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Exit from declining industries: "shakeout" or "stakeout"?

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Data on 30 chemical products are used to examine the sequence of divestment in declining industries. Small firms and plants might be expected to close first, given lack of scale economies. However, recent theories suggest that large producers may have greater incentives to exit or cut capacity. Both predictions receive some empirical support. Small plants had higher rates of closure, and most exiting firms were small. Holding the influence of plant size constant, large multiplant firms were more likely to close individual plants.

1. Introduction

■ In a declining industry, who exits first: large firms or small? If capacity can be reduced incrementally, who makes the largest or most frequent cuts? Do firm sizes tend to converge or diverge, and does concentration rise or fall? Indeed, can such generalizations be made, or does the pattern of divestment vary too greatly from one declining industry to another?

Several recent theoretical studies have addressed these issues of competition during decline. While they offer a number of predictions, verification has thus far been limited to interpretations drawn from a handful of industry case examples. This article evaluates the recent theories in the more rigorous context of a data sample covering 30 chemical products that have been declining for periods ranging from 5 to 25 years. The sample is large enough to allow statistical testing of hypotheses about the divestment process in declining commodity product industries.

The analysis is framed in terms of two contrasting sets of predictions. The first set of predictions is based on the observation that larger firms are often more efficient; size may convey economies of scale or reflect a process of more rapid growth by superior firms. Such differences in efficiency would cause smaller producers to be "shaken out" relatively early if prices fall during the decline phase. The second set of predictions is based on the Cournot-Nash result that in the absence of cost differences, smaller firms can remain profitable over a longer period as demand tapers off to zero. Given this superior ability of small firms to "stake out" as the industry devolves, larger firms would rationally choose to exit early or to mimic their smaller rivals by drastically cutting capacity.

Firms can divest by cutting capacity incrementally or by exiting. Incremental reductions

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can be carried out by closing part of an ongoing plant, or an entire plant in the case of a multiplant firm. The chemical products sample collected for this study contains information on these various forms of divestment. The sample also tracks changes in producer concentration and the coefficient of variation in firm sizes. The "shakeout" and "stakeout" models offer diverse predictions with respect to these empirically observable factors.

The remainder of this article is organized as follows. Section 2 surveys the theoretical and empirical literature on divestment in declining industries. Section 3 describes the chemical products sample. Section 4 reports summary statistics on the capacity reduction process, measured at the firm level. More disaggregate tests are provided in Section 5 in the form of a logit analysis of plant closures. Section 6 concludes the article and summarizes the main findings.

2. Prior theoretical and empirical findings on divestment in declining industries

■ **Theoretical studies.** Recent theoretical studies of competition in declining industries include Ghemawat and Nalebuff (1985, 1990), Londregan (1987), Reynolds (1988), and Whinston (1988). These studies use the logic of backward induction to predict the sequence of exits or capacity reductions when demand is perceived as ultimately diminishing to zero.[1] While the specific models differ slightly in their assumptions and results, all point out the potential strategic liability of large firm size.

Ghemawat and Nalebuff (1985) analyze the case in which producers have equal costs, demand is declining monotonically, and divestment is an all-or-nothing decision—firms either continue to operate at full capacity or exit the industry. Under these assumptions, Ghemawat and Nalebuff (hereafter G&N) prove the existence of a unique subgame-perfect Cournot-Nash equilibrium: the smaller of two equally efficient duopolists forces its larger rival to exit as soon as duopoly profits turn negative. The intuition behind this result is that the smaller producer, having lower output, can operate as a profitable monopolist over a longer period of time as demand falls. Recognizing this fact, the larger firm exits first.

Generalized to the oligopoly case, the G&N (1985) model implies that exit occurs in decreasing order of firm size. Ghemawat and Nalebuff argue that this sequence is robust to the existence of small interfirm cost differences. Moreover, the basic conclusions hold under more general conditions in which industry re-entry is permitted (Londregan, 1987).

In a subsequent paper, G&N (1990) analyze the case in which firms can divest incrementally rather than on an all-or-nothing basis. Here the (capacity-constrained) Cournot-Nash equilibrium dictates that "large firms reduce capacity first, and continue to do so until they shrink to the size of their formerly smaller rivals." The intuition in this case is that larger firms have lower marginal revenue and hence greater incentives to cut capacity. Following the onset of industry decline, the largest firm reduces its capacity until it has shrunk to the size of the second-largest firm; at this point both firms shrink together until their individual capacities equal that of the third-largest firm; and so forth. Industry concentration diminishes over time, as firm sizes become more equal.

Other models, based on the more restrictive assumption that divestment must be undertaken in lumpy decrements, have reached more ambiguous conclusions. Reynolds (1988) obtains results similar to those of G&N (1990) under the assumption that all plants are of equal size. However, Whinston (1988) shows that when firms have different-sized plants, multiple equilibria are possible—i.e., the largest firm will not necessarily be the first to exit or cut capacity.

[1] Other theoretical studies, which model exit decisions in a more general context, include Jovanovic (1982), Fudenberg and Tirole (1986) and Frank (1988).

In the absence of producer size differences, theoretical work confirms the intuitive prediction that the divestment sequence depends on relative cost. Reynolds (1988) demonstrates that high-cost plants will be closed before low-cost plants, and G&N (1985) show that high-cost firms will be first to exit. Fudenberg and Tirole (1986) show that in a duopoly environment with incomplete information the less efficient firm will exit first, assuming that firms hold symmetric expectations.

□ **Testable implications of the models.** This study uses data on declining chemical products to test the predictions of the theoretical models. The fundamental question is the following: Is large firm size a strategic liability in a declining industry, and if so, is this liability substantial enough to outweigh the cost advantage of achieving economies of scale? The liability of size could appear as higher exit rates for large firms (as implied by G&N (1985) and Londregan (1987)) or as higher rates of incremental capacity reduction (as implied by G&N (1990) and Reynolds (1988)). If large and small size confer disadvantages of similar magnitude, the two liabilities might offset each other, so that comparable rates of divestment would be observed for both large and small firms.

