The Aggregate Importance of Intermediate Input Substitutability

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Motivation

- Metals and Plastics used as intermediate inputs
- Increase in Metals sector TFP $\Rightarrow$ decrease in price

Intermediate Input Substitutability	Intermediate Input Share Metals & Plastics	Size of Metals Sector	Aggregate TFP
Cobb-Douglas		–	$\uparrow$

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Complements		$\downarrow$	$\uparrow$

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Cobb-Douglas		$-$	$\uparrow$
Complements		$\downarrow$	$\uparrow$
Substitutes		$\uparrow$	$\uparrow\uparrow$

This Paper

1. Estimate plant-level elasticities of substitution between inputs
   - At 3 levels of aggregation:
     - 8 categories of materials (plastics, metals, ...)
     - Energy, materials and services
     - Capital-labor and intermediates
   - Context: Indian manufacturing sector
     - Time horizon = 7 years
     - Trade liberalization ⇒ quasi-random changes in input prices

2. Embed estimates in a multi-sector GE model of Indian economy
   - Assess importance of elasticities for:
     - Aggregate impact of sectoral TFP increases
     - Misallocation
     - Gains from trade

Main findings

- Empirical estimates: material inputs highly substitutable
  - **Material inputs (8 categories) are substitutes: 4.7**
    - Atalay (2017), Barrot & Sauvagnat (2016), Boehm, Flaaen & Pandalai-Nayar (2019): ≈ 0
    - This paper: permanent shock to prices, longer-run response
  - **Energy, materials and services are complements: 0.4**
    - Atalay (2017), Oberfield & Raval (2019): < 1
  - **Intermediate inputs and capital/labor are complements: 0.6**
    - Atalay (2017), Oberfield & Raval (2019): < 1
- Quantitative model: deviations from Cobb-Douglas important
  - **Gains from closing US-India TFP gap in one sector: 76% larger**
    - Baqaee & Farhi (2019)
  - **Losses from misallocation of inputs across plants: 6 times larger**
    - Baqaee & Farhi (2020), Oberfield & Boehm (2020)

Plant Production Function ⇒ Estimating Equation

- $\text{Y}_i = \text{F}_i(\text{Capital}_i, \text{Labor}_i, \underbrace{\text{Intermediates}_i}_{\text{G}_i(\text{Energy}_i,\ \text{Materials}_i,\ \text{Services}_i)})$

$$\text{Materials}_i = \left[\sum_{j=1}^{J} \pi_{ij} M_{ij}^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}$$

j = Plastics, Metals, Chemicals, Woods, Minerals, Textiles, Agricultural, Other

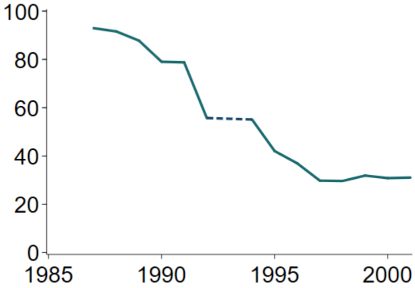
- Cost minimization ⇒

$$\Delta\ln\left(\frac{P_{ij}M_{ij}}{P_{ik}M_{ik}}\right) = (1-\theta)\,\Delta\ln\left(\frac{P_{ij}}{P_{ik}}\right) + \theta\Delta\ln\left(\frac{\pi_{ij}}{\pi_{ik}}\right)$$

- Why not run OLS? **Simultaneity bias** and **attenuation bias**
  ⇒ use Δ import tariffs to instrument for Δ domestic input prices

Setting: India's Trade Liberalization (1991-1997)

Average Import Tariffs (%)



- Policy 'experiment': IMF program after BoP crisis → **unanticipated**
- Large **permanent decline** in import tariffs (average = 50%)
- Tariff changes very **dispersed** (s.d. = 35%) and **quasi-random**
  - Uncorrelated with industry characteristics, etc.
  - Predicted by initial tariff levels (trade policy unchanged since 1950s)

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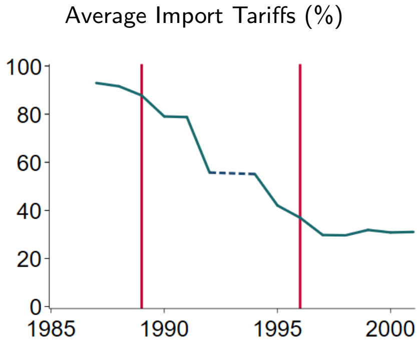

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Estimation Strategy: Plant-level Elasticities

Survey of **formal Indian manufacturing plants** in 1989 and 1996 (ASI)

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Bartik approach ⇒ plant-level prices and tariffs for Metals, ...

