

LIQUIDITY AND THE CHOICE TO ABANDON PRODUCTION IN DECLINING INDUSTRIES

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Abstract

The study presents tests of several theoretical hypotheses that are potential determinants of the choice to abandon production in declining industries. A binary qualitative choice model of the abandonment decision is estimated. The probability of choosing abandonment is found to be positively related to the firm's debt ratio, and negatively related to liquidity at the firm level, the level of efficiency of the operating unit, and uncertainty about liquidity at the operating unit level as measured by output and input price variability. Results are also presented for a multinomial choice model accounting for the full menu of capacity decisions open to the firm over time. The results are robust across all specifications as well as to alternative statistical assumptions.

Keywords: Capacity choice; Abandonment; Cash flow volatility; Liquidity; Efficiency

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I am grateful to Scott Linn, Louis Ederington, Gary Emery, Nandu Nayar, and participants in the seminar series at SUNY-Buffalo, the Universities of Otago and Oklahoma, and Chapman University for comments on earlier drafts of the paper. The usual caveats apply. A previous version of this paper circulated under the title "Exit and Price Volatility".

1. Introduction

The decision to expand or contract production generalizes the more specific problem of when to enter into an activity and when to exit. This study presents an empirical analysis of how financial, real and product market forces influence expansion and contraction. Special emphasis, however, is placed on the abandonment decision. As the issue is likely to be most acute in declining industries, the data examined herein are drawn from such situations.

Declining industries will generally be associated with temporary overcapacity (Jensen, 1993). Reasons for the emergence of overcapacity include the development of less expensive or better substitute products, a decrease in demand for follow-on products, higher input costs, newly discovered toxicity of the product or its follow-on products, changes in consumer tastes and changes in production technology.

Whatever the reason for overcapacity, as demand decreases industry output must also decline or a state of disequilibrium will arise. When industry overcapacity becomes large and prices fall, firms must either cut capacity or abandon production in order to survive, consequently allowing a new equilibrium to emerge (Kreps, 1990). Empirical observation suggests the firms comprising a declining industry do not shrink plant capacity simultaneously with the

decline in aggregate demand for their products but rather react with a lag.² We examine the influence of three factors suggested in the literature on corporate investment that are potential candidates for explaining this observation regarding the decision to abandon: The liquidity of the producer and the level of the producer's debt obligations, and the efficiency of the operating unit.

Deily (1988) argues that firms in declining industries decrease or completely terminate reinvestment in depreciating assets anticipating future abandonment. Without the need to reinvest in plants earmarked for abandonment, these firms may find themselves with excess cash. The misuse of excess funds through empire building or the consumption of excess perquisites by managers is a well-known agency problem (Jensen, 1986). Jensen (1986) postulates that debt can mitigate the managerial misuse of cash in excess of investment needs. Stulz (1990) and Harris and Raviv (1990) develop models in which this agency problem is minimized through the optimal choice of debt levels. The implication is firms with higher debt levels are more apt to walk away from a declining industry.

Another implication of excess liquidity on the choice to abandon is the strategic advantage it may impart to the firm faced with making the decision. In a war of attrition, (Tirole, 1992), characteristic of a

² Lieberman (1990).

declining industry, a firm may be able to use its superior liquidity position to wait out the abandonment decisions of its liquidity-poor rivals. Excess economic rents may then be possible once the industry has shrunk.

A third factor that may influence the choice to exit is the efficiency of the operation (Jovanovic, 1982; Fudenberg and Tirole, 1986; Dunne, Roberts and Samuelson, 1989; Lieberman, 1990). More efficient operations should, *ceteris paribus*, be better able to sustain a presence in the industry longer than less efficient operations.

Our study has several unique features. First, the sample focuses on product markets that were in decline, candidates ideally suited for assessing factors that may increase or decrease the probability of abandonment. Second, the data set includes year-by-year plant capacity choices for fourteen chemical products across all producers of those products in the U.S. These data provide us with the opportunity to examine both a binary specification of the abandon/not-abandon decision, as well as to explore the robustness of our conclusions about abandonment within the context of a multinomial model of capacity choice. In the latter case we account for the full menu of possible choices, abandonment, capacity reduction without abandonment, the decision to not change capacity, as well as expansion of capacity and entry. Third the data permit an analysis of the role of the financial characteristics of producers, specifically the influence of debt and liquidity, as well as the efficiency of the production units on the decision to exit. The firm-level liquidity measure we employ captures the variability of cash flow at the firm level. We also add the important dimension of examining the influence of aspects of plant-level cash flow variability by examining the relation between input and output price variability and the abandonment choice.

The emphasis of our study is close in spirit to the recent studies by Fan (2000) and Minton and Schrand (1999). Fan (2000) examines the effect of input price uncertainty on vertical integration in the petrochemical industry. His focus is on the influence of the oil shocks that took place during the 1970's on the choice of how to organize continuing operations. Although our sample of chemical products contains some of the products Fan examines, our focus is different. We concentrate on the financial and real determinants of the choice to abandon production rather than on how companies choose to organize continuing production. Minton and Schrand (1999) extend the literature on the relation between cash flow (liquidity) and investment (for instance, Fazzari, Hubbard and Petersen, 1988, 2000; Hubbard, Kashyap and Whited, 1995; Kaplan and Zingales, 1997; Cleary, 1999) by asking how cash flow variability influences investment spending. They find higher cash flow variability is associated with lower investment spending. Our study examines the decision to expand or contract and how it is related to

firm-level liquidity but specifically takes into account the efficiency of the assets involved as well as the influence of debt on that decision. In addition our inclusion of the underlying variability of the input and output prices faced by individual plants allows us to capture aspects of the variability of cash flows at the plant-level deepening our understanding of the influence of cash flow and liquidity.

The results of estimating binomial and multinomial qualitative choice models offer several interesting insights about the determinants of the abandonment decision in declining markets. The probability of choosing exit is positively related to the firm's debt ratio, and negatively related to liquidity at the firm level, the level of efficiency of the operating plant, and uncertainty about liquidity at the plant level as measured by output and input price variability. Further, our results are robust to an accounting for the full menu of capacity decisions open to the firm over time as well as to alternative statistical assumptions.

