ECO 2302 - Networks in Trade and Macroeconomics

Lecture 5 - Networks and Labor Markets

Motivation

- There is increasing debate on the role of firms in determining labor market outcomes
  - e.g. AKM (1999) model of log earnings for worker m at firm i, time t

$$w_{mit} = \underbrace{\delta_m}_{\text{worker effect}} + \underbrace{\mu_i}_{\text{firm effect}} + \underbrace{\epsilon_{mit}}_{\text{residual}}$$

  - variance decomposition using employer-employee data (Chile, 2005-2010):

$$\text{var}(w_{mit}) = \underbrace{\text{var}(\delta_m)}_{57\%} + \underbrace{\text{var}(\mu_i)}_{13\%} + \underbrace{2\text{cov}(\delta_m, \mu_i)}_{15\%} + \underbrace{(\epsilon_{mit})}_{15\%}$$

- But **why** do firms matter for inequality in worker earnings?
  - current literature: firms are different in some exogenous characteristics, e.g. "productivity"
- We now also have growing evidence of substantial heterogeneity in buyer-seller matching
  - yet relevance of this for worker outcomes is not well understood
- How do production networks shape **earnings inequality**?

Motivation

Huneeus, Kroft, and Lim (2020), "Earnings Inequality in Production Networks"

1. Administrative microdata from Chile, 2005-2010
   - employer-employee data + firm-to-firm transactions data + firm production data
2. Structural framework
   - heterogeneous buyer-seller linkages: network structure matters for firm outcomes
   - imperfect labor market competition: firm outcomes matter for earnings
3. Structural estimation
   - macro elasticities: labor supply, demand-price, labor-materials substitution
   - worker characteristics: ability
   - firm characteristics: factor-augmenting productivities
   - networks: active buyer-seller relationships, relationship-specific productivity
4. Counterfactuals
   - how important is production network heterogeneity for earnings inequality and volatility?

Data

1. **Firm-to-Firm VAT Transactions Data**
   - frequency: annual, 2005-2010
   - coverage: all suppliers of reporting firms, all sectors ($\sim$ 80% aggregate value-added)
   - key variables: origin and destination firm tax ID, flow transaction value

2. **Matched Employer-Employee Data**
   - frequency: annual, 2005-2018
   - coverage: universe of formal private firms and their employees
   - key variables: worker earnings, monthly employment, age, gender

3. **Firm Production Data**
   - frequency: monthly, 2005-2018
   - coverage: universe of formal private firms
   - key variables: sales, materials, investment, capital, main industry, HQ location

General environment

Workers

- heterogeneous in ability a, exogenous measure $L(a)$
- derive utility from three sources:
  - consumption goods produced by firms
  - amenities offered by employer
  - idiosyncratic preferences over employers (source of market power)
- observe ability-specific wage offers made by each firm and choose employer

Firms

- exogenous set Ω, heterogeneous in factor productivities, amenity values, network connections
- produce output by combining workers of different abilities with materials
- set ability-specific wages to hire workers
- source materials from suppliers in production network (exogenous)

Worker preferences

- Utility from consumption for a worker with ability a :

$$v_t(a) = \log \left[\sum_{i \in \Omega} x_{Fit}(a)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

- Take consumer price index as numeraire:
  - hence can treat worker income as real income
- In addition to consumption utility, workers derive utility from:
  - idiosyncratic preferences for employment at different firms
  - employer amenities

Worker preferences

- Utility of a worker with ability a from working at firm i:

$$u_{it}(a) = \underbrace{\log w_{it}(a)}_{\text{wages}} + \underbrace{\log g_i(a)}_{\text{amenities}} + \underbrace{\log \tau_t}_{\text{transfer}} + \underbrace{\beta^{-1}\epsilon_{it}}_{\text{taste shocks}}$$

