{\gamma_i} \Pi_g \left({x_{f,g,i}}^{\alpha_{g,i}} \right)}^{y_{f,i}}}_{\text{revenue}} - \underbrace{\sum_{g=1}^{G} r_g \tau_{f,g} \sum_{i=1}^{N} \tau_{f,g,i} x_{f,g,i}}_{\text{flex. input costs}} - \underbrace{\sum_{i=1}^{N} \omega \cdot 1[y_{f,i} > 0]}_{\text{fixed cost per crop}}$$

$$\text{s.t.} \quad \sum_{i=1}^{N} l_{f,i} \tau_{f,l,i} = L_f \qquad (\lambda_f)$$

- fixed cost ω per produced crop
  - $\rightarrow$ farms choose **crop set** in addition to **crop mix**
  - – farms don't all produce everything
  - $\rightarrow$ fit observed heterogeneity in crop sets

Farm: Concavity

$$\max \underbrace{\sum_{i=1}^{N} \left(p_i \overbrace{z_{f,i} {l_{f,i}}^{\gamma_i} \Pi_g \left({x_{f,g,i}}^{\alpha_{g,i}} \right)}^{y_{f,i}} \right)^{\eta}}_{\text{revenue}} - \underbrace{\sum_{g=1}^{G} r_g \tau_{f,g} \sum_{i=1}^{N} \tau_{f,g,i} x_{f,g,i}}_{\text{flex. input costs}} - \underbrace{\sum_{i=1}^{N} \omega \cdot 1[y_{f,i} > 0]}_{\text{fixed cost per crop}}$$

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- crop-level concavity term $\eta < 1$

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  - risk

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▶ *solution* ▶ *GE*

Reallocation Exercises

Benchmark Exercise

reallocation gain

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reallocation gain

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multi-product:	294%	
1-product:	212%	(28% ↓)

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▶ *reallocation exercise details* ▶ *sensitivity to concavity* ▶ *role of states, seasons*

Mechanisms

Mechanisms Contributing to 1-Product Model Error

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  - 1-product model misses consumer's ability to substitute toward high-RS products
  - → understates **misallocation**

Mechanisms Decomposition: Benchmark Reallocation

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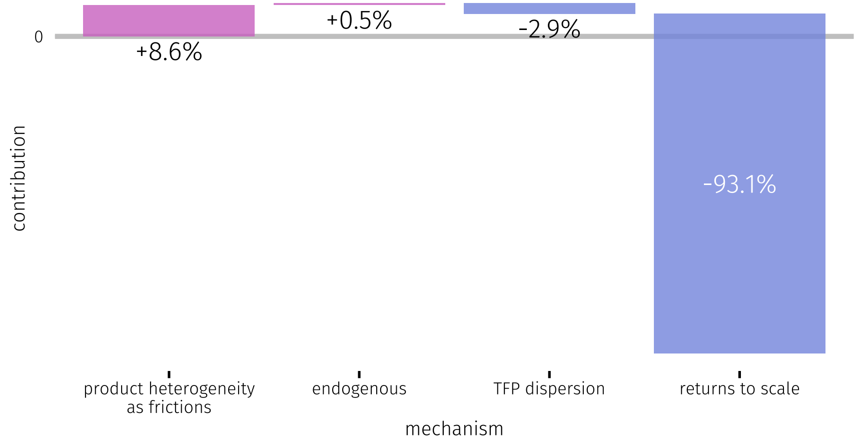

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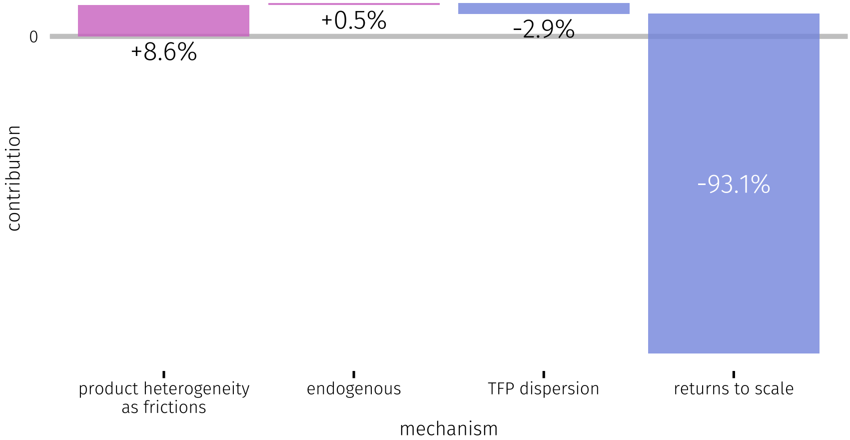

- assess total drag of misallocation → farms' ability to expand matters most
  → single-product model understates **misallocation**

