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Abstract: Dynamic competitive models of industry evolution suggest that firm profit will be more volatile and turnover will be lower in industries with higher sunk costs. These implications are consistent with empirical observation.

Keywords: Sunk costs; Entry and exit.

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1. Theoretical Foundations

The dynamic competitive approach to the study of industrial organization, exemplified by Dixit (1989), Lambson (1991,1992), and Hopenhayn (1992), highlights the role of sunk costs and the associated hysteresis effects in determining how industries behave over time. The theoretical models are inherently difficult. Commenting on his own work, Jovanovic (1982, p. 651) remarked that "a curious feature of the paper is that proofs of 'obvious' results are complicated." Such complexity precludes a canonical dynamic competitive model, but favors the development of various models focusing on different aspects of reality.

Despite the general difficulty of establishing robust theoretical results, there are some relationships that are intuitively compelling and consistent with a variety of dynamic competitive models. Two such predictions are the focus of this paper: (1) sunk costs should be positively correlated with the volatility of firm-level profits over time and (2) sunk costs should be negatively correlated with turnover.

Dixit's (1989) model generates a clear statement of the first prediction. His model analyzes the decision of a single firm that must sink an investment cost in order to enter the market. His is a continuous time framework in which the price for the firms' output follows a geometric Brownian motion. Because of sunk costs, there is a gap between the price that would induce the firm to enter, say α, and the lower price at which the firm would remain in the market had it previously entered, say ω. Dixit shows that α is increasing and ω is decreasing in the sunk cost. It then follows rather directly that if π_α and π_ω are the profits associated with these extreme prices, then the former is increasing and the latter is decreasing in the sunk entry cost. So $R(\pi) = \pi_\alpha - \pi_\omega$ is increasing in sunk costs, suggesting that the observed intertemporal range of profits will be higher for firms with higher sunk costs. Because Dixit focuses on a single firm facing an exogenous stochastic price path, his model is not well suited for discussing industry level turnover. However, the wider gap between extreme prices that results from higher sunk costs in the firm level analysis does suggest that turnover will be negatively affected by higher sunk costs in an industry level model as well.

One such model is by Lambson (1992), where firm values above the entry cost ξ induce entry while values below the scrap value χ motivate exit. The intertemporal range of firm values is thus $\xi - \chi$, which is a natural definition of sunk costs in the model. Thus if the range of current profits is positively related to the range of firm values, then the range of profits will be higher in high sunk cost industries, yielding the first prediction. The second prediction, that turnover will be lower in higher sunk cost industries, also arises in Lambson's (1992) framework. There, equilibrium can be characterized by a stochastic sequence of ordered pairs, $\{N(h),X(h)\}_{h\in H}$, where H is the set of finite histories of the exogenous variables. If y_t denotes the number (mass) of firms in the market at time t and the first t periods exhibit the history of exogenous variables h, then $y_t = \min\{X(h),\max\{N(h), y_{t-1}\}\}$. N(h) is non-increasing and X(h) is non-decreasing in the entry cost for all h, suggesting that the range of the number of firms is higher when the entry cost is higher.

Another example is due to Hopenhayn (1992), who modeled an industry where firms are buffeted by idiosyncratic shocks to their productivity. Firms that suffer a string of negative shocks fall below the trigger level of productivity and find it optimal to exit the market. This trigger level is lower when the entry cost is higher. The lower trigger level implies a lower rate of turnover. It also implies that a firm's profit can be lower without provoking exit; this suggests that high sunk cost industries will exhibit more volatility in firm-level profits over time.

