Lecture 3: Global Supply Chains

Economics 552

Esteban Rossi-Hansberg

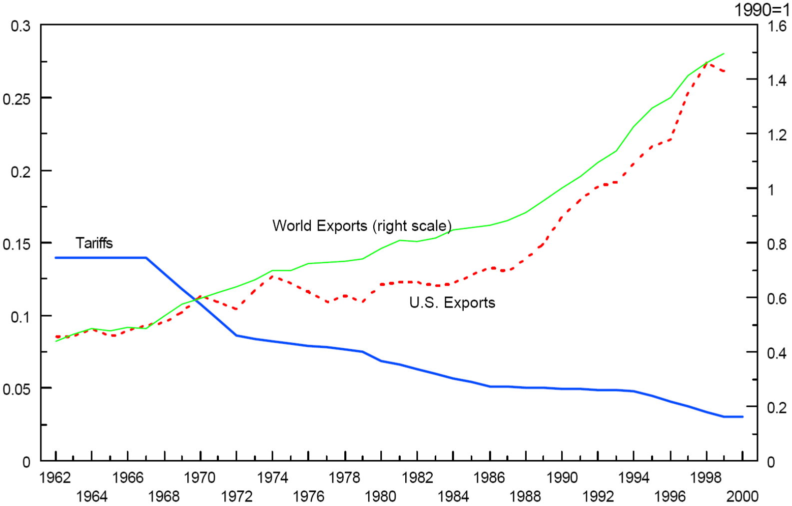
Princeton University

Can Vertical Specialization Explain the Growth of World Trade?, Yi (2003)

- Enormous expansion in world trade during the past half-century
  - World merchandise export share of output has almost tripled
  - World manufactured export share of output has almost quadrupled
  - In the United States, trade growth has been even faster:
    - Merchandise export share growth: 3.3% per year (since 1962)
    - Manufactured export share growth: 4.2% per year (since 1962)

Can Vertical Specialization Explain the Growth of World Trade?, Yi (2003)

FIGURE 1
Manufacturing Export Share of GDP and Manufacturing Tariff Rates



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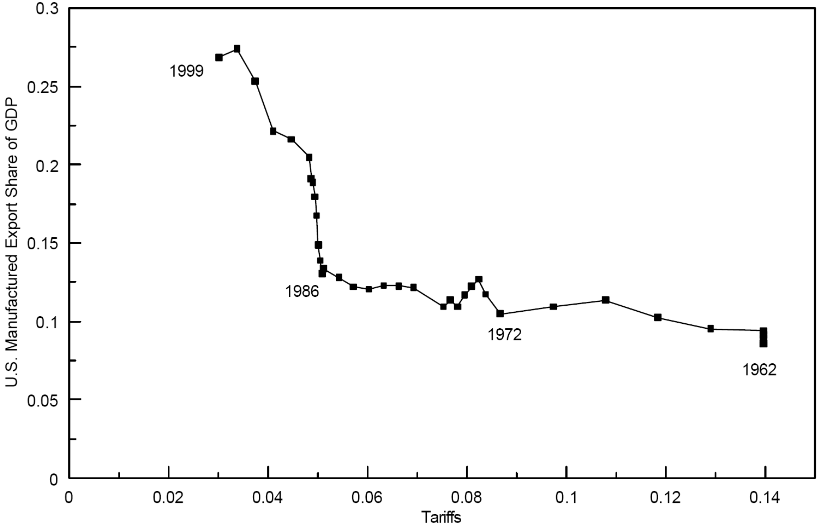


What Explains this Trade Growth?

- Standard Story:
  - Worldwide Reductions in Tariffs (and Transportation Costs)
  - Two Problems with Standard Story:

1. Tariffs (and transportation costs) have declined by only about 15 percentage points since the early 1960s
   1. The workhorse trade (monopolistic competition, Ricardian) and international real business cycle models can only explain the trade growth by assuming very high elasticities of substitution across goods (12 or higher)
2. Trade has grown more in the 1980s and 1990s than in the 1960s and 1970s, even though tariffs fell by more in the earlier period.
   1. Between 1962 and 1976, tariffs fell 6 percentage points. U.S. manufacturing trade (adjusted) grew by 36 percent.
   2. Between 1976 and 1997, tariffs fell 5 percentage points. U.S. manufacturing trade grew by 130 percent

- So we have 2 dynamic puzzles:
  1. Reconciling the large trade growth with relatively small reductions in tariffs (Magnitude)
  2. Explaining the greater "potency" of tariff reductions in the last two decades (Non-linearity)

Vertical Specialization

- To resolve these puzzles, need to go beyond the growth of trade because it is masking important changes occurring in the NATURE of trade:
- International trade increasingly involves interconnected vertical trading chains:
    1. U.S. produces and exports engine parts to Mexico
    2. Mexico produces engines and exports all of it to the U.S.
    3. U.S. produces automobiles with these engines, and some of the autos are exported.
- Specialization increasingly occurs in different stages of production
- Countries increasingly link sequentially to produce a good.
- Vertical Specialization:
    - Many other names and terms – disintegration of production, fragmentation, outsourcing, intra-product specialization, multi-stage production, etc.

Vertical Specialization

How can vertical specialization help us understand the growth of world trade? Intuitive story:

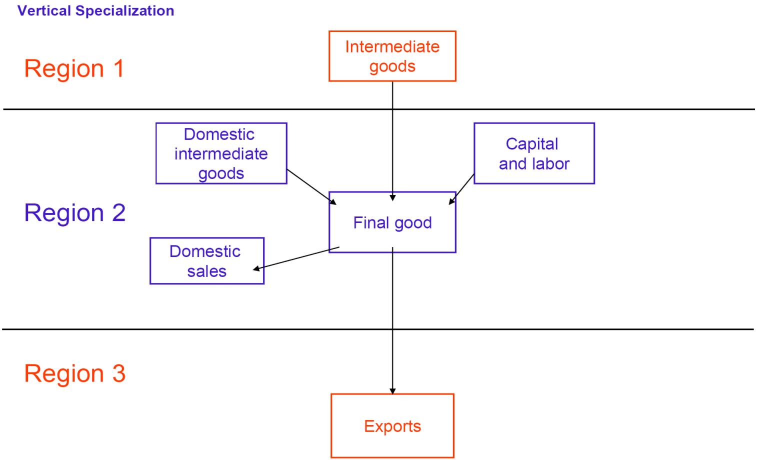
1. World-wide tariffs (and transportation costs) decline.
2. The cost of producing goods whose production processes involve multiple stages in multiple countries falls by more than the cost of producing "regular" goods, because the vertically specialized goods are "tariff-ed" multiple times while in process.
3. Vertical specialization trade increases by more than "regular" trade because:
    1. Magnified decline in costs for vertically specialized trade (internal margin)
    2. Some "regular" goods now become vertically specialized (external margin)
4. Total trade increases – because both regular trade and vertical specialization trade increase – by more than standard models predict.
5. Moreover, the effect is non-linear, because, if tariffs are high enough, so that there is no vertical specialization, then tariff reductions have only the standard effects on trade. Once vertical specialization kicks in, then the magnification effect kicks in

Vertical Specialization

1. A good is produced in two or more sequential stages.
2. Two or more countries provide value-added during the production of the good.
3. At least one country must use imported inputs in its stage of the production process, and some of the resulting output must be exported.

