Measuring the Upstreamness of Production and Trade

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Motivation

- Fragmentation of production now a key feature of the global economy
  - Involves multiple suppliers, multiple countries
- Raises questions related to how such fragmentation will affect trade patterns:
  - Are countries now specializing in particular stages of global production chains?
  - Are there systematic forces that affect whether countries specialize in more upstream vs more downstream stages?
- Answering such questions requires first and foremost a measure of an industry's relative production line position
- We propose such a measure, construct it using US and European Input-Output Tables, and explore some applications to trade

Closed-economy benchmark: Preliminaries

- Let's begin with the output identity for industries $i \in \{1, 2, \ldots, N\}$:

$$Y_i = F_i + Z_i = F_i + \sum_{j=1}^{N} d_{ij} Y_j \tag{1}$$

  - Y_i: gross output
  - F_i: final uses of i
  - Z_i: intermediate input use of i
  - d_{ij}: value of i needed to produce one dollar worth of j's output (direct requirements coefficient)

- Iterating:

$$Y_i = F_i + \sum_{j=1}^{N} d_{ij} F_j + \sum_{j=1}^{N} \sum_{k=1}^{N} d_{ik} d_{kj} F_j + \sum_{j=1}^{N} \sum_{k=1}^{N} \sum_{l=1}^{N} d_{il} d_{lk} d_{kj} F_j + \ldots$$

First measure: U_1

- Antràs and Chor (2011) propose weighting each term by their distance from final use (plus 1), then normalizing by Y_i:

$$U_{1i} = 1 \cdot \frac{F_i}{Y_i} + 2 \cdot \frac{\sum_{j=1}^{N} d_{ij} F_j}{Y_i} + 3 \cdot \frac{\sum_{j=1}^{N} \sum_{k=1}^{N} d_{ik} d_{kj} F_j}{Y_i} + 4 \cdot \frac{\sum_{j=1}^{N} \sum_{k=1}^{N} \sum_{l=1}^{N} d_{il} d_{lk} d_{kj} F_j}{Y_i} + \ldots \quad (2)$$

- $U_{1i} \geq 1$
- **Computation:** Numerator of U_{1i} is the i-th entry of $[I - D]^{-2} F$, where
  - D is the matrix of d_{ij}'s
  - F is the column vector whose i-th entry is F_i
  - Valid if $d_{ij} < 1$ for all (i, j), since $[I - D]^{-1}$ would exist

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- **Interpretation:** U_1 is a weighted average distance from final use at which an industry's output is used, where the weights are the industry's use at each stage.

Second measure: U_2

- Fally (2011) proposes the following alternative measure of upstreamness (recursively defined):

$$U_{2i} = 1 + \sum_{j=1}^{N} \delta_{ij} U_{2j}, \tag{3}$$

  where δ_{ij} is the share of i's total output that is purchased by j for intermediate input use.

- In a closed economy, we have

$$\delta_{ij} = \frac{d_{ij} Y_j}{Y_i}.$$

Second measure: U_2

- Fally (2011) proposes the following alternative measure of upstreamness (recursively defined):

$$U_{2i} = 1 + \sum_{j=1}^{N} \delta_{ij} U_{2j}, \tag{3}$$

- Once again: $U_{2i} \geq 1$
- **Computation:** $U_2 = [I - \Delta]^{-1} \mathbf{1}$, where
  - Δ is the matrix of δ_{ij}'s
  - $\mathbf{1}$ is a column-vector of ones
- **Interpretation:** Industries that sell mostly to relatively upstream industries should be upstream themselves.

Third Measure: U_3

- Finally, consider a third measure of upstreamness:

$$U_{3i} = \frac{1}{Y_i} \sum_{j=1}^{N} \frac{\partial Y_i}{\partial d_{jj}}. \tag{4}$$

  where derivatives are taken holding constant the demand for output for final use (F).

- **Interpretation:** In which industries does output increase the most when production becomes more circular?

A Result

All three measures are equivalent.

Proposition 1: $U_1 = U_2 = U_3$.

Sketch of Proof:

- For $U_1 = U_2$: Matrix manipulation
- For $U_3 = U_2$: Show that U_3 satisfies same recursive relationship as U_2

Open-Economy Adjustment

- Share of i's output that is purchased as inputs by industry j (at home or abroad) now

$$\delta_{ij} = \frac{d_{ij} Y_j + X_{ij} - M_{ij}}{Y_i}$$

  - X_{ij}: value of exports of i purchased by industry j overseas
  - M_{ij}: value of imports of i purchased by domestic producers in industry j

- Practical issues:

  1. In I-O Tables, d_{ij} does not distinguish between domestic and imported inputs
  2. X_{ij} and M_{ij} typically not observed