The potential strategic liability of size is straightforward to detect if it appears as a higher rate of exit by larger firms. (Such a test is provided in Section 4 below.) Less drastic forms of divestment are more difficult to assess, but I present several indicator measures in Section 4. These include the rate of incremental capacity reduction, the rate of total divestment (exits and incremental reductions combined), and the change over time in the coefficient of variation in firm sizes.

The G&N (1990) findings imply that as demand declines, capacity would gradually be shed by the largest firms. Producers with large capacity shares would therefore exhibit higher rates of incremental capacity reduction. But large producers may also show higher rates of incremental cutback for the simple reason that they tend to operate multiple plants. (Note that a plant closure constitutes an exit when made by a single-plant firm but an incremental reduction when made by a multiplant firm.) To determine whether the strategic liability of large firm size is substantial enough to offset cost advantages due to economies of scale, it is necessary to examine the distribution of total divestment. If the liability of large firm size outweighs the benefits of achieving economies of scale, then large-share firms would account for a disproportionate fraction of the total capacity shed from the industry.

Changes in the coefficient of variation in firm sizes (standard deviation divided by mean firm size) can also provide information on the interfirm distribution of divestment. This coefficient can be computed across all producers in the industry or across the cohort of firms that survive over the sample period. In the latter case, the number of firms included in the measure remains constant over time.

If computed across all firms in the industry, the coefficient of variation provides only a weak basis for distinguishing among the models. Both of the G&N models predict that the coefficient would diminish over time as the largest producers either exit the industry or shrink in relative size. The coefficient would also diminish if smaller firms are "shaken out" through a process of exit. Only if smaller firms shrink without exiting would the coefficient of variation increase over time. Thus a convergence in firm sizes would normally occur under both the "shakeout" and "stakeout" processes.

The coefficient of variation provides a stronger indicator if it is limited to the cohort of firms that survive over the sample period. The G&N (1985) model predicts no change in this coefficient, given that exiting firms are excluded. A "shakeout" process would also leave this coefficient unaffected, assuming that small firms exit. (If small firms shrink without exiting, the coefficient would increase.) Only the G&N (1990) model predicts a diminishing coefficient, as large firms shrink to the size of their smaller rivals. Thus a reduction in the coefficient of variation in the size of surviving firms implies that within the cohort of survivors, large firms shrank proportionately more than small firms.

A more comprehensive set of tests, presented in Section 5, involves the estimation of a logit model of plant closure. This model, which accounts for differences in both plant and firm size, allows the influences of plant-level scale economies and firm-level capacity share to be assessed independently.

□ **Evidence from prior empirical studies.** Empirical evidence on the pattern of capacity reduction in declining industries has been developed primarily from case studies. Many studies have found higher rates of closure for small firms and plants, but only limited evidence has been presented on the strategic liability of large firm size. G&N (1985, 1990) cite case studies of divestment in synthetic soda ash, steel castings, and basic steel. In all three of these industries, early capacity reductions were concentrated among the largest producers.[2]

Studies based on growing as well as declining industries have commonly found that smaller firms have higher exit probabilities. Mansfield (1962) uncovered this tendency in early work. Lieberman (1989) found that smaller entrants had significantly higher mortality rates in growing chemical markets. Evans (1987) and Dunne, Roberts, and Samuelson (1989b) confirmed this relation between exit and firm size using broad, cross-sectional data.

Similar findings have been obtained at the plant level. Deily (1988) and Tang (1989) noted that following the onset of industry decline, U.S. steelmakers divested first from their smaller, high-cost plants. In petroleum refining, Londregan (1988) observed that small refineries were more likely to be closed. Dunne, Roberts and Samuelson (1989a) found a similar pattern of plant closure in a range of industries.

Two studies have assessed divestment in declining sectors where cutbacks were coordinated through government-sanctioned cartels. These studies suggest that strong cartels often enforce a proportional divestment rule that overcomes the normal tendency for exits to be concentrated among small-share producers. Shaw and Shaw (1983) examined the European synthetic fibers industry during a period of decline in the late 1970s and early 1980s. They found that when an EEC-sponsored cartel was in place during the initial years of industry decline, firms cut capacity in proportion to their market shares. After the cartel was eliminated, smaller firms exited at disproportionately high rates. Peck, Levin, and Goto (1987) examined the behavior of declining industry cartels in Japan. These cartels led producers in concentrated industries to cut back in proportion to their capacities, so that initial shares were preserved. In more fragmented industries where the cartels were less effective, rationalization proceeded more rapidly as many smaller firms exited.

3. Data sample

■ Table 1 summarizes basic features of the data sample used in this study. The sample includes 30 chemical products, each of which experienced chronic decline in U.S. domestic output and capacity. Data were collected from the peak year of output or capacity (whichever occurred earlier) through the start of 1987.[3] On average, output declined by 42% and capacity by 38% from the historical peak. The magnitudes of capacity and output reduction were strongly (but far from perfectly) correlated, with $r = 0.64$. The number of producers fell by an average of 32%, nearly the same as industry capacity.

The data were obtained from chemical producer listings compiled by SRI International, supplemented by government and industry sources. The capacity data are from annual

[2] In his detailed study of the UK steel castings industry, Baden-Fuller (1989) found that the two largest producers accounted for about two-thirds of the capacity closed during the early years of decline. Nevertheless, these firms, which initially operated multiple plants, did not exit. Exits were concentrated among a group of diversified firms that were able to shift resources to other sectors at relatively low cost.

[3] For most products the output and capacity peaks roughly coincided. To be conservative, the analysis starts from the peak year of output or capacity, whichever occurred later.