2. Empirical Precedents

Section 1 reviewed two intuitively compelling predictions from the theoretical literature: (1) intertemporal profit variability should be higher and (2) turnover should be lower in high sunk costs industries. Empirical work on the first result is sparse.[1] By contrast, there is a substantial empirical literature devoted to entry and exit rates. Dunne, Roberts and Samuelson (1988, 1989) analyzed the patterns of firm entry and exit in U.S. manufacturing industries over the periods 1963-82 and 1967-77. They found a high and positive correlation between entry rates and exit rates and they found substantial and persistent differences in entry and exit rates across industries. However, they deferred the task of pursuing the causes of these differences. Later research analyzed the relationship between proxies for sunk costs (like economies of scale or capital intensity) and entry and exit rates. Examples can be found in Geroski and Schwalbach (1991), Siegfried and Evans (1992), and Audretsch (1995). Curiously, their analysis yielded either no relationship or counterintuitive, positive relationships. Audretsch (p. 46) remarked, "One of the most startling results that has emerged in empirical studies is that entry into an industry is apparently not substantially deterred or even deterred at all in capital-intensive industries in which scale economies play a role." More recently, Disney, Haskel and Heden (2003) analyzed entry, exit and establishment survival in UK manufacturing.

[1] Lambson and Jensen (1995, 1998) have documented positive correlation between the intertemporal range of firm values and proxies for sunk costs.

They also found strong correlation between industry entry rates and industry exit rates. They hypothesized that exit and entry rates might be correlated because industries differ in their sunk costs but they do not explicitly analyze the relationship between exit, entry and sunk costs.

In what follows, the empirical validity of the two theoretical predictions is tested. First, a positive correlation between the intertemporal variability of profits and sunk costs is established using a new data set constructed by supplementing Compustat data with data from Moody's Industrial Manual. The database is updated to the most recent available years and consists of annual observations. This contrasts with most of the previous studies, which use census data with observations at 5 (or 2) - year intervals. Annual observations allow for a more accurate description of entry and exit. Moreover, while most of the previous studies bring evidence only from the manufacturing sector, the present database contains additional economic sectors. Examples include mining, construction, transportation, communication, utilities, and finance. Second, a negative relationship between sunk costs and turnover - an intuitively and theoretically compelling but heretofore poorly documented phenomena - is established using annual data from the US Census Bureau.

3. Empirical Specifications and Data

3a. Intertemporal Profit Variability

The database used to explore the relationship between the intertemporal variability of profit and sunk costs contains information on about 162 publicly traded companies in the United States over the time period from 1950 to 2001. The companies were among the largest 500 (in terms of sales) in 1950 and managed to survive until 2001. Although there is selection bias it is irrelevant to the question because theory predicts more variable profitability among surviving firms on high sunk cost industries. The database was compiled from the following two sources: Standard and Poor's Compustat Services and Moody's Industrial Manual. Missing data from the Compustat time series was completed with data from the Moody's Industrial Manual, especially for the early years. The variables used are: Net Income (data18), Total Assets (data6) and Net Total Property, Plant and Equipment (data8). Net Income represents the income of a company after all expenses, including special items, income taxes, and minority interests, but before provisions for common and/or preferred dividends. Total Assets represent current assets plus net property, plant and equipment plus other noncurrent assets. Net Property, Plant and Equipment are the cost, of tangible fixed property used in the production of revenue, less accumulated depreciation.[2] All the values are real, having been adjusted by the GDP deflator with 1950 as the base year.

Net income was used as a proxy for profit. Two different ways of describing intertemporal variability were chosen: the range and the variance of net income. Since both dependent variables yield similar results, in the interest of brevity we report only the results for the range. The range was defined as the difference between the maximum and the minimum values of income observed for the firm between 1950 and 2001.

As a proxy for sunk costs, the net property plant and equipment cost were used. Now large firms are likely to exhibit greater intertemporal variability simply due to their size: for example, a two-plant firm will exhibit twice the variability of a one-plant firm if

[2] For more detailed definitions of the data see the Compustat Data Definitions.