- Part 3 is key: Vertical Specialization is related to but not the same as intermediate goods trade, which is consistent with 1 and 2, but not necessarily with 3.

Vertical Specialization



Vertical Specialization: Measurment

- For country k and good i:

$$VS_{ki} = \frac{\text{exports}_{ki} * \text{imported intermediates}_{ki}}{\text{gross output}_{ki}}$$

- VS is imported input content of country k's exports of good i.
- Country-level VS:

$$\frac{VS_k}{X_k} = \frac{\sum_i VS_{ki}}{\sum_i X_{ki}}$$

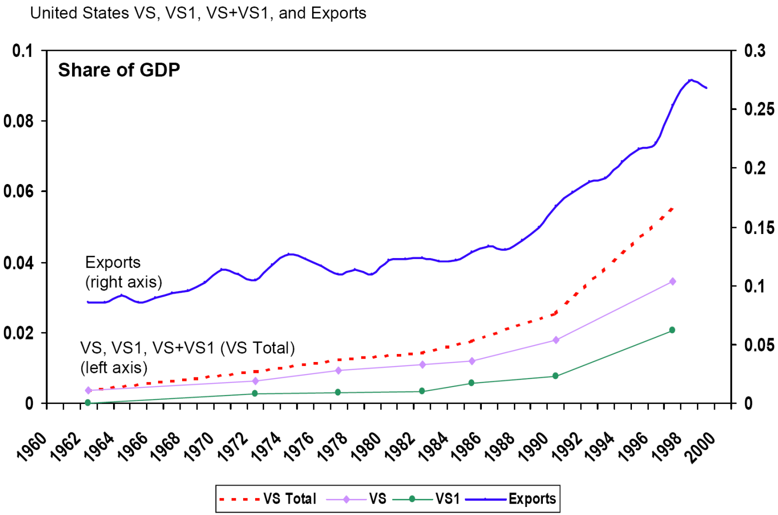
  or

$$VS_k = uA^M[I - A^D]^{-1}X$$

  where A^M is the $n \times n$ imported coefficient matrix, A^D is the $n \times n$ domestic coefficient matrix, X is an $n \times 1$ vector of exports, and n is the number of sectors
- Exports are also used as intermediates in other countries so calculate

$$VS1_{kij} = \frac{\text{exports}_{ij} * \text{exported intermediates}_{kij}}{\text{gross output}_{ij}}$$

Vertical Specialization: Measurment



Vertical Specialization: Measurment

- Growth Decomposition: What fraction of the change in the U.S. merchandise export share of GDP can be accounted for by vertical specialization?

	Total VS (share of exports)	Export share of total GDP	Export share of Merchandise GDP
1962	.042	3.67%	7.46%
1997	.219	8.52%	23.38%
Change:		4.85	15.92

- VS+VS1 account for 35.3% of increase in export share of total GDP
- VS+VS1 account for 30.2% of increase in export share of merchandise GDP

Dynamic Ricardian Vertical Specialization Model

- 2 countries, 2 factors (homogenous capital and labor)
- Continuum of goods indexed on unit interval
- Infinite horizon
- Capital accumulation, but no international capital flows (portfolio autarky)
- Exogenous growth

Production

- Each good is produced in three stages:
  - First stage produces intermediate good:

$$Y_1(z) = A_1(z) K_1(z)^{\alpha} L_1(z)^{1-\alpha}$$

  - Second stage produces a second intermediate good:

$$Y_2(z) = Y_1(z)^{\theta} \left(A_2(z) K_2(z)^{\alpha} L_2(z)^{1-\alpha} \right)^{1-\theta}$$

  - Third stage produces a non-traded final good used for consumption and investment:

$$Y = \exp \left(\int_0^1 Y_2(z)^{\frac{\sigma-1}{\sigma}} dz \right)^{\frac{\sigma}{\sigma-1}}$$

- Market Structure:
  - Perfect competition at all stages.
  - Stage 1 firms, stage 2 firms, and stage 3 firms all maximize profits taking prices as given.

Production

- Potentially, there are 4 production patterns for the first two stages of each good:

1. Home country produces stages 1 and 2 (HH)
2. Foreign country produces stages 1 and 2 (FF)
3. Home country produces stage 1, Foreign country produces stage 2 (HF)
4. Foreign country produces stage1, Home country produces stage 2 (FH)

- Ricardian Trade:
  - Comparative advantage is determined by relative technology (TFP) differences. Relative cost differences are determined by relative technology differences.
  - There is complete specialization (up to some "borderline" stages) in the production of each stage.
- Cases 3 and 4 involve vertical specialization

Specialization Pattern

- Vertical specialization occurs under free trade as long as:

$$\frac{A_1^H(z')}{A_1^F(z')} > \left(\frac{r^H}{r^F}\right)^{\alpha}\left(\frac{w^H}{w^F}\right)^{1-\alpha} > \frac{A_2^H(z')}{A_2^F(z')}$$

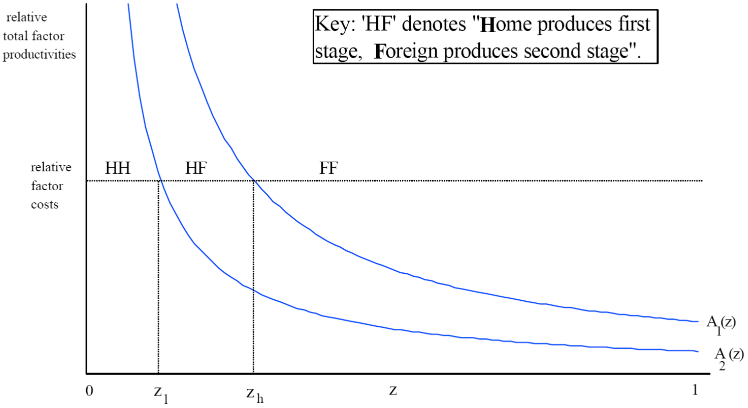
  or

$$\frac{A_1^H(z')}{A_1^F(z')} < \left(\frac{r^H}{r^F}\right)^{\alpha}\left(\frac{w^H}{w^F}\right)^{1-\alpha} < \frac{A_2^H(z')}{A_2^F(z')}$$