Open-Economy Adjustment

- Nevertheless, it seems sensible to assume: $\delta_{ij} = \frac{X_{ij}}{X_i} = \frac{M_{ij}}{M_i}$.
- **Interpretation:** Share of i's exports (imports) that are used by industry j is identical to the share of i's output used in industry j (at home or abroad)
- Our three measures of upstreamness in (2), (3), and (4) still coincide after replacing d_{ij} with

$$\hat{d}_{ij} = d_{ij} \frac{Y_i}{Y_i - X_i + M_i}$$

- Analogous correction for net changes in inventories: Value of Y_i in the denominator should exclude such net changes

Upstreamness in US Production

- Use the 2002 US benchmark Input-Output Tables from the BEA
- Highly disaggregate information on production linkages:
  426 industries, 279 from manufacturing
- Compute $[I - \Delta]^{-1}\mathbf{1}$, with open-economy and inventories adjustment

- Remarks:
  - Min: 1 (19 industries, none in manufacturing)
  - Max: 4.65 (Petrochemicals)
  - Mean of 2.09, sd of 0.85

Upstreamness in US Production

Table 1. Least and Most Upstream Industries (Manuf.)

US IO2002 Industry	Upstreamness
Automobile (336111)	1.000
Light truck and utility vehicle (336112)	1.001
Nonupholstered wood household furniture (337112)	1.005
Upholstered household furniture (337121)	1.007
Footwear (316200)	1.007
Motor home (336213)	1.012
Truck trailer (336212)	1.017
Manufactured home (mobile home) (321991)	1.019
Women's and girls' cut and sew apparel (315230)	1.024
Mattress (337910)	1.029
Plastics material and resin (325211)	3.571
Copper rolling, drawing, extruding and alloying (331420)	3.611
Alkalies and chlorine (325181)	3.611
Carbon and graphite product (335991)	3.748
Fertilizer (325310)	3.762
Alumina refining and primary aluminum (33131A)	3.814
Other basic organic chemical (325190)	3.853
Secondary smelting and alloying of aluminum (331314)	4.064
Primary smelting and refining of copper (331411)	4.355
Petrochemical (325110)	4.651

Upstreamness in other OECD Countries

- Important to verify the consistency of the upstreamness measure across different countries
- Use sample of 16 EU countries in OECD STAN database for which I-O Tables are aggregated in a consistent manner in year 2005
- However: More aggregate industry classification

  41 industries, 13 in manufacturing
- USA, EUR: Available, but imperfectly matched industries

Upstreamness in other OECD Countries

- High rank correlation of industry upstreamness across country-pairs (all significant at 1% level)
- Correlation slightly smaller for small, trade dependent economies

Table 2. Rank Correlations of Industry Upstreamness

	USA	EUR	CZE	DEU	DNK	ESP	ITA	LUX
USA	1.00							
EUR	0.85	1.00						
CZE	0.60	0.79	1.00					
DEU	0.78	0.94	0.80	1.00				
DNK	0.75	0.82	0.72	0.83	1.00			
ESP	0.79	0.92	0.80	0.86	0.78	1.00		
ITA	0.81	0.93	0.79	0.87	0.74	0.86	1.00	
LUX	0.66	0.76	0.56	0.75	0.72	0.61	0.74	1.00

Upstreamness of Country Exports

- Briefly explore how our measure can shed light on the relative production line position of countries' exports
- Combine our industry measure (from the disaggregate 2002 US I-O Tables) with HS6 product-level trade flow data
- Calculate country export upstreamness as the weighted average of industry upstreamness (using country-industry export values as weights)
- 181 countries for year 2002

