

# An Elementary Theory of Global Supply Chains

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EC 791, Fall 2016

# Outline

- 1 Motivation
  - Sequential Production in an International System
- 2 Contributions
  - Model
  - Basic Results
  - Extensions
- 3 Conclusion

# Production Isn't a Single Act

- Long known production occurs in a sequence.
  - Adam Smith: More than a dozen steps in making a pin
  - Thousands or millions of parts in modern products
- Still the case, and increasingly geographically spread.

# Goals of the Paper

- Justification for international pattern of production
- Why some countries produce at different points in the value chain
- Explain observed patterns of trade and income
- Based on endogenous reaction to nonspecific exogenous factors
- Examine how changing technology affects all of these

# Previous Work

- Value, Pattern, and Consequences of Trade:
  - Feenstra and Hanson (1996): Outsourcing and skill-level specialization
  - Yi (2003): Traditional trade barriers can't explain trade pattern before and after 1980
  - Grossman and Rossi-Hansberg (2008): Offshoring with differential factor endowments
- Hierarchies
  - Lucas (1978): Distribution of factors across managers in firms based on talent
  - Antràs (2006): Matching in a knowledge economy model
- Model
  - Sobel (1992), Kremer (1993)

# Environment

- Sequential production subject to mistakes
  - Worker skill, infrastructure, contract enforcement
- Fixed discrete countries  $c \in C \equiv \{1, \dots, C\}$
- One factor of production: labor supply in each country  $L_c$  with price  $w_c$
- Final good produced in continuum of steps  $s \in S \equiv (0, S]$ 
  - In each stage, combine 1 unit of previous intermediate good with 1 unit of labor to get 1 unit of next intermediate good
    - $q(s + ds) = (1 - \lambda_c ds)q(s)$
- Mistakes at rate  $\lambda_c > 0$ , constant within each country
  - A country will make mistakes at the same rate regardless of what stage of production it does
  - Countries ordered so  $\lambda_c$  strictly decreasing
  - If a mistake is made, unit lost with 0 recovery

# Environment

- Competitive markets
- No fixed or variable trade costs
- $p(s)$  is world price of good  $s$ 
  - $p(0) = 0$
  - $p(S) = 1$ : final good is numeraire
- Each firm has consecutive stages of production of measure  $> 0$ 
  - Finite sequence of firms in production

# Equilibrium Conditions

- Profit Maximization

- $p(s + ds) \leq (1 + \lambda_c ds)p(s) + w_c ds$
- Holds with equality if country  $c$  produces all products between  $s$  and  $ds$
- World price of output is weakly less than the price of inputs that could be used, and equal to the cost of inputs actually used

- Production

- $\sum_{c=1}^C Q_c(s_2) - \sum_{c=1}^C Q_c(s_1) = - \int_{s_1}^{s_2} \sum_{c=1}^C \lambda_c Q_c(s) ds$
- Difference in output over the value chain is all due to mistakes in production

- Factor Utilization

- $\int_0^S Q_c(s) ds = L_c$
- Full employment in all countries

# Structure of Production

- Stages  $S_0 \equiv 0 < S_1 < \dots < S_C = S$ , with  $Q_c(s) > 0$  iff  $s \in (S_{c-1}, S_c]$ 
  - The lower the rate of mistakes, the later in the value chain a country produces
  - Leverage: applying more efficient workers to tasks with higher non-labor inputs
  - Comparative advantage: lower labor cost share in later stages, so more efficient to produce in higher wage countries
- Wages  $w_{c+1} = w_c + (\lambda_c - \lambda_{c+1})p_c$ 
  - wages rise in proportion to difference in efficiency
- Prices  $p_c = \exp(\lambda_c N_c)p_{c-1} + (\exp(\lambda_c N_c) - 1)(w_c/\lambda_c)$
- Have unique structure of production for given environment

# Implications

- Rich countries trade more with rich countries, and poor with poor countries.
- Rich countries import and export more goods with high unit values.
- Expect “Lunder effects,” or relatively more trade between countries with similar GDP per capita in industries with high vertical fragmentation