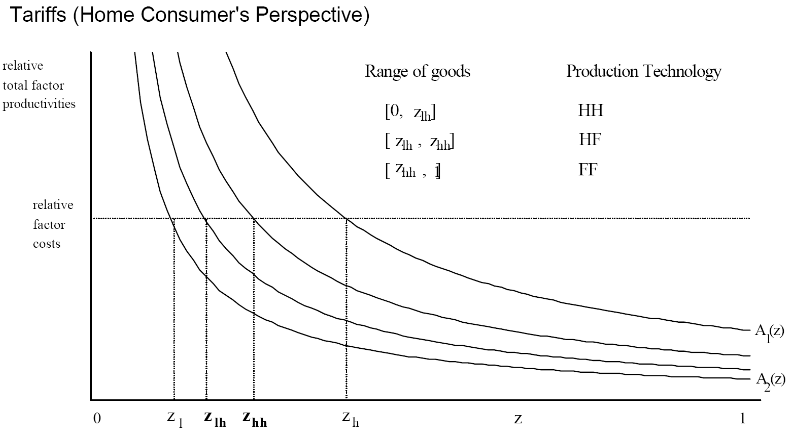
- Whenever it is cheaper to produce stage 1 in one country and stage2 in the other country
- Consumption part standard

Specialization Pattern

Free Trade



Specialization Pattern



External Margin

- In a static framework with no capital, tariff revenue is thrown in ocean, and A2(z) is a proportional shift of $A_1(z)$, the elasticity of the import share of GDP with respect to tariffs under vertical specialization (holding the terms of trade constant) is:

$$\frac{1+\theta}{1-\theta}\left[\frac{z_I}{(1-z_I)\,\eta_{A_2}}\right] \text{ since } \frac{w^H}{w^F} = (1+\tau)^{\frac{1+\theta}{1-\theta}}\,\frac{A_2^H(z_I)}{A_2^F(z_I)}$$

where z_I is the cutoff good for which the costs of production patterns HH and HF are the same (for the home stage-3 firm), and η_{A_2} is the elasticity of stage 2 relative productivity, $A_2(z)$, with respect to z.

- If there is no vertical specialization then the elasticity of the import share of GDP with respect to tariffs (holding the terms of trade constant) is:

$$\left[\frac{z_I}{(1-z_I)\,\eta_{A_2}}\right] \text{ since } \frac{w^H}{w^F} = (1+\tau)\,\frac{A_2^H(z_I)}{A_2^F(z_I)}$$

- If $\theta = 2/3$, then the effect of tariff reductions is 5 times larger under vertical specialization

Internal Margin

- Along the internal margin, z is held fixed. Under the same assumptions as above, and under vertical specialization, the elasticity of the export share of GDP with respect to tariffs is greater than $(1-\sigma)$
- If there is no vertical specialization, then the elasticity of the export share of GDP with respect to tariffs (holding the terms of trade constant) is $(1-\sigma)$
- Tariff reductions lower the cost of producing vertically specialized goods more than regular goods
- Tariff reductions without vertical specialization behave like standard models. Once a critical tariff rate is exceeded then further reductions generate magnified effects along both the internal and external margin.

Calibration

- 2 equal-sized countries: U.S. and R.O.W. (G7-U.S.)
- Initial conditions: Each country is at steady-state governed by initial tariff rate.
- Annual frequency; 1962+
- Parameters:
    - β (preference discount factor) $= 0.96$
    - α (Cobb-Douglas coefficient on capital) $= 0.36$
    - δ (depreciation rate on capital) $= 0.13$ (Jorgenson)
    - θ (share of first stage output in second stage production) $= 0.67$
    - τ (manufacturing tariffs, several sources) $= .1395$ in 1962, $.0301$ in 2000

Calibration

- Measure of A's: Use "Revealed Comparative Advantage" measure for industry j and stage k:

$$RCA_{US,j,k} = \frac{\frac{X_{US,j,k}}{X_{US}}}{\frac{X_{W,j,k}}{X_W}}$$

- 3 steps to construct A1(z) and A2(z) using RCA measures:

  1. Use OECD Input-Output tables (1985) to divide industries into stage 2 industries and stage 1 industries, based on whether demand for for industry output is intermediate demand or final demand:

     1. Stage 1: paper, industrial chemicals, drugs and medicines, petroleum and coal products, rubber and plastic products, non-metallic minerals, iron and steel, non-ferrous metals, and electrical apparatus.
     2. Stage 2: food, beverages and tobacco; textiles, apparel and leather; motor vehicles; shipbuilding; aircraft; office and computing machinery; radio and television; and non-electric machinery.

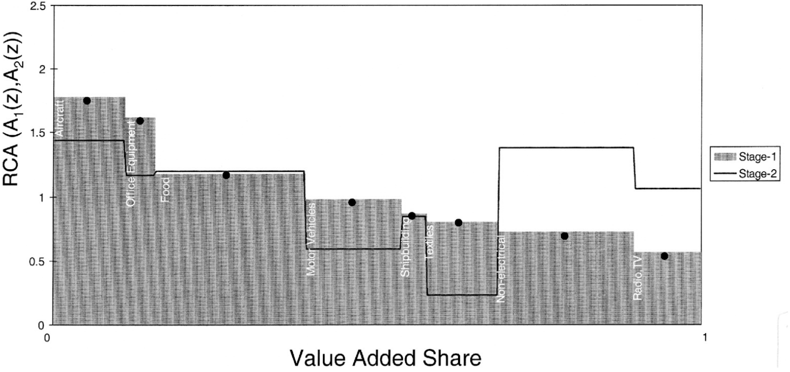
Calibration

2. Each stage 2 industry has a stage 1 "counterpart", which is a weighted average of the stage 2 industry and the stage 1 industries, where the weights depend on the stage 2 industries use of inputs from the stage 1 industries and itself. Use the "proportionality" method to calculate the stage 1 counterpart's exports. Stage 2 exports are total exports by stage 2 industries minus the exports assigned to stage 1 counterpart.
3. Calculate RCAs. Then discretize the [0,1] continuum with the eight stage 2 industries and estimate a quadratic regression of $A_1(z)$ on z, and similarly for $A_2(z)$

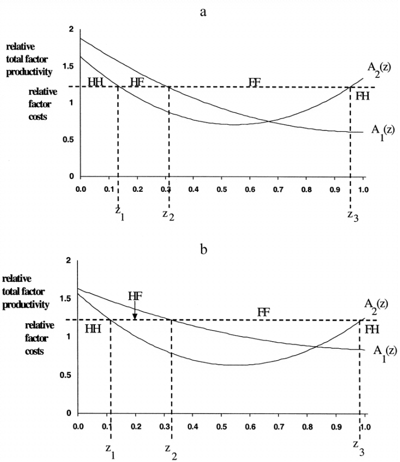
Narrow benchmark case

$$\begin{aligned} A_1(z) &= 1.26z^2 - 2.53z + 1.88 \\ A_2(z) &= 3.095z^2 - 3.38z + 1.63 \end{aligned}$$

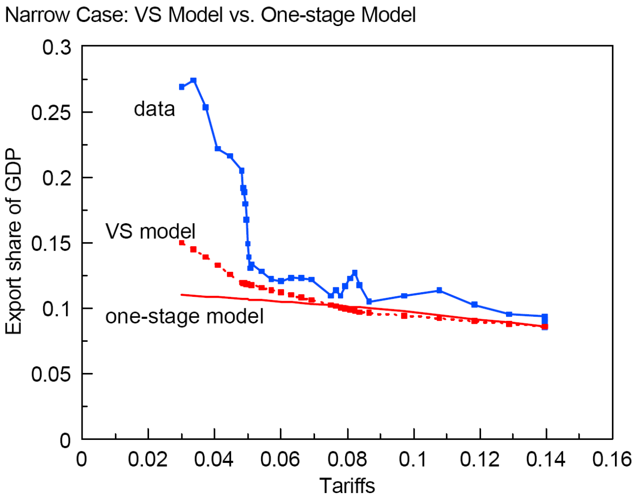
Calibration



Calibration



Results


Narrow Case: VS Model vs. One-stage Model
data
VS model
one-stage model
Export share of GDP
Tariffs
0
0.05
0.1
0.15
0.2
0.25
0.3
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16