- Assume ϵ_{it} is unobservable to firms, so wages can only be conditioned on ability a
- Each worker of ability a chooses employer i to maximize utility $u_{it}(a)$
  - a potentially complicated discrete choice problem
- For tractability, assume cross-sectional distribution of preference shocks is Gumbel (GEV-I):

$$F_\epsilon\left[\{\epsilon_{it}\}_{i\in\Omega}\right] = exp\left[-\left(\sum_{i\in\Omega} e^{-\frac{\epsilon_{it}}{\rho}}\right)^{\rho}\right]$$

  - $\rho \in (0, 1]$ is inverse measure of correlation between shocks

Worker sorting

- What is the probability $\mathbb{P}_{it}$ that a worker (of some ability) chooses to work at firm i?

$$\begin{aligned}\mathbb{P}_{it} &= \Pr[\log(w_{it}g_i) + \tfrac{1}{\beta}\epsilon_{it} \geq \log(w_{jt}g_j) + \tfrac{1}{\beta}\epsilon_{jt}, \forall j \neq i] \\ &= \Pr[\epsilon_{jt} \leq \log\left(\tfrac{w_{it}g_i}{w_{jt}g_j}\right)^{\beta} + \epsilon_{it}, \forall j \neq i]\end{aligned}$$

- Now let $F_{\epsilon i}\left[\epsilon_{it}, \{\epsilon_{jt}\}_{j\neq i}\right]$ denote the partial derivative of F_ϵ with respect to ϵ_{it}
- Then we can express selection probability as:

$$\mathbb{P}_{it} = \int_{-\infty}^{\infty} F_{\epsilon i}\left[\epsilon_{it}, \left\{\log\left(\tfrac{w_{it}g_i}{w_{jt}g_j}\right)^{\beta} + \epsilon_{it}\right\}_{j\neq i}\right] d\epsilon_{it}$$

Worker sorting

- Under the Gumbel form for F_ϵ:

$$\mathbb{P}_{it} = \int_{-\infty}^{\infty} e^{-\Psi_{it}^{\rho} e^{-\epsilon_{it}}} \Psi_{it}^{\rho-1} e^{-\epsilon_{it}} d\epsilon_{it}$$

  where $\Psi_{it} \equiv \sum_{j \in \Omega^F} \left(\frac{w_{jt} g_j}{w_{it} g_i} \right)^{\beta/\rho}$

- Now use change of variable $z = \Psi_{it}^{\rho} e^{-\epsilon_{it}}$ to write this as:

$$\begin{aligned} \mathbb{P}_{it} &= \frac{1}{\Psi_{it}} \int_0^{\infty} e^{-z} dz \\ &= \frac{\left(w_{it} g_i\right)^{\beta/\rho}}{\sum_{j \in \Omega^F} \left(w_{jt} g_j\right)^{\beta/\rho}} \end{aligned}$$

- Simple intuition:
  - firm i is more likely to be chosen if it offers higher wages w_{it} or better amenities g_i...
  - relative to wages and amenities offered by all other potential employers in the labor market

Firm-level labor supply

- The labor supply curve of ability a workers for firm i is then:

$$L_{it}(a) = \kappa_{it}(a) w_{it}(a)^{\gamma}$$

- Labor supply elasticity $\gamma \equiv \beta/\rho$
  - more elastic if shocks are less dispersed or more correlated
- Labor supply shifter:

$$\kappa_{it}(a) \equiv \underbrace{L(a)}_{\text{labor stock}} \times \underbrace{\left[\sum_{j \in \Omega} \left(g_j(a) w_{jt}(a)\right)^{\gamma}\right]^{-1}}_{\text{labor market competition}} \times \underbrace{g_i(a)^{\gamma}}_{\text{firm amenities}}$$

- Assume firms behave atomistically in setting wages:
  - take labor supply shifters κ_{it} as given
  - hence perceive a constant labor supply elasticity of γ

Production

- Firms produce by combining labor and materials:

$$X_{it} = T_{it} \sum_{a \in A} \left[\lambda^{\frac{1}{\epsilon}} \left[\phi_{it}(a) L_{it}(a) \right]^{\frac{\epsilon-1}{\epsilon}} + (1-\lambda)^{\frac{1}{\epsilon}} \left[M_{it}(a) \right]^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}$$