TABLE 1 Products Included in Declining Industries Sample

Product	Year of Peak Output	Year of Peak Capacity	Number of Producers at Peak Capacity	Percent Decline (Peak Year to 1987): Output	Capacity	Number of Producers	Reasons for Decline
Acetaldehyde	1969	1971	9	−61%	−68%	−78%	D, F
Acetone	1979	1981	16	−27%	−13%	−19%	G
Acetylene	1965	1965	13	−44%	−75%	−54%	F
Acrylic fibers	1980	1981	5	−21%	−22%	−20%	E
Adipic acid	1979	1979	4	−14%**	−12%	−25%	G
Calcium carbide	1964	1962	4	−81%	−64%	0%	E
Carbon black	1973	1975	8	−26%	−21%	13%	G
Carbon disulfide	1969	1971	4	−60%**	−20%	−25%	D, E
Cellophane	1960	1966	3	−68%‡	−82%	−33%	B
Cellulose acetate fibers	1968	1968	4	−58%	−65%	−50%	B
Chloroacetic acid	N/A	1977	3	N/A	−18%	0%	G
Chlorobenzene (mono)	1969	1971	8	−58%	−46%	−63%	D
Cresylic acid	1976	1982	9	−44%	−39%	−56%	C, G
Ethyl chloride	1976	1976	6	−76%	−45%	−17%	D
Fumaric acid	1973	1972	6	−30%	−22%	−33%	B, C
Hydrofluoric acid	1974	1974	9	−2%	−49%	−56%	C, D
Isopropyl alcohol	1976	1981	4	−34%	−12%	0%	F, G
Lead alkyls	1970	1969	4	−62%‡	−81%	−75%	A
Melamine	1974	1972	4	−23%*	−29%	−50%	C, G
Nitrile rubber	1974	1972	6	−34%	−2%	−33%	G
Phosphorus	1969	1969	8	−42%	−47%	−50%	D
Potassium sulfate	1977	1974	7	−61%	−65%	−14%	B, C, G
Rayon fibers	1968	1971	6	−62%	−57%	−33%	B
SBR rubber	1973	1972	11	−48%	−45%	−55%	B, G
Sodium	1973	1973	3	−60%**	−56%	−33%	D
Sodium bichromate	1974	1979	3	−29%**	−4%	−33%	B, C, G
Sodium phosphate	1970	1979	5	−48%	−12%	0%	A
Sodium sulfite	1967	1976	5	−51%	−41%	0%	A, B, C
Sodium tetraborate	N/A	1978	3	N/A	−6%	−33%	G
Sodium thiosulfate	1961	1973	4	−53%	−35%	−25%	B, G
Average			6	−42%	−38%	−32%	

Key to reasons for decline in demand:

A. Chemical was found to be environmentally hazardous.
B. Chemical was replaced by substitute product.
C. U.S. domestic production was replaced by imports.
D. Downstream product was found to environmentally hazardous.
E. Downstream product was replaced by substitute.
F. Change in manufacturing process for downstream product.
G. Other factors leading to reduced demand for downstream product.

‡ Data through 1981 only.
* Data through 1984 only.
** Data through 1985 only.

issues of the *Directory of Chemical Producers,* published by SRI International. This directory reports U.S. production capacities by product, firm, and plant, observed at the start of each calendar year. Output data were collected from various sources.[4] Chemical trade journals were consulted to determine why products in the sample were in decline.

[4] Annual data on total U.S. production of each product were obtained from *Synthetic Organic Chemicals,* published by the U.S. International Trade Commission, *Current Industrial Reports,* published by the Census Bureau,

The sample products were selected as follows. The *Directory of Chemical Producers* includes annual capacity listings for approximately 240 products. Output data were collected on each of these products to identify those that were declining. The sample includes all products with published capacity data that were observed to be declining over a period of five years or more, through the end of 1986.[5] The sample is believed to be a fairly representative cross-section of commodity product industries in decline.[6]

The last column of Table 1 summarizes the reasons why demand was falling for products in the sample. Decline often stemmed from a combination of factors. Three products had been found to be environmentally hazardous and were being restricted or phased out by regulatory agencies. Seven products served as inputs in the manufacture of downstream products that had been found hazardous. An additional seven products were being replaced by direct substitutes, and three products faced such replacement downstream. For three products, changes in downstream manufacturing processes reduced or eliminated demand for the product as an input. For seven products, competition from lower-priced imports was a factor contributing to the decline in U.S. output.

No data are publicly available on cost differences among individual plants and firms in the sample. Nevertheless, engineering studies offer some rough generalizations regarding cost behavior as a function of plant size. In the chemical industry, both capital and labor costs are typically subject to economies of scale. While capital costs can be ignored in a declining market given the existence of excess capacity, scale economies in the labor component of operating cost are often significant.[7]

Detailed engineering cost data for five products in the sample were obtained from the *Process Economics Program Handbook* published by SRI International (1976). Although a small subset, these five products are typical of the sample as a whole. The *Handbook* reports estimated capital and operating costs for plants whose "capacities are representative of sizes of competitive US plants" built in the mid-1970s. The *Handbook* also reports costs for plants one-half this size; these "half-size" plants suffered operating cost penalties ranging from about 2% to 9%.[8] While these penalties appear minor as a percentage of total operating costs (including materials costs) they can account for a large proportion of value added. Moreover, many plants in the sample at the start of the decline phase were much smaller than the "half-size" plants shown in the *Handbook* and hence suffered greater penalties in operating cost.

4. Empirical results at the firm level

■ **Producer concentration and variation in firm sizes.** Tables 2 through 7 give summary statistics on various characteristics of the capacity reduction process, measured at the firm level.

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and the *Chemical Economics Handbook,* published by SRI International. Output data are unavailable for two products: chloroacetic acid and sodium tetraborate. For several other products the available output data do not extend to 1986, the last full year of sample coverage.

[5] A few products were eliminated by the additional requirement that capacity as well as output be declining. Several others were excluded because they were produced primarily as by-products. Synthetic soda ash (discussed in G&N (1985, 1990) and Harrigan (1980)) was excluded in light of the fact that total U.S. demand for soda ash was increasing; only the fraction produced by synthetic means was in decline.

[6] One bias is that the *Directory of Chemical Producers* contains capacity listings only for chemicals with comparatively large markets. Hence, products in the sample typically have more producers than an average product listed in the *Directory* (but few producers compared with the number of firms observed in many manufacturing industries outside of the chemical sector). One would expect the "stakeout" models to be applicable only in reasonably concentrated industries, where marginal revenue differs significantly among producers.

