Productivity Dynamics and Industry Turnover

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Introduction

- In many areas of economics, researchers are interested in measuring the relative **productivity** of firms.
  - E.g. dispersion (misallocation?), technology innovation, competitive selection, business cycles, etc.
- **Definition:** A *Hicks neutral technical change* is a change in the production function of an industry or a firm that leaves the mix of input constant. Example:

$$Y = AF(K, L)$$

  A (or $\omega = \ln(A)$) is also called a *TFP* or *Solow residual* shock.
- Most of the productivity literature focusses on the Cobb-Douglas production function (or first-order approximation of $F(K, L)$):

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + \epsilon_{it}$$

  where ω_{it} is serially correlated productivity shock, and ϵ_{it} is an IID innovation (e.g. measurement error).

Identification Problem

- **Simultaneity:** Identification of (β_k, β_l) (and therefore ω_{jt}) is difficult because of three standard simultaneity problems
  1. *Optimal behavior:* Firms choose (l_{jt}, k_{jt}) after observing ω_{jt} (or something correlated with it)
  2. *Endogenous selection:* Surviving firms have different productivity levels than exiting firms.
  3. *Measurement error:* The presence of ϵ_{it} and errors in the measurement of labor and capital complicates things further (e.g. what units to use?)

- **Relevant Literature:**
  - Griliches and Mairesse (1995) surveys the early literature (including the related *cost function* literature)
  - **Dynamic panels:** Blundell and Bond (1998), and Blundell and Bond (2000)
  - **Control function approach:** Olley and Pakes (1996), Levinsohn and Petrin (2003), Ackerberg, Caves, and Frazer (2015)
  - **Recent extensions:** Doraszelski and Jaumandreu (2013) [R&D investment], De Locker and Warzynski (2012) [markup heterogeneity], Gandhi, Navarro, and Rivers (2014) [identification from FOCs]

Three Approaches

1. **Input Shares:** If all inputs are flexible **and** firms are price-takers in the input market, cost-minimization + Cobb-Douglas implies:

$$r = AF_K(L,K) = \beta_l A \frac{F(L,K)}{K} \text{ and } w = AF_L(L,K) = \beta_l A \frac{F(L,K)}{L}$$

$$\frac{rK}{Y} = \hat{\beta}_k \text{ and } \frac{wL}{Y} = \hat{\beta}_l \Leftrightarrow \hat{A} = \frac{Y}{K^{\hat{\beta}_k} L^{\hat{\beta}_l}}$$

Note: Input shares are typically calculated at the industry level.

2. **Instrumental Variables:** If we observe *exogenous* firm-level input prices, (β_l, β_k) can be estimated using IVs and productivity is simply

$$\hat{\omega}_{it} = y_{it} - \hat{\beta}_0^{iv} - \hat{\beta}_l^{iv} l_{it} - \hat{\beta}_k^{iv} k_{it}$$

3. **Dynamic panels:** If $\omega_{it} = \rho\omega_{it-1} + \xi_{it}$ and $E(\xi_{it}|I_{it-1}) = 0$, we can form *moment restrictions* based on the ρ-difference representation:

$$E\Big[(y_{it} - \rho y_{it-1}) - \beta_0(1-\rho) - \beta_l(l_{it} - \rho l_{it-1})$$

$$-\beta_k(k_{it} - \rho k_{it-1}) + \xi_{it} + (\epsilon_{it} - \rho\epsilon_{it-1})|I_{it-1}\Big] = 0$$

Note: If $\rho = 1$, this is the standard FE estimator.

The Control Function Approach

- Five assumptions:
  1. **Information set:** I_{it} includes current and past realizations of ω_{jt}, past input choices, and $E(\epsilon_{it}|I_{it}) = 0$.
  2. **Markov process:** Productivity evolves according to a first-order markov process, $\Pr(\omega_{it+1}|I_{it}) = p(\omega_{it+1}|\omega_{it})$.
  3. **Timing:** Capital is fixed in the short-run and is determined by investment: $k_{it} = \kappa(k_{it-1}, i_{it-1})$ where i_{it-1}. Labor (and material) are non-dynamic and chosen at t.
  4. **Scalar unobservable:** Firms' investment decisions are given by $i_{it} = f_t(k_{it}, \omega_{it})$
  5. **Strict monotonicity:** $f_t(k_{it}, \omega_{it})$ is strictly increasing in ω_{it}.
- **Comments:**
  - AR(1) is a special case (linear) of (2)
  - Assumptions (4) and (5) rules out the presence of idiosyncratic and persistent shocks to input prices or non-Hicks neutral shocks.
  - The investment function is indexed by t to reflect unobserved aggregate shocks to the input market.
  - **Extension:** Heterogenous input prices, $f_t(k_{it}, r_{it}, w_{it}, \omega_{it})$.

The Olley and Pakes (1996) estimator

- **Key idea:** Use the observed investment level to **proxy** for the unobserved productivity level.
- Assumptions (4) and (5) implies the existence of a unique inverse:

$$\omega_{it} = f_t^{-1}(k_{it}, i_{it})$$

- **Step 1:** Productivity inversion. Assumptions (1) and (4)-(5) implies the following moment restriction:

$$\begin{aligned} E\left[\epsilon_{it} | I_{it}\right] &= \\ E\left[y_{it} - \beta_l l_{it} - \Phi_t(k_{it}, i_{it}) | I_{it}\right] &= 0 \end{aligned}$$

  where $\Phi_t(k_{it}, i_{it}) = \beta_0 + \beta_k k_{it} + f_t^{-1}(k_{it}, i_{it})$. This *control function* can be approximated using non-parametric functions. This is a relatively "standard" partial linear model (Robinson 1988).

The Olley and Pakes (1996) estimator (continued)

- **Step 2:** Return to capital estimation
  - The first-order markov process assumption implies the following conditional mean restriction:

$$\omega_{it} = E(\omega_{it}|I_{it-1}) + \xi_{it} = g(\omega_{it-t}) + \xi_{it}, \text{ where } E(\xi_{it}|I_{it-1}) = 0$$

  - From the first-stage, we have the following identity:

$$\Phi_t(k_{it}, i_{it}) = \beta_0 + \beta_k k_{it} + \omega_{it}$$

  - This proxy relationship can be used to construct the following moment restriction:

$$E\left[y_{it} - \beta_0 - \beta_l l_{it} - \beta_k k_{it} - g\left(\Phi_t(k_{it-1}, i_{it-1}) - \beta_0 - \beta_k k_{it-1}\right)|I_{it-1}\right] = 0$$

  - In practice, β_l and $\Phi_t()$ are replaced by $(\hat{\beta}_l, \hat{\Phi}_t(\cdot))$, and $g(\cdot)$ can be approximated using a non-parametric function (e.g. polynomial or Kernel)

The Levinsohn and Petrin (2003) estimator

- A major problem with the "investment" proxy, is the discrete continuous nature of investments in most firm-level panels.
  - First-stage cannot be estimated when $i_{it} = 0$
  - In many cases, i_{it} is very *lumpy* (potential violation of strict monotonicity).
- Levinsohn and Petrin (2003) proposed to use **material** as an alternative proxy variable.
- Alternative production function:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \omega_{it} + \epsilon_{it}$$

- **Assumption:** The policy function governing the choice of material, $m_{it} = f_t(k_{it}, \omega_{it})$, is strictly increasing in ω_{it}.

The Levinsohn and Petrin (2003) estimator (continued)

- This leads to the same two-step semi-parametric estimator:
  1. **Return to labor+productivity inversion:**

$$E\left[y_{it} - \beta_l l_{it} - \Phi_t(k_{it}, m_{it}) | I_{it}\right] = 0$$

     where $\Phi_t(k_{it}, m_{it}) = \beta_0 + \beta_k k_{it} + \beta_m m_{it} + f_t^{-1}(k_{it}, m_{it})$.
  2. **Return to capital and material:**

$$E\Big[y_{it} - \beta_0 - \beta_l l_{it} - \beta_k k_{it} - \beta_m m_{it} \\ -g\left(\Phi_t(k_{it-1}, m_{it-1}) - \beta_0 - \beta_k k_{it-1} - \beta_m m_{it-1}\right) | I_{it-1}\Big] = 0$$

- This two-step semi-parametric estimator is **very** widely used, and is available in standard statistical packages (e.g. Petrin, Poi, and Levinsohn 2004)

The ACF Critique

- **Functional dependence:** Ackerberg et al. (2015) argue that OP and LP do not provide *consistent* estimates under the assumed timing of input choices. Why?
  - **Example:** Assume that material is flexible and chosen to minimize cost after observing ω_{it}

$$\text{FOC: } \exp(\omega_{it})\beta_m \frac{L_{it}^{\beta_l} K_{it}^{\beta_k} M_{it}^{\beta_m}}{M_{it}} = p_t^m$$

$$\Rightarrow y_{it} = \ln(1/\beta_m) + \ln p_{it}^m + m_{it} + \epsilon_{it}$$

  - This example clearly illustrates that controlling for "m_{it}" not-only eliminates productivity and capital... it also eliminates labor!
  - More generally, if labor is simultaneously chosen with m_{it} (or investment) after observing ω_{it}, it is impossible to identify β_l from the first stage.
- Why is it important?
  - If β_l is not separately identified, we cannot identify ω_{it}.

The ACF Critique

- Ackerberg et al. (2015) proposed alternative **timing** assumptions that can be used to validate the OP and LP approaches.
  1. Optimization error in l_{it} (but not in m_{it} or i_{it})
  2. IID input or output price shocks that are realized **after** m_{it} or i_{it} are chosen, but before l_{it} is chosen.
  3. Labor is chosen **before** investment, and **before** productivity is fully realized (in the context of OP).
- The last possibility is valid only in the OP framework because investment is **excluded** from the production function (unlike material in LP).
- **Comment:** The unattractive feature of these additional assumptions is they are very difficult to assess and test. The contribution of ACF is to clarify the DGP necessary to identify the model.

Alternative Moment Restriction

- **Assumption:** Perfect complementarity between material and (k_{it}, l_{it}) (i.e. Leontief).

$$F(A, K, L, M) = \min\{AL^{\beta_l}K^{\beta_k}, M^{\beta_m}\}$$

  where $A = \exp(\omega)\exp(\epsilon)$.
- **Timing**:
  1. Capital (and possibly labor) are chosen before ω_{it} is realized
  2. Material is chosen after observing ω_{it}

$$m_{it} = \tilde{f}(k_{it}, l_{it}, \omega_{it})$$

  3. IID shock is realized (ϵ_{it}) after all inputs are chosen
- Value-added production function:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{jt} + \omega_{it}$$

- **Note:** The Leontief assumption is analogous to an exclusion restriction. Material is correlated with productivity, but is excluded from the function transforming capital and labor in *per unit* output.

Alternative Moment Restriction (continued)

- This alternative model leads to a slightly different estimator:
  - **Step 1:** Productivity inversion

$$E\left[y_{it} - \Phi_t(l_{it}, k_{it}, m_{it}) | I_{it}\right] = 0$$

where $\Phi_t(l_{it}, k_{it}, m_{it}) = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + f_t^{-1}(k_{it}, l_{it}, m_{it})$.

  - **Step 2:** Production function estimation

$$E\Big[y_{it} - \beta_0 - \beta_l l_{it} - \beta_k k_{it} \\ -g\left(\Phi_t(l_{it-1}, k_{it-1}, m_{it-1}) - \beta_0 - \beta_k k_{it-1} - \beta_l l_{it}\right) | I_{it-1}\Big] = 0$$

- **Note:** Once again $\Phi_t(\cdot)$ and $g(\cdot)$ are non-parametric functions approximated using flexible polynomials or Kernels.

Example: AR(1) process

- **Assumption:** $\omega_{it} = \rho\omega_{it-1} + \xi_{it}$
- **First-stage:** Productivity inversion
  - Polynomial basis:

$$B(l_{it}, k_{it}, m_{it}) = \left[1, (l_{it}, k_{it}, m_{it}), (l_{it}^2, k_{it}^2, m_{it}^2), (l_{it} \cdot k_{it}, l_{it} \cdot m_{it}), \dots\right]$$

  - OLS regression (period-by-period):

$$y_{it} = B(l_{it}, k_{it}, m_{it})\theta_t + e_{it}, \text{ where } e_{it} = \epsilon_{it} + \text{Approximation error}$$

  - Let $\hat{\Phi}(l_{it}, k_{it}, m_{it}) = B(l_{it}, k_{it}, m_{it})\hat{\theta}_t$.
- **Second-stage:** GMM estimation of $\beta = (\beta_0, \beta_l, \beta_k)$
  - Let $Z_{it} = \left[1, k_{it}, l_{it-1}, \hat{\Phi}(l_{it-1}, k_{it-1}, m_{it-1})\right]$ be a vector of IVs in I_{it-1}
  - Unconditional moment restriction:

$$\begin{aligned} E\left[\xi_{it}(\beta) \times Z_{it}\right] &= 0 \\ \text{Where, } \xi_{it}(\beta) &= y_{it} - \beta_0 - \beta_l l_{it} - \beta_k k_{it} \\ & \quad -\rho\left(\Phi_t(l_{it-1}, k_{it-1}, m_{it-1}) - \beta_0 - \beta_k k_{it-1} - \beta_l l_{it}\right) \end{aligned}$$

Industry Turnover: Introduction

A few key papers and topics:

1. Patterns of entry/exit: Dunne, Roberts, and Samuelson (1988).
2. Firm size distribution and Gibrat's Law: Lucas (1978), Jovanovic (1982), Pakes and Ericson (1998).
3. Dynamics of prices and productivity: Olley and Pakes (1996), Foster, Haltiwanger, and Syverson (2008).
4. Competitive model of industry dynamics: Hopenhayn (1992), Melitz (2003) and Das, Roberts, and Tybout (2007)
5. Life-cycle of industries: Jovanovic and MacDonald (1994), Klepper and Simons (2000).
6. Imperfect competition and Industry dynamics: Ericson and Pakes (1995), Pakes and McGuire (1994), Benkard (2004), Doraszelski and Markovich (2005).

Patterns of Entry/Exit

Source: Dunne, Roberts, and Samuelson (1988)

- **Objective:** Summarize the patterns of Entry, growth and Exit of US firms in 4-digit SIC industries b/w 1963-1982.
- Original Features:
  - First study to use the US census of manufacturers (i.e. microdata files).
  - Identify the characteristics of three types of entrants: (i) New firms (NF/NP), (ii) Diversifying firms with new plants (DF/NP), (iii) Diversifying firms with new mixed of products (DF/PM).
  - Compare the E/E patterns over time and across 387 industries. Previous studies looked only at **net** flows (i.e. aggregate data on the number of firms).
  - Compare the post-entry performance of entrants with incumbents (i.e. size, market share, growth rate, failure rate).

Data

- Constructing a longitudinal panel of firms:
  - Start with plant-level micro-data from the Censuses of US Manufacturer (1963-1982 - every 5 years).
  - Match with firms identifiers to construct a firm-level panel data-base (taking into account ownership changes)
    Note: A firm can have multi-plants and be active in more than one industry.
  - The unit of observation is: Firm f in market i at census year t.
  - For each firm the dataset includes: (i) total output, (ii) fraction of output in industry i, (iii) market share in each industry, (iv) entry/exit dates (if not censured).
- Limitations of the data:
  - Five years gap between surveys (i.e. ignores year-to-year turnover).
  - Left censuring.
  - Ownership changes can create artificial exits.
  - Small plants are handled differently in the survey.

Notation for Key Variables

- NE_{it}: Nb. Entrants
- NT_{it}: Total Nb. Firms.
- NX_{it-1}: Nb. of Exiters b/w t and $t-1$.
- QE_{it}: Output of Entrants
- QT_{it}: Total output
- QX_{it-1}: Output of Exiters $t-1$.
- $ER_{it} = NE_{it}/NT_{it}$: Entry rate
- $XR_{it} = NX_{it-1}/NT_{it-1}$: Exit rate
- $ESH_{it} = QE_{it}/QT_{it}$: Entrants market share
- $XSH_{it} = QX_{it-1}/QT_{it-1}$: Exiters market share
- $ERS_{it} = \frac{QE_{it}/NE_{it}}{QT_{it}-QE_{it}/NT_{it}-NE_{it}}$: Entrants relative size
- $XRS_{it} = \frac{QX_{it-1}/NX_{it-1}}{QT_{it-1}-QX_{it-1}/NT_{it-1}-NX_{it-1}}$: Entrants relative size

Trends in the number of multi-product and multi-plant firms

TABLE 1 **Summary Data for Manufacturing Firms in Each Census Year**

	Total Firms		Single-Plant Firms			Multiplant Firms			
Census Year	Number of Firms	Average Number of Four-Digit Industries per Firm	Share of Number of Firms	Share of Total Value of Production	Average Number of Four-Digit Industries per Firm	Share of Number of Firms	Share of Total Value of Production	Average Number of Four-Digit Industries per Firm	Average Number of Plants per Firm
1963	265,779	1.31	.945	.215	1.23	.055	.785	2.75	3.72
1967	265,599	1.24	.942	.194	1.15	.058	.806	2.69	3.59
1972	263,169	1.25	.926	.146	1.13	.074	.854	2.70	3.54
1977	295,687	1.23	.928	.150	1.12	.072	.850	2.55	3.59
1982	294,394	1.22	.927	.152	1.08	.073	.848	2.52	3.50

Analysis 1: Aggregate Entry/Exit Statistics

TABLE 2 Entry and Exit Variables for the U.S. Manufacturing Sector (Averages over 387 Four-Digit SIC Industries)

	1963–1967	1967–1972	1972–1977	1977–1982
Entry Rate (*ER*):				
All firms	.414	.516	.518	.517
Smallest firms deleted	.307	.427	.401	.408
Entrant Market Share (*ESH*):				
All firms	.139	.188	.146	.173
Smallest firms deleted	.136	.185	.142	.169
Entrant Relative Size (*ERS*):				
All firms	.271	.286	.205	.228
Smallest firms deleted	.369	.359	.280	.324
Exit Rate (*XR*):				
All firms	.417	.490	.450	.500
Smallest firms deleted	.308	.390	.338	.372
Exiter Market Share (*XSH*):				
All firms	.148	.195	.150	.178
Smallest firms deleted	.144	.191	.146	.173
Exiter Relative Size (*XRS*):				
All firms	.247	.271	.221	.226
Smallest firms deleted	.367	.367	.310	.344

Main Observations

- Entry rates and exit rates are $+/-$ constants and equal (i.e. stationary industries).
- Entrants are significantly smaller than average incumbents:

$$ESH \in [0.14 - 0.18] < ER \approx 0.4$$

$$ERS \in [0.28 - 0.37]$$

- Exiters are significantly smaller than incumbents:

$$XSH \in [0.14 - 0.19] < ER \in [0.31 - 0.37]$$

$$XRS \in [0.31 - 0.37]$$

- Entry by types:

	NF/NP	DF/NP	DF/PM
ER	23%	3%	13%
ESH	8%	3%	6%
ERS	30%	**90%**	35%

Main Observations (continued)

- On average *DF* accounts for about 44% of new entrants, and 50% of new entrants' output.
- The DF/NP entrants are especially larger than the others.
- Exit rates by types:

	NF/*NP*	*DF*/*NP*	*DF*/*PM*
XR	[9% − 17%]	[1% − 2%]	[4% − 10%]

- Firms which entered as NF/NP are significantly more likely to exit.

Analysis 2: Within/Between Industry Variation

Two-Digit Sector	Rate	Market Share	Relative Size
	Entry Variables		
20 Food Processing	.239 (.08, .39)	.098 (.02, .19)	.313 (.10, .57)
21 Tobacco	.205 (.00, .63)	.021 (.00, .06)	.107 (.00, .27)
22 Textiles	.372 (.17, .60)	.177 (.05, .31)	.374 (.16, .56)
23 Apparel	.403 (.20, .65)	.262 (.11, .38)	.512 (.22, .82)
24 Lumber	.497 (.23, .90)	.264 (.09, .42)	.424 (.21, .64)
25 Furniture	.471 (.28, .69)	.239 (.13, .38)	.383 (.21, .65)
26 Paper	.314 (.07, .52)	.107 (.01, .24)	.304 (.10, .74)
27 Printing	.490 (.22, .91)	.228 (.09, .39)	.407 (.15, .71)
28 Chemicals	.325 (.12, .53)	.086 (.01, .18)	.217 (.08, .44)
29 Petroleum and Coal	.337 (.16, .58)	.140 (.02, .28)	.354 (.10, .83)
30 Rubber and Plastics	.431 (.10, .88)	.129 (.01, .26)	.224 (.06, .43)
31 Leather	.294 (.19, .48)	.186 (.06, .33)	.476 (.23, .83)
32 Stone, Clay, Glass	.344 (.13, .58)	.131 (.02, .29)	.330 (.07, .65)
33 Primary Metals	.319 (.08, .55)	.122 (.01, .26)	.328 (.10, .63)
34 Fabricated Metals	.429 (.23, .65)	.193 (.07, .35)	.376 (.15, .70)
35 Nonelectrical Machinery	.465 (.26, .66)	.167 (.06, .32)	.299 (.11, .52)
36 Electrical Machinery	.461 (.21, .78)	.095 (.03, .26)	.216 (.08, .45)
37 Transportation Equipment	.465 (.09, .73)	.141 (.01, .39)	.257 (.06, .73)
38 Instruments	.603 (.29, .88)	.189 (.06, .32)	.224 (.09, .39)
39 Miscellaneous	.402 (.21, .63)	.187 (.07, .30)	.351 (.15, .61)

	Exit Variables		
20 Food Processing	.313 (.16, .44)	.123 (.03, .23)	.303 (.11,
21 Tobacco	.223 (.03, .48)	.032 (.00, .09)	.110 (.00,
22 Textiles	.372 (.22, .52)	.179 (.06, .32)	.355 (.18,
23 Apparel	.453 (.34, .58)	.291 (.15, .45)	.517 (.27,
24 Lumber	.441 (.29, .57)	.264 (.12, .41)	.452 (.25,
25 Furniture	.431 (.32, .62)	.241 (.12, .36)	.418 (.22,
26 Paper	.299 (.14, .43)	.122 (.05, .24)	.324 (.13,
27 Printing	.429 (.33, .58)	.243 (.11, .40)	.439 (.19,
28 Chemicals	.285 (.13, .42)	.081 (.01, .17)	.213 (.08,
29 Petroleum and Coal	.297 (.13, .40)	.144 (.02, .27)	.373 (.09,
30 Rubber and Plastics	.302 (.09, .52)	.133 (.01, .25)	.316 (.09,
31 Leather	.390 (.28, .49)	.240 (.13, .40)	.487 (.33,
32 Stone, Clay, Glass	.307 (.13, .46)	.138 (.03, .29)	.357 (.08,
33 Primary Metals	.277 (.10, .43)	.120 (.01, .29)	.341 (.08,
34 Fabricated Metals	.355 (.21, .48)	.182 (.05, .31)	.406 (.13,
35 Nonelectrical Machinery	.373 (.29, .48)	.161 (.06, .28)	.328 (.12,
36 Electrical Machinery	.351 (.23, .48)	.119 (.03, .25)	.240 (.08,
37 Transportation Equipment	.327 (.05, .56)	.117 (.00, .28)	.233 (.06,
38 Instruments	.468 (.35, .61)	.182 (.08, .28)	.254 (.10,
39 Miscellaneous	.410 (.30, .49)	.222 (.10, .34)	.430 (.19,

Within industries comparisons

- There exists a lot of variation in ER: Both across industry groups (2-digit SIC) and within groups/year.
- Industries with high ER typically also have high XR.
- In all industries, entrants are significantly smaller.
- Time-series analysis:
  - **Positive** correlation of entry and exit rates across years: Industries with higher than average entry (exit) rates tend to have higher than average rates in the future.
  - The serial-correlation is **much** higher for the XR.
  - The persistence in the serial-correlations is the highest for Entrants/Exiters market shares: The structure of industries are highly persistent over time.
  - Entry/Exit rates and sizes are more affected by transitory shocks.

Serial correlations within-industries

	Entry Measures				Exit Measures			
	1963–1967	1967–1972	1972–1977	1977–1982	1963–1967	1967–1972	1972–1977	1977–1982
Entry Rate					Exit Rate:			
1963–1967	1.000	.310	.233	.251	1.000	.671	.594	.577
1967–1972		1.000	.274	.265		1.000	.681	.624
1972–1977			1.000	.306			1.000	.739
1977–1982				1.000				1.000
Entrant Market Share					Exiter Market Share:			
1967	1.000	.721	.697	.598	1.000	.777	.707	.649
1972		1.000	.804	.692		1.000	.778	.721
1977			1.000	.759			1.000	.787
1982				1.000				1.000
Entrant Relative Size					Exiter Relative Size:			
1967	1.000	.400	.455	.377	1.000	.569	.502	.501
1972		1.000	.610	.503		1.000	.617	.564
1977			1.000	.609			1.000	.555
1982				1.000				1.000

Correlations between Entry and Exit variables: Do Entry/Exit occur simultaneously?

TABLE 7 Correlations between Industry Entry and Exit Variables (387 Four-Digit Industries)

	No Correction for Fixed Industry Effects				Correction for Fixed Industry Effects			
	1963–1967	1967–1972	1972–1977	1977–1982	1963–1967	1967–1972	1972–1977	1977–1982
	Entry Rate				Entry Rate			
Exit Rate								
1963–1967	.180	.363	.387	.323	−.249	.071	.123	−.005
1967–1972	.447	.274	.273	.363	.371	−.191	−.177	.118
1972–1977	.358	.408	.321	.328	.051	.137	−.129	−.081
1977–1982	.237	.324	.389	.304	−.114	−.029	.147	−.028
	Entrant Market Share				Entrant Market Share			
Exiter Market Share								
1963–1967	.741	.725	.743	.691	.308	−.116	−.037	−.167
1967–1972	.722	.770	.759	.703	.124	.154	−.058	−.228
1972–1977	.681	.800	.788	.784	−.153	.160	−.044	.032
1977–1982	.571	.691	.758	.804	−.287	−.172	.132	.354

Correlations between Entry and Exit variables: Do Entry/Exit occur simultaneously?

- Without controlling for industry fixed effects: corr(ER,XR) and corr(ESH,XSH) are positive.
- After controlling for fixed effects, most correlations are either close to zero or negative (i.e. High entry rates are associated with low exit rates).
- The correlation patterns tend to be different for entrants and exiters market share: Contemporaneous positive and lagged negative. Industries with above than average entrants tend to have above than average exiters as well.
- This highlights the importance of controlling for fixed unobserved characteristics in cross-industries analysis.

Analysis 3: Longitudinal aspects

TABLE 8 **Market Shares, Average Firm Sizes, and Exit Rates of Entry Cohorts by Year (Means and Standard Deviations across 387 Industries)**

	1963	1967	1972	1977	1982
Market Shares					
1963 Firms	1.00	.861	.729	.657	.578
		(.104)	(.169)	(.202)	(.222)
1967 Entry Cohort		.139	.083	.067	.053
		(.104)	(.062)	(.054)	(.044)
1972 Entry Cohort			.189	.131	.099
			(.130)	(.088)	(.069)
1977 Entry Cohort				.147	.098
				(.109)	(.074)
1982 Entry Cohort					.173
					(.113)
Average Size of Surviving Firms Relative to All Firms in the Industry					
1963 Firms	1.00	1.49	2.13	2.92	3.76
		(.406)	(1.13)	(1.90)	(3.37)
1967 Entry Cohort		.352	.597	.915	1.32
		(.240)	(.485)	(.935)	(1.47)
1972 Entry Cohort			.396	.686	1.07
			(.250)	(.455)	(.867)
1977 Entry Cohort				.308	.560
				(.202)	(.357)
1982 Entry Cohort					.346
					(.204)
Cumulative Cohort Exit Rates					
1963 Firms		.419	.640	.741	.815
		(.116)	(.120)	(.118)	(.109)
1967 Entry Cohort			.639	.790	.876
			(.100)	(.075)	(.063)
1972 Entry Cohort				.575	.782
				(.103)	(.090)
1977 Entry Cohort					.632
					(.111)

Analysis 3: Longitudinal aspects

- The market share of surviving firms is **decreasing** for all cohorts: Change in the size of surviving firms and Exit of firms in each cohort.
- The average size of each surviving cohort is increasing (slowly) over time.
- The cumulative failure rate is high and increasing: 65% of new entrants exit within 1 census period, and 79% exit within 10 years.
- The high failure rate dominates the he growth rate of surviving entrants: The Market share of surviving entrants is decreasing over time for all cohort/types.
- The s.d. of the average size of survivors is increasing over time (i.e. the growth rates are very heterogeneous across industries).
- The s.d. of the failure rate and market shares of survivors is decreasing over time.
- The growth rates of DF/NP surviving entrants are higher than those of NF/NP or DF/PM (same for s.d.).

Selection on productivity or profitability?

Source: Foster, Haltiwanger, and Syverson (2008)

- **General argument:**
  - The theory and empirical literature on industry dynamics emphases the importance of idiosyncratic productivity differences as the key driver of industry turnover and aggregate productivity growth.
  - Typically authors measure productivity using deflated revenue rather than output: Technological productivity differences are confounded with price heterogeneity.
  - The link between productivity and industry turnover and growth might be overstated, if productivity and prices are not perfectly correlated or markups are not constant.
- **Main data innovation:**
  - Firm level prices are measured separately from physical output.
  - Compare revenue-based productivity measures with physical productivity and idiosyncratic demand shocks.
  - Select industries with **homogeneous** quality products (i.e. comparable units).

Productivity Measurement

- **Productivity:** Cobb-Douglas production function with constant-return to scale

$$\mathrm{TFP}_{it} = y_{it} - \beta_l l_{it} - \beta_k k_{it} - \beta_m m_{it} - \beta_e e_{it}$$

  where β's correspond to industry average cost shares.
- Three TFP measures:
  1. **TFPQ**: y_{it} is measured in units of output,
  2. **TFPT**: y_{it} is total revenue of firm i divided by industry price index (i.e. NBER shipment price index).
  3. **TFPR**: y_{it} is total revenue of firm i divided by firm-level price index.

Demand Shocks

- **Industry-level linear demand function:**

$$q_{it} = \alpha_0 + \alpha_1 \ln p_{it} + \alpha_t + \alpha_2 \ln \mathrm{Income}_{mt} + \eta_{it}$$

  where η_{it} is firm i idiosyncratic demand shock.
- What is included in η?
  - Location-based differentiation
  - Long-term supplier relationship
  - **Not** Quality (rely on industry selection).
- **Choice of IV:** Physical productivity. Valid instrument if η truly measures "horizontal" differentiation aspects of demand.
- **Sample selection:**
  - Select 11 industries with homogeneous products (assumption).
  - Select firms that are "specialized": More than 50% of output is devoted to the industry product.

Demand Estimates

TABLE 2—ESTIMATING PRICE ELASTICITIES BY PRODUCT

	IV estimation			OLS estimation	
Product	Price coefficient (α_1)		Income coefficient (α_2)	Price coefficient (α_1)	Income coefficient (α_2)
Boxes	−3.02		−0.03	−2.19	−0.03
	(0.17)	[0.61]	(0.02)	(0.12)	(0.02)
Bread	−3.09		0.12	−0.89	0.07
	(0.42)	[0.33]	(0.05)	(0.15)	(0.04)
Carbon black	−0.52		−0.21	−0.57	−0.21
	(0.38)	[0.50]	(0.11)	(0.21)	(0.11)
Coffee	−3.63		0.22	−1.03	0.20
	(0.98)	[0.41]	(0.14)	(0.32)	(0.13)
Concrete	−5.93		0.13	−0.83	0.15
	(0.36)	[0.10]	(0.01)	(0.09)	(0.01)
Hardwood flooring	−1.67		−0.20	−0.87	−0.24
	(0.48)	[0.61]	(0.18)	(0.47)	(0.18)
Gasoline	−1.42		0.23	−0.16	0.23
	(2.72)	[0.20]	(0.07)	(0.80)	(0.07)
Block ice	−2.05		0.00	−0.63	0.16
	(0.46)	[0.32]	(0.11)	(0.20)	(0.07)
Processed ice	−1.48		0.18	−0.70	0.16
	(0.27)	[0.37]	(0.03)	(0.13)	(0.03)
Plywood	−1.21		−0.23	−1.19	−0.23
	(0.14)	[0.89]	(0.10)	(0.13)	(0.10)
Sugar	−2.52		0.76	−1.04	0.72
	(1.01)	[0.15]	(0.13)	(0.55)	(0.12)

Notes: This table shows the results of estimating demand isoelastic curves separately for each product (shown by row). Two specifications are estimated for each product, one using IV methods and one using OLS for comparison. All regressions also include year fixed effects. Sample sizes by product are shown in Table A1 in the Web Appendix. Standard errors, clustered by plant, are in parentheses. Where applicable, Shea-corrected first-stage R^2 are listed in brackets. See text for details.

Descriptive Statistics: Productivity

Table 1—Summary Statistics for Output, Price, and Productivity Measures

Variables	Trad'l. output	Revenue output	Physical output	Price	Trad'l. TFP	Revenue TFP	Physical TFP	Capital
	Correlations							
Traditional output	1.00							
Revenue output	0.99	1.00						
Physical output	0.98	0.99	1.00					
Price	−0.03	−0.03	−0.19	1.00				
Traditional TFP	0.19	0.18	0.15	0.13	1.00			
Revenue TFP	0.17	0.21	0.18	0.16	0.86	1.00		
Physical TFP	0.17	0.20	0.28	−0.54	0.64	0.75	1.00	
Capital	0.86	0.85	0.84	−0.04	0.00	−0.00	0.03	1.00
	Standard deviations							
	1.03	1.03	1.05	0.18	0.21	0.22	0.26	1.14

Notes: This table shows correlations and standard deviations for plant-level variables for our pooled sample of 17,669 plant-year observations. We remove product-year fixed effects from each variable before computing the statistics. All variables are in logs. See the text for definitions of the variables.

Descriptive Statistics: Productivity

- All measures of size are highly correlated
- Productivity measures are highly dispersed (i.e. $s.d. \geq 20\%$)
- Prices and physical productivity are **negatively** correlated.
  - Firms who produce more per units of input charge lower prices, **or** firms with lower input price (i.e. unobserved) charge lower prices.
- Physical productivity is more dispersed: $\sigma_{tfpq} > \sigma_{tfpr}$.
  - Why? Negative correlation b/w productivity and prices, and positive correlation b/w prices and revenues.

Dynamics of Productivity and Demand

TABLE 3—PERSISTENCE OF PRODUCTIVITY, PRICES AND DEMAND SHOCKS

	Five-year horizon		Implied one-year persistence rates	
Dependent variable	Unweighted regression	Weighted regression	Unweighted regression	Weighted regression
Traditional TFP	0.249	0.316	0.757	0.794
	(0.017)	(0.042)		
Revenue TFP	0.277	0.316	0.774	0.794
	(0.021)	(0.042)		
Physical TFP	0.312	0.358	0.792	0.814
	(0.019)	(0.049)		
Price	0.365	0.384	0.817	0.826
	(0.025)	(0.066)		
Demand shock	0.619	0.843	0.909	0.966
	(0.013)	(0.021)		

- **Time persistence:**
  - Demand is a lot more persistent than productivity
  - Larger firms experience more persistent productivity and demand.

Entrants & Exiters *versus* Incumbents

TABLE 4—EVOLUTION OF REVENUE PRODUCTIVITY, PHYSICAL PRODUCTIVITY, PRICES AND DEMAND SHOCKS

	Unweighted regression		Weighted regression	
Variable	Exit dummy	Entry dummy	Exit dummy	Entry dummy
Traditional TFP	−0.0209	0.0014	−0.0164	−0.0032
	(0.0042)	(0.0040)	(0.0126)	(0.0188)
Revenue TFP	−0.0218	0.0110	−0.0197	−0.0005
	(0.0044)	(0.0042)	(0.0135)	(0.0183)
Physical TFP	−0.0186	0.0125	−0.0142	0.0383
	(0.0050)	(0.0047)	(0.0144)	(0.0177)
Price	−0.0033	−0.0015	−0.0055	−0.0388
	(0.0031)	(0.0028)	(0.0080)	(0.0141)
Demand shock	−0.3586	−0.3976	−0.5903	−0.2188
	(0.0228)	(0.0224)	(0.0968)	(0.1278)

- Entrants are **more** productive and charge **lower** prices than incumbents.
- Revenue-based productivity measures suggest that entrants are equally or less productive.
- Exiting firms are +/- equally productive, but face a much lower demand.

Aging and Experience

Table 5—Evolution of Productivity, Price and Demand with Age Effects

Variable	Exit	Entry	Young	Medium
	Plant age dummies			
Unweighted regressions				
Traditional TFP	−0.0211	0.0044	0.0074	0.0061
	(0.0042)	(0.0044)	(0.0048)	(0.0048)
Revenue TFP	−0.0220	0.0133	0.0075	0.0028
	(0.0044)	(0.0047)	(0.0051)	(0.0053)
Physical TFP	−0.0186	0.0128	0.0046	−0.0039
	(0.0050)	(0.0053)	(0.0058)	(0.0062)
Price	−0.0034	0.0005	0.0029	0.0067
	(0.0031)	(0.0034)	(0.0038)	(0.0042)
Demand shock	−0.3466	−0.5557	−0.3985	−0.3183
	(0.0227)	(0.0264)	(0.0263)	(0.0267)
Weighted regressions				
Traditional TFP	−0.0156	−0.0068	−0.0156	−0.0234
	(0.0127)	(0.0203)	(0.0171)	(0.0132)
Revenue TFP	−0.0191	−0.0038	−0.0180	−0.0165
	(0.0136)	(0.0200)	(0.0198)	(0.0131)
Physical TFP	−0.0142	0.0383	0.0056	−0.0050
	(0.0144)	(0.0186)	(0.0142)	(0.0135)
Price	−0.0049	−0.0421	−0.0236	−0.0114
	(0.0079)	(0.0147)	(0.0114)	(0.0096)
Demand shock	−0.5790	−0.2785	−0.3133	−0.3164
	(0.0972)	(0.1459)	(0.1695)	(0.1197)

Aging and Experience

- Results tend to favors theories of “vintage” capital:
  - New firms enter with better technology.
  - Learning-by-doing or start-up cost are not very important.
- Relatively slow convergence:
  - Significant differences with respect to demand shocks across all age groups.
  - Slow growth in consumer base, or selection effect?

Industry Selection

Table 6—Selection on Productivity or Profitability?

Specification:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Traditional TFP	−0.073 (0.015)						
Revenue TFP		−0.063 (0.014)					
Physical TFP			−0.040 (0.012)			−0.062 (0.014)	−0.034 (0.012)
Prices				−0.021 (0.018)		−0.069 (0.021)	
Demand shock					−0.047 (0.003)		−0.047 (0.003)
Controlling for plant capital stock							
Traditional TFP	−0.069 (0.015)						
Revenue TFP		−0.061 (0.013)					
Physical TFP			−0.035 (0.012)			−0.059 (0.014)	−0.034 (0.012)
Prices				−0.030 (0.018)		−0.076 (0.021)	
Demand shock					−0.030 (0.004)		−0.029 (0.004)
Capital stock	−0.046 (0.003)	−0.046 (0.003)	−0.046 (0.003)	−0.046 (0.003)	−0.023 (0.004)	−0.046 (0.003)	−0.023 (0.004)

- Significant attrition based on demand and productivity: Demand seems to be (marginally) more important than physical TFP
- Since prices and productivity are negatively correlated, the marginal effect of productivity alone is under-estimate if we don't control for prices.

Growth Decomposition

Productivity measure	Total growth	Within	Between	Cross	Entry	Exit	Net entry
		Components of decomposition (BHC/FHK)					
Traditional	2.30	0.82	−0.38	1.16	0.55	0.16	0.70
Revenue	5.13	3.34	−0.52	1.39	0.73	0.19	0.93
Physical	5.13	3.44	−0.41	0.76	1.23	0.12	1.35
		Components of decomposition (GR)					
		Within	Between		Entry	Exit	Net entry
Traditional	2.30	1.40	0.18		0.44	0.27	0.72
Revenue	5.13	4.03	0.16		0.55	0.39	0.94
Physical	5.13	3.82	−0.05		1.04	0.32	1.36

Notes: This table shows decompositions of industry-level productivity growth for three different productivity measures (shown by row) using equations (12) and (13) in text. The column labeled "Total Growth" reflects the weighted average five-year productivity growth for the industry. The remaining columns reflect the individual terms in the decomposition. Weights used in decompositions are revenue weights. Average industry revenues across the sample are used to calculate the results for the average industry. See text for details.

- Split industry growth between: within (growth of continuing firms), between (relative to industry level), cross-effect (change in weights of incumbent), entry and exit effects.

$$\Delta TFP_t = \sum_{i \in C} \theta_{it-1} \Delta tfp_{it} + \sum_{i \in C} (tfp_{it-1} - TFP_{t-1}) \Delta\theta_{it} + \sum_{i \in C} \Delta tfp_{it} \Delta\theta_{it}$$

$$+ \sum_{i \in N} \theta_{it} (tfp_{it} - TFP_{t-1}) - \sum_{i \in X} \theta_{it-1} (tfp_{it-1} - TFP_{t-1}),$$

Ackerberg, D., K. Caves, and G. Frazer (2015).
Identification properties of recent production function estimators.
Econometrica 83(6), 2411–2451.

Benkard, L. (2004, July).
A dynamic analysis of the market for wide-bodied commercial aircraft.
Review of Economic Studies.

Blundell, R. W. and S. T. Bond (1998).
Initial conditions and moment restrictions in dynamic panel data models.
Journal of Econometrics 87, 115–143.

Blundell, R. W. and S. T. Bond (2000).
Gmm estimation with persistent panel data: an application to production functions.
Econometrics Reviews 19, 321–340.

Das, S., M. Roberts, and J. Tybout (2007, May).
Market entry costs, producer heterogeneity, and export dynamics.
Econometrica.

De Locker, J. and F. Warzynski (2012).
Markups and firm-level export status.
American economic Review 102(6), 2437–2471.

Doraszelski, U. and J. Jaumandreu (2013).
R&d and productivity: Estimating endogenous productivity.

Review of Economic Studies 80, 1338–1383.

Doraszelski, U. and S. Markovich (2005).
Advertising dynamics and competitive advantage.
Forthcoming, Rand Journal of Economics.

Dunne, T., M. Roberts, and L. Samuelson (1988).
Patterns of entry and exit in u.s. manufacturing industries.
Rand Journal of Economics 19, 495.

Ericson, R. and A. Pakes (1995).
Markov-perfect industry dynamics: A framework for empirical work.
The Review of Economic Studies 62(1), 53–82.

Foster, L., J. Haltiwanger, and C. Syverson (2008, March).
Reallocation, firm turnover, and efficiency: Selection on productivity or profitability?
American Economic Review.

Gandhi, A., S. Navarro, and D. Rivers (2014).
On the identication of production functions: How heterogeneous is productivity,.
working paper, UW-Madison.

Griliches, Z. and J. Mairesse (1995).
Production functions: The search for identification.
NBER wp 5067.

Hopenhayn, H. A. (1992).
Entry, exit, and firm dynamics in long run equilibrium.
Economotrica 60, 1127–1150.

Jovanovic, B. (1982).
Selection and the evolution of industry.
Econometrica 50, 649–670.

Jovanovic, B. and G. MacDonald (1994).
The life cycle of a competitive industry.
Journal of Political Economy 102, 322–347.

Klepper, S. and K. L. Simons (2000).
The making of an oligopoly: Firm survival and technological change in the evolution of the us tire industry.
Journal of Political Economy 108, 728–760.

Levinsohn, J. and A. Petrin (2003).
Estimating production functions using inputs to control for unobservables.
Review of Economic Studies 70(2), 317–342.

Lucas, R. E. J. (1978).
On the size distribution of business firms.
The Bell Journal of Economics 9, 508–523.

Melitz, M. (2003).
The impact of trade on intra-industry reallocations and aggregate industry productivity.
Econometrica 71, 1695–1725.

Olley, G. S. and A. Pakes (1996).
The dynamics of productivity in the telecommunications equipment industry.
Econometrica: Journal of the Econometric Society 64(6), 1263–1297.

Pakes, A. and R. Ericson (1998).
Empirical implications of alternative models of firm dynamics.
Journal of Economic Theory 79, 1–45.

Pakes, A. and P. McGuire (1994).
Computing markov-perfect nash equilibria: Numerical implications of a dynamic differentiated product model.
The Rand Journal of Economics 25(4), 555–589.

Petrin, A., B. Poi, and J. Levinsohn (2004).
Production function estimation in stata using inputs to control for unobservables.
The Stata Journal 4(2), 113–123.

Robinson, P. M. (1988).
Root-n-consistent semi-parametric regression.
Econometrica 56(4), 931–954.