The study of business investment spending has a long history. Excellent surveys of this literature include, Jorgensen (1971), Chirinko (1993) and Hubbard (1998). The authors of several empirical studies conclude that liquidity and cash flow in general influence investment (Fazzari, Hubbard and Petersen, 1988, 2000; Hubbard, Kashyap and Whited, 1995, among others), but the interpretation of why the relation is observed has not been fully resolved (Kaplan and Zingales, 1997; Cleary, 1999). In addition, Minton and Schrand (1999) have recently extended this literature to include an examination of the relation between investment and cash flow variability. Their results suggest that higher cash flow variability is associated with lower total firm investment spending. Evans and Jovanovic (1989) and Huberman (1984) develop models that highlight the importance of liquidity in the investment decision. Lambrecht (2001) presents a model in which liquidity and the debt level jointly determine the choice to exit, and predicts that firms with more liquidity and less debt are less likely to abandon. Recent contributions to the empirical literature include Zingales (1998) who studies exit choice in the trucking industry and finds that more efficient firms are more likely to survive following deregulation, but that this is conditional on pre-deregulation debt levels. Kovenock and Phillips (1997) study the investment decisions of firms in industries where one of the majors undertook a leveraged buyout. They find that the debt level influences exit only in highly concentrated industries. Chevalier (1995) studies exit decisions in the supermarket industry when competitors engaged in leveraged buyouts and concludes that unleveraged firms are less likely to exit.

The next two sections describe the data on capacity choice and the financial and market characteristics of the firm's involved. Section 4 develops the empirical model of abandonment choice we use to test the hypotheses. In Section 5 we present

estimation results for a binary choice model. Section 6 presents estimation results for a full multinomial choice model designed to confirm the robustness of the conclusions drawn in Section 5. The final section presents a summary of our findings.

2. The sample

The initial sample consists of 144 different companies that produce one or more of 14 chemical products whose demand as identified by Lieberman (1990) was in decline during the period we study. Markets in decline offer an excellent opportunity for assessing the behavior of producers as such markets are natural candidates from which firms would exit. All fourteen of the chemicals represented in the sample are commodities and are inputs into other production processes. Thus, none of the products is a retail product nor do the manufacture and marketing of any require large expenditures on research and development or advertising. As commodities, however, they are subject to economies of scale. Table 1 presents a list of the chemical products and the documented reasons for the decline in the respective markets for these products.³

The chemicals listed as type O in Table 1 are organic chemicals and those listed as type I are inorganic. The column labeled "Beginning of decline" indicates the first year aggregate annual production declined. Column three presents reasons for the decline in demand.

The data reported in the *Directory of Chemical Producers* published by SRI International were used to identify changes in capacity for each plant in the sample. The *Directory of Chemical Producers* provides the names of all companies involved in domestic U.S. chemical production along with the names and capacities of the plants they operate, listed by chemical product. Companies producing each of the 14 chemical products represented in the final sample were identified in the *Directory*. A time series of annual capacity levels for each plant manufacturing a sample product, arranged by the company owning the plant, was then constructed. Each of the plants examined had capacity levels in the millions of tons, consistent with the importance of economies of scale in production.

There are five possibilities for changes in the reported capacity of each plant from one year to the next. We make the following assumptions about these reported changes in plant capacity. Reported capacity increases (decreases) are due to partial expansion (contraction) of the existing plant. Reported capacity for a plant not previously listed is

due to a new entrant, while delisting of a plant from the *Directory* indicates abandonment of the plant. Finally, when reported capacity remains unchanged we assume no changes to the plant were made from one year to the next. The actual change in capacity should occur with a lag relative to the time the decision was made due to such things as bureaucratic as well as construction lags. We therefore assume the actual decision was made in the year prior to the change reported in the *Directory*.

Plant closure is not the only method of abandonment. Abandonment can also occur when a firm sells, or spins-off a plant. The indicator of a sell-off or spin-off is a change in the name of the firm that owns the plant as reported in the *Directory*. *Moody's Manuals* and the *Wall Street Journal Index* are used to uncover the reason for each name change listed in the *Directory*. Name changes that were a result of a spinoff or sell-off are regarded as decisions to abandon while changes due to a simple corporate name change or merger, are not.

In our analysis of the determinants of capacity choice, several financial characteristics of the companies involved are employed. The Compustat Industrial files are the source of these financial data.

The final sample consists of 996 data observations from fifty-three firms operating 134 plants spanning the period 1977-1990. The 996 individual plant investment decisions include 57 exits, 126 capacity reductions (not including exit), 115 capacity expansions (not including entries), 27 entry decisions and 671 cases of no change in capacity. The relative distribution of events in the total sample is representative of the relative distributions by year: exit (5.7%), capacity reductions but not exits (12.7%), no change in capacity (67.4%), capacity expansions excluding entries (11.5%) and entries (2.7%). Table 2 presents statistics describing the sample firms. The companies in the sample have average sales of \$10.5 billion, average total assets of \$9.7 billion, and average market value of equity of \$5.2 billion. The average cash flow generated equals \$1.1 billion per year, and cash flow as a percent of total assets is on average equal to 11%.

3. The choice to abandon

The ability to sustain a plant from the cash flows of the company, the influence of efficiency and the variability of output and input prices are as we have suggested factors that may influence the choice to abandon. We discuss each below.

3.1 The effects of firm-level cash flow and liquidity

Numerous authors have suggested that the greater the extent to which a firm's managers have discretionary control over its free cash flow, the greater the possibility for inefficient investment, or through a logical extension of the argument, the greater the

³ The reasons listed are based upon the discussion in Lieberman (1990) along with our independent assessment as formed by a review of government statistics and industry analyses published by several sources including reports published in trade journals.

possibility of the prolongation of production activities which should be terminated (Jensen, 1986; Stulz, 1990; Harris and Raviv, 1990). This problem may be even more acute when the product market is in decline. The firm's use of debt can mitigate this problem by reducing managements' discretionary control over free cash flow. Jensen (1986, page 324) for instance has argued:

"The control function of debt is more important in organizations that generate large cash flows but have low growth prospects, and even more important in organizations that must shrink. In these organizations the pressures to waste cash flows by investing them in uneconomic projects is most serious."