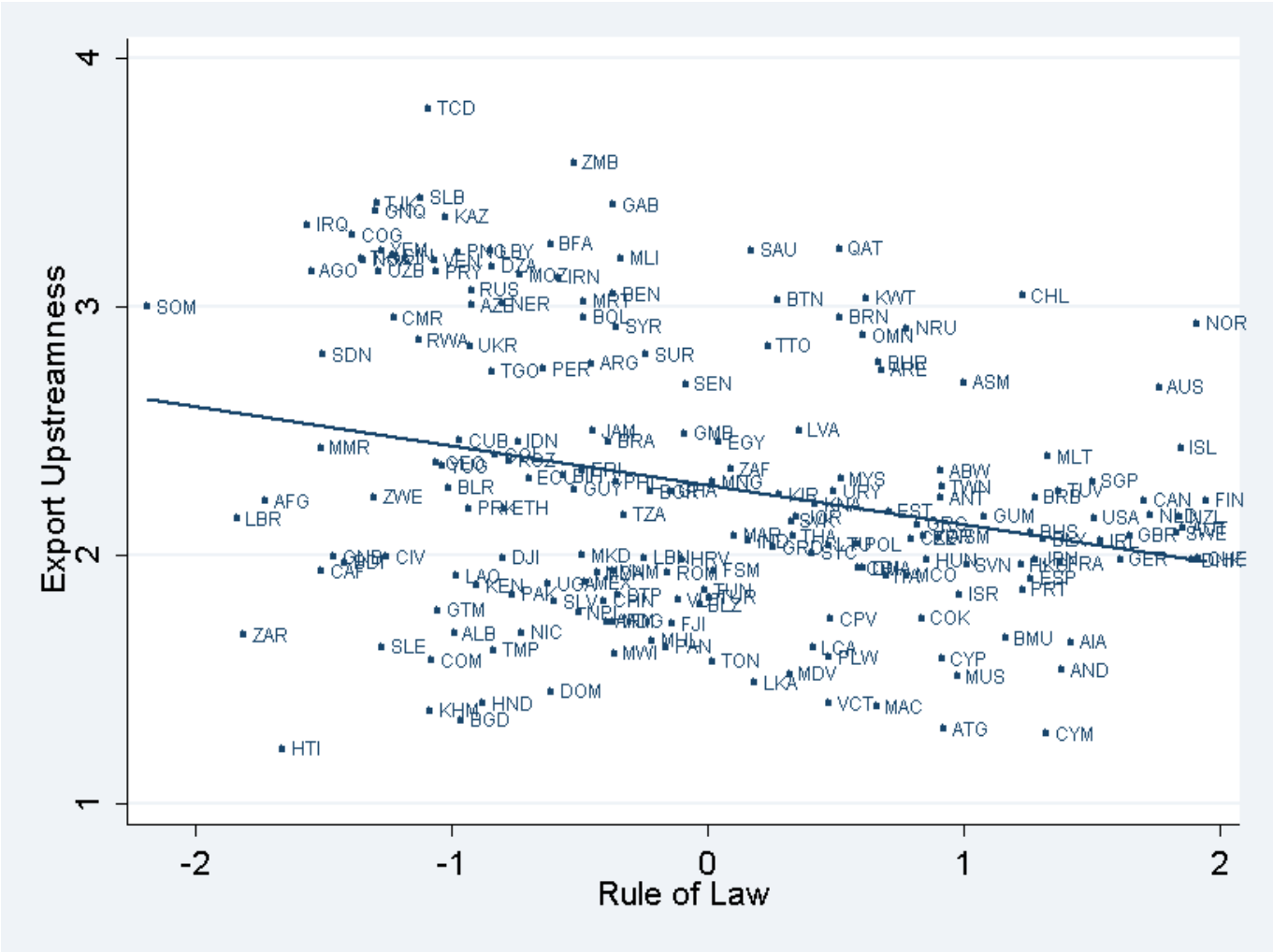
Export Upstreamness by Country Income Quartiles

	All		Manufacturing	
Income quartile	Mean	S.D.	Mean	S.D.
Bottom	2.41	0.69	2.03	0.60
2nd	2.30	0.60	1.98	0.48
3rd	2.23	0.55	2.11	0.51
Top	2.26	0.45	2.10	0.34

- Export upstreamness does not vary much by country income quartiles
- More distinctly: Much greater variation among poorer countries in terms of the production line position of their exports
- Eg: Bangladesh ($= 1.26$) vs Tajikistan ($= 3.53$)

Correlates of Country Export Upstreamness

- Stronger rule of law and better financial development associated with more downstream exports