Results

Export Growth

	(adjusted) U.S. Data		Narrow Case *VS Model*	Narrow Case *One-Stage Model*	Broad Case *VS Model*	Broad Case *One-Stage Model*
1962-1999	213.0%		74.8%	28.3%	113.0%	62.7%
	Fraction Explained		**35.1%**	**13.3%**	**53.0%**	**29.4%**
1962-1976	36.2%		16.2%	18.1%	47.4%	32.9%
1976-1999	130.0%		50.4%	8.7%	44.6%	22.4%
1962-1989	73.9%		37.9%	24.3%	87.2%	50.3%
1989-1999	80.1%		26.8%	3.2%	13.8%	8.2%

Results

Elasticity of Export Growth w.r.t Tariffs

	(adjusted) U.S. Data	Narrow Case *VS Model*	Narrow Case *One-Stage Model*	Broad Case *VS Model*	Broad Case *One-Stage Model*
1962-1999	22.0	7.8	2.9	11.8	6.5
1962-1976	6.9	3.1	3.4	9.0	6.2
1976-1999	28.4	11.0	1.9	9.7	4.9
1962-1989	9.4	4.8	3.1	11.1	6.4
1989-1999	42.1	14.1	1.7	7.3	4.3

Costinot and Vogel (2013)

The consequences of vertical specialization

- This global phenomenon has attracted a lot of attention among policy makers, business leaders, and trade economists alike
- On the academic side of this debate:
  How does the fragmentation of production processes across borders affect the volume, pattern, and consequences of international trade?
- Here, first look at a distinct, but equally important question:
  How does vertical specialization shape "interdependence of nations?"

This Paper

An elementary theory of global supply chains

- A simple trade model with sequential production:
  - Multiple countries, one factor of production (labor), and one final good
  - Production of final good requires a continuum of intermediate stages
  - Each stage uses labor and intermediate good from previous stage
  - Production is subject to mistakes (Sobel 1992, Kremer 1993)
- Key simplifications:
  - Intermediate goods only differ in the order in which they are performed
  - Countries only differ in terms of failure rate
  - All goods are freely traded

Main Results

Free trade equilibrium

- In spite of arbitrary number of countries, unique free trade equilibrium is characterized by simple system of first-order difference equations
- This system can be solved recursively by:
    1. Determining assignment of countries to stages of production
    2. Computing prices sustaining that allocation as an equilibrium outcome
- Free trade equilibrium always exhibits vertical specialization:
    1. More productive countries, which are less likely to make mistakes, specialize in later stages of production, where mistakes are more costly
    2. Because of sequential production, absolute productivity differences are a source of comparative advantage between nations
- Cross-sectional predictions are consistent with:
    1. "Linder" stylized facts
    2. Variations in value added to gross exports ratio (Johnson Noguera 10)

Main Results

Comparative statics

- Comprehensive exploration of how technological change, either global or local, affects different participants of a global supply chain
- Among other things, they show that:
  1. Standardization—uniform decrease in failure rates around the world—can cause welfare loss in rich countries: a strong form of immiserizing growth
  2. Spillover effects are different at the bottom and the top of the chain: monotonic effects at the bottom, but not at the top
- **Broad message:** Important to model sequential nature of production to understand consequences of technological change in developing and developed countries on trading partners worldwide

Extensions

1. Coordination costs
   - Competitive equilibrium remains Pareto optimal
   - But decrease in coordination costs may lead to “overshooting”
2. Simultaneous production and assembly
   - Poorest countries specialize in assembly
   - Richest countries specialize in later stages of most complex parts
3. Imperfect observability of mistakes
   - Countries with better “quality control” specialize in the earlier stages
4. General production functions
   - Provide sufficient conditions s.t. pattern of specialization still holds

Basic Environment

- Consider a world economy with multiple countries $c \in \mathcal{C} \equiv \{1, ..., C\}$
- There is one factor of production, labor:
  - Labor is inelastically supplied and immobile across countries
  - L_c and w_c denote the endowment of labor and wage in country c
- There is one final good:
  - To produce the final good, a continuum of stages $s \in \mathcal{S} \equiv (0, S]$ must be performed (more on that on the next slide)
- All markets are perfectly competitive and all goods are freely traded
  - They use the final good as our numeraire

Basic Environment (Cont.)

- At each stage, producing 1 unit of intermediate good requires a fixed amount of previous intermediate good and a fixed amount of labor
  - "Intermediate good 0" is in infinite supply and has zero price
  - "Intermediate good S" corresponds to final good mentioned before
- Mistakes occur at a constant Poisson rate, $\lambda_c > 0$
  - λ_c measures total factor productivity (TFP) at each stage
  - Countries are ordered such that λ_c is strictly decreasing in c
- When a mistake occurs, intermediate good is entirely lost
- Formally, if a firm combines $q(s)$ units of intermediate good s with $q(s)ds$ units of labor, the output of intermediate good $s + ds$ is

$$q\left(s + ds\right) = \left(1 - \lambda_c ds\right) q\left(s\right)$$

Free Trade Equilibrium

Definition 1 A free trade equilibrium corresponds to output levels $Q_c(\cdot) : S \longrightarrow \mathbb{R}^+$ for all $c \in C$, wages $w_c \in \mathbb{R}^+$ for all $c \in C$, and intermediate good prices $p(\cdot) : S \longrightarrow \mathbb{R}^+$, such that:

1. firms maximize profit

$$p(s+ds) \leq (1+\lambda_c ds)\, p(s) + w_c ds$$

with equality if $Q_c(s') > 0$ for all $s' \in (s, s+ds]$

2. good markets clear

$$\textstyle\sum_{c=1}^{C} Q_c(s_2) - \sum_{c=1}^{C} Q_c(s_1) = -\int_{s_1}^{s_2} \sum_{c=1}^{C} \lambda_c Q_c(s)\, ds$$

3. labor markets clear

$$\int_0^S Q_c(s)\, ds = L_c$$

Existence and Uniqueness

Vertical specialization

Proposition

In any free trade equilibrium, there exists a sequence of stages $S_0 \equiv 0 < S_1 < ... < S_C = S$ *such that for all* $s \in \mathcal{S}$ *and* $c \in \mathcal{C}$, $Q_c(s) > 0$ *if and only if* $s \in (S_{c-1}, S_c]$.