the plants are identical. In an attempt to control for size, the sunk costs proxy was divided by total assets. Then the average for each company over the given time period was calculated. In order to further control for size the mean of income over the time period for each company was added as an independent variable. Since neither the range of income nor the sunk costs can be negative, the log of these variables could be used.[3] The various specifications are listed in equations (1)-(6):

$$\text{Log Range}_t(\pi_t) = \alpha + \beta_\xi K + \varepsilon \qquad (1)$$

$$\text{Log Range}_t(\pi_t) = \alpha + \beta_\xi K/A + \varepsilon \qquad (2)$$

$$\text{Log Range}_t(\pi_t) = \alpha + \beta_\xi \text{Log } K + \varepsilon \qquad (3)$$

$$\text{Log Range}_t(\pi_t) = \alpha + \beta_\xi \text{Log } K/A + \varepsilon \qquad (4)$$

$$\text{Log Range}_t(\pi_t) = \alpha + \beta_\xi \text{Log } K + \beta_\theta \Pi + \varepsilon \qquad (5)$$

$$\text{Log Range}_t(\pi_t) = \alpha + \beta_\xi \text{Log } K/A + \beta_\theta \Pi + \varepsilon \qquad (6)$$

Here π_t is the net income of the company in year t, K is the firm's intertemporal mean of the sunk cost proxy, K/A is the mean of sunk costs divided by total assets, and Π is the mean of net income for each company over the time period 1950-2001. Results are in Table 1.

3b. Turnover

To explore the relationship between the rate of turnover and sunk costs, annual data from the US Census Bureau was used. Turnover was defined as (Entry + Exit)/2 for each industry in each year. With sponsorship from the US Small Business Administration (SBA), the Census Bureau produces data on establishment entries (births) and exits

[3] Since the mean income could be negative the log of mean income could not be used.

(deaths) by industry for the United States as a whole and for each State.[4] This database contains information about births, deaths and number of employees from 1990-2000 for each industry.[5]

Two different proxies were used for sunk costs: "Total Capital Expenditures for Structures and Equipment for Companies with Employees" divided by the number of employees (K/L) and "New Capital Expenditures for Structures and Equipment Companies with Employees" divided by the number of Employees (NewK/L). The two variables yield similar results. Time series from 1994-2001 (8 years) are available in the Annual Capital Expenditures Survey at the US Census Bureau.[6] Categories used in the survey were comprised primarily of three-digit and selected four-digit industries from the NAICS for the more recent years. The database has the disadvantage that it is not as finely subdivided (and therefore has not so many observations) as, for example, the Entry and Exit Data or the Annual Survey of Manufacturing.[7] On the other hand, it reflects more of the whole economy (including sectors like mining, construction, transportation and the like) and not just manufacturing.[8] The time period that is available for both variables is 1994-2000 (7 years).[9] The specifications used here are:

$$\log T = \gamma + \eta\, K/L + \mu \qquad (7)$$

$$\log T = \gamma + \eta\, NewK/L + \mu \qquad (8)$$

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[4] Available: http://www.sba.gov/advo/stats/data.html.
[5] More specific information about entries and exits, including links to statistical tables, is at: http://www.census.gov/csd/susb/susb2.htm#godyn1

[6] Available: http://www.census.gov/csd/ace/ace-pdf.html.
[7] The Annual Survey of Manufacturing contains about 300 observations (industry-categories) for each year, the Annual Capital Expenditures Survey contains around 100-140.
[8] See for example Audretsch 1995.

where logT is the logarithm of Turnover, and where K/L and NewK/L are the two proxies for sunk cost. The analysis was done for each year for all the sectors and subsectors together and just for the sectors alone. Sectors are major industry categories like mining, manufacturing, transportation and subsectors are their subdivisions. Results are presented in Table 2. Finally, Table 3 reports the results of the analysis for all the years together.

4. Empirical Results

The results for the relationship between the intertemporal variability of profit and sunk costs are summarized in Table 1. One star in the column labeled "significance" denotes significance at the 10% level or better, two stars denote significance at 5% level or better, and three stars denote significance at 1% level or better. Theory suggests a positive correlation between the logarithm of the range of a company's profit and a proxy for sunk costs. The coefficient of the sunk cost proxy is positive and significant at 5% or better in all specifications. The reported standard errors are cluster corrected at the industry level.[10]

The results for the relationship between the rate of turnover and sunk costs are presented in Table 2 and 3. Table 2 presents the results for each of the 7 available years (1994-2000) and Table 3 presents the results for all the years together. Theory suggests a negative relationship between the rate of turnover and sunk costs. In each of the seven years, for both specifications, the coefficient is negative and significant at 5% or better.