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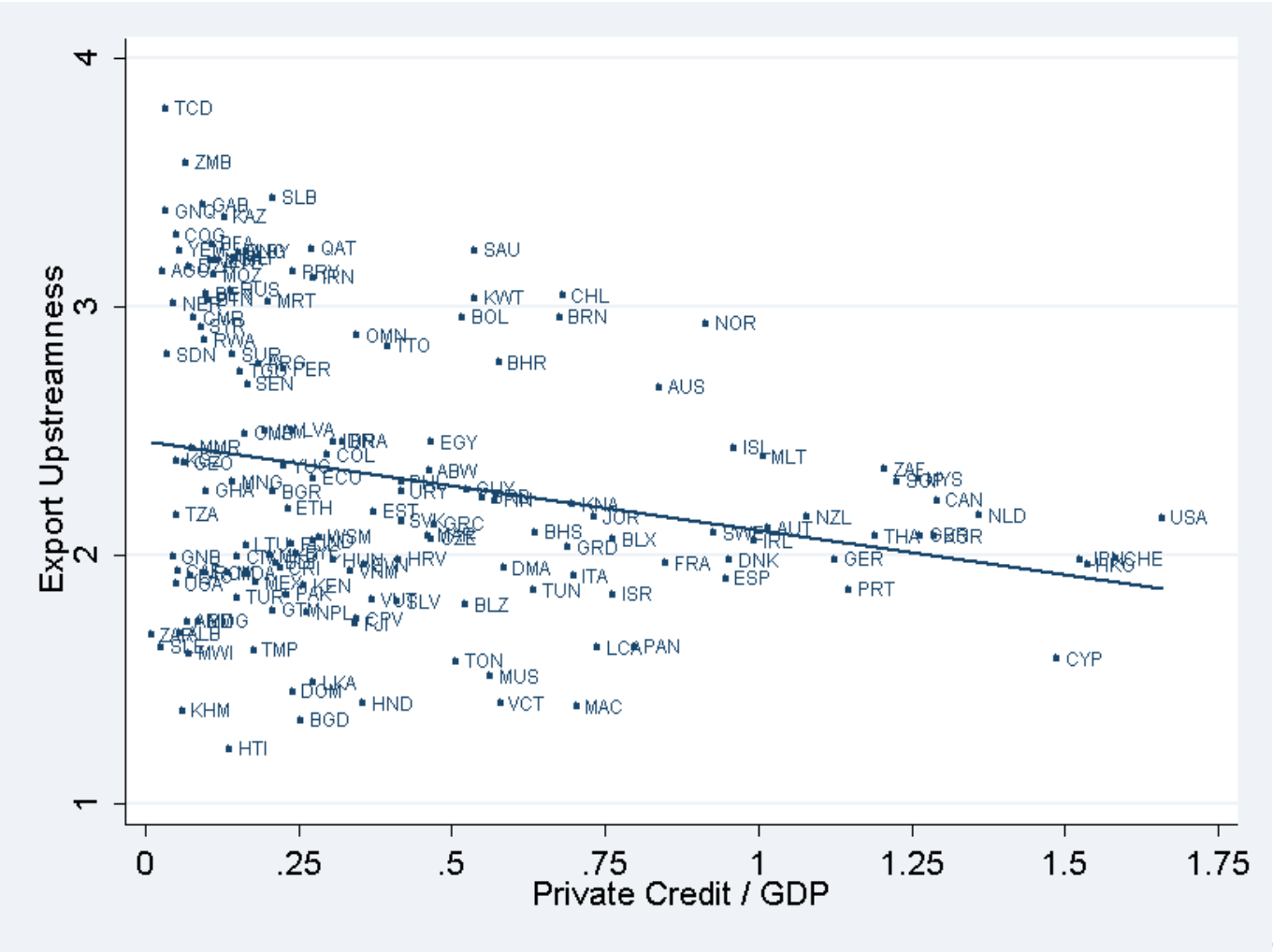

Correlates of Country Export Upstreamness

- Effect of better financial development is most robust
- Also: skill abundance is correlated with downstreamness

Panel A: Country Upstreamness, All Exports (2002)

	(1)	(2)	(3)	(4)	(5)
Log (Y/L)	−0.035	0.146***	0.100**	0.156**	0.083
	(0.032)	(0.054)	(0.047)	(0.060)	(0.142)
Rule of Law		−0.313***		−0.164*	−0.029
		(0.070)		(0.091)	(0.103)
Private Credit / Y			−0.585***	−0.404***	−0.437***
			(0.123)	(0.128)	(0.136)
Log (K/L)					0.156
					(0.131)
Years of Schooling					−0.085***
					(0.031)
N	181	181	151	151	120
R^2	0.01	0.11	0.09	0.11	0.15

Correlates of Country Export Upstreamness

- Caveat: When examining manufacturing exports only, results for rule of law and skill endowment not as robust

Panel B: Country Upstreamness, Manufacturing Exports (2002)

	(1)	(2)	(3)	(4)	(5)
Log (Y/L)	0.031	0.112**	0.115***	0.124**	0.056
	(0.028)	(0.053)	(0.042)	(0.061)	(0.140)
Rule of Law		−0.140**		−0.027	0.045
		(0.068)		(0.088)	(0.094)
Private Credit / Y			−0.312***	−0.282**	−0.274**
			(0.105)	(0.111)	(0.116)
Log (K/L)					0.053
					(0.118)
Years of Schooling					−0.026
					(0.027)
N	181	181	151	151	120
R^2	0.01	0.04	0.06	0.06	0.05

Conclusion

- Provided several theoretical foundations for a measure of industry upstreamness, that we then constructed from Input-Output Tables
- Preliminary findings intended to prompt further work in understanding the relationship between production line position and trade patterns
  1. How does upstreamness relate to industry value-added?
  2. How has industry upstreamness evolved over time?
  3. Can upstreamness explain patterns of comparative advantage in the cross-country, cross-industry data?
  4. How does upstreamness affect firm organizational decisions (the integration vs outsourcing of input suppliers)?
- See Fally (2011) on 1-3, Antràs and Chor (2011) on 4.