This is precisely the situation faced by companies in declining markets. This hypothesis suggests that a firm's leverage as well as the behaviour of its free cash flow may influence the choice of whether to abandon production or not. In contrast if leverage is irrelevant then we should observe no relation between the level of debt and the choice to exit.

We define leverage in the following manner

$$DEBT_{j(i),t} = \text{long-term debt}_{j(i),t} / \text{total assets}_{j(i),t}$$

where the notation $j(i)$ associates the leverage of the owner firm j with plant i . The book values of long-term debt and total assets are from the Compustat files. Leverage is measured at the end of the year prior to when a capacity change decision is made.

Firms with the highest levels of debt are predicted to have the greatest motivation to seek out more productive uses of their limited capital and should be more apt to exit from a shrinking industry (Jensen, 1986; Stulz, 1990; Harris and Raviv, 1990). If this is true then the probability of exit should be positively related to leverage. The average $DEBT$ variable for our sample firms is .23 with a median of .21. The comparison reported in Table 3 indicates that the mean debt ratio for the abandonment sample exceeds the mean for the non-abandonment sample. A t-test of the null hypothesis that the means of the two samples are equal, against the alternative that the mean of the abandonment sample is larger, rejects the null at the .10 level.

The firm's access to excess cash flow, what we will call financial liquidity, may also be important when it is considering whether or not to continue operating in a declining industry. The excess free-cash flow hypothesis (Jensen, 1986) would predict a negative relation between the probability of abandonment and financial liquidity if managers, *ceteris paribus*, have incentives to continue production when the optimal choice should be to abandon. Alternatively, Tirole (1992) presents a war of attrition model for an industry that contains too many competitors, i.e. some must exit for the others to survive. In his model each competitor plays a waiting strategy hoping rival firms will quit the industry first. Under these circumstances liquidity-rich firms are

able to induce liquidity-poor firms to abandon production before they otherwise would. Hence, liquidity-rich firms may be less likely to exit.

Fazzari, Hubbard and Petersen (1988), and Hubbard, Kashyap and Whited (1995) among others, present results suggesting that investment activity is related to internally generated cash flow, broadly consistent with the view that external financing is costly (Myers, 1984a; Myers and Majluf, 1984b; Greenwald, Stiglitz and Weiss, 1984). These studies find that investment by firms with low access to capital markets is more sensitive to internally generated cash flow. Conclusions regarding these results are however mixed. Kaplan and Zingales (1997) have questioned the reasons for the investment-cash flow sensitivities suggested by Hubbard and his coauthors, and recent empirical results presented by Cleary (1999) also raises questions regarding interpretation. If liquidity is nonetheless relevant, liquidity-poor firms could be more likely to abandon.

Minton and Schrand (1999) in a recent study extending the investment-cash flow literature, present results indicating firm-level cash flow variability may have a negative effect on firm-level investment. They suggest that higher cash flow variability causes firms to forego investment spending because smoothing cash needs over time means using costly external financing, where external financing is potentially costly due to circumstances as described in Myers and Majluf (1984b).

A measure of financial liquidity should reflect the ability to immediately capture cash, but also the overall prospects of cash flow generation and its stochastic properties. The liquidity measure developed by Emery and Cogger (1982) reflects these characteristics. Let the probability of negative net cash flow be given by

$$\xi = \Phi(-\lambda)$$

where

ξ = probability of default

$\Phi(\bullet)$ = the standard normal distribution function

λ = (cash + marketable securities + μ) / σ

μ = average cash flow over previous five years

σ = standard deviation of cash flow over previous five years.

Then the probability of positive net cash flow is given by⁴

$$L = 1 - \xi$$

⁴ The full liquidity measure as defined by Emery and Cogger (1982), what they label $F(T)$, is composed of two terms. The first term is the probability of negative net cash flow assessed at date t , as above. The second term is a correction factor that conditions for the fact that the firm has remained solvent up to the time t . Emery and Cogger studied the behavior of $F(T)$ and λ and found that rankings based on each measure were not significantly different.

The variable L is scaled so that it measures the firm's liquidity relative to its closest competitors:

$$LIQUIDITY_{j(i),t} = L_{j(i),t} / (\text{median } L)_{q(i),t}$$

where $(\text{median } L)$ is the median value of L for companies operating plants manufacturing the same product q as plant i in year t , and the notation $j(i)$ associates the measure L for owner firm j with plant i .

The data used to calculate the liquidity measure come from the Compustat files. Cash flow for calculation of μ and σ is defined as earnings before interest, taxes, and depreciation. The terms μ and σ are calculated over a rolling five-year period beginning five years prior to the decision year. The comparison reported in Table 3 indicates the variable $LIQUIDITY$ is smaller for the abandonment sample. A t -test of the null hypothesis that the means of the two samples are equal, against the alternative that the mean of the abandonment sample is smaller, rejects the null at the .05 level.

3.2 The effects of efficiency

Jovanovic (1982), Fudenberg and Tirole (1986), Dunne, Roberts and Samuelson (1989) and Lieberman (1990) have all argued that the efficiency of a plant should play an important role in the decision to change capacity. Jovanovic (1982) presents a model for markets similar in nature to the types in which commodity chemicals are sold and shows that plant size is positively related to efficiency and survival. Dunne, Roberts and Samuelson (1989) and Lieberman (1990) present empirical results consistent with the proposition that efficiency is related to the choice to abandon production. These authors employ a measure of size as their proxy for efficiency. Aside from this evidence, consideration of the technology used in the production of chemicals leads to a similar conclusion. In the chemical industry economies of scale are of great importance. Therefore, a chemical plant's size as measured by its output capacity, should be an excellent proxy for its operating efficiency.⁵

In order to compare plant capacity across different chemical products we construct the following measure of capacity size

$$CAPACITY_{i,t} = \text{plant capacity}_{i,t} / (\text{median capacity})_{q(i),t}$$

⁵ Profit contribution from a specific plant is not available. However, if we can argue that more efficient plants have lower costs, and hence, *ceteris paribus*, contribute more to overall firm profitability, then we can also argue that for this industry, larger plants typically contribute more because they are better able to exploit economies of scale in production.