- Wholesale price indices & tariffs for detailed input subcategories
- Weight using average plant shares (prices) or 1989 shares (tariffs)
- ⇒ variation in plant-level prices and tariffs

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Estimating Equations:

$$\text{First stage: } \Delta \ln(P_{ij}) = \rho\, \Delta\tau_{ij} + \mathsf{FE}_i + \mathsf{FE}_j + \eta_{ik}$$

$$\text{Second stage: } \Delta \ln\left(\frac{PM_{ij}}{PM_i}\right) = \beta\, \Delta \ln(P_{ij}) + \mathsf{FE}_i + \mathsf{FE}_j + \epsilon_{ik}$$

i = plant, j = material input category (e.g. Metals)

Estimates of elasticities of substitution

	θ 7 materials		θ^X E-M-S		ε KL-EMS	
	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Elasticity	**1.4**	**4.7**				
	[1.0, 1.7]	[2.9, 6.5]				
Obs	14,294	14,294				
# plants	5,411	5,411				

First stage: for θ, the regression of price changes on tariff changes yields a coefficient of 0.09 (F-stat 56) for θ^X, a coefficient of 0.14 (F-stat 26); for ε, a coefficient of 0.11 (F-stat 23). Standard errors clustered at industry-level.

- First stage: regress % price changes on pp. tariff changes
  - Coefficient: 0.09 (F-stat: 56)

Estimates of elasticities of substitution

	θ 7 materials		θ^X E-M-S		ε KL-EMS	
	OLS (1)	IV (2)	OLS (3)	IV (4)	OLS (5)	IV (6)
Elasticity	**1.4**	**4.7**	**0.5**	**0.4**		
	[1.0, 1.7]	[2.9, 6.5]	[0.1, 0.8]	[-0.3, 1.2]		
Obs	14,294	14,294	16,884	16,884		
# plants	5,411	5,411	8,616	8,616		

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- Similar estimation strategy for EMS and for KL vs. EMS

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	[1.0, 1.7]	[2.9, 6.5]	[0.1, 0.8]	[-0.3, 1.2]	[0.2, 0.8]	[0.0,1.2]
Obs	14,294	14,294	16,884	16,884	8,449	8,449
# plants	5,411	5,411	8,616	8,616	8,449	8,449

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Heterogeneity & Robustness

Robustness: Estimates

- Non-importers
- Top 2 inputs / minimum spending shares
- Extensive margin
- Price and tariff construction

Heterogeneity:

- Individual industry estimates in line with pooled estimates Figure
- Slightly lower substitutability for small plants Estimates
- Preliminary: lower substitutability for shorter time horizons

Estimates of industry-level elasticities similar to plant-level

Quantitative Model

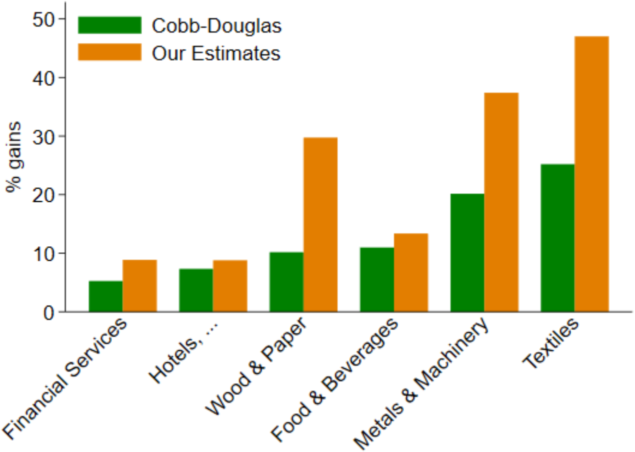
- Static open economy, multiple sectors, roundabout production
- Heterogeneous firms in each sector face CES demand
  - Production function has nested CES structure
  - Key elasticities of substitution: $\theta, \theta^X, \varepsilon$
  - Potentially face plant-specific input prices (distortions)
- Sectoral output used as intermediate or for final good production

Quantitative exercise: importance of $\theta >> 1$ for

1. Aggregate effect of increasing one sector's TFP to the US level?
2. Aggregate losses due to input distortions?
3. (Paper: gains from trade liberalization & revenue distortions)

Gains from closing TFP gap to the US

- **Gains are 76% larger** on average with an elasticity of 4.7.