[7] Scale economies in labor cost are obtained primarily through reductions in operating, maintenance, and overhead labor per unit of output.

[8] The cost penalties were as follows: isopropyl alcohol (2%), acetone (2%), acetaldehyde (4%), acetylene (7%), and adipic acid (9%).

Table 2 describes changes in producer concentration over the sample period. For each product, the table gives the change in the Herfindahl concentration index (H), the number of producers (N), and the coefficient of variation in firm sizes (V).[9] The products in Table 2 have been sorted in decreasing order of the percentage decline in total industry capacity. Given that a small amount of entry occurred over the coverage period,[10] two separate counts of the number of producers are provided for the terminal year: the total number of firms observed and the number of survivors remaining from the peak year. Similarly, two figures are reported for changes in the coefficient of variation: the first compares the size distribution of all producers in the peak year with the size distribution of all producers in the terminal year, whereas the second is computed over the subset of firms that survived from the peak year through the terminal year.

TABLE 2 Change in Herfindahl Index, Number of Firms, and Coefficient of Variation in Firm Sizes

Product	Percent Decline in Capacity	Number of Firms			Herfindahl Index		Coefficient of Variation in Firm Sizes		
		N_{Peak}	N_{87}*	N_{87}	H_{Peak}	H_{87}-H_{Peak}	V_{Peak}	V_{87}-V_{Peak}	V_{87}*-V_{Peak}*
Cellophane	−82%	3	2	2	.466	.034	.631	−.631	−.683
Lead alkyls	−81%	4	1	1	.352	.648	.639	−.419[a]	−.459[a]
Acetylene	−75%	13	5	6	.169	.112	1.096	−.269	−.064
Acetaldehyde	−68%	9	2	2	.324	.224	1.385	−1.074	−.023
Cellulose acetate fibers	−65%	4	2	2	.366	.332	.681	−.051	.329
Potassium sulfate	−65%	6	3	6	.280	−.035	.824	−.139	−.014
Calcium carbide	−64%	4	4	4	.425	−.081	.837	−.224	−.224
Rayon fibers	−57%	6	2	4	.345	−.040	1.033	−.564	−.545
Sodium	−56%	3	2	2	.362	.198	.292	.053	−.006
Hydrofluoric acid	−49%	9	4	4	.183	.177	.807	−.142	−.052
Phosphorus	−47%	8	4	4	.205	.068	.799	−.495	−.099
Chlorobenzene	−46%	8	3	3	.303	.101	1.192	−.735	.105
Ethyl chloride	−45%	6	4	5	.248	.010	.697	−.160	−.407
SBR rubber	−45%	11	4	5	.149	.107	.796	−.268	−.006
Sodium sulfite	−41%	5	3	5	.469	−.009	1.159	−.019	.315
Cresylic acid	−39%	9	3	4	.216	.230	.971	−.086	.000
Sodium thiosulfate	−35%	4	2	3	.334	.091	.580	−.054	−.131
Melamine	−29%	3	2	2	.370	.130	.333	−.333	.000
Acrylic fibers	−22%	5	4	4	.294	.034	.684	−.126	.027
Fumaric acid	−22%	6	3	4	.210	.126	.508	.076	.012
Carbon black	−21%	8	5	9	.160	.005	.532	.164	−.061
Carbon disulfide	−20%	4	3	3	.531	.215	1.060	.052	−.112
Chloroacetic acid	−18%	3	2	3	.482	−.008	.668	−.019	.050
Acetone	−13%	16	13	13	.145	.035	1.148	.009	−.003
Adipic acid	−12%	4	3	3	.450	.084	.894	−.118	.033
Isopropyl alcohol	−12%	4	4	4	.334	−.009	.580	−.032	−.032
Sodium phosphate	−12%	5	5	5	.249	.002	.495	.009	.009
Sodium tetraborate	−6%	3	2	2	.663	.175	.994	−.172	.108
Sodium bichromate	−4%	3	2	2	.374	.230	.348	.107	.015
Nitrile rubber	−2%	5	4	4	.306	.084	.727	.020	.160

* Survivor firms only. (Excludes firms that entered or exited between the peak year and 1987.)
[a] Based on last observation with two producers.

[9] These measures were computed from the capacity data. The Herfindahl index is $H = \sum s_i^2$, where s_i is the capacity share of firm i.

[10] Many of these entrants acquired the assets of exiting firms.

Table 2 reveals several strong tendencies. First, producer concentration increased for most products in the sample. Twenty-six products exhibited increases in the Herfindahl index, while four products exhibited slight decreases.

Given the identity relation, $H = (V^2 + 1)/N$, the observed increase in the Herfindahl index implies a reduction in the number of producers or an increase in the coefficient of variation of firm sizes (or both). Table 2 gives clear evidence of the former: all but three products had a reduction in the number of producers over the coverage period. There is, however, no evidence of increased variation in firm sizes. Indeed, Table 2 documents a general pattern of firm size convergence; the coefficient of variation declined for more than three-fourths of the products in the sample. This size convergence could reflect one or more underlying processes: (1) disproportionate exit of large firms, (2) disproportionate exit of small firms, (3) disproportionate shrinkage of large firms, or (4) disproportionate growth of small firms.

The last column of Table 2 offers evidence that size convergence was due, at least in part, to the disproportionate shrinkage of large producers. In this column, the change in the coefficient of variation is limited to the set of firms that survived from the peak year through the beginning of 1987. For the sample as a whole there was no strong tendency toward size convergence among surviving firms—only 17 of the 30 products exhibit such convergence. However, there is significant evidence of size convergence within the set of products that experienced the greatest decline. For example, of the 17 products with capacity reductions exceeding 35%, 13 show convergence in the size of surviving firms.[11] These findings for the products in steepest decline are consistent with the predictions of G&N (1990).