⁶ All the chemical groups report capacity similarly so that plant capacity can be compared directly within chemical groups. However, plant capacity for different chemical groups may be reported in different units of measure. Scaling capacity by the median of the group allows cross-group comparisons.

where the subscript i is for plant i and t is for year t . The quantity $(\text{median capacity})_{q(i),t}$ is the median capacity in year t of the capacities of all plants manufacturing the same product q as plant i in year t . This normalization creates a relative plant size variable that is comparable across all product groups.

If large plant capacity implies significant economies of scale, which is likely in the chemical industry, then it would be less likely that larger, more efficient plants would be closed in any year, *ceteris paribus*. Plant capacity data are collected from the annual *Directory of Chemical Producers*.⁷ The comparison reported in Table 3 indicates that the mean of the variable $CAPACITY$ for the abandonment sample is smaller than the mean for the non-abandonment sample. A t -test of the null hypothesis that the two sample means are equal, against the alternative that the mean of the abandonment sample is smaller, rejects the null at the .05 level.

3.3 Cash flow variability at the plant level

Plant-level cash flow variability may also influence the choice to abandon. One might for instance argue greater cash flow variability gives poorly performing investments a greater chance of recovering, and hence should be associated with a lower likelihood of abandonment.

For example, suppose a chemical plant faces a constant marginal cost of production but the price of the chemical produced is highly variable, so that the plant's cash flow is also highly variable. It may benefit the company to continue production even though demand for the product is declining, in hopes that the price will later rise. If, on the other hand, the price has little variability, thus giving little hope cash flow would recover to acceptable levels, the company would be more likely to abandon production. Analogously, if the prices of input materials are highly variable the company may hold on for a

⁷ The results in Deily (1990) suggest capital investment in a plant may predict future abandonment decisions. Actual dollar investments in plants are not available for our sample. However, the change in capacity prior to an event decision may be correlated with net new investment during that same period. We investigate the predictive power of the percentage change in capacity for a plant over the two years prior to the capacity choice decision and find no relation. We also investigated the relation between investment capacity choice and Tobin's Q ratio for the firm as a whole. The latter relation was not statistically significant, nor did the introduction of the firm level Q ratio as an independent variable influence the results presented below. However, as we show below, efficiency at the plant level is a significant predictor of abandonment. If it was possible to construct a plant level Q ratio we suspect that it to be significantly related to efficiency. Unfortunately, the data required for the calculation of plant level Q ratios is unavailable.

possible reduction in its cost of production.⁸

We use the crude oil price index and the price index for "nonferrous metals" both computed by the Bureau of Labor Statistics, U.S. Department of Labor, as proxies for input prices. If a plant manufactures an organic chemical then crude oil will be a major input. The inorganic chemicals in the sample are all nonferrous which is the justification for using the nonferrous metals price index as the input price proxy. Monthly observations on these price indices were obtained from the DRI Basic Economics database, which compiles the data from sources produced by the Bureau of Labor Statistics.

We obtain output price data from issues of the *Chemical Marketing Reporter*, which reports weekly prices for hundreds of chemicals. The *Chemical Marketing Reporter* presents price data in terms of units of output, such as gallons, pounds, or barrels depending on the particular chemical product. We account for these different units of measurement by standardizing our measure of the variability of output and input prices as follows.

$CVINPUT_{i,t}$ = coefficient of variation of input price for plant i in year t

$CVOUTPUT_{i,t}$ = coefficient of variation of product price for plant i in year t

Our measures of variability are computed in the same spirit as the cash flow variability measure utilized by Minton and Schrand (1999) who employ the coefficient of variation of firm-level cash flow in their analysis. We compute each of the variability measures for each year that a company is in the sample using a rolling twenty-four month period beginning two years prior to the year of interest.

Table 3 presents descriptive statistics for the two variables we use as measures of price variability for those cases defined as abandonment decisions and separately for those cases in which abandonment did not occur. For the output price, the mean coefficient of variation across the sample plants and years for the abandonment sample is .057. In comparison the mean value for the non-abandonment sample is .098. Therefore, $CVOUTPUT$ is smaller for the cases in which exit was the decision. For the input price variability measure, we see that the sample mean for the abandonment sample (3.515) is smaller than that for the non-abandonment cases (4.699). T-tests of the hypothesis that the mean values of $CVOUTPUT$ and $CVINPUT$ are equal for the two samples against the alternative that the means for the abandonment sample are smaller reject the null at the .05 level (Table 3). These results are consistent with the prediction that abandonment is less likely to occur the greater are output and input price variability. We turn next to a joint test of the aforementioned relations.

⁸ Dixit (1989) presents a model in which the variability of cash flow, through the variability of output prices, affects the ultimate decision of whether or not to exit.

4. Modeling capacity choice

We assume that the managers of a parent company perform an evaluation of the capacity of plant i each period and choose the capacity level that gives the maximum value conditional on the firm and market level characteristics discussed in Section 3. Consider the following capacity choice set $j = \{\text{abandon, contract but do not abandon, enter, expand an existing plant, leave capacity unchanged}\}$. Let the net benefit of the choice j for plant i be represented by

$$NB_{ij} = \beta'X_{ij} + \varepsilon_{ij} \quad (1)$$

where X is a vector of factors that influence the decision's value, β is a vector of parameters and ε_{ij} is a unique factor capturing effects which might be specific to the plant in question. The managers who administer plant i make choice j when

$$NB_{ij} > NB_{ik} \forall k \neq j.$$

Estimation of model (1) could tell us a great deal about the decision process. The values of NB are however not observable. What we can observe are the choices the managers actually made.