# Comparative Statics

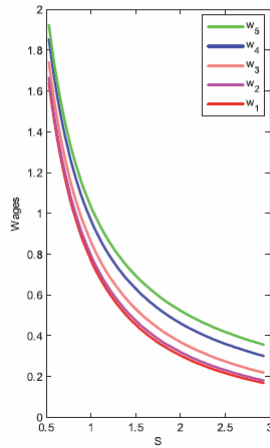
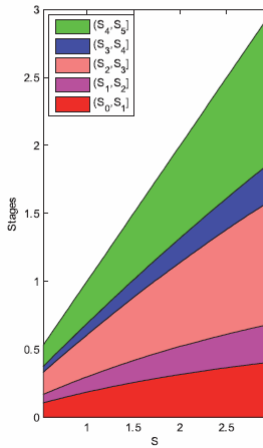
- Definitions

- Moving up the value chain:  $S'_c \geq S_c$  and  $S'_{c-1} \geq S_{c-1}$
- Income inequality increasing in group  $\{c_m, \dots, c_n\}$  if  $w'_{c+1}/w'_c \geq w_{c+1}/w_c$  for all  $c$  in group

# Increase in Complexity

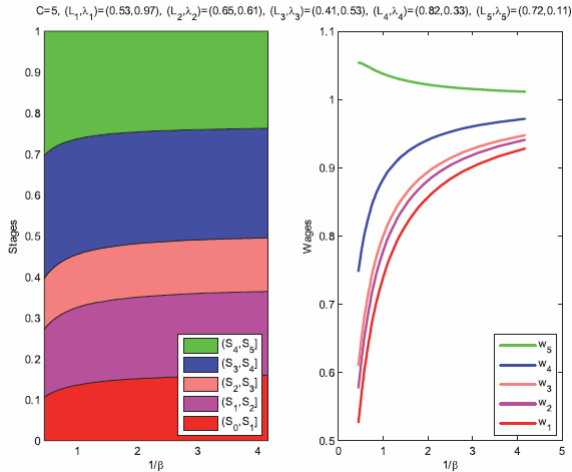
- $S' > S$ : more stages of production
- All countries move up supply chain
- Decreases output at all stages
- Increases inequality
  - Ricardian interpretation: low-mistake countries have comparative advantage in later stages of production

$C=5$ ,  $(L_1, \lambda_1)=(0.55, 0.78)$ ,  $(L_2, \lambda_2)=(0.30, 0.63)$ ,  $(L_3, \lambda_3)=(0.74, 0.37)$ ,  $(L_4, \lambda_4)=(0.19, 0.18)$ ,  $(L_5, \lambda_5)=(0.69, 0.08)$



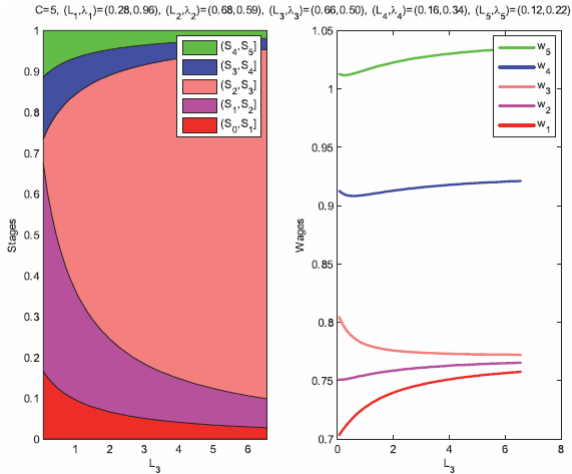
# Standardization

- Lower rate of mistakes:  $\lambda'_c = \beta \lambda_c, \beta < 1$
- Increases output at all stages
- Decreases inequality
- Equivalent to a reduction in complexity if normalize stages and prices by  $\beta$



