

MISALLOCATION AND PRODUCT CHOICE

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Jan 5, 2024

ES NAWM, ASSA 2024

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how does heterogeneous product choice affect
aggregate misallocation cost?

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- but mechanisms apply equally to other sectors

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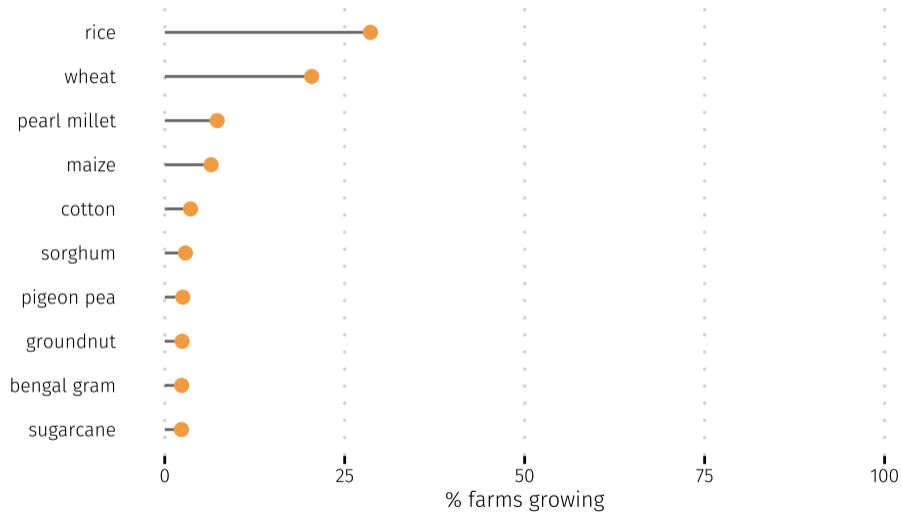
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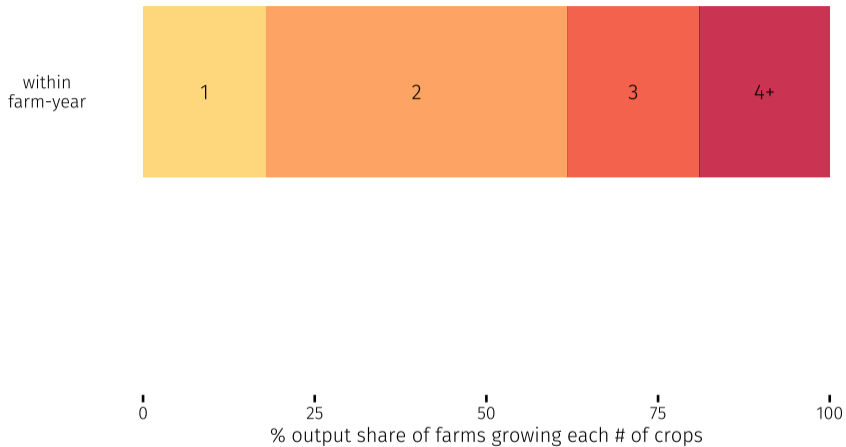
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MULTI-PRODUCT FARMS IN INDIA

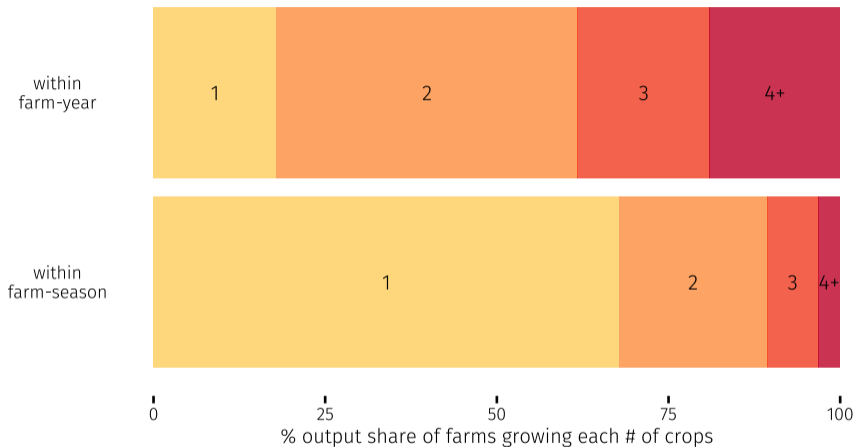
CROP CHOICE IS HETEROGENEOUS



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

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- production function:

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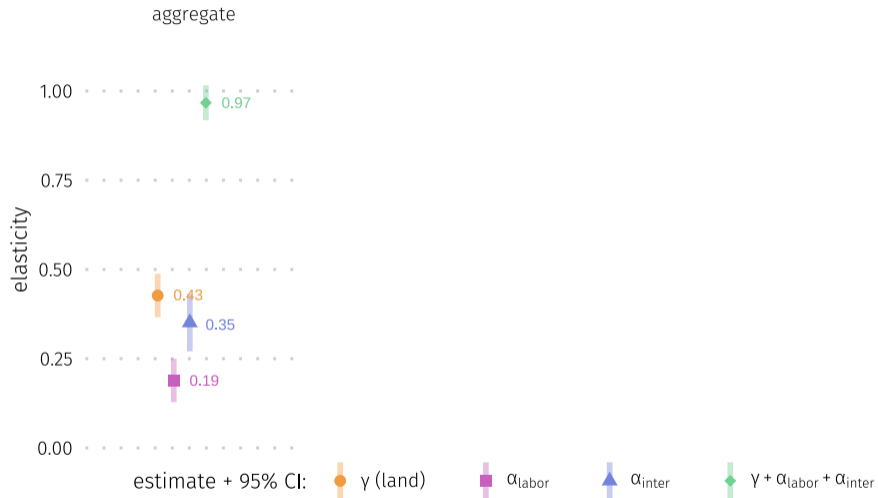
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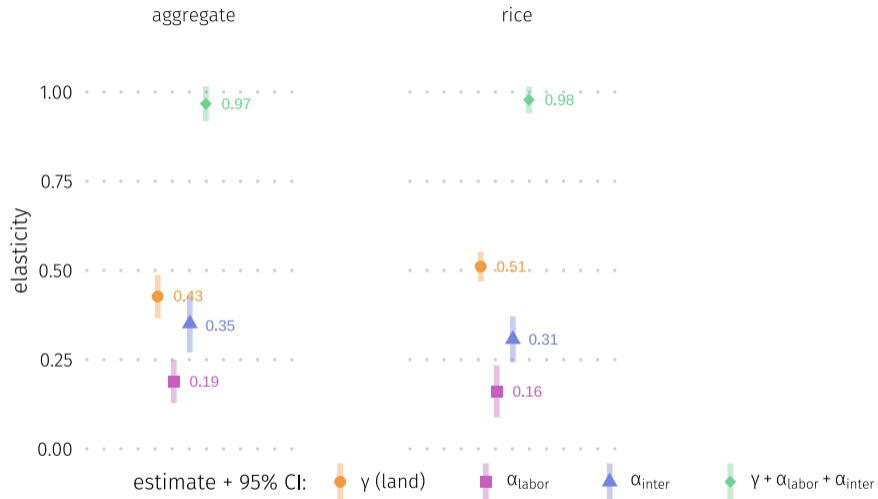
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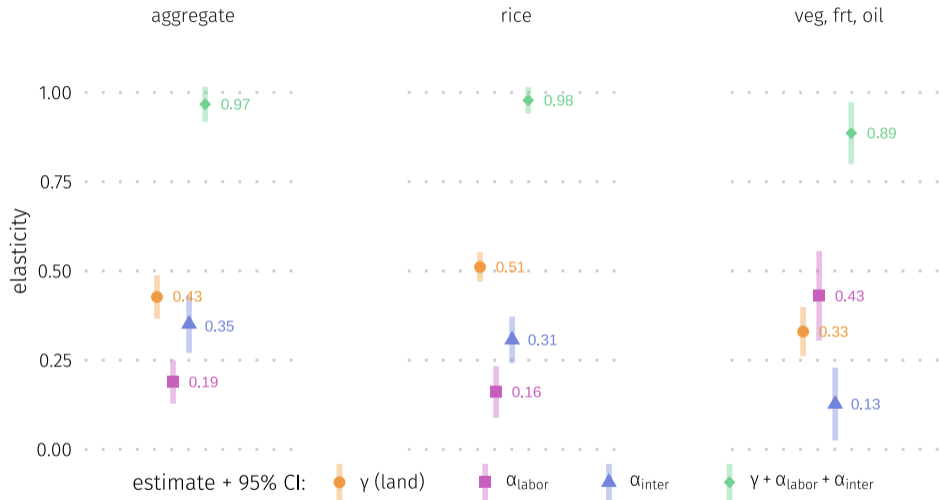
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- flexible inputs g : labor, intermediates
 - quantity $X_{f,g}$ rented at r_g

