Swimming Upstream: Input-Output Linkages and The Direction of Product Adoption

Johannes Boehm
Sciences Po

Swati Dhingra
LSE, CEP, CEPR, CESIfo

John Morrow
Essex, CEP

World Bank 30/03/16 Preliminary!

Motivation

- What determines the production structure?
- Idiosyncratic Production Capabilities→Production Structure→Income
- Industrial policy to develop capabilities.

Motivation

- What determines the production structure?
- Idiosyncratic Production Capabilities→Production Structure→Income
- Industrial policy to develop capabilities.

- Production Structure→Incomes.
- Cross-country exports and incomes. Hausmann et al 2007, 2011; Sutton and Trefler 2014.
- Poor countries become rich by producing what rich countries produce. Rodrik 2010

Motivation

- What determines the production structure?
- Idiosyncratic Production Capabilities→Production Structure→Income
- Industrial policy to develop capabilities.

- Production Structure→Incomes.
- Cross-country exports and incomes. Hausmann et al 2007, 2011; Sutton and Trefler 2014.
- Poor countries become rich by producing what rich countries produce. Rodrik 2010

- Idiosyncratic Production Capabilities→Production Structure.
- Identify input capabilties as a determinant of production structure.

Approach

- Products differ in the capabilities needed to make them and countries differ in the capabilities they have.
- Countries make products for which they have the requisite capabilities, and they tend to move to goods close to those they are currently specialized in (Hidalgo 2007).

Approach

- Products differ in the capabilities needed to make them and countries differ in the capabilities they have.
- Countries make products for which they have the requisite capabilities, and they tend to move to goods close to those they are currently specialized in (Hidalgo 2007).

- Microeconomic evidence for production structure of establishments (Sutton 2012).
- Input-specific capabilities determine specialization into industries (Penrose 1955, Teece 1980).

Summary

- Establishments with initial input mix more similar to the input mix needed in an industry are more likely to move into that industry.

Summary

- Establishments with initial input mix more similar to the input mix needed in an industry are more likely to move into that industry.

- Use input-specific policy changes to identify input mechanism.
- Input capabilties are a proximate determinant of production structure.
- Input-based specialization predicts higher profitability.

Summary

- Establishments with initial input mix more similar to the input mix needed in an industry are more likely to move into that industry.

- Use input-specific policy changes to identify input mechanism.
- Input capabilties are a proximate determinant of production structure.
- Input-based specialization predicts higher profitability.

- Does not rule out other determinants of industry specialization (demand complementarities).

Related Work

- Multiproduct: Bernard et al. 2010, 2011, Goldberg et al. 2009, Iacovone-Javorcik 2010, Mayer et al. 2012, Eckel-Neary 2010, Liu 2010, Dhingra 2013
- Firm heterogeneity/core competencies: Hottman, Redding, Weinstein 2015, Eckel et al. 2015, Aw and Lee 2009
- Vertical linkages and performance: Combes and Gobillon 2014, Lopez and Sudekum 2009, Antras and Chor 2013
- Growth: Hausmann et al 2007, 2011, Sutton and Trefler 2014
- Business: Scherer 1982, Robins and Wiersema 1995, Fan and Lang 2000, Bowen and Wiersema 2005, Bryce and Winter 2009
- Macro: Acemoglu et al 2003, Carvalho & Voigtlander 2014, Conley and Dupor 2003, di Giovanni et al 2014, Cai and Li 2014
- India: Goldberg et al 2009, Harrison et al 2013, 2014, Bollard et al 2013

Outline

Outline

Approach

- Manufacturing establishments in India.
- Observe product codes for inputs and outputs of establishments.
  - Construct an IO matrix (262×262) from all single-product establishments.
  - Relate it to an establishment's initial input mix.

Approach

- Manufacturing establishments in India.
- Observe product codes for inputs and outputs of establishments.
  - Construct an IO matrix (262$\times$262) from all single-product establishments.
  - Relate it to an establishment's initial input mix.

- Cotton Apparel producer moves into Cotton Hosiery because both need Cotton.
- Policy change in Cotton$\rightarrow$Adding Cotton Hosiery more likely for Cotton Apparel producer, rather than Silk Apparel producer.