Mechanisms Decomposition: "Least-Distorted State" Reallocation

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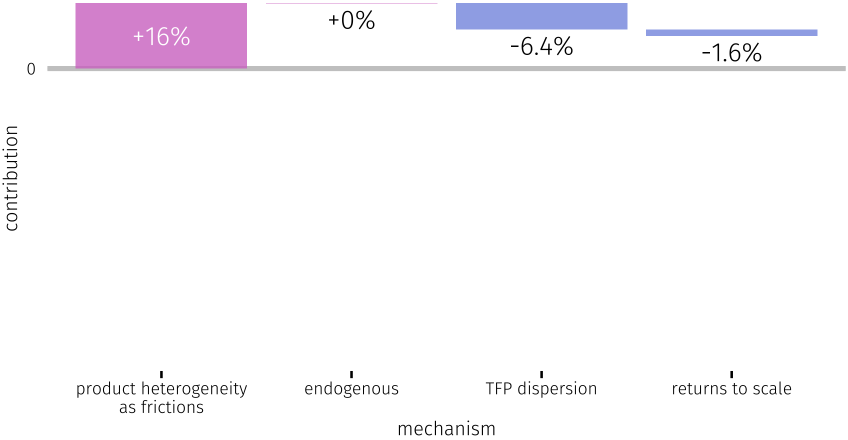

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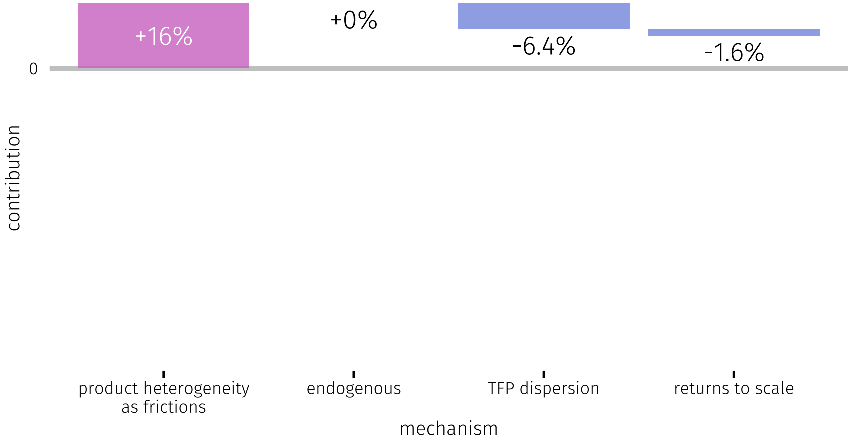

- consider partial reallocations → estimation of frictions matters most
  → single-product model overstates **misallocation** ▶ *details*

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  - $\rightarrow$ input choices may appear inefficient statically but be optimal dynamically

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  - firm-product (farm-crop) inputs and outputs are feasible to measure
  - products (crops) are $\sim$homogeneous across firms (farms)
- but mechanism applies to **non-agricultural** settings too
  - $\rightarrow$ relevant for *more* developed countries too

back

Farm Solution Expressions

$$\sum_{i \in I_f} \left(\lambda_f^{\frac{\eta \sum_g \alpha_{g,i} - 1}{1 - \eta \sum_g \alpha_{g,i} - \eta \gamma_i}} \right) \left((p_i z_{f,i})^{\eta} \, \eta \left(\frac{\gamma_i}{\tau_{f,l,i}} \right)^{1 - \eta \sum_g \alpha_{g,i}} \Pi_g \left(\frac{\alpha_{g,i}}{r_g \tau_{f,g} \tau_{f,g,i}} \right)^{\eta \alpha_{g,i}} \right)^{\frac{1}{1 - \eta \sum_g \alpha_{g,i} - \eta \gamma_i}} \tau_{f,l,i} = L_f$$

$$x_{f,g,i} = \frac{\alpha_{g,i}}{r_g \tau_{f,g} \tau_{f,g,i}} \left(\frac{\gamma_i}{\lambda_f \tau_{f,l,i}} \right)^{\frac{\eta \gamma_i}{1 - \eta \sum_g \alpha_{g,i} - \eta \gamma_i}} \left((p_i z_{f,i})^{\eta} \, \eta \Pi_h \left(\frac{\alpha_{h,i}}{r_h \tau_{f,h} \tau_{f,h,i}} \right)^{\eta \alpha_{h,i}} \right)^{\frac{1}{1 - \eta \sum_h \alpha_{h,i} - \eta \gamma_i}}$$

$$l_{f,i} = \left((p_i z_{f,i})^{\eta} \, \eta \left(\frac{\gamma_i}{\lambda_f \tau_{f,l,i}} \right)^{1 - \eta \sum_g \alpha_{g,i}} \Pi_g \left(\frac{\alpha_{g,i}}{r_g \tau_{f,g} \tau_{f,g,i}} \right)^{\eta \alpha_{g,i}} \right)^{\frac{1}{1 - \eta \sum_g \alpha_{g,i} - \eta \gamma_i}}$$