  - T_{it}: TFP; $\phi_{it}(a)$: labor productivity
- Materials produced by combining inputs from suppliers Ω_{it}^S

$$M_{it} = \left[\sum_{j \in \Omega_{it}^S} \psi_{ijt}^{\frac{1}{\sigma}} \left(x_{ijt} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

  - ψ_{ijt}: relationship-specific productivity
- As with labor market, firms behave atomistically in making production decisions
  - hence perceive constant price elasticity of demand $-\sigma$
- Firm's problem: choose $w_{it}(a)$ and x_{ijt} to maximize profits

Increasing marginal costs

- Main departure from standard models of production networks:
  - upward-sloping labor supply curves imply **increasing marginal costs**
- One key result preserved: still optimal for each firm to charge a single price
  - profit is maximized when marginal revenue = marginal cost
  - with CES demand, marginal revenue $\propto$ price
  - marginal cost depends only on *total* firm output
- But increasing marginal cost introduces two complications:
  - upstream and downstream equilibrium conditions cannot be solved separately
  - fixed-cost endogenous network models are no longer tractable

Wage determination

- Wages are a constant markdown of MRPLs:

$$w_{it}(a) = \underbrace{\frac{\gamma}{1+\gamma}}_{\text{markdown}} \times \underbrace{\phi_{it}(a) W_{it}}_{\text{MRPL}}$$

- Firm effect W_{it} depends on own productivity $\bar{T}_{it} \equiv \{T_{it}, \phi_i(\cdot)\}$ and network variables $\{D_{it}, Z_{it}\}$
- **Network demand** is the sum of demand shifters across downstream network connections:

$$D_{it} = \underbrace{\Delta_{Ft}}_{\text{final demand}} + \sum_{j \in \Omega_{it}^C} \underbrace{\Delta_{jt}\left(\bar{T}_{jt}, D_{jt}, Z_{jt}\right)}_{\text{demand shifter for customer } j} \psi_{jit}$$

- **Network supply** is the CES input price index arising from upstream network connections:

$$Z_{it}^{1-\sigma} = \sum_{j \in \Omega_{it}^S} \underbrace{\Phi_{jt}\left(\bar{T}_{jt}, D_{jt}, Z_{jt}\right)}_{\text{inverse cost for supplier } j} \psi_{ijt}$$

- In sum: network determines $\{D_{it}, Z_{it}\}$, which then determine W_{it} and hence wages $w_{it}(a)$

Comparative statics

- How do changes in network variables $\{D_{it}, Z_{it}\}$ and firm TFP T_{it} affect earnings?
- In response to marginal changes in $\{D_{it}, Z_{it}, T_{it}\}$, the firm-level wage W_{it}...
  1. is strictly increasing in D_{it}
  2. is strictly increasing in T_{it}
  3. varies with Z_{it} as follows:
     - strictly decreasing in Z_{it} if $\sigma > \epsilon$
     - strictly increasing in Z_{it} if $\sigma < \epsilon$
     - invariant with respect to Z_{it} if $\sigma = \epsilon$
- Intuition: scale vs. substitution effects

Network passthrough of shocks

- How do shocks to TFP T_{it} affect wages, accounting for effects on $\{D_{it}, Z_{it}\}$?
  - to develop intuition, assume no GE effects
- With no intermediates:

$$\hat{W}_t = \frac{\sigma - 1}{\gamma + \sigma} \hat{T}_t$$

- With $\sigma = \epsilon$ (so no upstream effects):

$$\hat{W}_t = \frac{\sigma - 1}{\gamma + \sigma} \left(\mathbb{I} - \Sigma_t^c\right)^{-1} \hat{T}_t$$