McFadden (1974, 1981) has shown that under the assumption of maximization and assuming the ε_{ij} in equation (1) are independent and identically distributed with Weibull density functions, the following probabilistic choice system is implied:

$$P_{i,j} = \frac{e^{\beta'X_{i,j}}}{\sum_{j=1}^J e^{\beta'X_{i,j}}} \quad (2)$$

where J represents the number of possible discrete choices available, and $P_{i,j}$ is the probability of choice j for plant i .⁹

We initially model the decision as a binary choice problem where the two choices are abandon or do not abandon and the errors in equation (1) have a logistic distribution. One feature of modeling the decision in this way is that the resulting predicted values can be interpreted as the predicted probability of abandonment. The binary model reduces to

$$P_{i,1} = \frac{e^{\beta'X_{i,1}}}{1 + e^{\beta'X_{i,1}}} \quad (3)$$

where $P_{i,1}$ represents the probability of abandonment. Define the limited dependent variable y , where y takes the value 1 if the decision to abandon is made and 0 otherwise. The assumption behind the model is: $Prob(y = 1) = P_{i,1} = F(\beta'X_{i,1})$ where the function $F(\bullet)$ depends upon the distributional assumption made regarding the errors in (1). We

⁹ We also estimate the model assuming that the errors in (1) are iid normal (the probit model) and find that the results are robust to which of these distributional assumptions is made.

estimate models (2) and (3) using maximum likelihood methods.¹⁰

5. Empirical results

5.1 Estimation results and the economic hypotheses

The estimated coefficients for model (3) under the assumption that the errors in (1) have the logistic distribution are as follows:

$$\beta X = -2.03 + 1.93 DEBT - 11.28 LIQUIDITY - 0.36 CAPACITY - 2.78 CVOUTPUT - 0.09 CVINPUT$$

(.0500) (.0382) (.0587) (.0705) (.0158)

The limited dependent variable y identifying the capacity choice takes the value 1 for abandonment and 0 for non-abandonment decisions. The p-values associated with tests of the predicted relations are presented in parentheses

Jensen (1986) points out that firms in declining industries may have a greater potential agency problem due to the possibility of large cash flow coupled with few growth opportunities. For these firms debt payments would be even more important than usual in minimizing the agency costs of excess free-cash flow. This hypothesis predicts a positive relation between a firm's level of debt financing and the probability of abandonment. The coefficient estimate for the variable *DEBT* (1.93) is positive and reliably significant ($p=.0705$), indicating that the greater the firm's use of debt the more likely it is to abandon assets in declining industries. This result is consistent with the agency cost of free-cash flow hypothesis.

As outlined earlier, a corollary to the above hypothesis is that firms with financial liquidity may be motivated to remain in a declining industry, thereby fighting a war of attrition, despite the fact that such a decision may run counter to the interests of shareholders.¹¹ This hypothesis predicts an inverse relationship between liquidity and the probability of abandonment. The estimated coefficient on the variable *LIQUIDITY* (-11.28, $p=.0500$) is consistent with this hypothesis. Firms with greater amounts of financial liquidity tend to remain rather than retreat.

The estimated coefficient for the efficiency proxy, *CAPACITY* is negative, -0.36, indicating that

¹⁰ See Greene (2000, Ch. 19) for details on estimating qualitative choice models.

¹¹ There are circumstances under which the use of financial liquidity to win the "war of attrition" could lead to gains to shareholders. For instance, if the industry becomes less competitive as a result of a reduction in the number of firms producing, those firms that remain may later exert oligopolistic power. Whether coalitions of such a nature can be sustained in commodity markets is suspect.

efficiency as we measure it is inversely related to abandonment. The p-value for the coefficient on *CAPACITY* (.0382) indicates that we can reliably reject the null hypothesis that plant efficiency has no bearing on the choice to abandon. This result is consistent with the hypothesis that more efficient plants are less likely to be abandoned.

Finally, the estimated coefficients on *CVOUTPUT* (-2.78) and *CVINPUT* (-0.09) are negative with p-values indicating that they are reliably negative (.0587 and .0158 respectively).¹² These results are consistent with the hypothesis that in the presence of higher variability of plant-level cash flow, proxied by output and input prices, firms are less likely to discontinue production.

5.2 Specification tests

We calculate a likelihood ratio test of the intercept-only model versus the full model. The test statistic is distributed asymptotically Chi-square with degrees of freedom equal to the number of independent variables. The Chi-square statistic for this test is 18.6, which, with five degrees of freedom, is significant at the one percent level ($p\text{-value} = .002$) indicating that the model we propose is significantly better than an intercept only model.

A goodness-of-fit test often used in the analysis of logistic regression models is Somer's D statistic.¹³ This statistic has the intuitive appeal that it is based on the predictive ability of the model. Let the decision response for firm i be classified as $y_i = 1$ when an abandonment occurs, and $y_i = 0$ when the firm does not abandon. Somer's D relies on a comparison of every possible pairing of responses with non-responses. A pairing is said to be concordant (discordant) if the predicted probability of the event response is greater (less) than the predicted probability of its paired non-response. The statistic is defined as $D = (c - d) / n = c/n - d/n$ where c is the number of concordant pairs and c/n is the percentage of all pairs that are concordant (64.2%); d is the number of discordant pairs and d/n is the percentage of all pairs that are discordant (34.4%); and n is the total number of pairs. A value of zero for the statistic implies the model has no predictive value. Somer's D

¹² One might think that the input price variability variable is little more than a dummy variable for whether the chemical is organic or inorganic. We estimated the models substituting such a dummy variable for the variability measures. The results indicate that such a dummy is not a substitute for *CVINPUT*.

¹³ As Greene (2000, Ch. 19) points out, goodness-of-fit may be a misnomer for logistic regression. In ordinary regression the goal is to minimize the sum of the squared residuals, which also maximizes the fit of the model. The method of maximum likelihood, on the other hand, sets out to maximize the density of the dependent variable to provide the best possible parameter estimates.

for the model in column one of Table 4 is .298 (= .642-.344) which, when divided by its asymptotic standard error of .025 (Freeman, 1987), results in a Z-statistic of 11.9 ($p < .0001$), suggesting that the model has significant predictive ability.¹⁴

5.3 The probability of exit

The coefficient estimates presented above do not represent the marginal effects of the respective independent variables on the probability of abandonment. However, those effects can be computed by using the structural form for the probability and the estimated coefficients of the model. The constructed probability is

$$\hat{P}_{i,t} = \frac{e^{\hat{\beta}' X_{i,t}}}{1 + e^{\hat{\beta}' X_{i,t}}} \quad (4)$$

where carats indicate the point estimates of the relevant coefficients of the model. Substituting in the point estimates for the coefficients and the mean values of the explanatory variables from Table 3 yields the expected probability of abandonment. By increasing or decreasing one variable at a time we can compute the marginal effects of changes in the explanatory variables on the probability of abandonment. Column (1) in Table 4 reports the coefficients of the estimated equation. Columns (2) and (3) present the means and standard deviations, respectively, of the independent variables. Columns (4) and (5) show the effects on the estimated probability of abandonment of a plus or minus one standard deviation change in the value of each explanatory variable from its mean.