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$$\max \underbrace{p z_f l_f^\gamma \prod_g (x_{f,g}^{\alpha_g})}_{\text{revenue}} - \underbrace{\sum_{g=1}^G r_g x_{f,g}}_{\text{flex. input costs}}$$

s.t. $l_f = L_f \quad (\lambda_f)$

- 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

$$\begin{aligned}
 \max \quad & \underbrace{\rho z_f l_f^\gamma \prod_g (x_{f,g}^{\alpha_g})}_{\text{revenue}} - \underbrace{\sum_{g=1}^G r_g \tau_{f,g} x_{f,g}}_{\text{flex. input costs}} \\
 \text{s.t.} \quad & l_f = L_f \quad (\lambda_f)
 \end{aligned}$$

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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 \blacktriangleright *details*

FARM: MULTIPLE PRODUCTS

$$\begin{aligned}
 \max \quad & \underbrace{\sum_{i=1}^N p_i z_{f,i} l_{f,i}^{\gamma_i} \Pi_g (X_{f,g,i}^{\alpha_{g,i}})}_{\text{revenue}} - \underbrace{\sum_{g=1}^G r_g \tau_{f,g} \sum_{i=1}^N \tau_{f,g,i} X_{f,g,i}}_{\text{flex. input costs}} \\
 \text{s.t.} \quad & \sum_{i=1}^N l_{f,i} \tau_{f,l,i} = L_f \quad (\lambda_f)
 \end{aligned}$$

- heterogeneous crops $i = 1 \dots N$

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

- heterogeneous crops $i = 1 \dots N$
- 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)*
 - justifies *Gollin, Udry (2021)* prod. fn. identification

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 - *Just, Zilberman, and Hochman (1983), Shumway, Pope, Nash (1984)*
 - justifies *Gollin, Udry (2021)* prod. fn. identification
- farm-input-crop distortions $T_{f,g,i}, T_{f,l,i}$
 - \rightarrow fit observed input ratio heterogeneity across crops within a farm

FARM: FIXED COST

$$\begin{aligned}
 \max \quad & \underbrace{\sum_{i=1}^N p_i Z_{f,i} l_{f,i}^{\gamma_i} \Pi_g (X_{f,g,i}^{\alpha_{g,i}})}_{\text{revenue}} - \underbrace{\sum_{g=1}^G r_g \tau_{f,g} \sum_{i=1}^N \tau_{f,g,i} X_{f,g,i}}_{\text{flex. input costs}} - \underbrace{\sum_{i=1}^N \omega \cdot 1[y_{f,i} > 0]}_{\text{fixed cost per crop}} \\
 \text{s.t.} \quad & \sum_{i=1}^N l_{f,i} \tau_{f,l,i} = L_f \quad (\lambda_f)
 \end{aligned}$$

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

FARM: CONCAVITY

$$\begin{aligned}
 \max \quad & \underbrace{\sum_{i=1}^N \left(p_i Z_{f,i} l_{f,i}^{\gamma_i} \Pi_g (X_{f,g,i}^{\alpha_{g,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}} \\
 \text{s.t.} \quad & \sum_{i=1}^N l_{f,i} \tau_{f,l,i} = L_f \quad (\lambda_f)
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- crop-level concavity term $\eta < 1$

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► *solution* ► *GE*

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reallocation gain

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► *sensitivity to concavity* ► *role of states, seasons*

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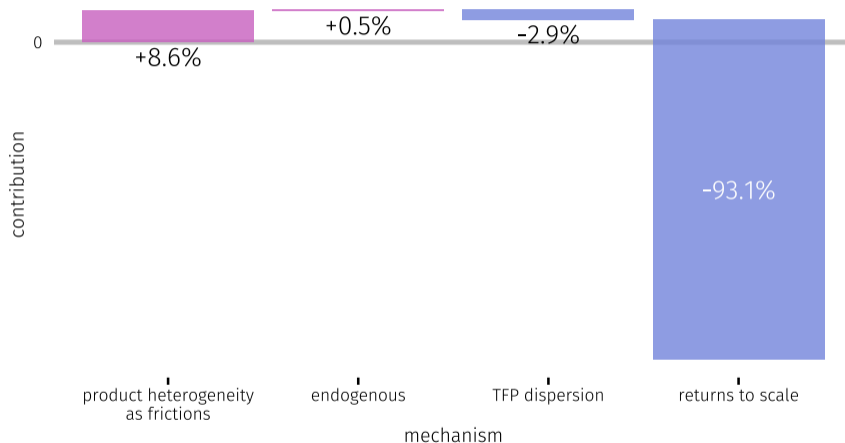
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- **benchmark:** single-product model **understates** gain by **82 pp** (28%)