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[9] Note that even if some studies use a longer time period the number of years is usually smaller because they use Census (5-year) data.

The results for the big sectors of the economy (agriculture, mining, utilities, construction, manufacturing etc.) are even stronger. Table 3 presents the results for all years (and all observations) together. All the coefficients are negative and highly significant. We conclude that the empirical evidence is consistent with the aforementioned predictions from the theoretical literature.

Table 1

Dependent variable: Logarithm of the range of company's income.[11]

Eq.	K	R.SE	K/A	R.SE	LogK	R.SE	Log K/A	R.SE	Π	R.SE	Adj. R^2	Sig K	Sig Π
1	0.0005	9.2E-05									0.378	***	
2			0.954	0.410							0.041	**	
3					0.828	0.042					0.775	***	
4							0.819	0.327			0.043	**	
5					0.728	0.048			0.0009	0.0003	0.790	***	***
6							0.536	0.185	0.0036	0.0005	0.460	***	***

Table 2

Dependent variable: logTurnover = log[(Entry+Exit)/2] per industry [12]

Year		K/L	R.SE	NewK/L	R.SE	Adj. R^2	Obs.	Sig.
1994	**Sectors**	-86.27	9.38			0.875	13	***
				-91.69	9.93	0.875	13	***
	All	-23.83	8.11			0.068	105	***
				-24.21	8.49	0.064	105	***
1995	**Sectors**	-85.22	9.85			0.860	13	***

[10] Since high leveraged firms are more risky and have a higher variation in profits we controlled for this including a debt measure (short-term or long-term debt divided by total assets) into the regression. The coefficients stayed positive and significant. See Opler and Titman (1994).
[11] K , Π and A are measured in millions of real dollars (base year 1950) per firm. The number of observations is always 162. Regression with heteroskedasticity and cluster correction of standard errors.
[12] K and NewK are measured in millions of current dollars.

				-88.89	10.22	0.862	13	***
	All	-23.75	7.51			0.080	105	***
				-24.87	7.23	0.101	97	***
1996	**Sectors**	-74.69	9.60			0.832	13	***
				-77.81	13.68	0.723	13	***
	All	-21.76	7.49			0.068	103	***
				-21.36	7.75	0.065	96	***
1997	**Sectors**	-58.26	8.18			0.806	13	***
				-60.51	8.50	0.806	13	***
	All	-15.73	6.39			0.045	108	**
				-15.90	6.50	0.045	108	**
1998	**Sectors**	-53.71	7.37			0.813	13	***
				-56.22	7.66	0.815	13	***
	All	-14.23	6.23			0.039	108	**
				-15.09	6.52	0.039	108	**
1999	**Sectors**	-32.97	12.65			0.243	19	**
				-34.65	13.20	0.246	19	**
	All	-12.54	4.52			0.046	140	***
				-13.09	4.70	0.046	140	***
2000	**Sectors**	-27.32	8.67			0.332	19	***
				-29.60	9.44	0.329	19	***
	All	-9.75	3.73			0.040	140	***
				-10.70	4.02	0.025	140	***

Table 3

Dependent variable: logTurnover = log[(Entry+Exit)/2] per industry

	K/L	R.SE	NewK/L	R.SE	Adj. R^2	Obs.	Sig.
Sectors	-46.679	4.231			0.542	103	***
			-49.441	4.528	0.537	103	***
All	-14.754	2.135			0.055	809	***
			-15.595	2.218	0.058	794	***

Table 4

Descriptive Statistics

	Mean	Median	Std. Dev.
Log $Range_t(\pi_t)$	2.068	2.088	0.603
K	374.714	163.579	686.728
K/A	0.364	0.337	0.128
Log K	2.139	2.214	0.641
Log K/A	-0.465	-0.472	0.152
Π	59.328	23.421	107.351
T	11368.994	2689.5	22902.306
K/L	0.018	0.007	0.032
NewK/L	0.017	0.007	0.031
LogT	7.76	7.90	2.02

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