back

List of crops

Crop list

Rice	Wheat	Other Cereals	Pulses	Oilseeds, Fruits and Vegetables		
				Oilseeds	Vegetables	Fruits /Condiments
		Barley	Black gram	Sesame	Ash gourd	Mango
		Maize	Green peas	Groundnut	Beet root	Papaya
		Sorghum	Pigeon peas	Castor	Bitter gourd	Grapes
		Pearl millet	Horse gram	Sunflower	Bottle gourd	Plum
		Finger millet	Cowpea	Niger	Eggplant	Cardamom
		Others	Kidney bean	Soybean	Board bean	Chilli
			Lentil	Safflower	Cabbage	Cumin
			Chickpeas	Rapseed	Cauliflower	Dill seed
			Others	Linseed	Carrot	Indian mustard
				Others	Potato	Other
					Cucumber	
					Peas	

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- **2SLS first stage**:

$$M_{j,i,t} = Z_{k \neq j,i,t} + \mu_{j,i,t}$$

  - M = land, labor, intermediates
  - $Z_{k \neq j,i,t}$: instruments **from other plots within farm**
    - > agricultural shocks interacted with plot characteristics
    - > household, community characteristics & shocks interacted with plot characteristics

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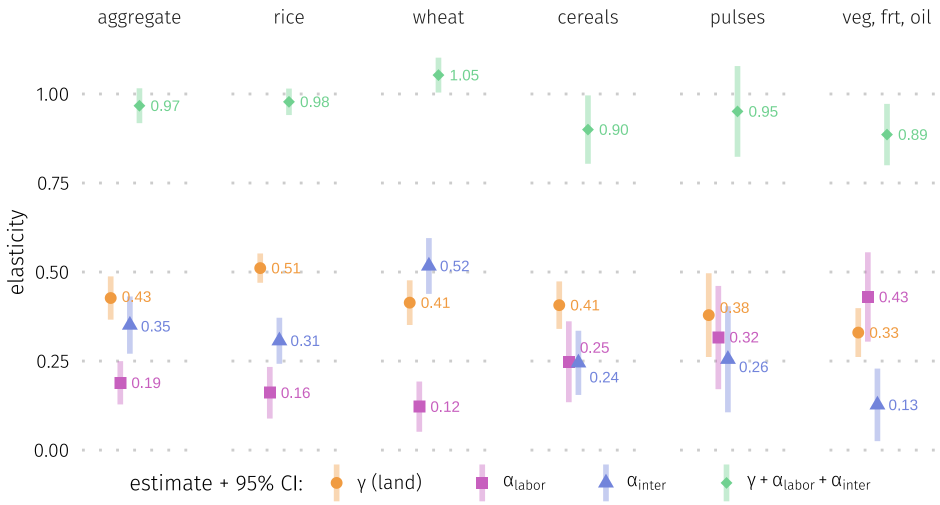
Production Functions: All Crops



back

Production Functions: Table

	Aggregate	Rice	Wheat	Other Cereals	Pulses	Veg, Frt, Oil
Land	0.427	0.511	0.414	0.407	0.379	0.330
	(0.031)	(0.021)	(0.032)	(0.034)	(0.060)	(0.035)
Labor	0.189	0.161	0.122	0.248	0.316	0.430
	(0.031)	(0.037)	(0.036)	(0.058)	(0.074)	(0.064)
Intermediates	0.351	0.307	0.517	0.245	0.255	0.127
	(0.041)	(0.033)	(0.040)	(0.046)	(0.076)	(0.052)
Observations	14,705	4,807	3,566	2,779	1,128	2,338
R^2	0.624	0.742	0.713	0.590	0.417	0.572
Village FEs	Y	Y	Y	Y	Y	Y
Season FEs	Y	Y	Y	Y	Y	Y
			First Stage: F statistics			
Land	77.0	62.0	40.3	37.8	15.7	19.3
Labor	49.3	34.7	17.7	25.2	12.9	14.8
Intermediates	35.8	31.7	21.5	19.9	8.9	11.8
K-Paap Wald F statistic	51.1	40.4	16.0	30.8	12.4	12.7

back

Production Functions: Pairwise Equality Test P-Values

γ

	rice	wheat	cereals	pulses
veg, frt, oil	<0.01	0.95	0.62	0.73
pulses	0.05	0.7	1	
cereals	<0.01	0.57		
wheat	<0.01			

α_{labor}

	rice	wheat	cereals	pulses
veg, frt, oil	<0.01	<0.01	0.08	0.43
pulses	0.01	0.03	0.3	
cereals	0.17	0.33		
wheat	0.65			