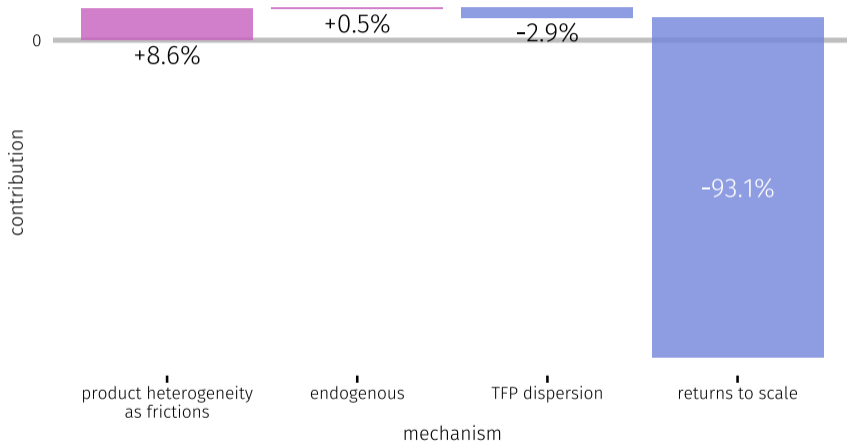
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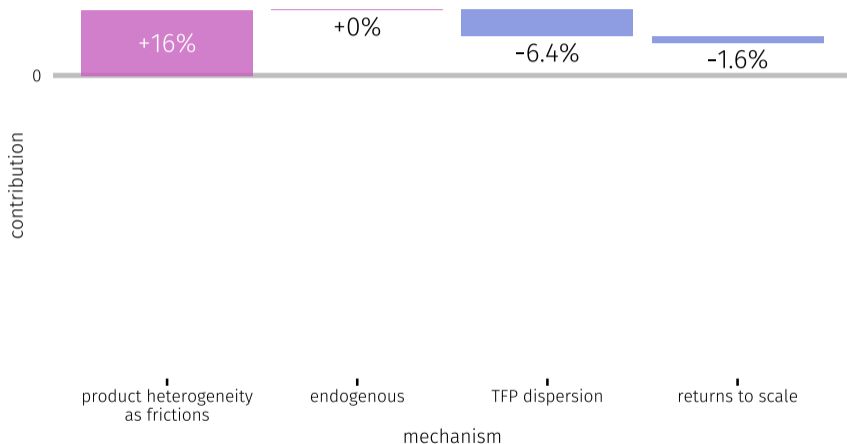
- assess total drag of misallocation → firms' ability to expand matters most
→ single-product model **understates** misallocation

MECHANISMS DECOMPOSITION: “LEAST-DISTORTED STATE” REALLOCATION

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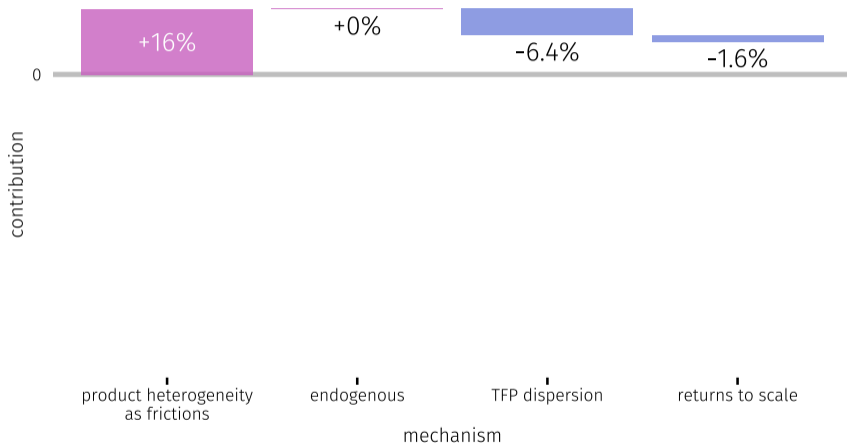
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- consider partial reallocations → estimation of frictions matters most
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- but mechanism applies to **non-agricultural** settings too
 - relevant for *more* developed countries too