Data

- Annual Survey of Industries conducted by the Ministry of Statistics
- All formal manufacturing establishments>100 employees (census)+ fifth of all manufacturing establishments>20 employees (sample)
- 2001/02 to 2007/08: Consistent product classification

Industry Definition

ASIC Product Codes	**ASI**	GKPT	BRS
4-digit Products	**1,108**	1,886 CMIE	1,440 5-digit SIC
3-digit Products	**262**	108 4-digit NIC	455 4-digit SIC
2-digit Products	**64**	22 2-digit NIC	20 2-digit SIC

6 Textile and Textile Articles

- 63 Cotton, Cotton yarn and Fabrics
  - 633 Cotton Fabrics incl. Cotton hosiery fabrics; 634 Made up articles of cotton incl. Apparel; 638 Processing/Services of Cotton, Cotton yarn and Fabrics; 639 Other cotton textile goods nec

Outline

Input Mix of Establishments and Industries

- Establishment j's type is a vector of input expenditure shares the first time it is observed, θ_j.
- Industry k's type is a vector of aggregate input expenditure shares, $\overline{\theta}_k$, derived from a national IO table of single-industry establishments.

- Establishment j is similar in input use to industry k if their expenditure shares across different inputs are correlated.

Input Similarity

- Establishment j is similar in input use to industry k if their expenditure shares across different inputs are correlated.

$$\text{inputSimilarity}_j^k = \sum_{n=1}^{N} \theta_{\mathbf{j}}^{\mathbf{n}} \overline{\theta}_k^n$$

- $\text{inputSimilarity}_j^k = 0$ when no common 3-digit inputs between firm j and industry k.

Input Similarity

- Establishment j is similar in input use to industry k if their expenditure shares across different inputs are correlated.

$$\text{inputSimilarity}_j^k = \sum_{n=1}^{N} \theta_j^n \overline{\theta}_{\mathbf{k}}^{\mathbf{n}}$$

- $\text{inputSimilarity}_j^k = 0$ when no common 3-digit inputs between firm j and industry k.

Input Similarity

- Establishment j is similar in input use to industry k if their expenditure shares across different inputs are correlated.

$$\text{inputSimilarity}_j^k = \sum_{\mathbf{n=1}}^{\mathbf{N}} \theta_j^n \overline{\theta}_k^n$$

- $\text{inputSimilarity}_j^k = 0$ when no common 3-digit inputs between firm j and industry k.

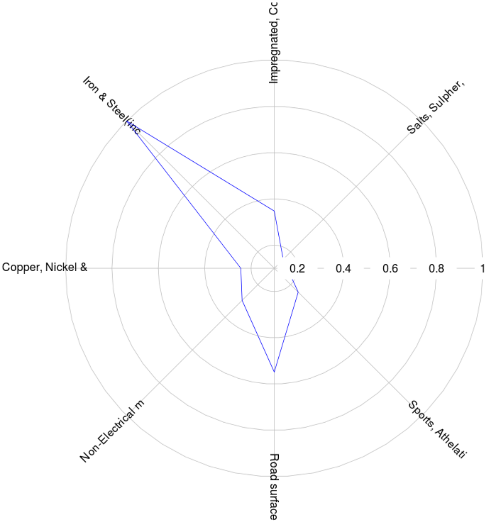
Input Similarity Definition

- Establishment j is similar in input use to industry k if their expenditure shares across different inputs are correlated.

$$\text{inputSimilarity}_j^k = \sum_{n=1}^{N} \theta_j^n \overline{\theta}_k^n \Big/ \sqrt{\left(\sum_{n=1}^{N} \left(\theta_j^n\right)^2\right)\left(\sum_{n=1}^{N} \left(\overline{\theta}_k^n\right)^2\right)}$$

- $\text{inputSimilarity}_j^k = 0$ when no common 3-digit inputs between firm j and industry k.

Example: Aggregate Input Similarity



Empirical Motivation

- Standard measure of multidimensional correlation.
  Jaffe 1986, Bloom et al. 2013
- Additive in policy change, so direct interpretation.
  - $\text{inputSimilarity}_j^k = \sum_{n=1}^N \theta_j^n \overline{\theta}_k^n / \sqrt{\left(\sum_{n=1}^N \left(\theta_j^n\right)^2\right)\left(\sum_{n=1}^N \left(\overline{\theta}_k^n\right)^2\right)}$

