An Industrial Organization Perspective on Productivity

The Second Half

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Outline

Empirical Facts About Productivity at the Producer Level

A Simple Model of Equilibrium Productivity Dispersion

Productivity Analysis

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Empirical Facts About Productivity at the Producer Level

- Dispersion
- Persistence
- Correlations

Dispersion

Definition

Productivity Dispersion refers to **the range of differences in productivity levels** among production units within an economy.

- **Distribution Spread**: Whether most firms have similar productivity levels (low dispersion) or if there's a wide gap between highly productive leader firms and less productive laggard firms (high dispersion).

Dispersion

Measurement

90-10 percentile TFP ratio refers to the TFP level of the entity at the 90th percentile of the TFP distribution divided by the TFP level of the entity at the 10th percentile of the TFP distribution.

- The 90th percentile represents **the top 10% most productive**; the 10th percentile represents **the bottom 10% least productive**.
- Example: The typical manufacturing industry in the U.S. or Canada has a 90-10 percentile TFP ratio of roughly **2:1**.

Persistence

Definition

Producers near the top end of their TFP distribution in this period are likely to be near the top in the next period. Low-productivity producers are similarly likely to stay that way.

- Whatever factors influence producers' productivity levels, they have **staying power**.
- Rule out **classical measurement error or white-noise productivity process** as sources of the documented productivity dispersion.

Correlations

Higher productivity producers are:

- More profitable,
- Larger,
- Faster-growing,
- More likely to survive,
- Low price-setters,
- Higher-wage payers.

A Simple Model of Equilibrium Productivity Dispersion

- Demand
- Supply
- Equilibrium
- Empirical Implications

Assumptions

Melitz and Ottaviano (2008): Market Size, Trade, and Productivity.

- **Industry Structure**: There exists an industry comprising a continuum of producers.
- **Product Differentiation**: Each producer i offers a unique product (variety), with the set of varieties denoted by I.
- **Consumers**: There is a representative consumer whose preferences cover all product varieties within the industry.

Assumptions

- **Production Technology**: Producer i uses a linear production technology,

$$Q_i = \Omega_i X_i,$$

  where X_i is a composite input with price P^X. This implies that each producer has a constant marginal cost:

$$c_i = \frac{P^X}{\Omega_i}.$$

  Differences in cost c_i reflect differences in productivity Ω_i.
- **Market Entry**: Potential producers must pay a fixed entry cost f_E to learn their productivity Ω_i. Productivity is drawn from a specific distribution.

$$G(\Omega) = 1 - \frac{\Omega_M}{\Omega}, \quad \Omega \in [\Omega_M, \infty)$$

Demand

Representative Consumer Utility Function:

$$U = y + \alpha \int_{i \in I} Q_i \, di - \frac{\eta}{2} \left(\int_{i \in I} Q_i \, di \right)^2 - \frac{\gamma}{2} \int_{i \in I} Q_i^2 \, di$$

where y is the quantity of a numeraire good, Q_i is the quantity of variety i consumed, and $\alpha > 0$, $\eta > 0$, and $\gamma \geq 0$.

- α and η index the substitution pattern between the differentiated varieties and the numeraire good.
- γ indexes the degree of substitutability between the differentiated varieties.
  - γ is large, implying that substitutability is low.
  - $\gamma \to 0$ implies perfect substitutability.

Demand

- **Consumer Budget Constraint:**

$$y + \int_{i \in I} p_i Q_i \, di = E,$$

where E is total expenditure.

- **Utility Maximization:** Set up the Lagrangian:

$$L = y + \alpha \int_{i \in I} Q_j \, dj - \frac{\eta}{2} \left(\int_{i \in I} Q_j \, dj \right)^2 - \frac{\gamma}{2} \int_{i \in I} Q_j^2 \, dj + \lambda \left(E - y - \int_{i \in I} p_j Q_j \, dj \right).$$

- **FOCs:**
  - With respect to y:

$$\frac{\partial L}{\partial y} = 1 - \lambda = 0 \implies \lambda = 1.$$

  - With respect to Q_i:

$$\frac{\partial L}{\partial Q_i} = \alpha - \eta \left(\int_{i \in I} Q_j \, dj \right) - \gamma Q_i - \lambda p_i = 0.$$