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FARM SOLUTION EXPRESSIONS

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

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

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LIST OF CROPS

Crop list

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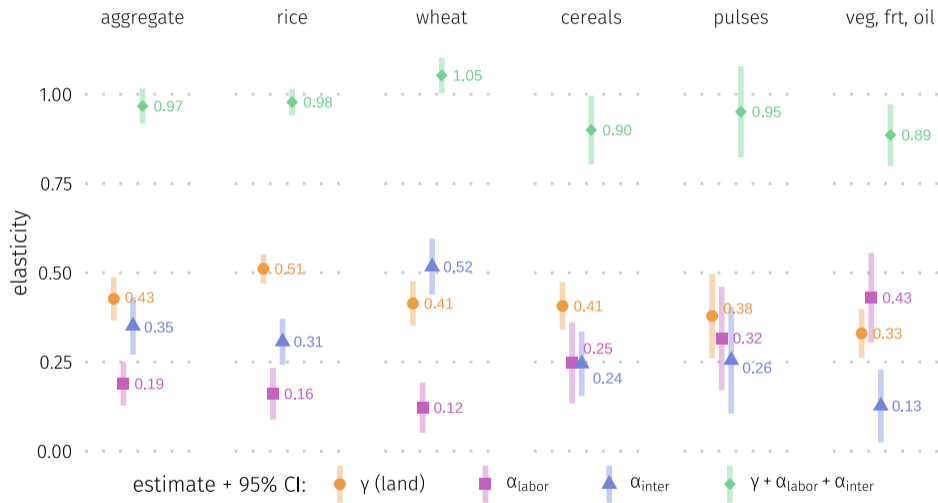
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PRODUCTION FUNCTIONS: ALL CROPS



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PRODUCTION FUNCTIONS: TABLE

	Aggregate	Rice	Wheat	Other Cereals	Pulses	Veg, Frt, Oil
Land	0.427 (0.031)	0.511 (0.021)	0.414 (0.032)	0.407 (0.034)	0.379 (0.060)	0.330 (0.035)
Labor	0.189 (0.031)	0.161 (0.037)	0.122 (0.036)	0.248 (0.058)	0.316 (0.074)	0.430 (0.064)
Intermediates	0.351 (0.041)	0.307 (0.033)	0.517 (0.040)	0.245 (0.046)	0.255 (0.076)	0.127 (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

PRODUCTION FUNCTIONS: PAIRWISE EQUALITY TEST P-VALUES



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- for each farm, pick profit-maximizing crop set

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- crop-level markets are monopolistically competitive
 - intermediate crop aggregator combines farms' varieties:

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

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 - but the appropriate way to define GE may be different

EXTRACTING DISTORTIONS

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

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

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► *splitting distortions*

SPLITTING DISTORTIONS

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

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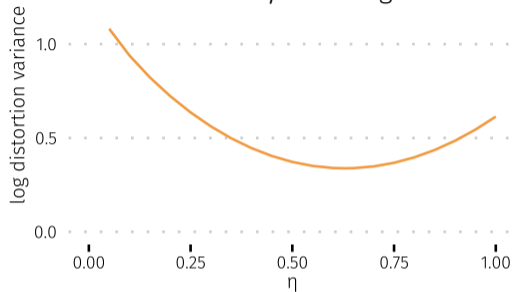
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	$\log s_{h,i}$
σ	1.699
$\log p_{h,i}$	-0.699 (0.067)
Observations	40,833
Kleibergen-Paap F stat	230.9

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

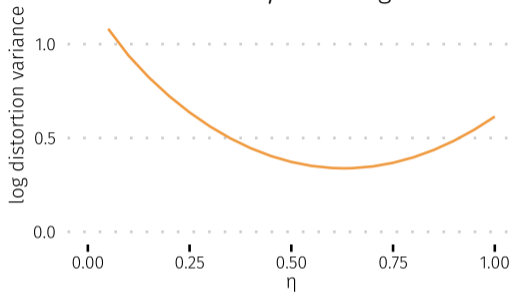
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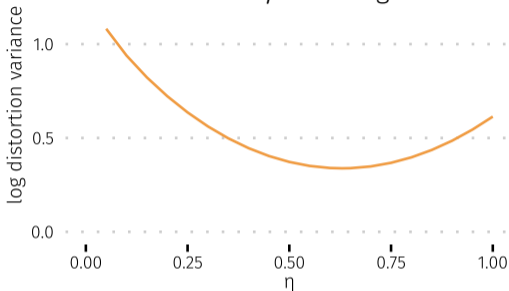
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→ data farm size “**too varied**”, farms mix crops “**too little**” → extreme distortions

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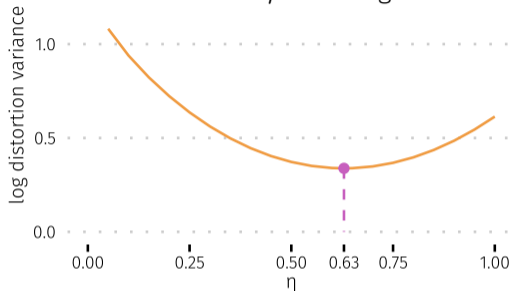
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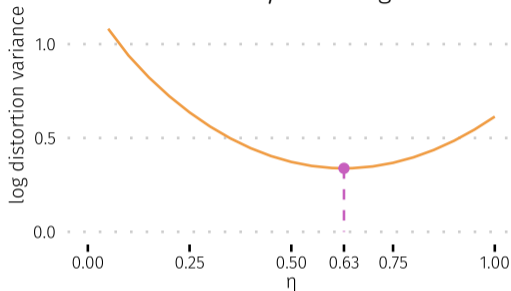
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► *details*

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.