Empirical Motivation

- Standard measure of multidimensional correlation.
  Jaffe 1986, Bloom et al. 2013
- Additive in policy change, so direct interpretation.
  - $\text{inputSimilarity}_j^k = \sum_{n=1}^N \theta_j^n \overline{\theta}_k^n / \sqrt{\left(\sum_{n=1}^N \left(\theta_j^n\right)^2\right)\left(\sum_{n=1}^N \left(\overline{\theta}_k^n\right)^2\right)}$
  - $\text{Policy}_t \cdot \text{inputSim}_j^k = \sum_{n=1}^N \delta_t^n \cdot \theta_j^n \overline{\theta}_k^n / \sqrt{\left(\sum_{n=1}^N \left(\theta_j^n\right)^2\right)\left(\sum_{n=1}^N \left(\overline{\theta}_k^n\right)^2\right)}$
  - Establishment j produces in industry k:
    $\text{Produce}_{jt}^k = \beta_0 \text{inputSimilarity}_j^k + \beta_1 \left(\text{Policy}_t \cdot \text{inputSimilarity}_j^k\right) + \varepsilon_{jt}^k.$

Theoretical Motivation

- Each establishment j has an idiosyncratic input productivity vector a_j.
- The production function to produce k with inputs M_{jt} at time t is

$$F\left(M_{jkt}, a_j\right) \equiv \prod_i \left(a_{ij} M_{ijkt}\right)^{\beta_{ik}} \varepsilon_{jkt} \qquad \sum_i \beta_{ik} = 1$$

Theoretical Motivation

- Each establishment j has an idiosyncratic input productivity vector a_j.
- The production function to produce k with inputs M_{jt} at time t is

$$F\left(M_{jkt}, a_j\right) \equiv \prod_i \left(a_{ij} M_{ijkt}\right)^{\beta_{ik}} \varepsilon_{jkt} \qquad \sum_i \beta_{ik} = 1$$

- At input prices S_{it}, the unit cost to produce k is $c_{jkt}/\varepsilon_{jkt}$ where

$$c_{jkt} \equiv \prod_i \left(S_{it}/a_{ij}\beta_{ik}\right)^{\beta_{ik}}.$$

Theoretical Motivation

- Each establishment j has an idiosyncratic input productivity vector a_j.
- The production function to produce k with inputs M_{jt} at time t is

$$F\left(M_{jkt}, a_j\right) \equiv \prod_i \left(a_{ij} M_{ijkt}\right)^{\beta_{ik}} \varepsilon_{jkt} \qquad \sum_i \beta_{ik} = 1$$

- At input prices S_{it}, the unit cost to produce k is $c_{jkt}/\varepsilon_{jkt}$ where

$$c_{jkt} \equiv \prod_i \left(S_{it}/a_{ij}\beta_{ik}\right)^{\beta_{ik}}.$$

- Inverse demand for k is $p_{jkt} = D_{kt} q_{jkt}^{\rho_k - 1}/\rho_k$ where D_{kt} is a industry-time demand shifter.

Theoretical Motivation

$$\ln R_{jkt} = \alpha_{kt} + \underbrace{\frac{\rho_k}{1-\rho_k}\sum_i \beta_{ik} \ln a_{ij}}_{\text{Firm}-\text{Product Effect } Z_{jk}} + \underbrace{\frac{\rho_k}{1-\rho_k} \ln \varepsilon_{jkt}}_{\text{iid noise}}$$

Theoretical Motivation

$$\ln R_{jkt} = \alpha_{kt} + \underbrace{\frac{\rho_k}{1-\rho_k}\sum_i \beta_{ik} \ln a_{ij}}_{\text{Firm}-\text{Product Effect } Z_{jk}} + \underbrace{\frac{\rho_k}{1-\rho_k} \ln \varepsilon_{jkt}}_{\text{iid noise}}$$

- If $\ln a_{ij}$ are iid, symmetric around $\mathrm{E}_j\left[\ln a_{ij}|i\right] = \mu_i$, finite variance σ^2:

$$\frac{\mathrm{Cov}_j\left(Z_{jk}, Z_{jk'}\right)}{\sqrt{\mathrm{Var}_j\left(Z_{jk}\right)}\sqrt{\mathrm{Var}_j\left(Z_{jk'}\right)}} = \frac{\sum_i \beta_{ik}\beta_{ik'}\sigma^2}{\sqrt{\sum_i \beta_{ik}^2\sigma^2}\sqrt{\sum_i \beta_{ik'}^2\sigma^2}} \equiv \mathrm{inputSimilarity}_{kk'}$$

- 0 if no idiosyncratic input productivities or no input similarity.

