Heterogeneous Workers in International Trade

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Traditionally, causes and consequences of trade addressed in models with **broad factor categories**: capital, unskilled/skilled labor, raw materials ...

- Comparative advantage driven by differences in aggregate endowments
- Distributional effects of trade: wages vs. profits, skill premium ...
- Efficiency of labor market allocation: sectoral misallocation

Recently, **matched employer-employee data sets** allow us to study issues at finer level of detail

- Ask whether/how **distributions** of factors differentiated by quality/skill/talent affect patterns of comparative advantage
- Ask **how trade affects compensation across the entire wage distribution**
- Ask how trade affects productivity/efficiency by altering match of heterogeneous workers to firms and formation of production teams
Some Motivating Observations

1. **Skill Dispersion is Source of Comparative Advantage**
   - Cross-country differences in skill *dispersion* (from International Adult Literacy Survey) larger than differences in means.
   - Countries with less skill dispersion specialize in sectors with more important skill complementarities in production.

2. **Positive Assortative Matching of Firms and Workers**
   - Regress wage on worker and firm characteristics, fixed effects.
   - Estimate “quality” of worker and firm based on observed characteristics and unobservables (fixed effects).
     - Good workers earn higher wages.
     - Good firms pay higher wages.
   - Correlation between worker and firm “quality” about 0.10.
Some Motivating Observations (cont’d)

Wages Vary Widely for Same Occupation and Sector

- Decompose Brazilian wage inequality into “within” and “between” components for sectors, occupations, and sector-occupations.
- Substantial inequality in same industry within same occupation
  - Within sector-occupation (12/5) component accounts for 67% of 1990 level of inequality.
  - Even with very detailed sector and occupation categories (283/348), within component accounts for 52% of inequality.
- Similar findings for UK.
Exporters Pay a Wage Premium, but ...

- Many studies find exporters pay higher average wages than non-exporters, after controlling for firm characteristics.
- But plant-level estimation suffers from aggregation bias if no control for observable and unobservable worker heterogeneity.
- With worker or worker-firm fixed effects, premium smaller or disappears.
  - Schank et al. find insignificant coefficient for export status, positive and significant (but diminished) coefficient for export share.
  - Suggests that unobserved worker characteristics positively correlated with export behavior – matching and/or sorting.
  - Helpman et al. find exporter premium in Brazil after controlling for firms size and observable worker characteristics.
Trade Affects PAM in Export-Oriented Industries

- Measure “degree of matching” in industry and year as correlation between firm and worker total (observable plus fixed) effects
- Measure openness by foreign tariffs faced by Swedish goods
- Greater openness associated with greater PAM in export-oriented industries, but find no significant effect in import-competing industries
Modeling Worker Heterogeneity

- Output $x_i$ of good $i$ in country $k$

\[ x_i = \text{Productivity}(\text{Input Qualities}) \ast f(\text{Input Quantities}) \]

- **Productivity** of factors: $\psi^k_i (q_L, q_H)$
  - Contribution of worker “ability” to productivity can differ across industries and countries
  - Complementarity/substitutability between factors or team members

- **Quantities** of factors: $f^k_i (\ell, h)$
  - Scarcity of managerial “time” or congestion on machines can generate diminishing returns to labor
  - Factor intensities can differ across industries
A Digression on Terminology

- **Complementarities** play important role for sorting and matching
  - More able workers may be more productive in all activities, but which activities are complementary with ability?
  - More able workers may be more productive with all partners, but which partnerships generate greatest synergies?

- A function is **supermodular** if \( (B = \text{better}, W = \text{worse}) \)

\[
F(B, B) - F(W, B) \geq F(B, W) - F(W, W)
\]

  - Second argument could represent industry or occupation
  - Second argument could represent type of partner

- A function is **log supermodular** if

\[
\frac{F(B, B)}{F(W, B)} \geq \frac{F(B, W)}{F(W, W)}
\]

  - Compares relative return to worker ability?
  - Stronger notion of complementarity than supermodularity
Sorting Workers to Industries

- Sorting but no matching:
  - Output is sum of what is produced by all workers “assigned” to industry \( i \) in country \( k \)
    - No interactions between factor types in determining productivity
    - No interactions between factor quantities; i.e., no diminishing returns
  - Workers make independent choices based on prices and productivities in different industries
    - Worker has a “virtual” wage in each industry: \( w^k_i(q) = p_i \psi^k_i(q) \)
    - Workers sort to industries that will pay them the most
Sorting With Linear Production