α_{inter}

	rice	wheat	cereals	pulses
veg, frt, oil	<0.01	<0.01	0.08	0.27
pulses	0.53	<0.01	0.94	
cereals	0.35	<0.01		
wheat	<0.01			

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     - *expressions*
- for each farm, pick profit-maximizing crop set

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- subsistence farmer with love of variety
  - farmer minimizes costs of providing utility U:

$$U = \left(\sum_i \varphi_i y_{f,i}^{\eta} \right)^{\frac{1}{\eta}}$$

  $\rightarrow$ mix crops to provide a diverse diet
- crop-level markets are monopolistically competitive
  - intermediate crop aggregator combines farms' varieties:

$$Y_i = \left(\sum_f y_{f,i}^{\eta} \right)^{\frac{1}{\eta}}$$

  $\rightarrow$ mix crops due to downward-sloping demand in each crop
- both setups produce farm-level FOCs that are identical to the main model
  - but the appropriate way to define GE may be different

back

Extracting Distortions

- unobserved **distortions** map to observed **marginal revenue products**:

$$r_g \tau_{f,g} \tau_{f,g,i} = \frac{\alpha_{g,i} \eta \left(p_i y_{f,i} \right)^{\eta}}{x_{f,g,i}} = mrpg_{f,i}$$

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distorted economy

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▶ *splitting distortions*

back

Splitting Distortions

- splitting $r_g \tau_{f,g} \tau_{f,g,i}$ into 3 terms is arbitrary from farm f's POV

back

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back

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  - but will matter for *partial* reallocation exercises $\rightarrow$ come up with a sensible split

back

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- split $r_g \tau_{f,g}$ from $\tau_{f,g,i}$:

back

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back

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- likewise restrict $\tau_{f,l,i}$:
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back

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- split of r_g from $\tau_{f,g}$ imposed by GE

back

Estimate the Elasticity of Substitution

- from consumption FOC:

$$\log\left(\frac{p_i C_i}{\sum_j p_j C_j}\right) = -\log\left(\sum_j \varphi_j^{\sigma} p_j^{1-\sigma}\right) + (1-\sigma)\log p_i + \sigma \log \varphi_i$$

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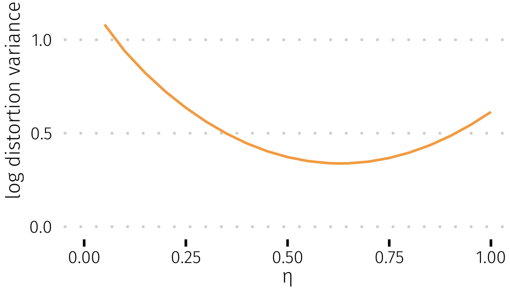
	$\log s_{h,i}$
σ	1.699
$\log p_{h,i}$	-0.699 (0.067)
Observations	40,833
Kleibergen-Paap F stat	230.9

Village-level instruments: Elevation × rain, ruggedness × rain, pucca roads availability

back

Choose η That Minimizes Implied Dispersion

- τs reproducing data need to be extreme if η is too high or too low



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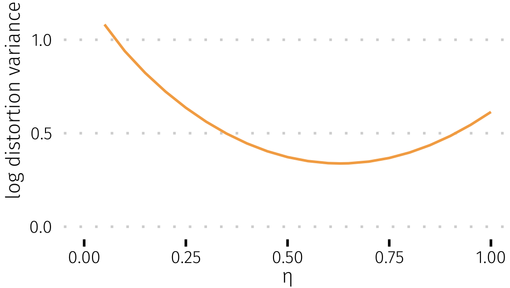

- **low** η: farm, farm-crop output more uniformly distributed in efficient allocation
  $\rightarrow$ data farm size **"too varied"**, farms mix crops **"too little"** $\rightarrow$ extreme distortions

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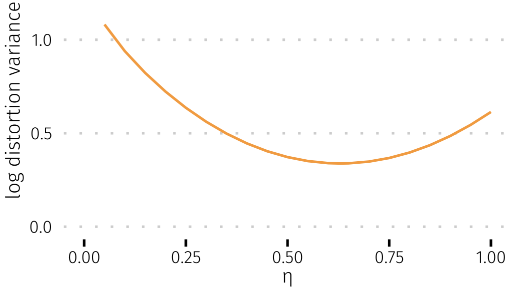

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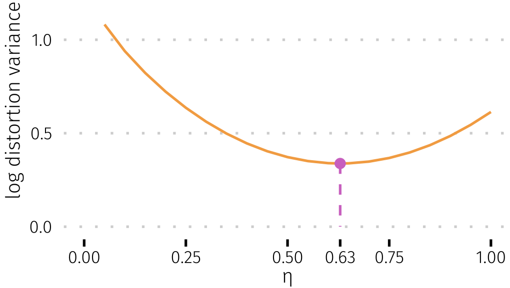