- **Intuition 1 (hierarchy):**
  - Countries that are producing at later stages can leverage their productivity on larger amounts of inputs
  - Thus, efficiency requires countries to be more productive at the top
- **Intuition 2 (trade):**
  - Intermediate goods at later stages have lower labor cost shares
  - This makes them relatively cheaper to produce in high wage countries

Existence and Uniqueness

Allocation

Lemma

The pattern of vertical specialization and export levels satisfy

$$
\begin{aligned}
S_c &= S_{c-1} - \left(\frac{1}{\lambda_c}\right) \ln\left(1 - \frac{\lambda_c L_c}{Q_{c-1}}\right), \text{ for all } c \in \mathcal{C}, && (1) \\
Q_c &= e^{-\lambda_c (S_c - S_{c-1})} Q_{c-1}, \text{ for all } c \in \mathcal{C}, && (2)
\end{aligned}
$$

with boundary conditions $S_0 = 0$ *and* $S_C = S$.

- **Notation:** $(S_1, ..., S_C) \equiv$ "pattern of vertical specialization"; $Q_c \equiv Q_c(S_c) \equiv$ "export level from country c"
- **Intuition (market clearing):**
  - (1): exogenous supply of labor in country c must be equal to the amount of labor demanded to perform all stages from S_{c-1} to S_c
  - (2): intermediate goods get lost at a constant rate when produced in c

Existence and Uniqueness

Prices

Lemma

The world income distribution and export prices satisfy

$$\begin{aligned} w_{c+1} &= w_c + (\lambda_c - \lambda_{c+1})\, p_c, \text{ for all } c < C, & (3) \\ p_c &= e^{\lambda_c N_c} p_{c-1} + \left(e^{\lambda_c N_c} - 1\right)(w_c/\lambda_c), \text{ for all } c \in \mathcal{C}, & (4) \end{aligned}$$

with boundary conditions $p_0 = 0$ *and* $p_C = 1$.

- **Notation:** $(w_1, ..., w_C) \equiv$ "world income distribution"; $p_c \equiv p(S_c) \equiv$ "price of exports from c"; and $N_c \equiv S_c - S_{c-1}$
- **Intuition (zero profit):**
  - (3): unit cost of production of S_c must be equal in c and $c+1$
  - (4): export price of c depends on import price + total labor cost

Existence and Uniqueness

Putting things together

Proposition

There exists a unique free trade equilibrium. In this equilibrium, the pattern of vertical specialization and export levels are given by (1) *and* (2)*, and the world income distribution and export prices by* (3) *and* (4)*.*

- **Sketch of proof:**
  1. Use (1) and (2) to construct unique pattern of vertical specialization and vector of export levels (with Q_0 set to satisfy $S_C = S$)
  2. Use (3) and (4) to construct unique world income distribution and vector of export prices (with w_1 set to satisfy $p_C = 1$)

Summary

- Free trade equilibrium always exhibits vertical specialization
  - Compared to standard Ricardian models, absolute productivity differences are a source of comparative advantage between nations
- Note that according to our elementary theory of global supply chains:
  1. Poor countries have higher shares of primary production
  2. Rich countries tend to trade relatively more with rich countries
  3. Rich countries tend to import and export goods with higher prices

  $\Rightarrow$ Supply-side explanation of "Linder" stylized facts
- Our model also implies that after controlling for GDP, poor countries have higher ratio of value added to gross exports
  $\Rightarrow$ consistent with Johnson and Noguera (2010)

Comparative Statics

- **Definition 2** A country $c \in C$ is moving up (resp. down) the supply chain relative to the initial free trade equilibrium if $S'_c \geq S_c$ and $S'_{c-1} \geq S_{c-1}$ (resp. $S'_c \leq S_c$ and $S'_{c-1} \leq S_{c-1}$)
- **Definition 3** Inequality is increasing (resp. decreasing) among a given group $\{c_1, ...c_n\}$ of adjacent countries if $w'_{c+1}/w'_c \geq w_{c+1}/w_c$ (resp. $w'_{c+1}/w'_c \leq w_{c+1}/w_c$) for all $c_1 \leq c \leq c_n$
- Definition 2 aims to speak to major concern in developed countries
  - "China is moving up the value chain"
- Definition 3 offers simple way to conceptualize changes in world income distribution in an economy with multiple countries.
  - Definition 3 is in terms of wages per efficiency unit

Increase in Complexity

Proposition

An increase in complexity (S) leads all countries to move up the supply chain and increases inequality between countries around the world.

- **Vertical specialization intuition:**
  - $S \uparrow$ decreases total output at all stages of production
  - Since labor supply must remain equal to demand, this must be accompanied by $N_c \uparrow$ in all countries

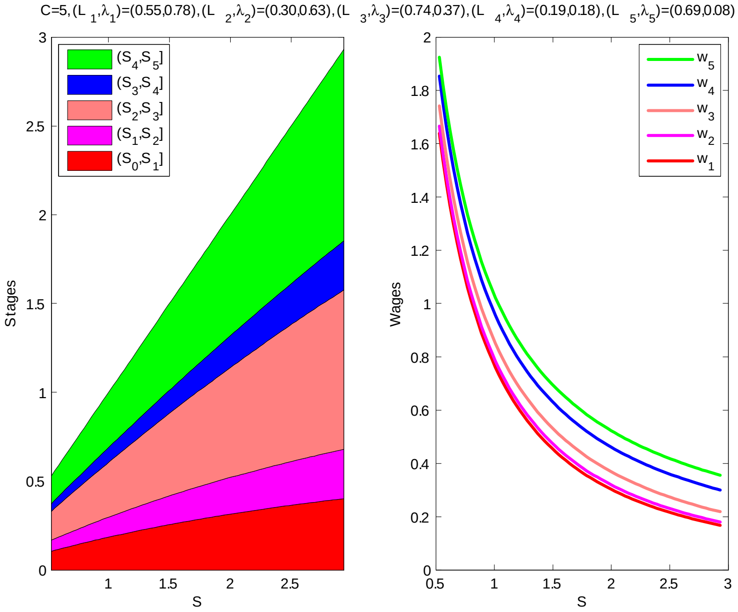
Increase in Complexity

Inequality intuition:

- From wage equation, relative wages satisfy

$$\frac{w_{c+1}}{w_c} = 1 + \frac{\lambda_c - \lambda_{c+1}}{(w_c/p_c)}, \text{ for all } c < C$$

  $\Rightarrow w_{c+1}/w_c$ decreasing in labor cost share, w_c/p_c, of c's export
- Countries are
  - Moving up into higher stages $\Rightarrow$ tends to raise p_{c-1}
  - Performing more stages
    - $\uparrow$ imports necessary to produce one unit of export, $e^{\lambda_c N_c}$
    - $\uparrow$ labor necessary to transform imports into exports, $\left(e^{\lambda_c N_c} - 1\right)/\lambda_c$
  - All effects tend to raise p_c, and in turn, to decrease labor cost share



C=5, (L 1,λ1)=(0.55,0.78), (L 2,λ2)=(0.30,0.63), (L 3,λ3)=(0.74,0.37), (L 4,λ4)=(0.19,0.18), (L 5,λ5)=(0.69,0.08)
(S4,S5]
(S3,S4]
(S2,S3]
(S1,S2]
(S0,S1]
Stages
S
w5
w4
w3
w2
w1
Wages
S