The expected probability of abandonment, 7.7%, is found by setting all of the explanatory variables equal to their means. When all variables are set to one standard deviation above their respective means the probability of abandonment is 2.4%; when all are set to one standard deviation below their respective means the probability of abandonment increases to 28.0%. These represent changes of roughly -69 percent and +264 percent, respectively, from the baseline value of 7.7%. Regarding the effects of the individual regressors, a positive (negative) change in *DEBT* of one standard deviation from its mean, holding every other regressor constant, leads to a probability of abandonment of 10.8% (6.9%) a change of +40 percent (-10 percent). The other four regressors are inversely related to the probability of abandonment. When *LIQUIDITY* is increased (decreased) one standard deviation, the predicted probability of abandonment decreases (increases) -5 (+32) percent. A one standard deviation increase (decrease) in the plant efficiency measure *CAPACITY*

produces a -13 (+55) percent change in the probability of exit. Changes in output price variability have the greatest effect on the predicted probability of abandonment. A positive (negative) change in output price variability by one standard deviation from the mean leads to a predicted probability of 4.6% (13.1%), a decrease (increase) in abandonment probability of -40 (+70) percent relative to the expected probability of 7.7%. A one standard deviation change in input price variability produces a -31(+45) percent change in the probability of exit.

Correlations among the independent variables can influence the coefficient estimates and their significance levels. Table 5 presents the estimated correlation coefficients for the independent variables. None of the computed correlations have an absolute value greater than .10 and only two are reliably significant at the .05 level. We conclude from these statistics that correlation between the independent variables is not an issue as far as interpretation of the estimation results is concerned.

6. Robustness tests

6.1 Further specification issues

We examine the robustness of our findings that financial characteristics of the firm are important determinants in the abandonment choice. As we have discussed, the data set includes information on entry, expansion and contraction, in addition to abandonment and the case of no modifications to capacity (no change). A natural reformulation would involve the specification of a model in which all five capacity choice decisions are jointly accounted for. We discuss the robustness of the effects documented in Section 5 on the probability of abandonment for two such multinomial choice models.¹⁵

In order to estimate a model in which all five choices are jointly represented, one of the decisions must be chosen to act as the reference decision. The decision to "do nothing" is the reference decision in the multinomial models we estimate. The model in general form:

$$Prob(y_i = j) = \frac{e^{\beta'_j X_{i,j}}}{1 + \sum_{j=1}^J e^{\beta'_j X_{i,j}}} \quad \text{for capacity choice } j \neq \text{"do nothing"}$$

$$Prob(y_i = \text{"do nothing"}) = \frac{1}{1 + \sum_{j=1}^J e^{\beta'_j X_{i,j}}}$$

Each of the five decisions has its own structural model so that the vector of sensitivity coefficients for decision j is unique to decision j. Within this framework however the probability of abandonment is a complex function of the coefficients of the estimated equations. The multinomial model is estimated using maximum likelihood methods under

¹⁴ Results based upon the assumption of iid normal errors are qualitatively the same, with all of the estimated coefficients having the same sign as those shown and roughly equal or smaller p-values.

¹⁵ The general k-choice multinomial model is the analogue of the general k-vector multivariate regression model (Greene (2000, Ch. 19)).

the assumption that the errors are iid and have Weibull density functions.

6.2 Accounting for fixed effects

We begin by commenting on a restricted case in which only the intercepts of the respective models are permitted to vary across capacity choices. The validity of this structural form rests on the null hypothesis that the estimated coefficients other than the intercept are constant across models. While we found that the intercepts do differ across the models, additional tests lead us to reject the null hypothesis that the slope coefficients of all five plant capacity decisions were equal. Thus the constraint on the slope coefficients is inappropriate. We therefore turn next to a more general specification.¹⁶

6.3 An unordered general choice model

A full multivariate model in which not only the intercepts but also the slope coefficients are free to vary across the five alternative capacity choices was estimated. Table 6 presents the maximum likelihood analysis of variance results for an unconditional, unordered multinomial model. This structure allows joint estimation of models for all five decisions where "do nothing" is the reference decision. The results presented in Table 6 show that within this more general structural framework, *DEBT* becomes less statistically significant, although the p-value still remains at a tolerable level ($p=.15$). The variables *LIQUIDITY*, *CAPACITY*, *CVOUTPUT* and *CVINPUT* all remain significantly related to the plant capacity decision at significance levels below the .05 level. The null hypothesis for the likelihood ratio test presented at the bottom of Table 6 is that the total variability of the dependent variable vector is explained by the system. The likelihood ratio test statistic has a χ^2 distribution under the null hypothesis. The calculated value of the test statistic has a value of 1934, which, with 3888 degrees of freedom is insignificant ($p=1.0$), indicating that we do not reject the null that the model fits the data well.

The unordered multinomial regression provides a set of four estimated equations, 24 coefficients altogether (including intercepts). However, the coefficients of these equations are difficult to directly interpret because they interact in a complex nonlinear manner in the determination of the probability of any particular choice (Greene, 2000, Ch. 19)). A preferred and more intuitive way to interpret the estimated model is, as we have done previously in Table 4, to examine the marginal effects on the probability of abandonment that arise from changes in

the values of the independent variables. We begin by identifying the benchmark expected probability of abandonment using the respective mean values of the independent variables. This baseline estimated probability is equal to 5%. Then, one at a time, we vary the mean values of the independent variables by plus one standard deviation. Table 7 presents the results of these calculations.¹⁷ The column labelled "none" presents the benchmark probability of abandonment. Each of the columns to its right varies one independent variable at a time by plus one standard deviation from its mean. The table presents the level of the probability as well as the percentage difference from the baseline probability. The results in Table 7 indicate that the probability of abandonment is positively related to changes in the variable *DEBT* and negatively related to changes in the variables *LIQUIDITY*, *CAPACITY*, *CVOUTPUT*, and *CVINPUT*, consistent with the results presented earlier. The percentage changes for the probability of abandonment reported in Table 7 all agree with respect to sign with the binary model. We conclude that our prior results on the marginal effects on the probability of abandonment that arise from changes in the debt level of the firm, its financial liquidity, the plant's efficiency, and output and input price variability are the same within a multinomial framework that accounts for all of the possible choices available to management.