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$\rightarrow$ pick η that minimizes distortions required to explain observed output distribution

- $\rightarrow$ conservative misallocation estimates

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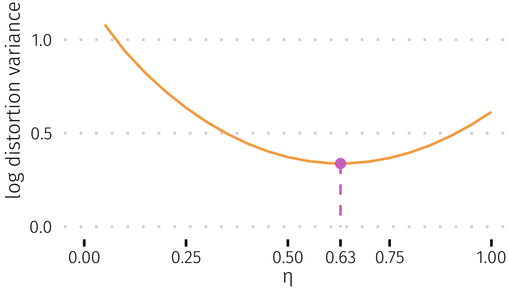

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▶ *details*

back

General Equilibrium

- representative consumer buys crops, sells inputs, receives profit from owned farms

$$\max_{\{C_i\}_{i=1}^N} \left(\sum_i \varphi_i C_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

s.t.

$$\sum_i p_i C_i = \sum_g r_g X_g^{agg} + \Pi$$

back

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back

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▶ *profits details*

back

Choose η That Minimizes Implied Dispersion

- farm-crop revenue:

$$p_i y_{f,i} = \underbrace{\left(\left(\frac{1}{\lambda_f \tau_{f,m,i}} \right)^{\gamma_i} \Pi_g \left(\frac{1}{\tau_{f,g} \tau_{f,g,i}} \right)^{\alpha_{g,i}} \right)^{\frac{1}{1-\eta(\sum_g \alpha_{g,i}+\gamma_i)}}}_{\text{composite distortion, } dist_{f,i}} \underbrace{\left(p_i z_{f,i} \gamma_i^{\gamma_i} \eta^{\sum_g \alpha_{g,i}+\gamma_i} \Pi \left(\frac{\alpha_{g,i}}{r_g} \right)^{\alpha_{g,i}} \right)^{\frac{1}{1-\eta(\sum_g \alpha_{g,i}+\gamma_i)}}}_{\text{“objective” factors}}$$

back

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- $Var(\log dist_{f,i})$ needed to match observed output dispersion depends on chosen η

back

GE Profits

$$\Pi = \sum_f \left[\sum_{i=1}^{N} p_i y_{f,i} - \sum_{g=1}^{G} r_g \sum_{i=1}^{N} x_{f,g,i} \right]$$

- distortions τ, fixed costs ω, concavity η are not reflected in dividends sent to consumer
  - farmers act *as if* frictions they face had monetary representations
  - but these are non-monetary and not added/subtracted from dividends
- equivalent formulation: τs, ωs are monetary taxes/subsidies, administered by consumer
  - show up in dividends and consumer's BC as government revenue/expense
- choice is arbitrary: both formulations (or any mixture) produce identical equilibrium conditions

back

Reallocation

- to quantify **aggregate cost** of distortions, conduct **counterfactual reallocations**

back

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- treat each season as a separate economy
  - to prevent double-booking of inputs in a single season
  - sum aggregate output across seasons

back

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  - **reallocation gain** = Δoutput between counterfactual and current

back

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  - sum aggregate output across seasons
- compute counterfactual Δoutput
  - **reallocation gain** = Δoutput between counterfactual and current
  - aggregate inputs are fixed $\rightarrow$ aggregate output $\uparrow$ reflects aggregate TFP $\uparrow$

back

REALLOCATION

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  - **reallocation gain** = Δoutput between counterfactual and current
  - aggregate inputs are fixed $\rightarrow$ aggregate output $\uparrow$ reflects aggregate TFP $\uparrow$
  - farm-level TFPs are fixed $\rightarrow$ aggregate TFP $\uparrow$ reflects pure **reallocation gain** or **misallocation cost**

back

Reallocation

- to quantify **aggregate cost** of distortions, conduct **counterfactual reallocations**
- equalize (or reduce) distortions τ between farms
- prohibit product set switching
  $\rightarrow$ don't need productivities, frictions for unobserved farm-product combinations
- treat each season as a separate economy
  - to prevent double-booking of inputs in a single season
  - sum aggregate output across seasons
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  - aggregate inputs are fixed $\rightarrow$ aggregate output $\uparrow$ reflects aggregate TFP $\uparrow$
  - farm-level TFPs are fixed $\rightarrow$ aggregate TFP $\uparrow$ reflects pure **reallocation gain** or **misallocation cost**
- compare **reallocation gain** between **multi-product** model and **1-product** model

▶ *reallocation exercise details*

back

Reallocation Exercise Details

- **reallocation 1**: equalize land and labor distortions, crop sets fixed

back

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  - farms can't change crop sets, but can change crop ratios