Case I: Ricardian

- Suppose workers in a country have **same relative productivity** in all sectors

\[
\frac{\psi_i^k(B)}{\psi_j^k(B)} = \frac{\psi_i^k(W)}{\psi_j^k(W)}
\]

⇒ If \( B \) prefers working in sector \( i \) to \( j \), so does \( W \)

- Different countries are relatively more productive in different industries
  - Suppose we can order countries and industries so that productivity is log supermodular as function of country and industry ⇒ more developed countries relatively more productive in more sophisticated industries
  - Then more developed countries produce and export in more sophisticated industries
  - Trade has no effect on distribution of income: determined by relative productivity of workers, which is independent of industry of employment
Suppose workers have different relative productivity in different sectors, but workers of given ability have same relative productivity everywhere

\[
\frac{\psi_i^k(B)}{\psi_j^k(B)} = \frac{\psi_i(B)}{\psi_j(B)} \quad \text{and} \quad \frac{\psi_i^k(W)}{\psi_j^k(W)} = \frac{\psi_i(W)}{\psi_j(W)}
\]

⇒ given type sorts to same industry no matter where he is located

Suppose we can order industries so that productivity as function of industry and ability is log supermodular ⇒ more able workers relatively more productive in more sophisticated industries

Suppose we can order countries so that more able workers are relatively more abundant in more developed countries

Then more developed countries produce relatively more of (and export) more sophisticated goods.
North-South Trade:
- Let North have superior distribution of worker quality: i.e., relatively more of the more able workers for any pair of worker types
- In North, trade causes workers to sort to more sophisticated sectors
- In North, trade causes relative wage to rise for the more able workers
- Opposite effects in South

North-North Trade:
- Let West have more diverse distribution of worker ability than East; i.e., relatively more of the lower ability workers for any pair with abilities less than some $q'$ and relatively more of the high ability workers for any pair with qualities above $q'$
- In West, trade causes workers to sort to more extreme sectors
- In West, trade causes relative wage to rise for more extreme workers ("polarization")
- Opposite effects in East
Output of unit with one manager and \( \ell \) workers of type \( q \):

\[
x_i = \psi_i(q)f^i(\ell)
\]
Sorting with Homogeneous Managers

- Output of unit with one manager and \( \ell \) workers of type \( q \):
  \[
x_i = \psi_i(q)f^i(\ell)
  \]

- Choice of worker type: In industry \( i \), compare \( \frac{\varepsilon_{\psi_i}(q)}{\gamma_i} \) vs. \( \varepsilon_w(q) \)
Output of unit with one manager and $\ell$ workers of type $q$:

$$x_i = \psi_i(q)f^i(\ell)$$

Choice of worker type: In industry $i$, compare $\frac{\epsilon_{\psi_i}(q)}{\gamma_i}$ vs. $\epsilon_w(q)$

Wage schedule:

- Firms in industry $i$ prefer particular worker type unless wage rises with quality at just the “right” rate
- So, labor market equilibrium requires

$$\frac{\epsilon_{\psi_i}(q)}{\gamma_i} = \epsilon_w(q)$$

for all workers that sort to industry $i$
Sorting with Homogeneous Managers

- Output of unit with one manager and $\ell$ workers of type $q$:
  \[ x_i = \psi_i(q) f^i(\ell) \]

- Choice of worker type: In industry $i$, compare $\frac{\varepsilon \psi_i(q)}{\gamma_i}$ vs. $\varepsilon_w(q)$

- Wage schedule:
  - Firms in industry $i$ prefer particular worker type unless wage rises with quality at just the “right” rate
  - So, labor market equilibrium requires
    \[ \frac{\varepsilon \psi_i(q)}{\gamma_i} = \varepsilon_w(q) \]
    for all workers that sort to industry $i$

- Sorting of more able workers to Sector 1:
  \[ \frac{\varepsilon \psi_1(q)}{\gamma_1} > \frac{\varepsilon \psi_2(q)}{\gamma_2} \]
Sorting of More Able Workers to Sector 1
Sorting with Homogeneous Capital

Pattern of Trade

- Suppose countries have same distributions of worker ability but different relative endowments (numbers) of managers to workers
  - ⇒ Labor rich country produces relatively more of $L$-intensive good
- Suppose countries have same relative endowments but ability distribution is shifted to right in North
  - North produces relatively more of good with greater elasticity of $\psi^i$
  - This may or may not be good that attracts the highest quality workers
Sorting with Homogeneous Capital