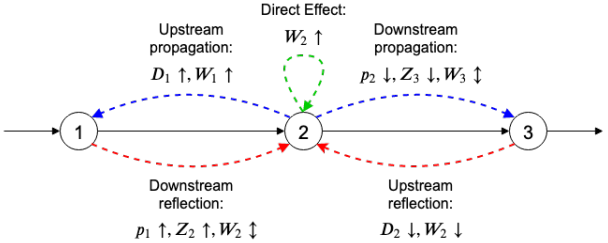
- Intuition:
  - can write $\left(\mathbb{I} - \Sigma_t^c\right)^{-1} = \mathbb{I} + \Sigma_t^c + \left(\Sigma_t^c\right)^2 + \cdots$
  - (i, j)-element of this matrix summarizes share of firm j in firm i's sales
  - both directly and indirectly through the production network

Network passthrough of shocks

- General case:

$$\hat{W}_t = \Psi\left(\gamma, \sigma, \epsilon, \Sigma_t^C, \Sigma_t^S, \Lambda_t\right) \hat{T}_t$$

  - Σ_t^C: $|\Omega| \times |\Omega|$ matrix of sales shares
  - Σ_t^S: $|\Omega| \times |\Omega|$ matrix of input purchase shares
  - Λ_t: $|\Omega| \times 1$ vector of labor costs as share of total costs



Additional assumptions

1. Worker ability comprised of permanent and transient components, $\{\bar{a}, \hat{a}_t\}$
   - necessary for identification of worker and firm effects
2. Labor productivity $\phi_{it}(a_t) = \bar{a}^{\theta_i}\hat{a}_t\omega_{it}$; amenities $g_i(a) = g_i(\bar{a})$
   - worker-firm production complementarity captured by θ_i, firm labor productivity by ω_{it}
   - for identification of θ_i, worker-firm sorting cannot depend on unobserved time-varying $\hat{a}_t$
3. Firm productivity variables follow first-order Markov process
   - determines appropriate instruments in production function estimation
4. Firm-level productivity shocks and worker-level ability shocks are orthogonal
   - important for identification of labor supply elasticity γ

Outline of estimation approach

1. Labor supply elasticity γ
   - estimated from pass-through of firm wage bill shocks to worker wages
   - intuition: γ determines how important firm outcomes are for worker earnings

2. Labor-materials substitution elasticity ϵ, labor productivity ω_{it}
   - estimated from regression of relative labor-material inputs on relative prices
   - labor price constructed from firm effects in step 3
   - materials price constructed from seller effects of suppliers in step 4
   - intuition: two-way decompositions for labor/intermediates allow "correct" factor price aggregation

3. Worker ability $\{\bar{a}, \hat{a}\}$, worker-firm complementarity θ_i
   - estimated from worker-firm decomposition of wages
   - intuition: worker-firm effect $= \theta_i \log \bar{a}$, firm effect $= W_{it}\omega_{it}$, residual $= \hat{a}_t$,

4. Network demand shifter Δ_{it}, efficiency Φ_{it}, relationship productivity ψ_{ijt}
   - decompose F2F sales into buyer and seller effects
   - intuition: important buyers have high Δ_{it}, important sellers have high Φ_{it}, residual $= \psi_{ijt}$

Outline of estimation approach

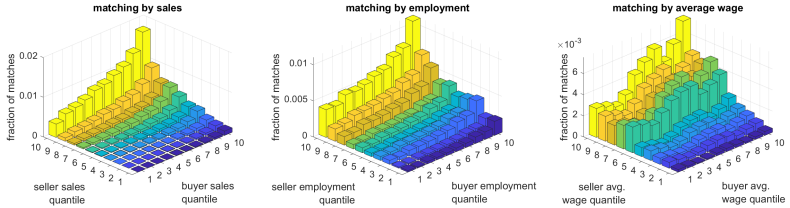
5. Demand price elasticity σ
   - estimated from firm profit-sales ratio
   - intuition: σ controls output market power and hence profit margins
6. Amenities $g_i(a)$
   - estimated from ability-specific employment shares and wages
   - intuition: given wages, higher employment implies better amenities
7. TFP T_{it}
   - estimated by fitting firm effects in worker earnings decomposition
   - intuition: all other determinants of firm effect pinned down except TFP

Estimation results

- Parameter estimates:

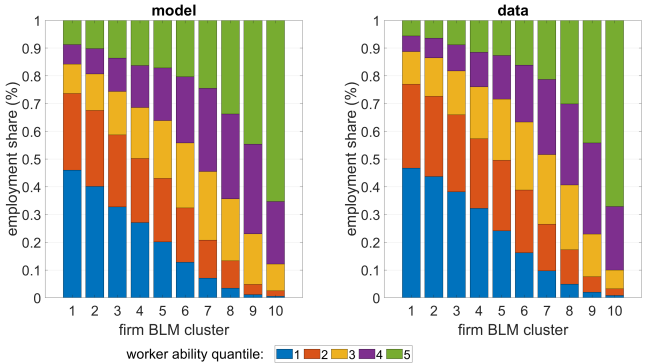
labor supply elasticity	γ	6.5
product substitution elasticity	σ	4.5
labor-materials substitution elasticity	ϵ	1.1

- Network matching:



Estimation results

- Worker-firm sorting:



note: "BLM cluster" indicates k-means cluster of firm based on percentiles of within-firm earnings distribution

Counterfactuals

- How important is production network heterogeneity for worker earnings inequality?
  - and how does this compare with importance of other sources of firm heterogeneity?
- Model implies the following equation for log earnings of worker m at firm i, time t

$$\log w_{mit} = \underbrace{\theta_i \log \bar{a}_m}_{\substack{\text{worker-firm} \\ \text{effect}}} + \underbrace{f_{it}}_{\substack{\text{firm} \\ \text{effect}}} + \underbrace{\log \hat{a}_{mt}}_{\substack{\text{worker} \\ \text{effect}}}$$

- We now have a **structural interpretation** of the firm effects f_{it}, which depend on:
  - own-firm time-varying productivities $(T_{it}, \omega_{it}, \psi_{it})$
  - amenities $g_i(\cdot)$
  - network connections with customers and suppliers
- To quantify importance of each source of heterogeneity for var(w_{mit})...
  - simulate counterfactual earnings after shutting down different dimensions of heterogeneity

Counterfactuals

	(1) earnings variance	(2) worker effect variance	(3) firm effect variance	(4) sorting covariance	(5) interactions
share of earnings variance (data)	100	57.0	10.8	19.8	-2.0
share of earnings variance (model)	100	52.5	9.8	20.8	3.1
of which:					
a. worker permanent ability, $\bar{a}_m$	53.8	48.6	-1.5	4.1	2.6
b. worker transient ability, $\hat{a}_{mt}$	13.8	-	-	-	-
c. supplier network, $\{m_{ijt}, \psi_{ijt}\}_{j \in \Omega_{it}^S}$	11.9	0.9	7.9	2.7	0.4
d. customer network, $\{m_{jit}, \psi_{jit}\}_{j \in \Omega_{it}^C}$	8.6	-0.1	6.7	1.5	0.4
e. firm productivities, $\{T_{it}, \omega_{it}\}$	6.1	7.5	-4.3	3.3	-0.5
f. production complementarities, θ_i	4.6	-4.0	-2.7	8.6	2.6
g. amenities, $g_i(\cdot)$	1.2	-0.4	3.6	0.5	-2.6

- Network heterogeneity accounts for 21% of total earnings variance
  - supplier heterogeneity slightly more important than customer heterogeneity
  - in contrast, heterogeneity in own-firm characteristics explain around 12%

Summary

- Summary:
  - microdata allows us to simultaneously observe employer-employee and firm-to-firm linkages
  - study this using model with imperfect competition in labor markets + firm production network
  - network heterogeneity is quantitatively important for earnings inequality
- Related papers:
  - Adao et al (2020) – individual-level exposure to trade shocks (Ecuador)
  - Alfaro-Urena et al (2020) – effects on workers when employer supplies to MNC (Costa Rica)
  - Demir et al (2020) – quality complementarity and skill upgrading in production networks (Turkey)
  - Dhyne et al (2021) – network passthrough of demand shocks to changes in average wages (Belgium)