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

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► *profits details*

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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: τ s, ω s 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

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 - aggregate inputs are fixed → aggregate output \uparrow reflects aggregate TFP \uparrow

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 - to prevent double-booking of inputs in a single season
 - sum aggregate output across seasons
- compute counterfactual Δ output
 - **reallocation gain** = Δ output between counterfactual and current
 - aggregate inputs are fixed → aggregate output \uparrow reflects aggregate TFP \uparrow
 - farm-level TFPs are fixed → aggregate TFP \uparrow reflects pure **reallocation gain** or **misallocation cost**

REALLOCATION

- to quantify **aggregate cost** of distortions, conduct **counterfactual reallocations**
- equalize (or reduce) distortions τ between farms
- prohibit product set switching
 - don't need productivities, frictions for unobserved farm-product combinations
- treat each season as a separate economy
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- compare **reallocation gain** between **multi-product** model and **1-product** model
 - ▶ *reallocation exercise details*

REALLOCATION EXERCISE DETAILS

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

back

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back

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back

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back

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back

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 - need to parameterize **unconditional** z, τ distributions and calibrate to match observed **conditional** distributions

back

BENCHMARK EXERCISE SENSITIVITY

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
ζ 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
	1.1	1.3	1.5	1.7 σ	1.9	2.1	2.3

(a) reallocation gain, %

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σ

(a) reallocation gain, %

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
	1.1	1.3	1.5	1.7	1.9	2.1	2.3

σ

(b) single-product model error, %

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

REALLOCATION: ROLE OF STATES AND SEASONS

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

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MECHANISM I: PRODUCT HETEROGENEITY AS FRICTIONS

- 1-product model misinterprets crop heterogeneity as frictions

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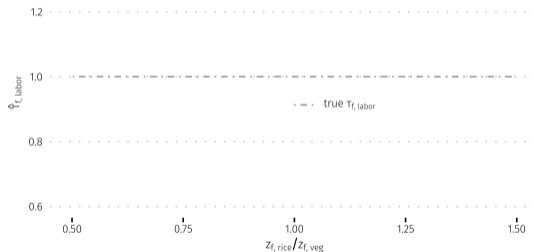
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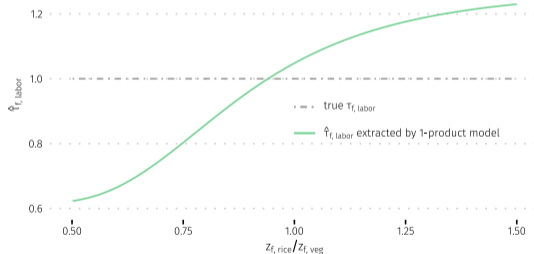
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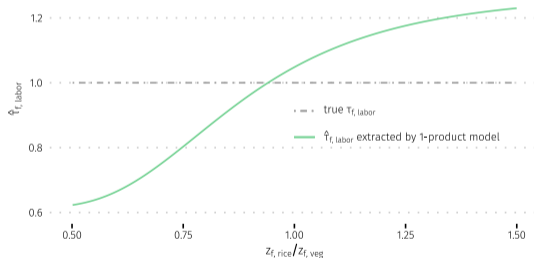
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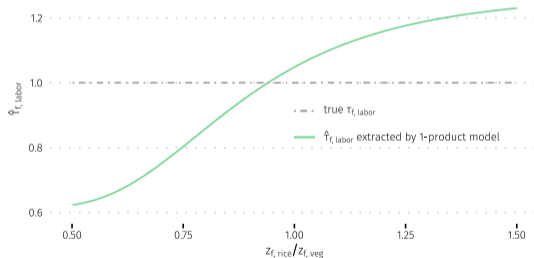
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- **exercise to isolate:** apply 1-product model to counterfactual reallocation data generated by multi-product model