- **Pattern of Trade**
  - Suppose countries have same distributions of worker ability but different relative endowments (numbers) of managers to workers
    - $\Rightarrow$ Labor rich country produces relatively more of $L$-intensive good
  - Suppose countries have same relative endowments but ability distribution is shifted to right in North
    - North produces relatively more of good with greater elasticity of $\psi^i$
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- **Income Distribution**
  - Trade has no effect on within-industry wage distribution
  - Effects on between-industry and between-factor distribution:
    - If $\frac{\epsilon_{\psi_1}(q)}{\gamma_1} \approx \frac{\epsilon_{\psi_2}(q)}{\gamma_2}$ $\Rightarrow$ real wages of workers in both sectors rise when price of labor intensive good rises
    - If $\gamma_1 \approx \gamma_2$ $\Rightarrow$ real wages of workers rise in export sector and fall in import competing sector
• One sector: international teams but no international trade.
• Choice of occupation: Manager vs. Worker
• Production involves “solving problems”
  • Worker with ability $q_L$ can solve fraction $q_L$ of problems and, if so, produce one unit of output
  • If worker cannot solve, asks manager, who can solve fraction $q_H$
  • Each problem passed on to manager uses fraction $c$ of her time, whether she knows the answer or not
  • ⇒ Manager can supervise $1/ \left[ c \left(1 - q_L \right) \right]$ workers

• Output of a managers of type $q_H$:

$$x = \frac{q_H}{(1 - q_L) c}$$
Equilibrium Conditions for Production Hierarchies

- More able individuals with $q_L > q_L^*$ become managers
- Supermodularity of productivity $\Rightarrow$ positive assortative matching
- If North better endowed with high-ability workers:
  - Effects of globalization on matching:
    - Number of Southern workers expands. Southern workers improve their matches. Matches for Southern managers deteriorate.
    - Best Northern workers and worst managers improve matches. Matches of worst workers and (possibly) best managers deteriorate
  - Effects of globalization on inequality:
    - Wage inequality rises in South, as worker skills more scarce in globalized economy, as more workers compete for the better managers, and as more agents become workers
    - Wage inequality in North may rise or fall, as fewer agents are workers, but more competition for best managers
One sector à la Melitz

Firms have different “technologies” \( q_H \)

Each firm chooses number of employees of some type \( q_L \). Output:

\[
x = \psi (q_H, q_L) \ell
\]

where \( \psi \) is log supermodular

Firms produce differentiated products, face constant elasticity of demand

Firms face fixed entry and production costs; can export at fixed cost.
Matching: Log supermodularity of $\psi$ generates PAM

Optimal hiring: elasticity of wage schedule equals elasticity of $\psi$ wrt $q_L$ (but taking into account optimal match)

Labor Market Clearing: Distribution of workers must “match” distribution of firms, considering optimal hiring and optimal employment

Selection of best firms into exporting $\Rightarrow$ exporter wage premium

Effects of trade or trade liberalization:

- All workers match with better firms (due to exit of worst firms)
- Pervasive rise in wage inequality
Suppose heterogeneous workers are teamed with heterogeneous managers, so that labor quantity has diminishing returns:

Output of unit with manager of type $q_H$ and $\ell$ workers of type $q_L$

$$x_i = \psi_i(q_H, q_L)f^i(\ell)$$

Choice of worker type: In industry $i$, compare $\frac{\varepsilon_{\psi iL}(q_L)}{\gamma_i}$ vs. $\varepsilon_w(q_L)$

Choice of manager type: In industry $i$, compare $\frac{\varepsilon_{\psi iH}(q_H)}{1-\gamma_i}$ vs. $\varepsilon_r(q_H)$

Note that productivity elasticities can depend on worker-manager combinations that arise in equilibrium $\Rightarrow$ sorting of each factor typically depends on match possibilities/outcomes.
Matching and Sorting of Heterogeneous Factors
Cobb-Douglas Productivity

- Suppose

\[ \psi_i (q_H, q_L) = q_H^{\beta_i} q_L^{\alpha_i} \]

- Productivity elasticities independent of matches
- Wage schedule must have elasticity \( \alpha_i / \gamma_i \) for workers in industry \( i \)
- Sorting of workers: \( \alpha_1 / \gamma_1 \) vs. \( \alpha_2 / \gamma_2 \)
- Sorting of managers: \( \beta_1 / (1 - \gamma_1) \) vs. \( \beta_2 / (1 - \gamma_2) \)