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  $\rightarrow$ need to parameterize **unconditional** z, τ distributions and calibrate to match observed **conditional** distributions

back

Benchmark Exercise Sensitivity

η \ σ	1.1	1.3	1.5	1.7	1.9	2.1	2.3
0.93	1588	1781	1961	2123	2267	2393	2503
0.83	1300	1472	1635	1787	1924	2047	2157
0.73	762	837	909	977	1040	1098	1152
0.63	277	284	289	*294*	299	303	306
0.53	139	140	140	141	141	142	142
0.43	99	99	99	99	99	100	100
0.33	79	79	80	80	80	80	80

(a) reallocation gain, %

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(a) reallocation gain, %

η \ σ	1.1	1.3	1.5	1.7	1.9	2.1	2.3
0.93	+6	-6	-14	-21	-26	-30	-33
0.83	+3	-9	-18	-25	-30	-34	-38
0.73	-38	-43	-48	-52	-55	-57	-59
0.63	-23	-25	-27	-28	-29	-30	-31
0.53	-2	-3	-3	-4	-4	-4	-5
0.43	+2	+2	+2	+2	+2	+1	+1
0.33	+2	+2	+2	+2	+2	+2	+2

(b) single-product model error, %

- misallocation estimates are always sensitive to calibrated concavity
  - firms can expand grow more easily in reallocation $\rightarrow$ greater gain
- sign and magnitude of single-product model's error also depends on calibration

back

Reallocation: Role of States and Seasons

	main	within state	no split by season
multi-product:	294%	107%	314%
1-product:	212%	124%	260%

back

Mechanism I: Product Heterogeneity as Frictions

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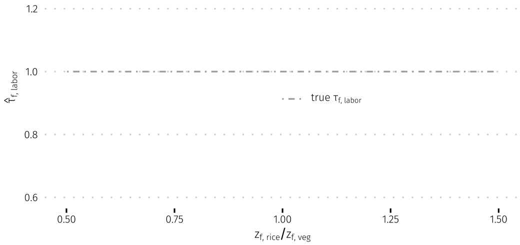

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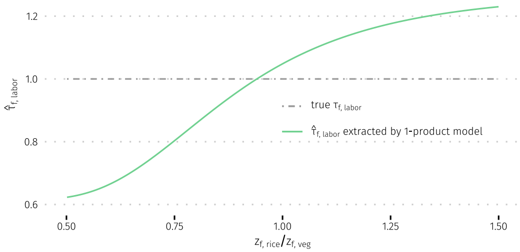

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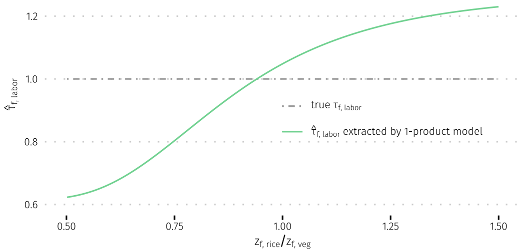

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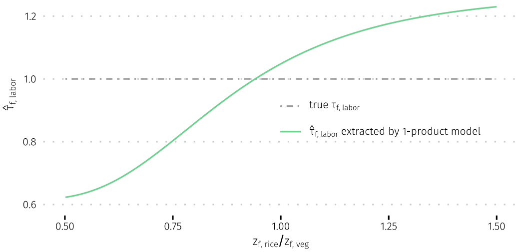

- **exercise to isolate**: apply 1-product model to counterfactual reallocation data generated by multi-product model

Mechanism II: TFP Dispersion

- 1-product model understates TFP dispersion

back

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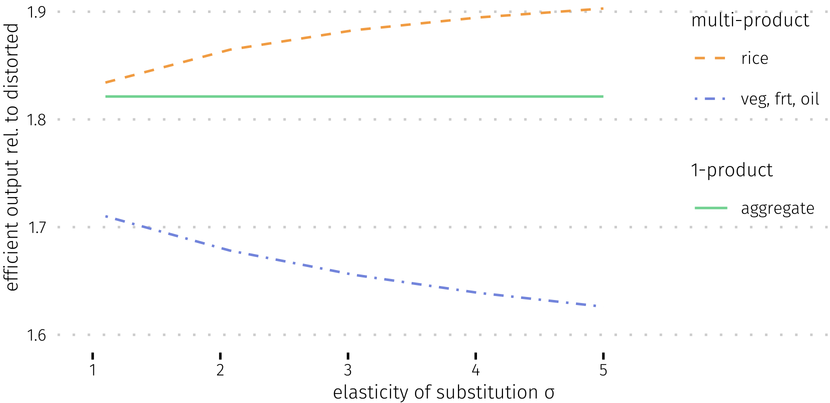
- **exercise to isolate**: treat farm-crops as separate farms for 1-product model

back

Mechanism III: Returns to Scale

- some products have higher returns to scale → some farms grow more in reallocation