Dereservation Policy

- Small if <Rs 10mn in Plant & Machinery at historical cost in 1999.
- Products reserved for production by small-scale sector (not in ASI).
- About 600 (of 1000) products de-reserved between 1997-2007.

Number of Products Dereserved by Year

Year	1997	1999	2001	2002	2003	2004	2005	2006	2007	2008
Number	15	9	15	51	75	85	108	180	212	107

Impact of Dereservation on Input Expenditures

- $\delta_t^n = 1$ if there is a de-reservation in input n at time t. (Stays 1 in $t' \geq t$).
- At the intensive margin within an establishment, dereservation increases input expenditure by 3%.

	Input expenditure$_{jt}^k$
	(1)
DeReserve$_t^k$	0.0305**
	(.0141)
Firm-Year FE α_{jt}	yes
Firm-Industry FE α_j^k	yes
N	477,133
R^2	0.922

Notes:** 5%, *** 1% levels of significance.

Disentangling IO Linkages

- Establishment j adds 3-digit industry k at time t:

$$Add_{jt}^{k} = \beta_0 \text{inputSimilarity}_j^k + \beta_1 \text{DereserveInputSim}_{jt}^k + \alpha_{jt} + \alpha_t^k + \alpha_t^{kk'} + \varepsilon_{jt}^k$$

- $\text{inputSimilarity}_j^k = \sum_{n=1}^{N} \theta_{jn} \overline{\theta}_{kn} / \sqrt{\left(\sum_{n=1}^{N} \theta_{jn}^2\right)\left(\sum_{n=1}^{N} \overline{\theta}_{kn}^2\right)}$
- $\text{DereserveInputSim}_{jt}^k = \sum_{n=1}^{N} \delta_t^n \theta_{jn} \overline{\theta}_{kn} / \sqrt{\left(\sum_{n=1}^{N} \theta_{jn}^2\right)\left(\sum_{n=1}^{N} \overline{\theta}_{kn}^2\right)}$

Disentangling IO Linkages

- Establishment j adds 3-digit industry k at time t:

$$Add_{jt}^{k} = \beta_0 \text{inputSimilarity}_j^k + \beta_1 \text{DereserveInputSim}_{jt}^k + \alpha_{jt} + \alpha_t^k + \alpha_t^{kk'} + \varepsilon_{jt}^k$$

- $\text{inputSimilarity}_j^k = \sum_{n=1}^{N} \theta_{jn}\overline{\theta}_{kn} / \sqrt{\left(\sum_{n=1}^{N} \theta_{jn}^2\right)\left(\sum_{n=1}^{N} \overline{\theta}_{kn}^2\right)}$
- $\text{DereserveInputSim}_{jt}^k = \sum_{n=1}^{N} \delta_t^n \theta_{jn}\overline{\theta}_{kn} / \sqrt{\left(\sum_{n=1}^{N} \theta_{jn}^2\right)\left(\sum_{n=1}^{N} \overline{\theta}_{kn}^2\right)}$

- α_{jt}= Establishment-Year FE to control for rates of adoption.
- α_t^k= Industry-Year FE to control for Demand-Supply shocks.

Disentangling IO Linkages

- Establishment j adds 3-digit industry k at time t:

$$Add_{jt}^{k} = \beta_0 \text{inputSimilarity}_j^k + \beta_1 \text{DereserveInputSim}_{jt}^k + \alpha_{jt} + \alpha_t^k + \alpha_t^{kk'} + \varepsilon_{jt}^k$$

- $\text{inputSimilarity}_j^k = \sum_{n=1}^N \theta_{jn} \overline{\theta}_{kn} / \sqrt{\left(\sum_{n=1}^N \theta_{jn}^2\right)\left(\sum_{n=1}^N \overline{\theta}_{kn}^2\right)}$
- $\text{DereserveInputSim}_{jt}^k = \sum_{n=1}^N \delta_t^n \theta_{jn} \overline{\theta}_{kn} / \sqrt{\left(\sum_{n=1}^N \theta_{jn}^2\right)\left(\sum_{n=1}^N \overline{\theta}_{kn}^2\right)}$
- α_{jt}= Establishment-Year FE to control for rates of adoption.
- α_t^k= Industry-Year FE to control for Demand-Supply shocks.
- $\alpha_t^{kk'}$= Industry k-Main Industry k' of Estab j-Year FE.
    - Control for industry-level sources of co-occurrence.
    - What remains are idiosyncratic input linkages of estabishments.