7. Summary

This study examines how financial, real and product market forces influence the decision to abandon production. Our sample represents investments in products that are in decline, products for which abandonment may be the most efficient decision. Extant theory suggests that discretionary control over a firm's free cash flow can lead to inefficient investment decisions. Jensen (1986) argues that debt financing can help mitigate this agency problem. Hence we expect firms with greater levels of debt will be more likely to abandon production in declining markets. However, Tirole (1992) develops a "war of attrition" model in which competing firms play a waiting strategy hoping that rivals will abandon production before they are forced to do so themselves. In this setting financial liquidity may prove to be an important weapon in the "war" and we do not expect firms with greater liquidity to make the exit decision as frequently as those with less liquidity. Several empirical studies suggest that cash flow and investment are related (Fazzari, Hubbard and Petersen, 1988, 2000; Hubbard, Kashyap and Whited, 1995). The study by Minton and Schrand (1999)

¹⁶ For brevity we do not present the results for the common coefficient model. The results will be made available upon request.

¹⁷ We restrict the table to the analysis of only increases in the dependent variables. The effects of decreases in the independent variables are largely symmetric to those presented.

further suggests that firm-level cash flow variability and firm-level investment are related. Finally, Leiberman (1990) and others have shown that firms are more likely to abandon production at less efficient plants. We test these propositions using a data set containing plant level capacity choices for products whose markets are in decline. We find that the probability of abandonment increases with a firm's level of debt financing and decreases with its level of financial liquidity, both of which are consistent with the agency arguments outlined above. We also find, consistent with Leiberman, firms tend to abandon smaller, less efficient plants. Finally the choice to abandon is inversely related to aspects of plant-level cash flow variability proxied by output and input price variability for the plant's product. These propositions are first confirmed within the framework of a binary choice model in which the choices are abandon and do not abandon and then within a multinomial framework in which all five possible capacity choices are accounted for.

References

- Chevalier, J., 1995, Debt and product market competition: Local market entry, exit, and expansion decisions of supermarket chains, *American Economic Review* 85, 415-435.
- Chirinko, R., 1993, Business fixed investment spending: Modeling strategies, empirical results and policy implications, *Journal of Economic Literature* 31, 1875-1911.
- Cleary, S., 1999, The relation between firm investment and financial status, *Journal of Finance* 54, 673-692.
- Deily, M. E., 1988, Investment activity and the exit decision, *The Review of Economics and Statistics* 70, 595-602.
- Dixit, A., 1989, Entry and exit decisions under uncertainty, *Journal of Political Economy* 97, 620-638.
- Dunne, T., M. J. Roberts and L. Samuelson, 1989, The growth and failure of U.S. manufacturing plants," *Quarterly Journal of Economics* 104, 671-698.
- Emery, G. and K. Cogger, 1982, The measurement of liquidity, *Journal of Accounting Research* 20, 290-303.
- Evans, D. and B. Jovanovic, 1989, An estimated model of entrepreneurial choice under liquidity constraints, *Journal of Political Economy* 97, 808-827.
- Fan, J.P.H., 2000, Price uncertainty and vertical integration: An examination of petrochemical firms, *Journal of Corporate Finance* 6, 345-376.
- Fazzari, S.M., R.G. Hubbard and B.C. Petersen, 1988, Financing constraints and corporate investment, *Brookings Papers on Economic Activity* 1, 141-195.
- Fazzari, S.M., R.G. Hubbard and B.C. Petersen, 2000, Financing constraints and corporate investment: Response to Kaplan and Zingales, *Quarterly Journal of Economics* 115, 695-705.
- Fudenberg, D. and J. Tirole, 1986, A theory of exit in duopoly," *Econometrica* 54, 943-960.
- Freeman, D. H., 1987, *Applied Categorical Data Analysis*, Marcel Dekker, Inc., New York.
- Greene, W. H., 2000, *Econometric Analysis*, 4th Edition, Prentice Hall, Upper Saddle River, New Jersey.
- Greenwald, B., Stiglitz, J., Weiss, A., 1984, Information imperfections in the capital market and macroeconomic fluctuations, *American Economic Review (Papers and Proceedings, 1983 Annual Meeting of the American Economics Association)* 74, 194-199.
- Harris, M. and A. Raviv, 1990, Capital structure and the informational role of debt, *The Journal of Finance* 45, 321-349.
- Hubbard, R.G., A. K. Kashyap and T.M. Whited, 1995, Internal finance and firm investment, *Journal of Money, Credit, and Banking* 27, 683-701.
- Hubbard, G., 1998, Capital-market imperfections and investment, *Journal of Economic Literature*, 193-225.
- Huberman, 1984, External financing and liquidity, *Journal of Finance* 39, 895-980.
- Jensen, Michael C., 1986, Agency costs of free cash flow, corporate finance, and takeovers, *American Economic Review* 76, 323-329.
- Jensen, Michael C., 1993, The modern industrial revolution, exit, and the failure of internal control systems," *The Journal of Finance* 48, 831-880.
- Jorgensen, D.W., 1971, Econometric studies of investment behavior: A survey, *Journal of Economic Literature* 9, 1111-1147.
- Jovanovic, B., 1982, Selection and the evolution of industry, *Econometrica* 50, 649-670.
- Kaplan, S. and L. Zingales, 1997, Do financing constraints explain why investment is correlated with cash flow, *Quarterly Journal of Economics* 112, 169-215.
- Kovenock, D. and G.M. Phillips, 1997, Capital structure and product market behavior: An examination of plant exit and investment decisions," *Review of Financial Studies* 10, 767-803.
- Kreps, D., 1990, *A course in microeconomic theory*, Princeton University Press: Princeton, NJ.
- Lambrecht, B.M., 2001, The impact of debt financing on entry and exit in a duopoly, *Review of Financial Studies* 14, 765-804.
- Lieberman, M. B., 1990, Exit from declining industries: "Shakeout or "Stakeout"?" *RAND Journal of Economics* 21, 538-554.
- McFadden, D., 1974, Conditional logit analysis of qualitative choice behavior," in *Frontiers in Econometrics*, P. Zarembka, ed., Academic Press: New York, 105-142.
- McFadden, D., 1981, Econometric models of probabilistic choice, in *Structural Analysis of Discrete Data with Econometric Applications*, C.F. Manski and D. McFadden, eds., MIT Press: Cambridge, MA, 198-272.
- Minton, B. A., Schrand, C., 1999, The impact of cash flow volatility on discretionary investment and the costs of debt and equity financing, *Journal of Financial Economics* 54, 423-460.
- Myers, S.C., 1984a, The capital structure puzzle, *Journal of Finance* 39, 575-592.
- Myers, S.C., Majluf, N.S., 1984b, Corporate financing and investment decisions when firms have information that investors do not have, *Journal of Financial Economics* 13, 187-221.
- Stulz, R. M., 1990, Managerial discretion and optimal financing policies," *Journal of Financial Economics* 26, 3-27.