Complexity and World Income Distribution

- Mechanism is reminiscent of mechanism underlying terms-of-trade effects in standard Ricardian models
- Intuitively, $w_{c+1} / w_c \uparrow$ because c moves into sectors in which it has a comparative disadvantage (relative to $c + 1$)
  - In our model, since c has a lower wage, these are the sectors with lower labor cost shares
  - In a standard Ricardian model, this would be the sectors in which c is relatively less productive
- There is, however, one important difference:
  - In our model, the pattern of comparative advantage depends on endogenous differences in labor cost shares across stages
  - In a standard Ricardian model, the same pattern only depends on exogenous productivity differences

Standardization

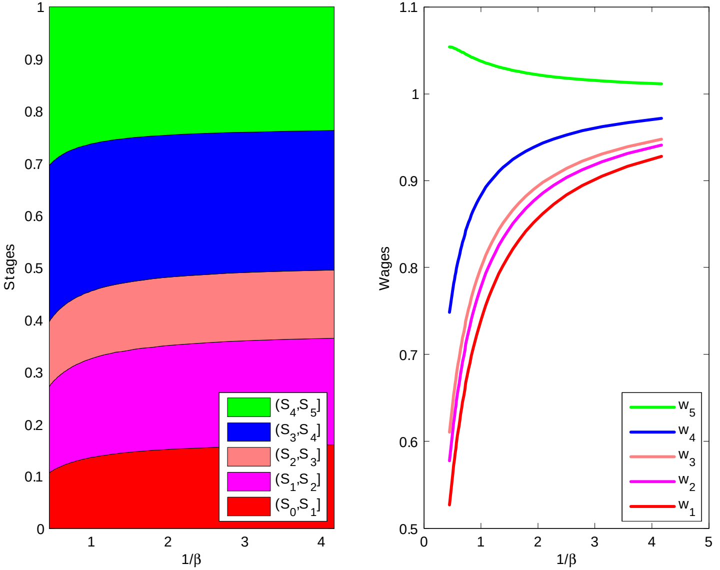
- **Standardization:** uniform decrease in failure rates from λ_c to $\lambda'_c \equiv \beta\lambda_c$ for all $c \in C$, with $\beta < 1$

Proposition

Standardization leads all countries to move up the supply chain and decreases inequality between countries around the world.

- **Intuition:**
  - Standardization raises output (and labor demand) at all stages
  - Must be offset by a reduction of output at earlier stages
    $\Rightarrow$ Poor countries reduce output at each stage, pushing all countries up
  - Direct effect of standardization on relative wages is to decrease inequality (if $\beta = 0$, having lower failure rate λ_c provides no benefit)
    $\Rightarrow$ Direct effect necessarily dominates

C=5, (L_1,λ_1)=(0.53,0.97), (L_2,λ_2)=(0.65,0.61), (L_3,λ_3)=(0.41,0.53), (L_4,λ_4)=(0.82,0.33), (L_5,λ_5)=(0.72,0.11)



Standardization, Product Cycles, and Immiserizing Growth

- Standardization leads to **product cycles**:
  - Standardization induces poor countries to perform more stages
  - Results reminiscent of Vernon's (1966) "product cycle hypothesis"
  - As this happens, inequality between nations decreases around the world
- Standardization may lead to **immiserizing growth**:
  - Welfare may fall in the most technologically advanced countries because of a deterioration of their terms-of-trade
  - Compared to Bhagwati (1958):
    1. Standardization proportionately lowers failure rates in all countries
    2. Standardization proportionately lowers failure rates at all stages

Labor-augmenting technical progress

Pattern of vertical specialization

Labor endowment growth: Increase in labor endowment L_{c_0}

Proposition

Labor-endowment growth in c_0 leads all countries $c < c_0$ to move down the supply chain and all countries $c > c_0$ to move up.

- **Intuition:**
  1. $\nearrow$ in labor supply in c_0 $\nearrow$ total output at all stages
  2. Since labor supply = labor demand, $N_c \searrow$ for all $c \neq c_0$
  3. By iteration, this decrease in N_c can only occur if all countries below c_0 move down and all countries above c_0 move up
  4. Since the total measure of stages is constant, $N_{c_0} \nearrow$

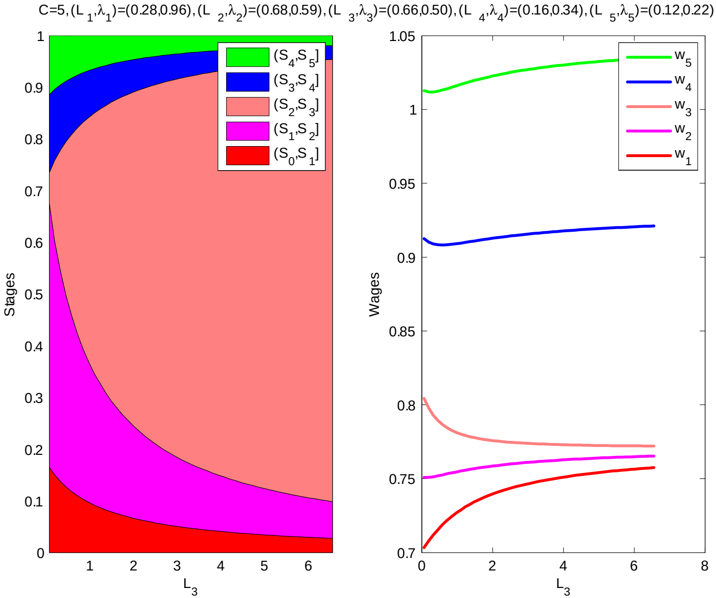
Labor-augmenting technical progress

World income distribution

Proposition

Labor-endowment growth in c_0 decreases inequality among countries $c \in \{1, ..., c_0\}$, increases inequality among countries $c \in \{c_0, ..., c_1\}$, and decreases inequality among countries $c \in \{c_1, ..., C\}$, with $c_1 \in \{c_0 + 1, ..., C\}$.

- **Intuition (bottom of the chain):**
  1. At the bottom of the chain countries (i) move down into lower stages and (ii) perform fewer stages
  2. Both effects $\searrow$ the price of goods traded in that region of the chain, and in turn, $\nearrow$ their labor cost share
  3. Thus, w_{c+1}/w_c $\searrow$ as the labor cost share, w_c/p_c, of c's exports $\nearrow$
- **Intuition (top of the chain):**
  - Endogenous differences in labor cost shares $\Rightarrow$ non-monotonic effects



C=5, (L 1,λ1)=(0.28,0.96), (L 2,λ2)=(0.68,0.59), (L 3,λ3)=(0.66,0.50), (L 4,λ4)=(0.16,0.34), (L 5,λ5)=(0.12,0.22)
(S4,S5]
(S3,S4]
(S2,S3]
(S1,S2]
(S0,S1]
Stages
L3
w5
w4
w3
w2
w1
Wages
L3

Comparison with "Simultaneous" Ricardian models

- Consider Ricardian model w/ ladder of countries (e.g. Krugman 1986)
- If richest countries move up, inequality increases
  - Relative wage = relative productivity in "cutoff" sector
  - Richer countries are relatively more productive in sectors higher up (otherwise they would not be specializing in these sectors!)
- Here as richest countries move up, inequality may decrease
  - Later stages have lower labor cost shares in a given equilibrium
  - But endogeneity $\Rightarrow$ labor cost share of later stages in new equilibrium may be higher than of earlier stages in initial equilibrium

Routinization

Pattern of vertical specialization

Routinization: Decrease in failure rate λ_{c_0}

Proposition

Routinization in c_0 increases the measure of stages performed in all countries $c < c_0$ and decreases the measure of stages performed in all countries $c > c_0$. In turn, all countries $c \neq c_0$ move up the supply chain.