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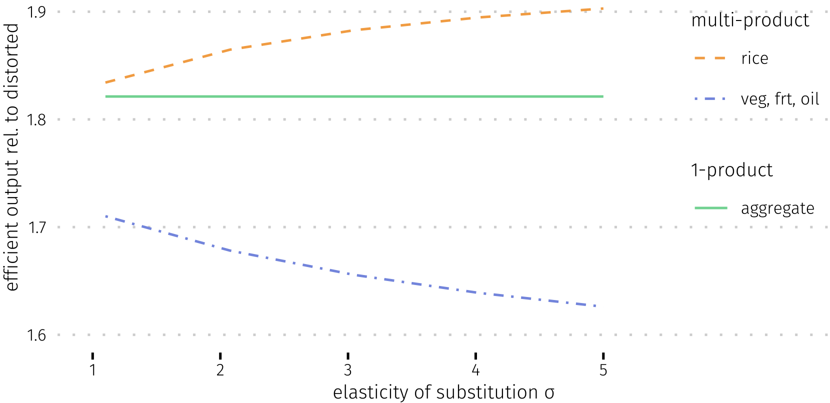
- $\rightarrow$ consumer can substitute toward high-RS products to take advantage



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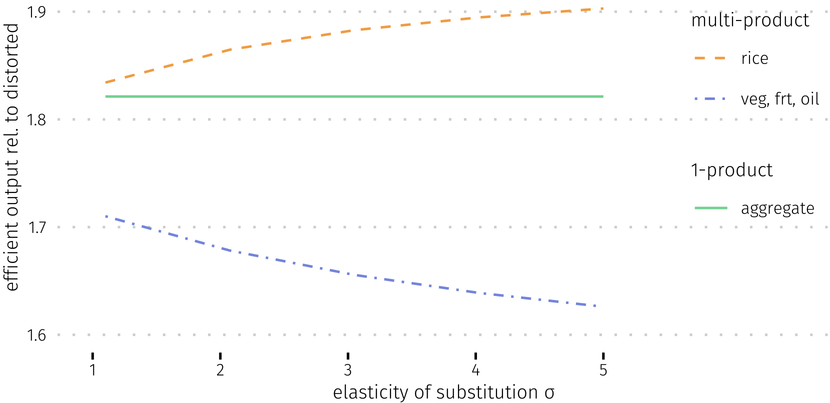

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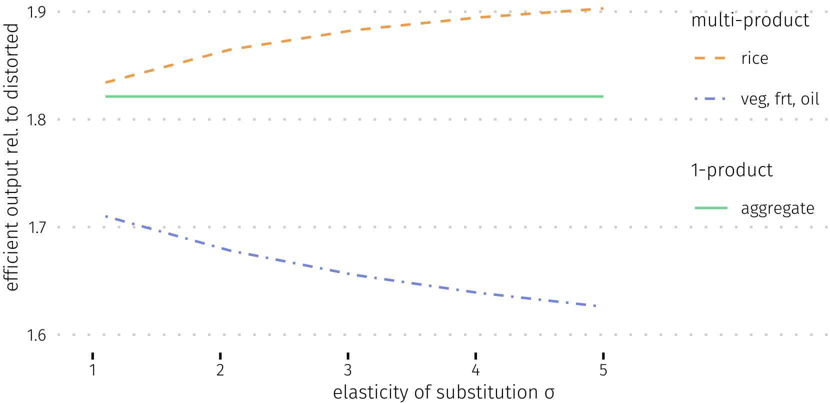
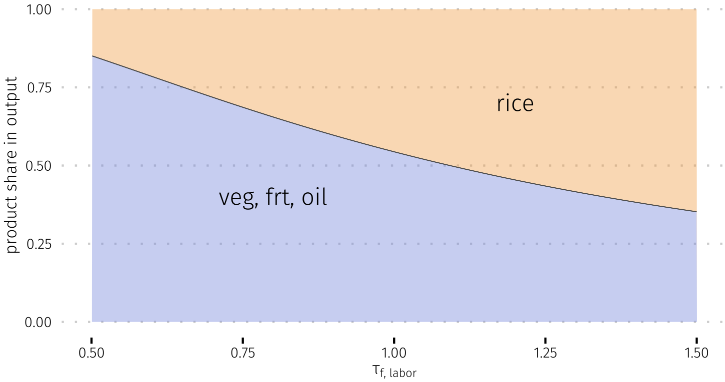
- **exercise to isolate**: rescale input elasticities to equalize returns to scale



Mechanism IV: Endogenous Product Choice

- simulated multi-product farm as labor distortion $\tau_{f,labor}$ is varied:



- $\tau_{f,labor} \uparrow \rightarrow$ shift from labor-intensive vegetables to land-intensive rice