Outline

Summary Statistics

Description	Obs	Mean	Std. Dev.	Min	Max
Added an industry	61,205,507	0.0007	0.026	0	1
Input Similarity Index	61,205,507	0.0331	0.119	0	1
Dereserve·Input Similarity	61,205,507	0.0005	0.013	0	1
Dropped an industry	363,807	0.1150	0.319	0	1
Input Similarity Index	363,807	0.4833	0.362	0	1
Dereserve·Input Similarity	363,807	0.0070	0.063	0	1

Correlation

	Add	IS	Drop	IS
Input Similarity	0.06		-0.18	
Dereserve·Input Sim	0.01	0.11	-0.01	0.06

Add which industries?

	(1) Add_{jt}^{k}
Input Similarity_j^k	0.005^{***}
	(.0002)
DereserveInput Similarity_j^k	0.006^{***}
	(.0014)
Establishment-Year FE α_{jt}	yes
Industry-year FE α_t^k	yes
Industry-Main Industry-Year FE $\alpha_t^{kk'}$	yes
N	61,189,821
R^2	0.037

- A 1 Std deviation increase in input similarity increases the mean industry adoption rate by 11%.

Add which industries? Robustness

	(1) Add_{jt}^{k}	(2) Drop_{jt}^{k}
Input $\text{Similarity}_{j}^{k}$	0.005***	-0.071***
	(.0002)	(.0051)
DereserveInput $\text{Similarity}_{j}^{k}$	0.006***	0.001
	(.0014)	(.0295)
Establishment-Year FE α_{jt}	yes	yes
Industry-year FE α_{t}^{k}	yes	yes
Industry-Main Industry-Year FE $\alpha_{t}^{kk'}$	yes	yes
N	61,189,821	174,870
R^2	0.037	0.669

- A 1 Std deviation increase in input similarity increases the mean industry adoption rate by 11%.

Add which industries? Robustness

Dependent variable	(1) Add_{jt}^{k}	(2) Drop_{jt}^{k}
$\text{inputSimilarity}_{j}^{k}$	0.004***	-0.059***
$\text{outputSimilarity}_{j}^{k}$	0.027***	-0.212***
$\text{expectedUpstream}_{j}^{k}$	0.004	0.046***
$\text{expectedDownstream}_{j}^{k}$	0.007***	0.003
$\text{DereserveInputSim}_{jt}^{k}$	**0.005***	**0.018**
$\text{DereserveOutputSim}_{jt}^{k}$	0.003	-0.044***
$\text{DereserveExpUp}_{jt}^{k}$	0.017***	0.026
$\text{DereserveExpDown}_{jt}^{k}$	-0.001***	-0.038
Establishment-Year FE α_{jt}	yes	yes
Industry-year FE α_{t}^{k}	yes	yes
Industry-Main Industry-Year FE $\alpha_{t}^{kk'}$	yes	yes
N	61,189,821	174,870
R^2	0.037	0.672

Input similarity increases profitability

- Profit = Sales - Cost on material, labor & capital (6% of NV).

Dependent variable: $\ln\text{Profit}_{jt}$	(1)	(2)	(3)
$\text{DereserveInputSim}_j^{k_1}$	0.595	0.710*	0.718*
$\text{DereserveInputSim}_j^{k_2}$		0.723*	
$\text{DereserveOutputSim}_j^{k_1}$			0.033
$\text{DereserveExpUp}_j^{k_1}$			-0.041
$\text{DereserveExpDown}_j^{k_1}$			-0.466
Establishment FE α_j	yes	yes	yes
Industry k_n-year FE $\alpha_t^{k_n}$	yes	yes	yes
N	187,835	187,835	187,835
R^2	0.940	0.941	0.941

Outline

Conclusion

- Input capabilities determine industry specialization of establishments.
  - A 1SD rise in the Input Similarity of an establishment increases its industry adoption by 11%, on average.
- A 1SD rise in Input Similarity of the top industry of an establishment increases its profitability by 1%, on average.
- Micro-evidence for Idiosyncratic Production Capabilities→Production Structure→Profits.