MECHANISM II: TFP DISPERSION

- 1-product model understates TFP dispersion

back

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back

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 - severe frictions \rightarrow farm mostly grows rice \rightarrow avg TFP = $z_M < z_H$

back

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back

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back

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back

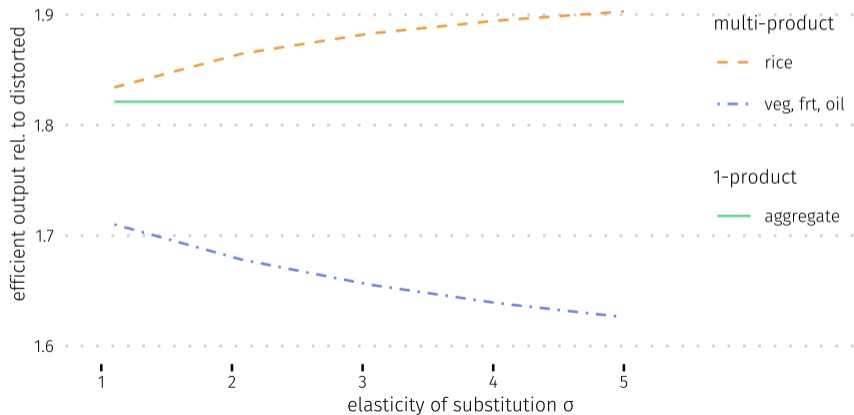
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- **exercise to isolate:** treat farm-crops as separate farms for 1-product model

back

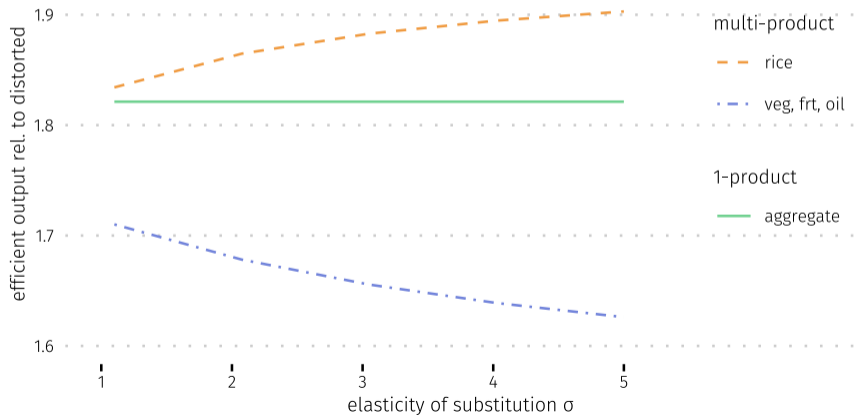
MECHANISM III: RETURNS TO SCALE

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



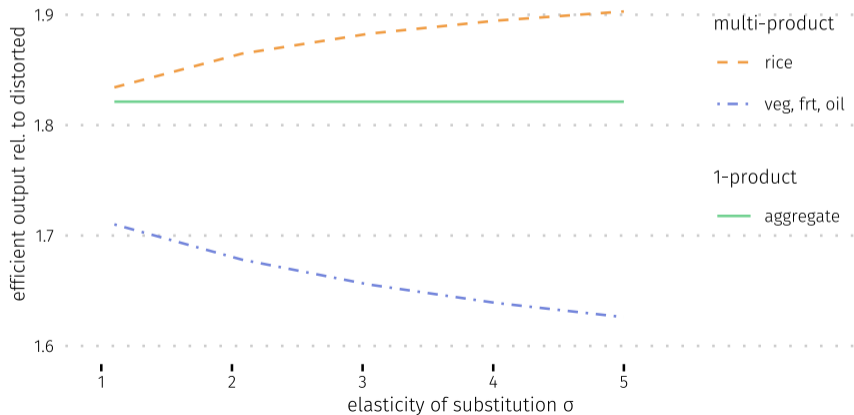
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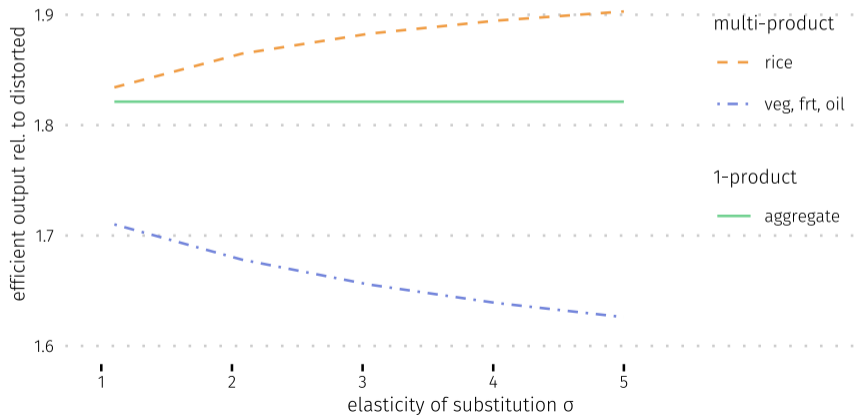
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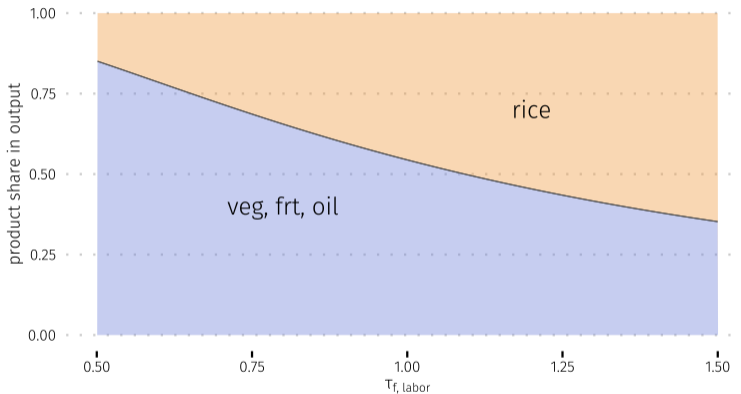
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- **exercise to isolate:** rescale input elasticities to equalize returns to scale