□ **Exit rates by size rank of producer.** Table 3 gives information on the relative size of exiting firms. The table is in the form of a matrix in which the columns correspond to the number of producers at the start of the exit year and the rows correspond to the size rank of the firm (based on capacity at the start of the year). Within each column, exit rates have been normalized to sum to unity.

Table 3 shows that small firms had disproportionately high exit rates. Within each column of the table, the majority of exits lie below the mean rank. This propensity of smaller

TABLE 3 Frequency Distribution of Exits, by Number of Producers and Rank of Firm

	Number of Producers at Time of Exit								
Rank of Firm (Based on capacity at time of exit)	2	3	4	5	6	7	8	9	10 or more
1	—	.09	.17	—	—	—	—	—	—
2	1.00	.27	.25	.09	—	.14	—	—	—
3		.64	.25	.27	.21	.14	.17	.13	—
4			.33	.09	.07	—	.17	—	.11
5				.55	.29	.14	—	.38	—
6					.43	.29	.17	.13	.22
7						.29	.17	—	—
8							.33	.13	.11
9								.25	.11
≥10									.44
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Number of Exits:	1	11	12	11	14	7	6	8	9

[11] The null hypothesis of no convergence can be rejected at the .05 level, based on a binomial test.

firms to exit is highly significant statistically.[12] Results are similar if marginal producers are excluded from the analysis,[13] or if firms are ranked on the basis of capacity in the peak year rather than the exit year.[14]

Thus the data sample offers no support for the G&N (1985) model, which predicts that the largest producers will be first to exit. Indeed, of the firms with largest capacity for each product in the peak year, only three of the 30 exited, as compared with 38% of firms in the sample as a whole.

□ **Incremental capacity reductions.** While exit is the most dramatic form of divestment, capacity is more commonly eliminated through a process of incremental reduction (closure of part of an ongoing plant, or of an entire plant in a multiplant firm).[15] Table 4 focuses on such incremental cutbacks. It is in matrix form, similar to Table 3.

Table 4 reports the relation between the frequency of capacity reduction and the relative size rank of firm. The table shows that firms above the mean rank (shaded region) accounted for the vast majority of incremental reductions. Thus large-share firms made incremental capacity reductions more frequently than small-share firms.[16]

The results in Table 4 do not necessarily imply that large producers undertook more incremental divestment; this depends on the average magnitude of cutbacks as well as their

TABLE 4 **Frequency of Incremental Capacity Reductions, by Number of Producers and Rank of Firm**

		Number of Producers								
		2	3	4	5	6	7	8	9	10 or more
Rank of Firm (Based on capacity prior to reduction)	1	.63	.48	.48	.24	.41	.24	.36	.33	.14
	2	.37	.33	.20	.24	.12	.26	.14	.33	.19
	3		.19	.16	.28	.24	.09	.07	—	.05
	4			.16	.14	.06	.12	.07	—	.10
	5				.10	.12	.09	—	.17	.10
	6					.06	.15	.14	—	.05
	7						.06	.14	—	.14
	8							.07	—	.10
	9								.17	.05
	≥10									.10
		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Number of Capacity Reductions:		16	21	44	29	17	34	14	6	21

[12] Tests were based on a binomial model, assuming a null hypothesis of equal exit probabilities for small and large firms. Firms below the mean rank accounted for 77% of all exits, which allows rejection of the null hypothesis at the .01 level. Results are similar when the sample is limited to products with high producer concentration or products in very steep decline.

[13] Fringe producers operating well below minimum efficient scale might account for a large fraction of the industry population measured in numbers but only a minuscule proportion of industry output and capacity. To avoid this bias, Table 3 was recomputed after screening out firms whose peak-year capacity fell below 10% of the largest producer. Eliminating such firms had little effect on the results.

[14] Producers with considerable peak-year capacity might divest incrementally and hold only very small market shares at the time of exit. To correct this possible bias, firms were classified according to their rank in the peak year. This reclassification led to only minor changes in Table 4.

[15] Roughly half of the incremental capacity reductions included in Table 4 were cutbacks at ongoing plants, and half were plant closures in multiplant firms.

[16] Firms above median rank accounted for 67% of the incremental capacity reductions shown in Table 4. The null hypothesis that large- and small-share firms had equal probabilities of making such reductions can be rejected at the .01 level.

TABLE 5 **Average Size of Incremental Capacity Reductions (as a Fraction of Firm's Existing Capacity)**

Rank of Firm (Based on capacity prior to reduction)	Number of Producers: 2	3	4	5	6	7	8	9	10 or more
1	−.25	−.29	−.25	−.24	−.24	−.12	−.11	−.05	−.25
2	−.36	−.17	−.25	−.12	−.33	−.21	−.19	−.07	−.12
3		−.22	−.16	−.18	−.19	−.22	−.14	—	−.29
4			−.28	−.27	−.48	−.21	−.08	—	−.13
5				−.27	−.21	−.24	—	−.31	−.22
6					−.20	−.31	−.10	—	−.20
7						−.38	−.25	—	−.22
8							−.13	—	−.33
9								−.07	−.03
≤10									−.41
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Average Size of Reduction:	−.29	−.24	−.24	−.20	−.25	−.22	−.14	−.10	−.22
Number of Capacity Reductions:	16	21	44	29	17	34	14	6	21

frequency. Table 5 reports the fraction by which firms reduced their capacity, given that an incremental reduction was made. On average, firms cut capacity by a margin of about 20% to 25%. No strong pattern is evident with respect to firm size—large and small firms cut capacity by roughly the same percentage margin. This finding, combined with the results in Table 4, implies that large firms undertook more incremental divestment than small firms.