- Similar amplification in model with cross-product substitution Figure

Input Misallocation

- **Huge heterogeneity in factor shares** even within industry
  - Could be due to technology or plant-specific "distortions"
  - Transportation costs, markups charged by suppliers, taxes,...
- Distortions create **misallocation**
  - How large are losses from input distortions?
  - Role of substitutability between intermediate inputs?
- Conservative way to back out distortions
  - 1/3 of dispersion in factor shares from distortions
- Aggregate losses from adding input distortions?

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- Conservative way to back out distortions
  - 1/3 of dispersion in factor shares from distortions
- Aggregate losses from adding input distortions?
  - **36% of GDP with our estimates vs. 6% with Cobb-Douglas**

Conclusion

- Material inputs are **substitutable over the medium-run**
  - Elasticity of 4.7
  - More flexibility than existing short-run estimates
- Inputs more **complementary at higher levels of aggregation**
  - Energy, Materials and Services are complements
  - Intermediate input and capital/labor are complements
- Substitutability has **large effects on the macroeconomy**
  - Gains from raising TFP to US level $\approx$ 76% larger
  - Losses from input misallocation $\approx$ 6 times larger

Robustness of θ estimate

	Top 2 Inputs		Non-importers		No Extensive Margin		Industry Prices and Tariffs	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Elasticity	**1.4**	**3.6**	**1.3**	**4.4**	**1.5**	**4.6**	**1.2**	**3.5**
	[1.0, 1.7]	[2.0, 5.2]	[1.0, 1.7]	[2.3, 6.5]	[1.0, 2.0]	[1.9, 7.4]	[0.9, 1.6]	[1.2, 5.9]
		First Stage		First Stage		First Stage		First Stage
Δtariffs		0.091		0.084		0.078		0.100
		(.014)		(.013)		(.011)		(.022)
F-stat		44.2		40.1		44.7		17.7
Observations	10,822	10,860	10,932	10,932	4,386	4,386	14,294	14,294
# plants	5,430	5,430	4,148	4,148	1,562	1,562	5,411	5,411

Notes: Standard errors clustered at industry-level.

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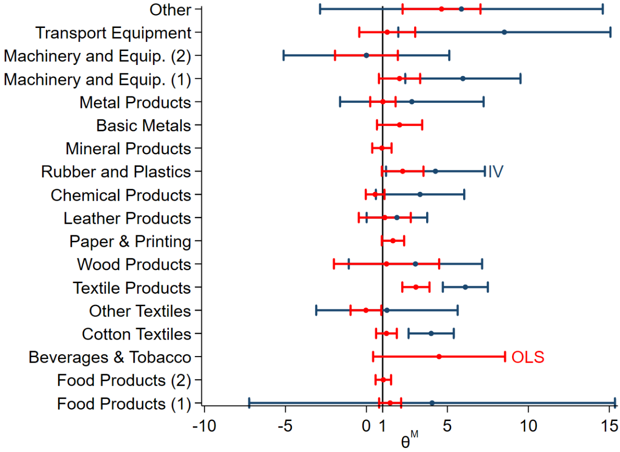
θ heterogeneity across using industries



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θ heterogeneity for small vs. large plants

	Below Median Size		Above Median Size	
	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
Elasticity	**1.41**	**3.57**	**1.29**	**5.85**
	[1.0, 1.8]	[1.2, 5.9]	[0.9, 1.7]	[3.6, 7.1]
Observations	6,919	6,919	7,375	7,375
# plants	2,706	2,706	2,705	2,705

First stage: for plants below median size, the regression of price changes on tariff changes yields a coefficient of 0.09 (F-stat 37) for plants above median size, a coefficient of 0.08 (F-stat 48.4). Standard errors clustered at industry-level.

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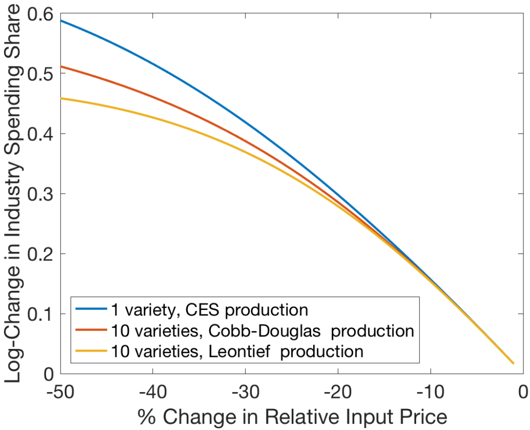
Substitution Between Products



- Large relative input price changes ⇒ similar predicted changes in industry spending shares ⇒ similar amplification Back