- Through fragmentation of the production process across borders, routinization in one country leads all its trading partners to move up (even in the absence of TFP growth in any of these countries)
- Labor-augmenting technical progress and routinization have the exact same effects at the top, but opposite effects at the bottom

Routinization

Pattern of vertical specialization

- **Basic idea:**
  Labor markets must clear both before and after a given TFP shock
- **Intuition (top of the chain):**
  1. $\searrow$ in failure rate in c_0 $\nearrow$ total output at all stages
  2. Since labor supply $=$ labor demand, $N_c \searrow$ for all $c \neq c_0$ etc.
- **Intuition (bottom of the chain):**
  1. $\searrow$ in failure rate in c_0 $\nearrow$ total labor demand of countries $c \geq c_0$
  2. Thus, countries at the bottom must $\nearrow$ number of stages they perform and move up to offset excess labor demand at the top

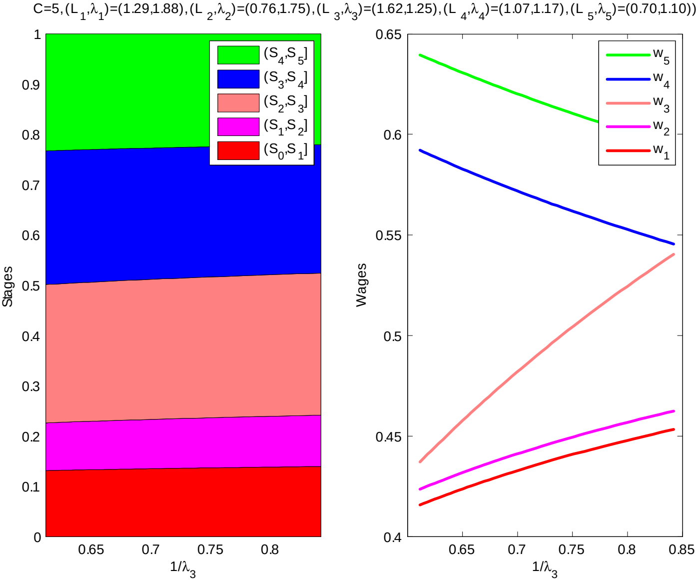
Routinization

World income distribution

Proposition

Routinization in c_0 increases inequality among countries $c \in \{1, ..., c_0 - 1\}$, decreases inequality among countries $c \in \{c_0, c_0 + 1\}$, increases inequality among countries $c \in \{c_0 + 1, ..., c_1\}$, and decreases inequality among countries $c \in \{c_1, ..., C\}$, with $c_1 \in \{c_0 + 1, ..., C\}$.

- As before, changes in the pattern of vertical specialization naturally translate into changes in inequality between nations
- At the bottom, routinization increases inequality between nations
- Though poor countries are moving up, they are relatively worse off
  - Since technological change comes from abroad, they still have a comparative disadvantage in later stages of production


C=5,(L 1,λ1)=(1.29,1.88),(L 2,λ2)=(0.76,1.75),(L 3,λ3)=(1.62,1.25),(L 4,λ4)=(1.07,1.17),(L 5,λ5)=(0.70,1.10))
Stages
(S4,S5]
(S3,S4]
(S2,S3]
(S1,S2]
(S0,S1]
1/λ3
Wages
w5
w4
w3
w2
w1
1/λ3

Summary

- They have developed an elementary theory of global supply chains
  - Because of the sequential nature of production, absolute productivity differences are a source of comparative advantage among nations.
- Using this theory, they have taken a first step towards analyzing how vertical specialization shapes the interdependence of nations
- Among other things, they have shown that:
  - Standardization can cause welfare loss in rich countries
  - Local technological progress tends to spill over very differently at bottom and top of the chain

Antras and Chor (2013)

- Develop a model of firm production with a continuum of uniquely sequenced production stages
  - In each stage: Firm contracts with a distinct supplier for a stage-specific input that needs to be made compatible with all other stage inputs
  - In an incomplete contracts setting, obtain a sharp characterization of the optimal ownership structure along the value chain
- Derive analytical results related to the integrate vs outsource decisions for securing each stage input
  - Production line position matters
- Empirically, test predictions of the model using:
  - the intrafirm trade share (to capture the prevalence of integration);
  - novel measures of the downstreamness of particular inputs (which we develop from Input-Output Tables)

Basic Setup: Prodution Function

- Production requires the completion of a continuum of stages indexed by $j \in [0, 1]$
- Unique sequence of stages: j increases as production moves downstream
- Let $x(j)$ be the services of compatible intermediate inputs that supplier j delivers to the Firm. Quality-adjusted volume of final-good production is

$$q = \theta \left(\int_0^1 x(j)^{\alpha} I(j) \, dj \right)^{1/\alpha},$$

$$I(j) = \begin{cases} 1, & \text{if input } j \text{ is produced after all inputs } j' < j, \\ 0, & \text{otherwise.} \end{cases}$$

- $\alpha \in (0, 1)$: captures how substitutable the stage inputs are
- θ: firm productivity parameter

Basic Setup: Supply of Inputs

- Each intermediate input needs to be produced by a different supplier
- Suppliers need to undertake a relationship-specific investment to produce a compatible input
- One unit of investment generates one unit of $x(j)$, the services of the stage j compatible input
- Marginal cost of investment is common for all suppliers and equal to c (although this can be relaxed)
- Incompatible inputs can be produced by all agents (including the Firm) at a negligible marginal cost, but they add no value to final-good production (other than allowing completion)

Basic Setup: Final Good Demand

- Consumers have preferences:

$$U = \left(\int_{\omega \in \Omega} \left(\varphi\left(\omega\right) \tilde{q}\left(\omega\right) \right)^{\rho} d\omega \right)^{1/\rho}, \text{ with } \rho \in (0,1)$$

  - $\varphi\left(\omega\right)$: quality of a variety
  - $\tilde{q}\left(\omega\right)$: consumption in physical units

- Implied revenue function of any firm in the industry is concave in quality-adjusted output $q\left(\omega\right) = \varphi\left(\omega\right) \tilde{q}\left(\omega\right)$ with a constant elasticity ρ:

$$r = A^{1-\rho} q^{\rho} = A^{1-\rho} \theta^{\rho} \left(\int_0^1 x\left(j\right)^{\alpha} dj \right)^{\rho/\alpha}$$