The fact that industry demand was declining did not prevent some firms from expanding their facilities. Most of these expansions were the result of plant debottlenecking, a common practice in the chemical industry. Such expansions, which enable plants to achieve greater economies of scale, can often be implemented at trivial financial cost.[17] Table 6 gives the

TABLE 6 **Frequency of Incremental Capacity Additions,* by Number of Producers and Rank of Firm**

Rank of Firm (Based on capacity prior to expansion)	Number of Producers: 2	3	4	5	6	7	8	9	10 or more
1	.25	.40	.24	—	.29	.10	—	—	—
2	.75	.10	.27	.29	.29	.30	.33	—	.27
3		.50	.24	.14	.14	.10	.17	—	—
4			.24	.29	.14	.20	.17	—	.27
5				.29	—	.20	.17	—	.09
6					.14	—	—	—	—
7						.10	.17	.50	.09
8								.50	.18
9									—
≥10									.09
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Number of Capacity Additions:	8	10	33	7	7	10	6	2	11

* Excludes expansions smaller than 5% of the firm's existing capacity.

[17] Debottlenecking is carried out by modifying equipment at points in the plant that are found to limit productive capacity.

frequency of capacity increases as a function of the firm's rank. No strong pattern is apparent—large firms were about as likely to expand capacity as small firms.

□ **Total divestment.** The preceding analysis shows that small firms were more likely to exit, whereas large firms were more likely to cut capacity incrementally. Which group, on balance, accounted for the bulk of industry divestment? Table 7 addresses this question by aggregating the various forms of capacity change (exit, incremental divestment, and capacity addition) into a single summary measure. If all groups cut back by the same average proportion, the total net capacity reduction would be distributed evenly across size classes. However, if large (small) firms divested to a greater extent, then one would observe large (small) firms accounting for a disproportionate share of the total reduction in industry capacity.

To derive the results in Table 7, a computer program was written to sort firms into the top, middle, and bottom thirds of the industry, based on peak-year capacity, and to keep track of subsequent capacity changes.[18] The allocation among size classes becomes arbitrary for products where the aggregate reduction in industry capacity was small. To avoid this problem, the mean values reported in Table 7 are limited to the 17 products for which the total net reduction in industry capacity exceeded 35%. The figures in Table 7 reveal a remarkably balanced pattern of capacity reduction. Very close to one-third of all divestment was undertaken by firms in each of the three size classes.

Despite the fact that incremental reductions were made at ongoing plants, most divestments ultimately took the form of plant closures. On average across the 17 products included in Table 7, capacity fell by 51% between the peak year and late 1986. Plant closures by exiting firms eliminated 26% of peak-year capacity; plant closures by surviving firms eliminated 23%. Various other capacity changes occurred but were less important. Surviving

TABLE 7 Distribution of Total Divestment by Size Class of Firm[a]

		Capacity Percentile of Firm in Peak Year		
	Total	Top Third	Middle Third	Bottom Third
All firms	100%	33.3%	35.7%	31.0%
Exiting firms	60.6%	7.4%	21.5%	31.7%
Surviving firms	39.4%	25.9%	14.2%	(0.7%)[b]
Average number of plants per firm in peak year		2.8	1.8	1.3
Average plant scale in peak year (Largest plant in operation = 1.0)		.70	.67	.30

[a] Data are averages across the 17 products for which industry capacity declined by more than 35%. (All products given equal weight.)
[b] Net increase in capacity by surviving firms.

[18] This program operated as follows. Producers were first arranged in decreasing order of peak-year capacity. Based on this ordering, the program identified whether the firm was in the top, middle, or bottom third of the capacity distribution. Firms that straddled a cutoff point were assigned to two categories in proportion to the fraction of their capacity falling in each category. All exits and incremental capacity changes between the peak year and 1987 were then allocated on the basis of these peak-year assignments. Finally, the total capacity change for each group was divided by the total capacity reduction observed for the product as a whole. Table 6 reports the simple average of these values across the 17 products with aggregate reductions greater than 35%.

firms expanded some of their remaining plants and cut capacity at others; on average, such expansions added 6% to peak-year capacity while such cutbacks reduced capacity by 8%. Plant sales by exiting firms accounted for 7% of peak-year capacity; these plants were sold to surviving incumbents or new-entrant firms, although many of the plants were ultimately closed.

□ **Summary of firm-level findings.** In the declining products sample, small producers suffered disproportionately high mortality rates, whereas large-share firms made more frequent incremental reductions of capacity. Nearly all plant closures by "bottom third" producers were exits, whereas "top-third" firms typically remained as producers despite closure of some plants. When exit and incremental divestment are combined, the total capacity reductions made by large and small firms were about equal. For survivor firms in the most steeply declining products, there is evidence that firm sizes converged, owing to more rapid divestment by the largest producers.

These findings at the firm level can be viewed as consistent with both the "shakeout" model and G&N (1990). Many of the findings are also consistent with a more naive model of divestment. Assume that (1) large firms differ from small firms solely in the number of plants that they operate and (2) the probability of plant closure is uncorrelated with firm size. Under these conditions one would naturally observe more frequent exits by small producers, even though the rate of divestment, on average, is independent of firm size. The one finding inconsistent with this naive model is that of convergence within the cohort of surviving firms. A further basis for rejecting the naive model is provided by findings on plant-level divestment, reported in the next section.

5. Analysis of plant closures

■ Here I consider divestment at the plant level, using logit analysis to identify factors that influenced firms' decisions to close individual plants. The results show that small plants were more likely to be closed; but controlling for plant size, the probability of closure increased with the firm's capacity share, as predicted by the G&N (1990) model. Additional factors that might serve as "exit barriers" along the lines proposed by Caves and Porter (1976) and Harrigan (1980) are also evaluated.

□ **Multiplant operation and average plant scale.** The lower part half of Table 7 gives summary statistics on multiplant operation and average plant scale by size class of producer in the peak year. Larger producers typically operated multiple plants. Firms in the "top third" category operated an average of 2.8 plants in the peak year, as compared with 1.3 plants for "bottom third" producers. For 12 of the 17 products included in Table 7, the largest producer was a multiplant firm.

Plant scale was measured relative to the capacity of the largest plant in the industry. For producers in the "top third" category, an average plant had capacity equal to 70% of the largest industry plant for that product. Plants operated by firms in the "middle third" category were of nearly this size. However, firms in the "bottom third" operated plants that were, on average, less than half as large. Hence, significant scale-related cost penalties were experienced by many "bottom third" producers.