Demand

- **Inverse Demand Function:** Substitute $\lambda = 1$ into the FOC for Q_i to get the inverse demand function for variety i:

  $$p_i = \alpha - \eta \int_{i \in I} Q_j \, dj - \gamma Q_i.$$

  Let $Q = \int_{i \in I} Q_j \, dj$ represent the total quantity consumed in the market. Then:

  $$p_i(Q_i, Q) = \alpha - \eta Q - \gamma Q_i.$$

  This shows that the price of variety i depends on its own sales Q_i and the total market sales Q.

Supply

Producer i chooooses Q_i to maximize profit π_i.

- Profit Function:

$$\pi_i = p_i Q_i - c_i Q_i.$$

- Insert inverse demand function:

$$\pi_i = (\alpha - \eta Q - \gamma Q_i) Q_i - c_i Q_i.$$

- Solve for optimal Q_i by FOC:

$$Q_i(c_i) = \frac{\alpha - \eta Q - c_i}{2\gamma}.$$

Supply

- Optimal Price:

$$p_i(c_i) = \alpha - \eta Q - \gamma Q_i = \frac{1}{2}(\alpha - \eta Q + c_i).$$

- Optimal Profit:

$$\pi_i(c_i) = (p_i - c_i)Q_i = \frac{(\alpha - \eta Q - c_i)^2}{4\gamma}.$$

- Optimal revenue:

$$r_i(c_i) = p_i Q_i = \frac{(\alpha - \eta Q)^2 - c_i^2}{4\gamma}.$$

Supply

Define the cutoff cost $c_D = \alpha - \eta Q$. A producer i will only produce in the market and earn non-negative profits if its marginal cost $c_i \leq c_D$.

- Optimal Quantity:
$$Q_i = \frac{c_D - c_i}{2\gamma}$$
- Optimal Price:
$$p_i = \frac{c_D + c_i}{2}$$
- Optimal Profit:
$$\pi_i(c_i) = \frac{(c_D - c_i)^2}{4\gamma} \quad \text{(only if } c_i \leq c_D\text{)}$$
- Optimal Revenue:
$$r_i(c_i) = p_i Q_i = \frac{c_D^2 - c_i^2}{4\gamma} \quad \text{(only if } c_i \leq c_D\text{)}$$

Equilibrium

Recall: Productivity is drawn from a specific distribution:
$G(\Omega) = 1 - \frac{\Omega_M}{\Omega}, \quad \Omega \in [\Omega_M, \infty)$. Alternatively, costs c are drawn from **a uniform distribution on** $[0, c_M]$, where c_M is the upper bound and $c_D \leq c_M$

- **Free entry condition**: The expected benefit of paying for a productivity draw equals the entry cost f_E:

$$\int_0^{c_D} \frac{(c_D - c)^2}{4\gamma} \cdot \frac{1}{c_M} \, \mathrm{d}c = f_E$$

- **Solving for the equilibrium cutoff cost** c_D:

$$c_D = (12\gamma c_M f_E)^{1/3}$$

Empirical Implications

Equilibrium cutoff cost c_D:

$$c_D = (12\gamma c_M f_E)^{1/3}$$

- **Productivity Dispersion**: How much dispersion exists in equilibrium depends on the magnitudes of γ and f_E.
  - **As substitutability falls (γ rises)**, consumers are less willing to shift their purchases from one variety to another, which makes it easier for higher-cost producers to profitably operate, **increasing** c_D.
  - **Higher entry costs** f_E protect producers with low productivity draws from competition by limiting the mass of producers that take entry draws, **increasing** c_D.
- **Productivity Persistence**: As the model is static and all producers have fixed productivity draws.
  - Asplund and Nocke (2006): Include models with similar structures that allow more dynamic productivity process.

Empirical Implications

Size and suivival

- **Size**: Recall
$$Q_i = \frac{c_D - c_i}{2\gamma}$$
Equilibrium quantities decline in the producer's marginal cost.
- **Suivival**: Firms do not produce when receiving a productivity draw too low to be profitable in equilibrium.