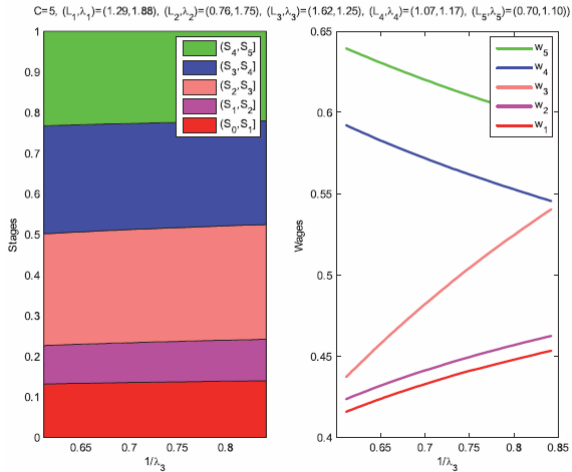
# Labor Force Growth in One Country $c_0$

- Pushes poorer countries down value chain, richer countries up
- Non-monotonic results
  - Decreases inequality between countries poorer than  $c_0$
  - Increases inequality between countries from  $c_0$  to some  $c_1$
  - Decreases inequality between countries richer than  $c_1$
- Since labor cost shares come out of the model, labor share may rise at end of supply chain such that poorer rich countries may benefit more than richest



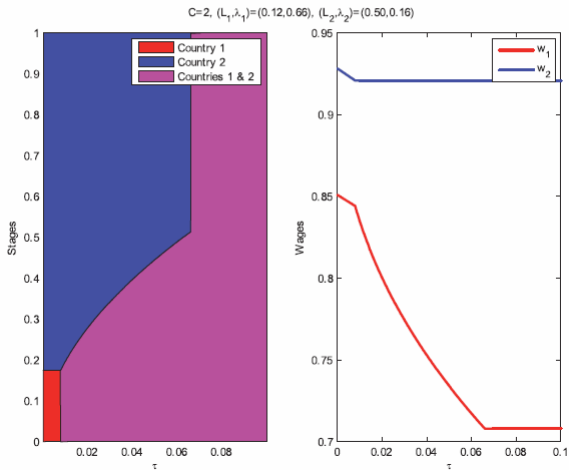
# Routinization in One Country $c_0$

- Reduced rate of mistakes:  $\lambda'_{c_0} < \lambda_{c_0}$
- All countries move up value chain
- Non-monotonic results
  - Increases inequality between countries poorer than  $c_0$
  - Decreases inequality between  $c_0$  and  $c_0 + 1$
  - Increases inequality between countries from  $c_0 + 1$  to some  $c_1$
  - Decreases inequality between countries richer than  $c_1$



# Coordination Costs

- Each border crossing introduces probability  $\tau < 1$  of defect not observed until final product
- Still have decreasing  $\lambda_c$  in any supply chain with specialization
- May no longer have all units produced by same sequence
  - Unless low enough  $\tau$ , then same as free trade
  - With high enough  $\tau$ , no specialization
  - Intermediate, see poorer country move up supply chain compared to free trade
- Smaller countries benefit more from trade



# Simultaneous Production

- $N$  chains of intermediate goods for parts
- Assembled in final stage  $Y_c = F(X_c^1, \dots, X_c^N)$ 
  - Assembly error-free, done by poorest countries
- If a country produces any parts, all richer countries only produce parts
- Still have lower-error countries specialize later in value chain
  - Some high wage countries may not produce even last stage of low-complexity parts
- Predict trade more concentrated between countries with comparable income in industries with more complex production

# Imperfect Observation of Mistakes

- Mistakes observed with probability  $\beta_c$  unique to each country
- Pushes in opposite direction as lower error rate
  - Lower  $\beta_c$ , lower  $\lambda_c$  both drive country earlier in value chain
  - Want to avoid putting additional factors into defective product

# Conclusion

- The paper studies the pattern of multinational production with vertical specialization.
- The model allows for endogenous sorting along the value chain without directly assigning a country different absolute underlying productivity to different stages.
- It accounts for a pattern of trade in which rich countries trade mainly with rich countries, and poor countries with poor countries.
- It offers predictions of which industries will see the most rich-rich and poor-poor trade.
- Explores reaction to technological changes and several extensions.

# Conclusion

Thank you for your time.