Some Key Features

- Value generated up to stage m if all inputs are compatible:

$$r(m) = A^{1-\rho}\theta^{\rho}\left[\int_0^m x(j)^{\alpha}\, dj\right]^{\frac{\rho}{\alpha}}$$

- Incremental value generated at stage m by a compatible input:

$$r'(m) = \frac{\partial r(m)}{\partial m} = \frac{\rho}{\alpha}\left(A^{1-\rho}\theta^{\rho}\right)^{\frac{\alpha}{\rho}}\left[r(m)\right]^{\frac{\rho-\alpha}{\rho}} x(m)^{\alpha}$$

- How does the value of production up to stage m affect the marginal contribution of supplier m?
  - If $\rho > \alpha$, the effect is positive (sequential complements case)
  - If $\rho < \alpha$, the effect is negative (sequential substitutes case)

Some Key Features

- Intuition for $\rho \gtrless \alpha$:
  - From a technological point of view, all inputs are complements since $\alpha \in (0, 1)$
  - But when ρ is small, firm faces an inelastic demand function, so marginal revenue falls quickly with quality-adjusted output
  - Large investments prior to stage m therefore discourage supplier effort at stage m
  - It turns out that when $\rho < \alpha$, this revenue effect is strong enough to dominate the physical input complementarity effect

Benchmark: Complete Contracts

- If contracting frictions are absent, firm signs a contract with each input supplier specifying the optimal level of compatible inputs, $x(j)$, to maximize:

$$\pi_F = A^{1-\rho}\theta^{\rho}\left(\int_0^1 x(j)^{\alpha}dj\right)^{\frac{\rho}{\alpha}} - c\int_0^1 x(j)dj$$

- Solution entails:
  - A common investment level, $x = \left(\rho A^{1-\rho}\theta^{\rho}/c\right)^{1/(1-\rho)}$, for all inputs j
  - Suppliers are paid their marginal cost: cx
  - Even though

$$r'(m) = \frac{\partial r(m)}{\partial m} = \frac{\rho}{\alpha}\left(A^{1-\rho}\theta^{\rho}\right)^{\frac{\alpha}{\rho}}\left[r(m)\right]^{\frac{\rho-\alpha}{\rho}} x(m)^{\alpha},$$

    the Firm internalizes the downstream effects of upstream investments

Incomplete Contracting

- Suppose that the environment is one of incomplete contracts
  - Compatibility cannot be verified and enforced by a third-party court
  - But Firm and suppliers have symmetric information regarding compatibility
  - Contracts contingent on total revenue are not useful in our context
  - Abstract from mechanisms
  - Suppliers' payoffs are determined in *ex post* (re)-negotiation, after $x(m)$ has been produced

Bargaining

- Supplier m and Firm engage in generalized Nash bargaining over the incremental value contribution made by supplier m, $r'(m)$
- Supplier m's outside option normalized to 0
- Under integration, Firm's control rights tilt the ex-post division of surplus in its favor relative to under outsourcing (as in Grossman and Hart, 1986). Firm recovers a fraction $\delta(m)$ of the inputs $x(m)$
  - Under outsourcing: $\delta(m) = 0$
  - Under integration: $\delta(m) = \delta \in (0, 1)$
- Let $\beta(m)$ be the share of $r'(m)$ that accrues to the firm in the bargain:

$$\beta(m) = \begin{cases} \beta_O & \text{if the firm outsources stage } m \\ \beta_V > \beta_O & \text{if the firm integrates stage } m \end{cases}$$

Timing

1. Firm posts contracts for suppliers for each stage $j \in [0, 1]$, stating the organizational mode (integration vs outsourcing).
2. Suppliers apply. Firm chooses one supplier for each stage j.
3. Production takes place sequentially. At the beginning of each stage m, the supplier is handed the good completed up to stage m.The supplier chooses $x(m)$ after observing the value of $r(m)$.
4. At the end of stage m, the supplier and Firm bargain over $r'(m)$. Firm pays the supplier.
5. Output of the final good, q, is realized once the final stage is completed. Total revenue, $A^{1-\rho}q^{\rho}$, $\rho \in (0, 1)$, from the sale of the final good is collected by the Firm.

Timing

- Firm and the supplier bargain only at stage m; the terms of exchange are not renegotiated at a later stage and do not reflect the outcome of subsequent negotiations
- Bargaining is over supplier's marginal contribution at stage m, not its ultimate (or average marginal) contribution
- Can be rationalized by limited commitment frictions: Hart and Moore (1994), Thomas and Worrall (1994)
- Supplier does not want to delay receiving payment; or Firm might be constrained in borrowing more than $r'(m)$

Key Tradeoffs

- Ownership confers a higher fallback option to the firm and allows it to extract more surplus
- But foreseeing a lower return to their investments, integrated suppliers will under-invest relatively more, ie choose a lower $x(m)$:

$$\max_{x(m)} \quad (1-\beta(m))\, r'(m) - cx(m)$$

- Downstream effect: on the incentives to invest of all suppliers that are positioned downstream relative to the supplier being integrated
- This downstream effect is negative in the complements case, but it is positive in the substitutes case

The Make-or-Buy Decision

Before production begins, firm chooses $\beta(j) \in \{\beta_V, \beta_O\}$ for $j \in [0,1]$ to maximize firm profits

In the complements case ($\rho > \alpha$), there exists a unique $m_C^* \in (0,1]$, such that: (i) all production stages $m \in [0, m_C^*)$ are outsourced; and (ii) all stages $m \in [m_C^*, 1]$ are integrated within firm boundaries.

In the substitutes case ($\rho < \alpha$), there exists a unique $m_S^* \in (0,1]$, such that: (i) all production stages $m \in [0, m_S^*)$ are integrated within firm boundaries; and (ii) all stages $m \in [m_S^*, 1]$ are outsourced.
Remark: m_C^* and m_S^* can be solved for in closed-form

The Make-or-Buy Decision

Additional predictions:

Whenever integration and outsourcing coexist along the value chain, i.e., $m_C^* \in (0,1)$ when $\rho > \alpha$ or $m_S^* \in (0,1)$ when $\rho < \alpha$, a decrease in ρ will necessarily expand the range of stages that are vertically integrated.

- Intuition:
  - When ρ is low, firm has high market power, and hence will focus on the rent extraction motive for integration
  - When β is low, firm's primitive bargaining power is low, so this raises the incentive to integrate

Conclusions

- Developed a model of organizational decisions for a production function with a continuum of sequential stages
- For each stage, firm's make-or-buy decision depends on that stage's position in the value chain
    - When stage inputs are sequential complements: Outsource upstream and Integrate downstream
    - When stage inputs are sequential substitutes: Integrate upstream and Outsource downstream
    - Intuition driven by how effort choices of upstream stage suppliers affect effort levels downstream
- Can be readily embedded into existing global sourcing frameworks
- Evidence based on U.S. related-party trade shares is broadly consistent with the model's predictions