Productivity Analysis

- Producer-level productivity analysis
  - Identifying producer-level drivers
  - Sources of productivity differences
- Aggregate analysis
  - Sources of aggregate productivity gains
  - Potential output losses due to inefficient production

Identify Producer-level Drivers

Standard approach:

$$\omega_{it} = \delta A_{it} + \text{controls} + \epsilon_{it}$$

- First estimate productivity ω_{it} and then use a regression model to analyze the impact of potential drivers A_{it}.
- **Exogenous Drivers:** the impact of policy reforms on firm-level productivity, e.g., tax incentives.
- **Endogenous Drivers:** the results of the producer's own actions, e.g., R&D investments.

Identify Producer-level Drivers

Standard approach:

$$\omega_{it} = \delta A_{it} + \text{controls} + \epsilon_{it}$$

Challenges with standard approaches:

- **Internal consistency issue**: Refers to contradictions or lack of logical coherence in the relationships between assumptions and variables within a model.
- **Endogeneity issue**: Endogenous drivers are chosen by the producer, and direct regression leads to biased estimates.

Identify Producer-level Drivers

Improved Methods:

$$\omega_{it} = g(\omega_{it-1}, A_{it-1}) + \xi_{it}.$$

Incorporate the driver A directly into the law of motion $g(.)$ for productivity.

- Achieves internal consistency by integrating the driver into the dynamic process of productivity.
- Allows drivers to have heterogeneous effects on productivity.
- Reference:
  - De Loecker (2013): Investigates "learning-by-exporting" by including past export experience A_{it-1} in the law of motion, identifying significant heterogeneous effects of exporting on future productivity.
  - Doraszelski and Jaumandreu (2018): Uses detailed R&D data for Spanish producers to estimate the impact of innovation on productivity, confirming dispersion in R&D effectiveness across producers with different productivity levels.

Sources of productivity differences

Managerial Practices:

- Bloom and Van Reenen(2007): Confirms a robust positive correlation exists between the quality of managerial practices and firm productivity.
- **Operational management**: How the producer coordinates its production process.
  - Target setting and evaluation
  - Inventory management
  - Human capital management
  - Customer relationship management
- **Strategic management**: How the producer its primary scope of operations.
  - Selection of product offerings
  - Identification of target markets
- **Manager effect**: Distinguishing manager-specific effects from practice-specific effects is crucial for **understanding transferability and policy implications**.

Sources of productivity differences

Intangible Capital:

- **Definition:** Assets that contribute to production but are difficult or impossible to measure directly. e.g., reputation, brand equity, production know-how, organizational culture.
- **Specific intangibles affect different aspects:**
  - Production know-how potentially boosts TFPQ through technical efficiency.
  - Brand capital primarily enhances TFPR via pricing power.
- **Empirical approach:** Utilize proxies for intangible capital to link them to firm performance and productivity.
  - Reference: Saunders and Brynjolfsson (2016); Peters and Taylor (2017); Crouzet and Eberly (2020)

Aggregate Analysis

- Sources of aggregate productivity gains
- Potential output losses due to inefficient production

Aggregate Industry Productivity

In empirical research, aggregate industry productivity is typically measured as a share-weighted average of producer-level productivity.

$$A_t = \sum_i s_{it}\omega_{it}$$

- ω_{it} denotes the productivity of producer i in period t.
- s_{it} represents the share weight of producer i in period t. This weight is often based on the share of sales.

Sources of aggregate productivity gains

Olley-Pakes(1996) Decomposition Method:

$$A_t = \bar{\omega}_t + \text{cov}_t(s_{it}, \omega_{it})$$

where $\bar{\omega}_t$: The unweighted average productivity of producers in period t.

- **Within-Producer effect**: Refers to increases or decreases in the productivity of incumbent producers, captured by $\bar{\omega}_t$.
  - Technological progress, managerial improvements, or R&D investments
- **Between-Producer effect**: Involves the redistribution of market share among producers with different productivity levels, captured by $\text{cov}_t(s_{it}, \omega_{it})$.
  - **Positive Covariance**: Indicates that producers with higher market shares tend to have higher productivity.
  - **Increasing Covariance**: Implies a strengthening reallocation effect, contributing positively to aggregate productivity growth.
  - Increased competition, deregulation, or technological change.

Sources of aggregate productivity gains

Collard-Wexler and De Loecker (2015):

- **Context:** Examined the impact of the introduction and diffusion of a new technology (minimills) in the steel industry on industry productivity.
- **Methodology:** First estimated a production function to recover plant-level productivity estimates, then performed within-between decompositions to help identify the sources of industry productivity growth.
- **Findings:**
  - **Between effect:** The shift in market share from older technology to the new technology accounted for approximately one-third of the industry's productivity growth.
  - **Within effect:** Even surviving firms using the older technology achieved substantial productivity gains under competitive pressure.
- **Implication:** Underscores the crucial interplay between reallocation effects driven by technological change and within-firm improvement effects in understanding aggregate productivity dynamics.

Potential Output Losses Due to Inefficient Production

Asker et al. (2019): Market power and Production Inefficiency Loss

- **Background:**
  - OPEC: An intergovernmental organization and its member countries are among the world's major oil exporters, possessing substantial low-marginal-cost oil reserves compared with non-OPEC producers.
  - OPEC cartel: Regarded as functioning like a cartel by coordinating oil production levels to influence global oil prices.
- **Research context:** Analyzed the impact of the OPEC cartel on the efficiency of global crude oil production.
- **Perspective:** Emphasized the production inefficiency loss caused by market power, distinct from the traditional quantity distortion.

Potential Output Losses Due to Inefficient Production

Asker et al. (2019): Market power and Production Inefficiency Loss

- **Methodology:** Quantified the production inefficiency loss due to OPEC's market power by comparing the actual allocation of oil production with a counterfactual cost-minimizing allocation, holding total output constant.
- **Findings:**
  - The net present value of the welfare loss resulting from this misallocation was estimated to be substantial, around $750 billion.
  - This loss component can be conceptualized as a **"Welfare Rectangle"**, capturing the increased production cost at a given output level.
- **Implication:** Market power can induce significant welfare losses not only by restricting output but also by distorting the allocation of production across producers with varying efficiencies.

Potential Output Losses Due to Inefficient Production

Hsieh and Klenow (2009): Wedge Approach and Misallocation

- **Key Point:** In an idealized, perfectly competitive, frictionless economy, the Marginal Revenue Product (MRP) of any given input factor should be equalized across all producers using it.
- **Methodology:**
  - Interpreted the observed dispersion in MRPs across producers in reality as evidence of underlying market frictions or distortions (termed "wedges").
  - These wedges prevent resources from flowing to their highest MRP users, thus causing misallocation.
- **Findings:** Applying this approach to manufacturing data from China and India, they estimated that if capital and labor were reallocated to equalize MRPs to the extent observed in the U.S. manufacturing sector, manufacturing TFP could increase by **30-50% in China and 40-60% in India.**

Conclusion and Future Work

Main Findings:

- **Productivity Disperision:** Substantial productivity differences exist among firms within the same industry.
- **Producer-Level Drivers:** Managerial practices and intangible capital investments significantly influence firm-level productivity variations.
- **Aggregate Productivity Gains:** Both within-producer improvements and between-producer reallocation effects contribute to industry productivity growth.
- **Efficiency Losses:** Market power and resource misallocation create significant potential output losses.

Conclusion and Future Work

Future Work: Measuring market power using production data.
Define Markup:

$$\mu \equiv \frac{P}{c}$$

where c denotes marginal cost.

- **Production Approach:**

$$\mu_{it} \equiv \theta_{it}^{V} \frac{P_{it} Q_{it}}{P_{it}^{V} X_{it}^{V}}$$

  where θ_{it}^{V} represents the output elasticity with respect to the input X^{V}.
  - Assumption: Producers minimize cost by optimally choosing those inputs that are free from frictions in a given period.
  - Key Point: Cost minimization of a variable input of production.

$$\min_{X^V} P^V X^V \quad \text{s.t.} \quad Q = F(X^V, X^F)$$

- De Loecker and Warzynski (2012): Markups and firm level export status.