□ **Logit analysis of plant closures.** To further distinguish the effects of plant scale from those of firm size, a logit model of plant closures was estimated. The unit of observation in this analysis is an individual plant in a given year. The dependent variable equals one if the plant was closed during the year; zero if the plant remained open.

The probability of plant closure was related to the following explanatory variables:

SCALE = capacity of the plant, divided by the capacity of the largest plant in the industry, both observed at the start of the observation year.

SHARE = capacity share of the firm at the start of the observation year.
MULTPLANT = one if the firm had multiple plants producing the product at the start of the observation year; zero if the firm operated only a single plant.
SPECIALIST = one if the firm was undiversified, making only a single chemical product; otherwise zero.
MAJORSITE = one if the firm operated plants making other chemical products at the same geographic site as this plant; zero if the site was devoted to a single product.
CU = total industry output of the product during the year preceding the observation year, divided by total industry capacity at the start of the observation year.

SCALE and SHARE are included to provide tests for the "shakeout" and "stakeout" mechanisms, respectively. A significant negative coefficient for SCALE—indicating that larger plants were less likely to close—implies "shakeout" of smaller plants. To distinguish between the G&N (1985) and (1990) models of "stakeout" behavior, SHARE is split into two separate terms depending on whether the firm operated a single plant or multiple plants at the start of the observation year.[19] The G&N (1985) model implies that the incentive for a single-plant firm to close its plant (i.e., exit) increases with the firm's market share. The G&N (1990) model implies that the incentive for a multiplant firm to close one of its plants increases with market share. Hence, if both models apply one should observe significant positive SHARE coefficients for both single-plant and multiplant firms.

The variables, MULTPLANT, SPECIALIST and MAJORSITE test for potential "barriers to exit." Controlling for divestment incentives related to plant scale and the firm's total capacity share, one might expect a single-plant firm to be more reluctant to shut its plant, given that such closure implies exit from the product market. Similarly, a firm that is specialized in the production of a single product might take greater steps to avoid plant closures, given that exit normally implies dissolution of the firm. For diversified chemical producers a related argument can be made at the plant level: some plants are located within large diversified plant complexes that produce a variety of chemical products, whereas other stand-alone plants are geographically isolated. Firms may be reluctant to close isolated plants where the labor force would need to be laid off or relocated. These "exit barrier" hypotheses imply positive logit coefficients for MULTPLANT and MAJORSITE and a negative coefficient for SPECIALIST.

One would also expect closure decisions to be influenced by the speed of demand decline and the gap between output and capacity, as reflected by CU. If closures are stimulated by low rates of utilization, a negative CU coefficient should be obtained.

□ **Logit results.** Table 8 reports the logit results. The logit sample includes the 17 products that declined by more than 35% over the sample period. The first two columns list the independent variables and their values at the sample mean. Logit equations 8.1 and 8.2 include all observations; equation 8.3 omits observations for which output data required to compute CU are unavailable. The coefficients in these equations are the partial derivatives of the logit probability of plant closure with respect to the independent variables, calculated at the sample mean.[20]

SCALE appears negative as expected and highly significant in Table 8, confirming that larger plants were less likely to close. The coefficient of −.183 in equation 8.1 implies that

[19] In Table 8, the single-plant measure equals SHARE if the firm was a single-plant firm, and zero otherwise; the multiplant measure equals SHARE if the firm was a multiplant firm, and zero otherwise.

[20] If $\hat{\beta}$ is the vector of maximum likelihood estimates of the logit function, the partial derivative of the logit probability with respect to X_k is $(\exp[X'\hat{\beta}])(1 + \exp[X'\hat{\beta}])^{-2}\hat{\beta}_k$. It is the value of this partial derivative evaluated at the sample mean that appears in Table 8.

TABLE 8 Logit Analysis of Plant Closures[a]

Independent Variable	Mean Value	8.1	8.2	8.3
Constant	1.0	−.136‡	−.131‡	−.093‡
		(.017)	(.019)	(.031)
SCALE	.46	−.183‡	−.170‡	−.150‡
		(.034)	(.037)	(.039)
SHARE	.24	.138‡		
		(.061)		
SHARE* [multiplant firm]	.35[b]		.148‡	.140†
			(.062)	(.068)
SHARE* [single-plant firm]	.16[c]		.055	.060
			(.120)	(.153)
MULTPLANT	.45	−.017	−.030	−.035
		(.019)	(.025)	(.026)
SPECIALIST	.10	−.055†	−.054†	−.043
		(.032)	(.032)	(.033)
MAJORSITE	.60	.021	.019	.026
		(.016)	(.016)	(.016)
CU	.54			−.055
				(.040)
Number of observations		1646	1646	1480
Number of closures		124	124	104
Probability of closure		7.5%	7.5%	7.0%
Log likelihood		−417.8	−417.4	−353.4

[a] Data cover 17 products with industry capacity reductions exceeding 35%. (Equation 8.3 includes data for 15 products only.) Coefficients are derivatives of the logit probability evaluated at the sample mean. Numbers in parentheses are standard errors.
[b] Mean value of SHARE for subsample of multiplant firms.
[c] Mean value of SHARE for subsample of single-plant firms.
‡ Significant at the .01 level, one-tailed test.
† Significant at the .05 level, one-tailed test.

an increase of 0.1 in relative plant scale (e.g., from 46% to 56% of the capacity of the largest plant) would have reduced the probability of closure in a given year by 1.8% (from 7.5% to 5.7%).