- Matching is indeterminate
- Trade pattern as with homogeneous managers
- Income Distributional Effects of Trade:
  - Within industry: no effects
  - Between industry: As before, Stolper-Samuelson vs. Ricardo-Viner
Log supermodularity ⇒ PAM in each industry

Sorting can be HH/LL, HL/LH, or more complex

Trade will affect matching and within-industry wage inequality in both sectors
Matching and Sorting Distributions with Heterogeneous Factors
An Equilibrium with HL/LH Sorting
Matching and Sorting Distributions with Heterogeneous Factors
An Equilibrium with HH/LL
Matching and Sorting Distributions of Labor and Capital

More Complex Sorting Pattern

Graph showing the relationship between two variables, $q_H$ and $q_L$, with curves for Sector 1 and Sector 2.
Matching and Sorting Distributions with Heterogeneous Factors

- **Pattern of Trade:**
  - If sorting pattern is HL/LH or HH/LL: Countries with identical distributions will trade as in Heckscher-Ohlin

- **Distributional Effects of Trade:**
  - HL/LH and $p_2 ↑$
    - Sector 2 attracts better workers and worse managers
    - Sector 1 sheds worst workers and best managers
    - Matches deteriorate (improve) for workers (managers) initially in sector 2 or who remain in sector 1
    - Within industry wage (salary) inequality falls (rises)
  
  - HH/LL and $p_2 ↑$
    - Sector 2 attracts better workers and better managers
    - Sector 1 sheds worst workers and worst managers
    - Worker matches might improve in one sector and deteriorate in other, depending on factor intensities
Suppose matching involves members of a production team
- Each member performs a task needed for positive output
- Teams have exactly two workers
- Output of team depends on qualities of workers
- Tasks contribute symmetrically to output

\[ \psi_i (q_H, q_L) = \psi_i (q_L, q_H) \]

Assume symmetric distributions of worker quality

Countries East and West have same mean worker ability, but West has greater diversity; i.e., more workers at the extremes of the ability distribution
Matching and Sorting with Production Teams

- Suppose $\psi_1(q_L, q_H)$ is supermodular but $\psi_2(q_L, q_H)$ is submodular
  - In industry 2, tasks are substitutes
  - Keep the best, discard the rest? Research?

- With submodular technology, efficiency dictates cross-matching of resources devoted to a sector
  - In competitive equilibrium economy allocates extreme qualities to industry 2, intermediate qualities to industry 1
  - West relatively more productive in industry 2
  - West exports good 2 in trade equilibrium

- In country with more diverse work force, trade:
  - Benefits the lowest quality workers
  - Harms an intermediate set of workers
  - May benefit or harm highest quality workers (redistributes income to workers in export sector, but also to lower quality worker in any team)
Imperfect Matching

All of the discussion until now takes place in setting with competitive, frictionless labor markets

- No issues of unemployment
- No issues of mismatch between worker characteristics and job

But these are some of the most interesting and important questions

- How does globalization affect structural unemployment?
- How does globalization affect productivity via matching?

Research on these questions still in its infancy
Consider simplified model with two types of workers and two types of firms
- Hi-tech requires high-ability workers
- Lo-tech can use high or low ability workers

Random (costly) matching, wage determined by bargaining

If revenue of high-tech and low-tech firms sufficiently close, high ability workers will accept low-tech jobs when opportunity arises

Suppose only high-tech firms are exporters. As trade costs fall:
- Export profitability increases, high-tech firms benefit most, making it more difficult for low-tech firms to attract high-ability workers. Less mismatch.
- Import penetration increases, reducing profitability of home sales, can be bigger adverse effect for high-tech firms, more mismatch
Introduce costly search and unemployment

Ex post, match-specific heterogeneity in worker productivity

- Worker quality not directly observable by firms
- Firms screen workers $\Rightarrow$ better firms more incentive to screen $\Rightarrow$ betters firms have higher average quality

Opening of trade in closed economy increases wage inequality

- larger firms pay higher wages
- trade increases dispersion of firm revenues

Effects of opening trade on unemployment ambiguous

- Tightness of labor market (fraction of those searching for jobs that are matched) can rise or fall
- Reallocation toward firms that screen more intensely reduces hiring rate among those matched
Conclusions

- Richer models that allow distribution of factor “quality” to determine types of goods that countries export
- Richer models that allow trade to affect intra-industry distribution of income
- Richer models that allow trade to affect productivity by affecting team formation, mismatch, unemployment
- Empirical predictions can be examined using new data sets with matched worker-firm information