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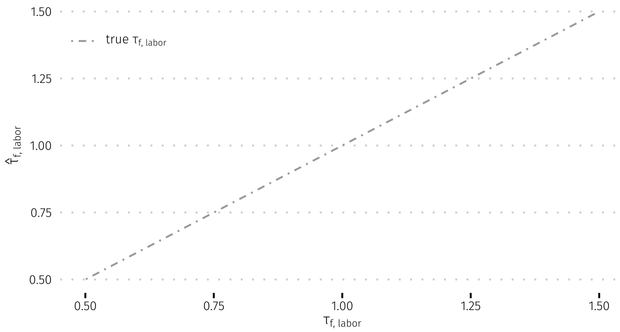
Mechanism IV: Endogenous Product Choice

- apply **single**-product model to extract frictions from simulated **multi**-product data



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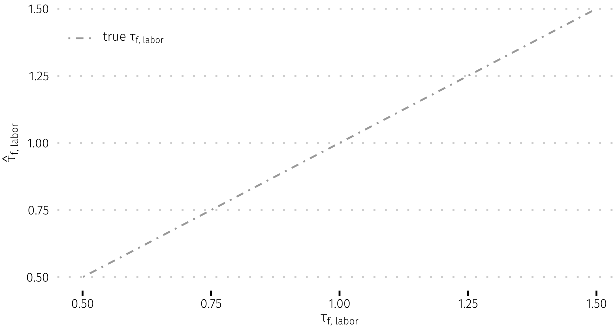
Mechanism IV: Endogenous Product Choice

- apply **single**-product model to extract frictions from simulated **multi**-product data
- **multi-product model**: optimal product choice response to frictions
  - modest $\tau_{f,labor}$ increase $\rightarrow$ shift to land-intensive rice $\rightarrow$ hire even more land rel. to labor



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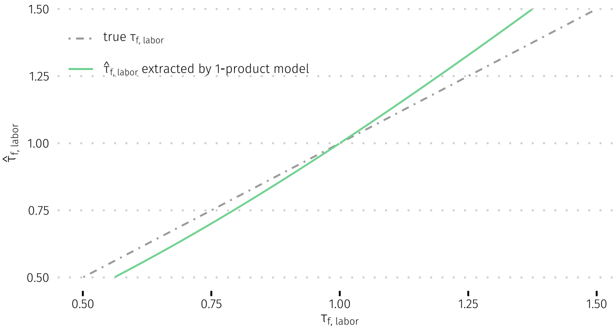

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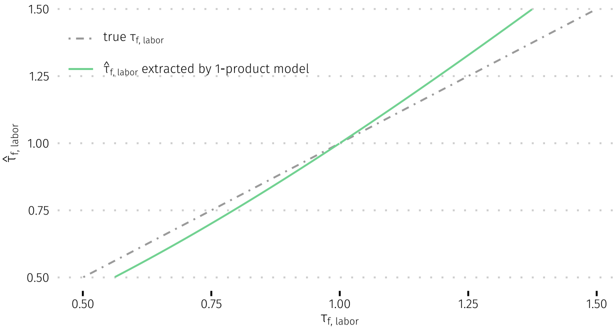


back

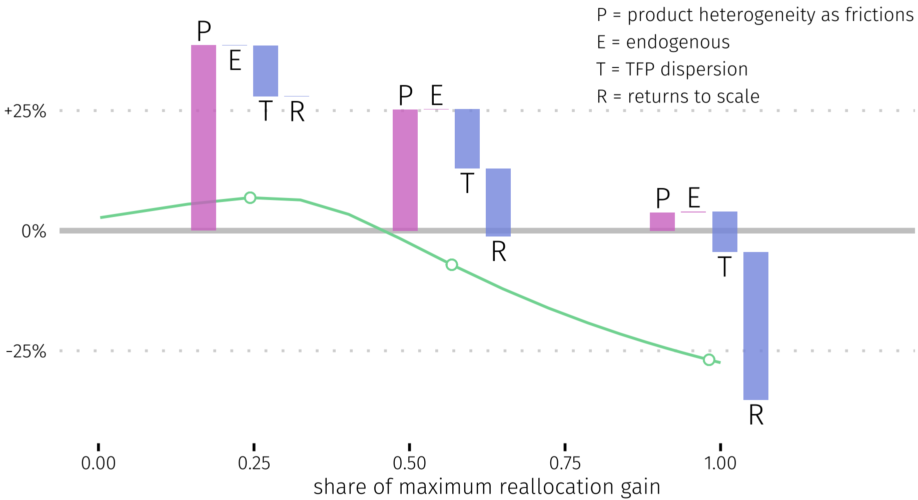
Mechanism IV: Endogenous Product Choice

- **exercise to isolate**: prohibit farms in multi-product model to change product choice in counterfactuals
  - keep product sets fixed
  - keep input allocation across crops fixed: farm can choose $\sum_i x_{f,g,i}$ but $x_{f,g,i}$ gets a fixed share of total

back

Remove More Distortions → 1-Product Model Overstates

- 1-product error when conducting increasingly expansive reallocations:



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