The SHARE coefficient appears positive and significant in equation 8.1, indicating that firms with larger shares of industry capacity were more likely to close plants, *ceteris paribus.* In equations 8.2 and 8.3 the SHARE coefficient is estimated separately for single-plant and multiplant firms. The coefficient is positive and significant for multiplant firms, in conformance with the predictions of G&N (1990). For single-plant firms the coefficient is insignificant; hence, there is no evidence that the probability of exit increased with share, as predicted by G&N (1985).[21]

The magnitude of the SCALE and SHARE coefficients offers further perspective on their counterbalancing effects. Consider the coefficients from equation 8.2, and assume for ease of interpretation that the probability derivatives remain constant for a doubling of SCALE and SHARE from their values at the sample mean. A doubling of plant scale (from 46% to 92% of the size of the largest plant) would have reduced the probability of closure in a given year by 7.8%, *ceteris paribus.* By comparison, a doubling of the firm's capacity share (from 24% to 48%) would have raised the probability of closure by 3.6% for a multiplant firm but only 1.3% for a single-plant firm. For single-plant firms, changes in SCALE are

[21] For single-plant firms there is strong correlation between SCALE and SHARE. (In the subsample of single-plant firms the simple correlation coefficient equals .88, versus .63 in the subsample of multiplant firms). This leads to a larger estimated standard error in the logit coefficient for SHARE.

always accompanied by the same proportionate changes in SHARE; for these firms the coefficients imply that relative scale was the dominant factor. For many multiplant firms, however, the two effects may have roughly balanced each other, depending on the specific values of SCALE and SHARE.

The "exit barrier" measures in Table 8 give weak evidence of some of the hypothesized effects. MULTPLANT is not significant, indicating that firms exhibited no particular reluctance to close their last plant. SPECIALIST is negative as expected and marginally significant in the first equation, suggesting that single-product companies may have been comparatively reluctant to shut their plants. The estimated coefficient implies that single-product companies had a probability of plant closure that was 5.5 percentage points lower than that of other firms. MAJORSITE appears with the expected positive sign, but the coefficient is not statistically significant.[22]

Table 8 shows that industry capacity utilization had little influence on the rate of plant closure. The CU coefficient in equation 8.3 appears negative as expected, but it is statistically insignificant.[23] Moreover, the coefficient is small; it implies that a ten percentage point drop in industry capacity utilization would have increased the probability of closure by only 0.5%. This is roughly the same effect as a 3% reduction in relative plant scale. Indeed, the low rates of utilization observed for most products in the sample (only 54% on average for those covered in Table 8) imply that redundant capacity was often maintained for long periods before finally being shut down. This contrasts with the strong and immediate link between increases in utilization and additions to capacity in growing chemical markets, as documented in Gilbert and Lieberman (1987) and Lieberman (1987).

In general, the plant-level results in Table 8 confirm and extend the firm-level findings reported in Section 4. Smaller plants had a higher probability of closure. Holding plant scale constant, multiplant firms with large shares of industry capacity were more likely to close individual plants. Various other potential "exit barriers" appear to have been less important in influencing divestment behavior.

6. Conclusions

■ For the declining chemical products included in this study, exit behavior appears to have been influenced by two frequently offsetting factors: (1) scale economies favoring the survival of large plants and firms and (2) the strategic liability of large firm size. For the products in steepest decline these two forces appear to have roughly balanced each other, as indicated by the fact that on average, aggregate divestment was distributed evenly across firm size classes.

The findings are consistent with multiple theories of divestment in declining industries. As predicted by the "shakeout" theory, small-share firms exhibited high rates of exit, and small-scale plants were most likely to close. Other findings support the "stakeout" models of G&N (1990) and Reynolds (1988). Controlling for plant size, the probability of plant closure increased with the firm's capacity share, assuming that the firm operated multiple plants. Within the cohort of surviving firms, large producers cut capacity by a greater percentage than small producers, leading to convergence of firm sizes. Despite this disproportionate shrinkage by large-share firms, there is no support for the more extreme prediction of G&N (1985) that large producers would be most likely to exit.

These findings imply that interfirm differences in both cost and marginal revenue can influence the order of divestment. Thus the "shakeout" and "stakeout" theories provide

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[22] Dummy variables were also defined for plants owned by major chemical companies and major petroleum companies, to determine whether such firms of large absolute size might differ from others in their propensities to shut plants. No significant differences were detected.

[23] Various measures of the rate of output decline were also tested and found insignificant.

complementary explanations of exit behavior. While both sets of influences appear to have been present in the sample, no simple divestment rule (or combination of rules) offers a high degree of predictive accuracy. The exit sequence was presumably affected by numerous factors in addition to the size-related determinants examined here.[24]

Declining industries vary in the extent to which cost and marginal revenue differ among producers. Large differences in marginal revenue stem from asymmetric market shares combined with high producer concentration. Moreover, the evidence obtained here suggests that the strategic liability of large firm size arises only in steeply declining industries, where producers recognize that demand reductions are likely to be permanent. Plant-level economies of scale are responsible for significant cost differentials in chemicals manufacturing, but such economies may be less important in other industries, particularly those that are labor-intensive. Additional research is required to confirm that the basic conclusions of this study can be generalized to other types of declining industries.

Finally, to provide further perspective on the declining industry results, a sample of 30 growing chemical products was selected as a benchmark for comparison. Production capacity for these products expanded at rates ranging from 3% to 25% per annum from the late 1950s (or early 1960s) through 1973.[25] The two samples showed an almost identical tendency for exits to be concentrated among small firms. In the growing products sample, 76% of exiting firms were in the bottom half of the size distribution based on rank in the year prior to exit; in the declining products sample the comparable figure was 77%. The samples did, however, exhibit major contrasts in the shifting distribution of firm sizes. The declining products sample showed a strong trend toward size convergence, resulting from the exit of small firms and the shrinkage of large firms. In the growing products sample there was no significant trend toward either convergence or divergence; changes in the coefficient of variation in firm sizes were almost evenly split between increases and decreases.[26] For a typical product in this sample, small exiting firms were replaced by new entrants, large producers continued to expand, and the mean firm size gradually increased over time.

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[24] The absence of a strongly ordered exit sequence is also consistent with Whinston's (1988) theoretical observation that multiple equilibria can occur when plants are lumpy and differ in size.

[25] The products are those with the highest rates of growth in the sample described in Lieberman (1987). The time series used for comparison run through 1973 only, as subsequent inflation in oil prices led to slower output growth for most products.

[26] The coefficient of variation, computed across all producers in the initial year of coverage and again in 1973, increased for 17 products and decreased for 13.

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