MECHANISM IV: ENDOGENOUS PRODUCT CHOICE

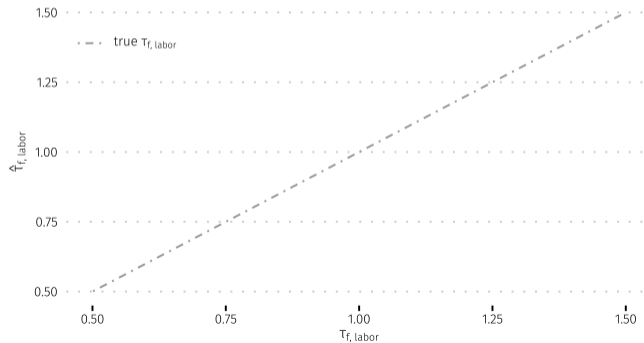
- simulated multi-product farm as labor distortion $\tau_{f,labor}$ is varied:



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

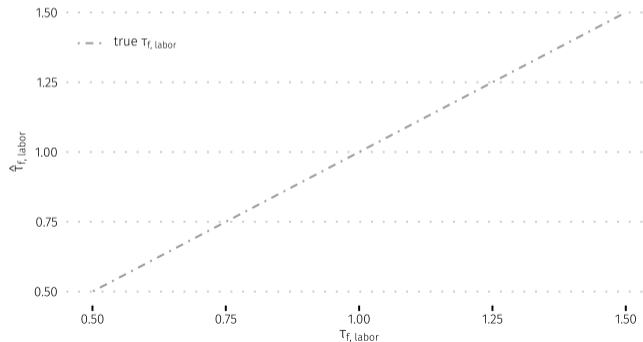
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- apply **single**-product model to extract frictions from simulated **multi**-product data



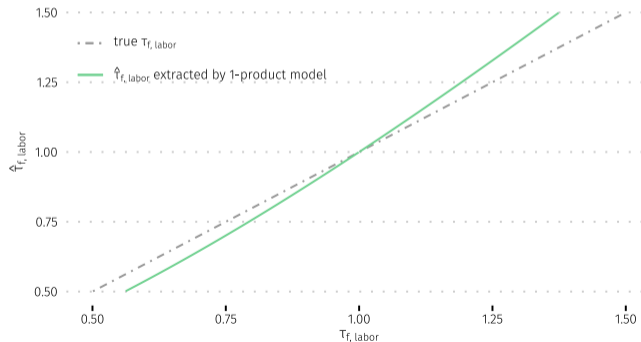
MECHANISM IV: ENDOGENOUS PRODUCT CHOICE

- 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



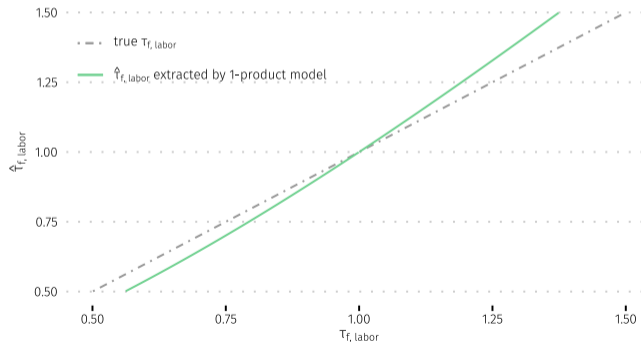
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- **1-product model**: high input ratio dispersion \rightarrow infer large heterogeneity in frictions
 - \rightarrow 1-crop model **overstates** misallocation



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

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REMOVE MORE DISTORTIONS → 1-PRODUCT MODEL OVERSTATES

- 1-product error when conducting increasingly expansive reallocations:

