The Slow Growth of New Plants: Learning about Demand?

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Firm Heterogeneity Important in IO, Macro, Trade, Labor

Large dispersion in measured productivity within narrowly defined sectors (interquartile range for TFP is 30 log points)

- IO: Understanding industry evolution—passive and active learning and selection, size distribution of activity
- Macro: Productivity enhancing reallocation (or, sometimes, misallocation)
- Trade: Understanding micro patterns of trade, potential productivity gains from trade liberalization (improved selection, competition)
- Labor: Job creation and destruction (flow approach to labor market dynamics)

Standard Heterogeneous-Producer Industry Models

The Workhorse:

- Producers i differ in a profitability component ω_i, usually taken to represent costs/productivity
- Profits depend on ω_i and industry state S: $\pi_i = \pi_i(\omega_i, S)$ $\quad \omega_i \sim G(\omega)$
- There is some critical ω^* such that producers with $\omega_i < \omega^*$ have NPVs below outside option and therefore exit the industry
- Industry state S typically depends on endogenously determined distribution of ω_i among producers (add'l free entry assumption and assumptions about curvature of profit function).
- Examples: Jovanovic (1982), Hopenhayn (1992), Ericson and Pakes (1995), Melitz (2003), Asplund and Nocke (2007)

Extending Heterogeneous-Producer Industry Models

Recently, a small literature starts in a new direction:

- More than just technical efficiency likely to be idiosyncratic
- Demand-side market features probably vary across producers too
- Technological and demand fundamentals could follow separate (even independent) stochastic processes
- Typical “productivity” measures actually confound idiosyncrasies from both sides of the market

Examples:

- Das, Roberts, and Tybout (2007); Eslava et al. (2008)
- Foster, Haltiwanger, and Syverson (2008)

Premise

This paper: carry technology-vs.-demand distinction into analysis of a well-documented empirical pattern

Large literature has found systematic differences between entrants and incumbents in the same industry—one of the best documented is size

New plants/businesses are smaller than incumbent plants/businesses, and *much* smaller than "established" producers in same industry

Earlier work explored productivity/cost differences as explanation for size differences

- E.g., Dunne, Roberts, and Samuelson (1989); Bahk and Gort (1993); Bartelsman and Doms (2000) survey

Premise

But we show new plants' technical efficiency (TFPQ) is just as high—even slightly higher than—older plants'

- New plants' prices are slightly lower
    - New plants are small *in spite of* their prices, not because of them
    - Traditional revenue-based TFP measures (TFPR) confound price and TFPQ
        - Note that Std(TFPQ)=0.26 and Std(TFPR)=0.22
        - Negative covariance between TFPQ and prices

Premise

Thus idiosyncratic demand factors seem to be driving size difference, even in commodity-type product industries

In this paper, we model and estimate these demand-side features

Our sample contains industries where we can separately measure idiosyncratic technology and demand profitability components

Premise: Supply-side vs. Demand-side Fundamentals

$$y_{it} = \alpha_0 + \alpha_1 Entrant_{it} + \alpha_2 Young_{it} + \alpha_3 Medium_{it} + \alpha_4 Exit_{it} + \varepsilon_{it}$$

	Plant Age Dummies			
Variable	Entrant	Young	Medium	Exiter
Physical TFP	0.013	0.004	-0.004	-0.018
	(0.005)	(0.006)	(0.006)	(0.005)
Demand Shock	-0.550	-0.397	-0.316	-0.339
	(0.022)	(0.024)	(0.026)	(0.021)

Entrants: 0-4 years old (first Census of Manufactures)
Young: 5-9 years old (second CM)
Medium: 10-14 years old
Old: 15+ years old (excluded)
Exit: death by next CM, regardless of age

Premise: Supply-side vs. Demand-side Fundamentals

Entrants' TFP is higher than old incumbents

- But difference becomes insignificant by the time plant is 5+ years old

Very different patterns for idiosyncratic demands (i.e., differences in relative quantities sold if all plants charged the same price)

- Big initial gap
  - New plants would sell 58% the quantity of plants 15+ years old

- Slow convergence
  - Young plants sell 67%
  - Medium-aged plants sell 73%

Premise: Our Proposed Explanation

Growth patterns reflect dynamic demand-side forces that take considerable time to play out

- Growth of a customer base
- Building a reputation
- Demand uncertainty can create option value of waiting to expand

Examples of models:

- Caminal and Vives (1999)
- Radner (2003)
- Fishman and Rob (2003)

Note: customer "learning" more complicated than just finding a producer

- Details of product attributes
- Quality and quantity of bundled services
- Consistency of operations
- Expected longevity
- More generally: building relationship-specific capital

Data: Census of Manufactures

1977, 82, 87, 92, and 97 CMs, including product data supplement with plants' SIC 7-digit product revenues and output in physical units

Our 10 "industries" are based on these products

- Corrugated and solid fiber boxes (boxes)
- White pan bread (bread)
- Carbon black
- Roasted coffee beans (coffee)
- Ready-mixed concrete (concrete)
- Oak flooring (flooring)
- Block ice
- Processed ice
- Hardwood plywood (plywood)
- Raw cane sugar (sugar)

Data: Sample Inclusion Criteria

Administrative record (AR) plants are excluded

- Small plants (typically < 5 employees) with imputed product data
- These *are* included when determining entry and exit

Product-level data must be available and consistent with other CMs (e.g., no concrete data in 1997)

- Crucial for constructing separate physical productivity and demand measures

Exclude plants with likely reporting errors

Data: Sample Inclusion Criteria

Plants must have >50% of revenue coming from our products

- Average plants is highly specialized (~ 90% of revenue) in 7 of our industries anyway

- Less specialization in bread, flooring, gasoline, and block ice

- Specialization criterion serves two purposes
  - Closely ties product-specific performance and growth/exit
  - Reduces measurement error due to apportioning inputs

- Entry and exit measures also not influenced by criterion

Data: Overall Sample (About 17,000)

Industry	Average No. Plants/Yr	Revenue Share (%)	Avg. Entry Rate	Avg. Exit Rate
Boxes	962	6.0	12.4	12.2
Bread	126	2.2	7.6	18.9
Carbon Black	23	0.6	4.8	13.4
Coffee	76	4.5	9.1	15.6
Concrete	3041	6.0	26.6	21.8
Flooring	17	0.2	18.7	11.9
Block Ice	28	0.0	24.5	26.5
Processed Ice	129	0.1	23.1	27.7
Plywood	52	0.6	7.4	10.3
Sugar	33	1.1	3.9	17.0

Measuring Plant-Level Demand

Estimate product demand curves; plant-specific residual is idio. demand

$$\ln q_{it} = \alpha_o + \alpha_1 \ln p_{it} + \alpha_2 \ln(INCOME_{mt}) + \sum_t \alpha_t YEAR_t + \eta_{it}$$

q_{it}—physical output of plant *i* in year *t*
p_{it}—plant unit price
$INCOME_{mt}$—average income in the plant's local market *m*
$YEAR_t$—year dummy
η_{it}—plant-year disturbance term

Plant demand:

$$\hat{\theta}_{it} = \hat{\eta}_{it} + \hat{\alpha}_2 \ln(INCOME_{mt}) = \ln q_{it} - \hat{\alpha}_o - \hat{\alpha}_1 \ln p_{it} - \sum_t \hat{\alpha}_t YEAR_t$$

I.e., residual is plant quantity sold that can't be accounted for by unit price or local income differences

- Use $TFPQ_{it}$ to instrument for prices (captures production costs)

Facts about Plant-Level Demand: Firm Multi-Unit Status

$$\hat{\theta}_{it} = \sum\nolimits_{A} \beta_A Age_{it} * I\left(Multi\text{-}Unit\ Firm_{it}\right) + \sum\nolimits_{IT} \beta_{IT} IndYear_{IT} + u_{it}$$

	Plant age dummies				
Variable	Entrant	Young	Medium	Old	Exiter
Demand shock	-0.318 (0.034)	-0.176 (0.035)	-0.150 (0.038)	Excl.	-0.183 (0.031)
Demand shock x multi-unit firm indicator	0.106 (0.038)	0.132 (0.041)	0.237 (0.045)	0.530 (0.026)	-0.283 (0.042)

Idiosyncratic demand higher at all ages for plants in MU firms (add coefficients together by column to get MU demand levels)

- 65% higher demand at entry, over 65% when 10-14 years old

Convergence still slow, even for MU firms (old MU plants much larger)

Facts about Plant-Level Demand: Firm Age

Variable	Plant age dummies: Entrant	Young	Medium	Old	Exiter
Demand shock	-0.317 (0.034)	-0.178 (0.036)	-0.147 (0.036)	Excl.	-0.183 (0.031)
Demand shock x firm is multi-unit and an entrant	0.168 (0.066)	N/A	N/A	N/A	-0.167 (0.110)
Demand shock x firm is multi-unit and young or medium	0.004 (0.074)	0.139 (0.044)		N/A	-0.120 (0.077)
Demand shock x firm is multi-unit and old	0.091 (0.042)	0.122 (0.044)	0.267 (0.048)	0.538 (0.026)	-0.332 (0.045)

- Entrants relatively small regardless of firm age
- Convergence still slow
- Curious: New plants in old MU firms not systematically larger, though they are by medium-age

Dynamic Model

We want to learn more about demand-building process

Build explicit model and fit to data

Let plant-specific demand evolve due to exogenous and endogenous factors

- Exogenous: demand accumulation by “being”
- Endogenous: demand accumulation by “doing”

Use plants’ dynamic behavior to identify sources of demand evolution

Dynamic Model

Plant faces demand curve: $q_t = \theta_t Age_t^{\phi} Z_t^{\gamma} p_t^{-\eta}$

θ — exogenous demand shock, AR(1) process
Age — plant age
Z — "demand stock" that links plant past sales to current demand

$$Z_t = (1-\delta)Z_{t-1} + (1-\delta)R_{t-1}$$

Production function: $q_t = A_t x_t$

Plant's profits: $\pi_t = \theta_t^{\frac{1}{\eta}} Age_t^{\frac{\phi}{\eta}} Z_t^{\frac{\gamma}{\eta}} \left(A_t x_t\right)^{1-\frac{1}{\eta}} - c_t x_t - f$

Dynamic Model

Plant's dynamic problem:

$$V\left(Z_t, A_t, Age_t, \theta_t\right) =$$

$$\max\left\{0, \sup_{x_t} \theta_t^{\frac{1}{\eta}} Age_t^{\frac{\phi}{\eta}} Z_t^{\frac{\gamma}{\eta}} A_t^{1-\frac{1}{\eta}} x_t^{1-\frac{1}{\eta}} - c_t x_t - f + \beta EV\left(Z_{t+1}, A_{t+1}, Age_{t+1}, \theta_{t+1}\right)\right\}$$

This yields Euler equation (conditional on survival):

$$\frac{c_t}{(1-\delta) p_t A_t} - \frac{1}{1-\delta}\left(1-\frac{1}{\eta}\right)\theta_t^{\frac{1}{\eta}} Age_t^{\frac{\phi}{\eta}} Z_t^{\frac{\gamma}{\eta}} \left(A_t x_t\right)^{-\frac{1}{\eta}} p_t^{-1}$$

$$= \beta E\left\{\theta_{t+1}^{\frac{1}{\eta}} Age_{t+1}^{\frac{\phi}{\eta}} Z_{t+1}^{\frac{\gamma}{\eta}} \left(A_{t+1} x_{t+1}\right)^{-\frac{1}{\eta}} p_{t+1}^{-1}\left[\frac{\gamma}{\eta}\frac{p_{t+1} A_{t+1} x_{t+1}}{Z_{t+1}} - \left(1-\frac{1}{\eta}\right)\right] + \frac{c_{t+1}}{p_{t+1} A_{t+1}}\right\}$$

It is a mess, and it includes unobserved state variable θ. But we can use demand equation to substitute out

Dynamic Model

After substitution, we get a simplified Euler equation that we estimate with plant data:

$$\frac{c_t}{p_t A_t} - \left(1 - \frac{1}{\eta}\right) = \frac{\beta(1-\delta)\gamma}{\eta} \frac{1}{Z_{t+1}} E\left[R_{t+1}\right] + \beta(1-\delta)\left\{ E\left[\frac{c_{t+1}}{p_{t+1} A_{t+1}}\right] - \left(1 - \frac{1}{\eta}\right)\right\}$$

c — marginal cost
p — price
A — TFP
R — revenue
Z — "demand stock"

Note: LHS is inverse of price-cost margin minus optimal static markup

- Should be zero in static model
- Isn't here; cutting today's markup shifts tomorrow's demand out
- How much of a shift related to $E[R]/Z$

Estimation

Practical issues with constructing and interpreting Z

- Some plants are left-censored—already exist in 1963 (about 30%)
  - Here, estimate with and without these plants
- We only see revenues every fifth year
  - We're essentially assuming sales are constant between CMs and depreciation is "composite"
- We only see Z for survivors in Euler equation—selection
- Initializing Z in first year of plant's existence

$$Z_{0e} = \left(K_{0e}\right)^{\lambda_1} \left(\frac{K_{0s(e)} + K_{0e}}{K_{0e}} \right)^{\lambda_2}$$

where K_{0e} is the initial physical capital stock of e, $K_{0s(e)}$ is the *sum* of the physical capital stocks of plant e's siblings (i.e., the total capital stock that year of the other plants owned by the same firm)

Estimation

Demand shock follows AR(1) process with i.i.d. innovation:

$$\theta_{t+1} = \rho\theta_t + \upsilon_{t+1}$$

We quasi-difference logged demand:

$$\upsilon_{t+1} = \ln q_{t+1} - \rho \ln q_t - \phi(\ln Age_{t+1} - \rho \ln Age_t) - \gamma(\ln Z_{t+1} - \rho \ln Z_t) + \eta(\ln p_{t+1} - \rho \ln p_t)$$

- Quasi-difference should be uncorrelated with variables dated t and earlier; we can estimate with GMM
  - We can instrument current price using plant's physical productivity
  - Also use lagged revenues (up to six lags), lagged price, local income, age and year dummies
- Demand estimation exploits quantity variation across plants taking advantage of differences in age vs. accumulated demand stock
- Pooled estimates across products includes product*year effects

Estimation

Further simplify EE multiplying price-cost margins by x in each period:

$$\frac{C_t}{R_t} - \left(1 - \frac{1}{\eta}\right) = \frac{\beta(1-\delta)\gamma}{\eta} \frac{1}{Z_{t+1}} E\left[R_{t+1}\right] + \beta(1-\delta)\left\{E\left[\frac{C_{t+1}}{R_{t+1}}\right] - \left(1 - \frac{1}{\eta}\right)\right\}$$

Euler equation estimates dynamic parameters by exploiting producers' deviations from static MR = MC rule as they attempt to accumulate demand stock

The greater the role of today's sales in creating tomorrow's sales (embodied in first term on RHS), the larger the deviation from static pricing rule

Estimation

Assume expectation errors are additively separable and mean zero to get second moment for GMM (we set $\beta = 0.98^5$):

$$E[\varepsilon_{t+1}] = \frac{C_t}{R_t} - \left(1 - \frac{1}{\eta}\right) - \frac{\beta(1-\delta)\gamma}{\eta}\frac{R_{t+1}}{Z_{t+1}} - \beta(1-\delta)\left(\frac{C_{t+1}}{R_{t+1}} - \left(1 - \frac{1}{\eta}\right)\right) = 0$$

Instruments: Lagged *R*, and *C*/*R* ratios from period *t* and earlier, lagged price, age dummies

Results (All Products)

Parameter	[1]	[2]
γ (elasticity of future demand to the demand stock)	0.287 (0.068)	0.795 (0.014)
$-\eta$ (price elasticity of demand)	-2.576 (0.235)	-1.808 (0.082)
Young dummy (demand shift for entering and young plants)	-0.179 (0.073)	-0.066 (0.031)
Medium age dummy (demand shift for medium-aged plants)	-0.051 (0.055)	-0.025 (0.026)
ρ (persistence of exogneous demand shocks θ)	1.188 (0.035)	0.366 (0.085)
λ_1 (elasticity of initial demand to plant's own K)	1.803 (0.177)	0.651 (0.051)
λ_2 (elasticity of initial demand to ratio of firm's K to plant's K)	0.103 (0.340)	0.548 (0.063)
Competitor's Price (Local Products Only)	0.315 (0.334)	0.338 (0.073)
δ (demand depreciation rate)		0.893 (0.026)
Inverse Mills Ratio, Demand (selection correction, demand equation)	0.052 (0.020)	-0.022 (0.009)
Inverse Mills Ratio, EE (selection correction, Euler equation)	0.002 (0.003)	0.026 (0.005)

Results (Local Products and Ready-Mix Concrete)

Parameter	Local	Concrete
γ (elasticity of future demand to the demand stock)	0.843 (0.010)	0.751 (0.023)
$-\eta$ (price elasticity of demand)	-1.705 (0.077)	-2.321 (0.141)
Young dummy (demand shift for entering and young plants)	-0.102 (0.027)	-0.211 (0.043)
Medium age dummy (demand shift for medium-aged plants)	-0.027 (0.022)	-0.066 (0.033)
ρ (persistence of exogneous demand shocks θ)	-0.142 (0.043)	0.277 (0.061)
δ (demand depreciation rate)	0.787 (0.023)	0.500 (0.048)
Competitor's Price	0.317 (0.064)	1.416 (0.225)
λ_2 (elasticity of initial demand to ratio of firm's K to plant's K)	0.285 (0.055)	0.410 (0.033)
Inverse Mills Ratio, Demand (selection correction, demand equation)	-0.035 (0.010)	-0.018 (0.013)
Inverse Mills Ratio, EE (selection correction, Euler equation)	0.030 (0.004)	0.017 (0.003)

Results (Multi-Units vs. Single-Units)

Parameter	Entire Sample	Local		Entire Sample	Local
γ	0.705	0.770	γ*MU	0.084	0.030
	(0.030)	(0.023)		(0.037)	(0.025)
η	-2.507	-2.140	η*MU	0.407	-0.055
	(0.173)	(0.188)		(0.158)	(0.209)
Young dummy	-0.026	0.053	Young dummy*MU	-0.305	-0.347
	(0.075)	(0.044)		(0.105)	(0.062)
Medium age dummy	0.038	0.036	Medium age dummy*MU	-0.169	-0.123
	(0.051)	(0.042)		(0.068)	(0.053)
ρ	0.571	0.240	ρ*MU	0.451	0.137
	(0.095)	(0.093)		(0.096)	(0.115)
λ_1	1.106	1.028			
	(0.035)	(0.025)			
λ_2	0.397	0.442			
	(0.050)	(0.031)			
δ	0.584	0.673	ρ*MU	-0.104	-0.144
	(0.069)	(0.043)		(0.079)	(0.049)
Competitor's Price	0.733	0.338	δ*MU	-0.475	0.042
	(0.171)	(0.186)		(0.161)	(0.207)

Results: Discussion

1. Estimates have reasonable precision, robust across specifications
2. Price elasticity of –2 to –3 (on average) are plausible
   - Correspond roughly to elasticities in FHS (2008)
3. Demand-accumulation by "doing" (or demand stock Z) matters:
   a. $\gamma = 0.7$ to 0.8. Large quantitative effect. More on this below.
4. Demand-accumulation by "being" exists at young ages but is modest for medium-aged businesses
5. Equivalent annual persistence of demand shock (ρ) is around 0.8
6. Initial capital stock (including of siblings) matters.
7. Some non-trivial "forgetting". Annual depreciation rate of about 0.36 for all products.
8. Selection not quantitatively important
9. Results interacted with MU dummy don't show dramatic differences
   a. Slightly higher γ but most effects picked up by initial capital stock
   b. Roughly consistent with basic facts (MU a shift variable).

Endogenous Demand Accumulation – Magnitudes:

Consider all products results:

1. A 10 percent reduction in price yields 26 log point change in quantity
2. With γ and δ, 13 log point increase in demand next year.
3. Five-year persistent 10 percent reduction in price yields 57 log point increase in demand

Alternative Explanations

Two basic concerns:

1. (More minor) Our idiosyncratic demand measures don’t reflect plant’s actual demand state

2. (More important) We have only one source of dynamics in the model—demand accumulation.

   Model will interpret any other dynamic factors affecting plant decisions through demand accumulation lens

Alternative Explanations: Idiosyncratic Demand Measures

By construction, our demand measures reflect variations in quantity sold that are orthogonal to plant costs, as reflected in TFPQ

- Big plant with high demand measure is *not* big simply because low costs/prices
- Always true

Remaining concern: observed patterns reflect low capital utilization by young plants

- Story: new plants basically same size as old ones, but are "grown into"

First, this still seems consistent with demand accumulation story

Second, data (w/ two capital utilization proxies) isn't consistent with this

No Clear Capacity Utilization Effects

A. Plant ln(K/Q):

	Plant Age Dummies				
	Entrant	Young	Medium	Old	Exit
Age dummy	-0.110 (0.019)	-0.086 (0.020)	-0.042 (0.022)	Excl.	-0.022 (0.018)
Age dummy X *I*(Multi-unit) = 1	-0.077 (0.021)	-0.087 (0.023)	-0.099 (0.025)	-0.111 (0.015)	0.055 (0.024)

B. Plant ln(E/K):

	Plant Age Dummies				
	Entrant	Young	Medium	Old	Exit
Age dummy	0.090 (0.029)	-0.021 (0.031)	-0.057 (0.033)	Excl.	0.074 (0.027)
Age dummy X I(Multi-unit) = 1	-0.070 (0.033)	0.012 (0.035)	-0.003 (0.039)	-0.022 (0.023)	-0.017 (0.036)

Alternative Explanations: Other Dynamic Forces

1. Physical productivity
   - Certainly TFPQ process has persistence at plant level
   - But average levels simply not strongly correlated with plant ages (whole motivation for paper)
   - Matters for some things, but not question at hand

2. Financing constraints
   - We don’t have good data on availability of credit or capital costs
   - But results with plants in multi-unit firms suggest slow convergence isn’t about credit access

3. Capital adjustment costs
   - Again, certainly matter for some phenomena
   - But taking “best-practice” estimates from literature suggests our measured demand gap could be completely closed in 1-3 years if only caused by capital adjustment costs, not 15+ years

Concluding Remarks

- Entering markets is difficult, even in commodity markets and even for established firms

- Demand-side fundamentals appear to be more important than supply-side factors in explaining average business growth patterns

- It is not just learning by “being” but active learning by doing that is important here.

- Different perspective on size distribution and evolution of firms over the life cycle.