35. Tirole, J., 1992, *The Theory of Industrial Organization*, MIT Press: Cambridge, MA.
36. Zingales, L., 1998, Survival of the fittest or the fattest? Exit and financing in the trucking industry, *Journal of Finance* 53, 905-937.

Appendices

Table 1. Chemical products whose manufacturers are represented in the sample

Product ^a	Type	Beginning of decline	Reason for decline
Acetone	O	1981	1
Acrylic fibers	O	1981	2
Adipic Acid	O	1979	0
Carbon black	O	1975	3
Cresylic acid	O	1982	4
Ethyl chloride	O	1976	1
Fumaric acid	O	1972	2,4
Hydrofluoric acid	O	1974	1,4
Isopropyle alcohol	O	1981	5
Melamine	O	1972	4
Sodium bichromate	I	1979	4,6
Sodium phosphate	I	1979	7
Sodium sulfite	I	1976	6,7
Sodium tetraborate	I	1978	0

^a Chemical products produced at the plants in the final sample of facilities for which the decision to abandon is examined. The label Type indicates whether the chemical product is organic (O) or inorganic (I). The table indicates the first year that demand for the product began to decline and the reasons for the decline, which are: 0 - unknown, 1 - downstream product found to be hazardous, 2 - substitute found for downstream product, 3 - downstream product changed, 4 - displaced by imports, 5 - downstream product manufacturing process changed, 6 - substitute found for chemical, 7 - chemical found to be hazardous.

Table 2. Descriptive statistics for the firms owning and operating the chemical plants in the sample

Variable ^a	Mean	Median	Standard Deviation
SALES	\$10.5	\$6.4	\$13.2
TOTAL ASSETS	\$9.7	\$5.8	\$11.5
DEBT	23%	21%	10%
MVE	\$5.2	\$2.7	\$7.0
Operating Cash Flow	\$1.1	\$0.6	\$1.4

^a All balance sheet quantities measured as of the end of the fiscal year; all flow quantities are based upon fiscal year performance. DEBT= long-term debt / total assets, MVE= market value of equity (stock price times number of outstanding

shares), *Operating Cash Flow* = net income before extraordinary expenses plus depreciation. All dollar values are measured in billions. Data sources include the Compustat and CRSP files. Measurement is over all manufacturers and years.

Table 3. Descriptive statistics for the explanatory variables by abandon and Not-abandon cases

Variable ^a	Exits		Does Not Exit		t ^b
	Mean	Median	Mean	Median	
<i>DEBT</i>	0.246	0.210	0.223	0.214	1.64**
<i>LIQUIDITY</i>	-0.006	0.000	-0.002	0.000	2.01*
<i>CAPACITY</i>	0.855	0.821	1.085	1.000	1.88*
<i>CVOUTPUT</i>	0.057	0.041	0.098	0.051	1.69**
<i>CVINPUT</i>	3.515	2.289	4.699	3.796	2.25*

^a Abandon and not-abandon cases are identified from the annual record of capacity choice decisions made at 134 chemical manufacturing plants over the period 1977-1990. Fifty-three corporations are represented in the final sample, and 728 choices are represented in the table. The variables listed in the table are defined as: *DEBT*= long-term debt / total assets for the corporation that operates the chemical plant in year t, *LIQUIDITY*= Emery and Cogger (1982) liquidity measure. Let the probability of negative net cash flow be given by $\xi = \Phi(-\lambda)$ where ξ = probability of default, $\Phi(\bullet)$ = the standard normal distribution function, $\lambda = (\text{cash} + \text{marketable securities} + \mu) / \sigma$, μ = average cash flow over previous five years, σ = standard deviation of cash flow over previous five years. Then the probability of positive net cash flow is given by $L = 1 - \xi$. The variable *L* is scaled so that it measures the firm's liquidity relative to their closest competitors: $LIQUIDITY_{j(i),t} = L_{j(i),t} / (\text{median } L)_{q(i),t}$, where (median *L*) is the median value of *L* for companies operating plants manufacturing the same product q as plant i in year t, and the notation j(i) associates the measure *L* for owner firm j with plant i, *CAPACITY*= plant capacity / median plant capacity for plants manufacturing the same chemical in the same year, *CVOUTPUT*= coefficient of variation of product price, *CVINPUT*= coefficient of variation of input good price.

^b Absolute value of the t-statistic for tests of the hypothesis that the reported means are equal against the alternative that the means of a) *CVOUTPUT*, *CVINPUT*, *CAPACITY*, and *LIQUIDITY* are smaller for the abandon sample than for the not-abandon sample, and b) for the variable *DEBT* that the mean for the abandon sample is greater than for the not-abandon sample. * (**) indicates that the null is rejected in favor of the alternative at the .05 (.10) level.

Table 4. Marginal effects on the probability of abandonment from changes in explanatory variables

Variable ^a	Model Coefficients	Variable Mean	Variable Standard Deviation	P+1 (%)	P-1 (%)
	(1)	(2)	(3)	(4)	(5)
<i>Intercept</i>	-2.03				
<i>DEBT</i>	1.93	0.023	0.099	10.8	6.9
<i>LIQUIDITY</i>	-11.28	-0.0003	0.014	7.3	10.2
<i>CAPACITY</i>	-0.36	1.07	0.887	6.7	11.9
<i>CVOUTPUT</i>	-2.78	0.09	0.17	4.6	13.1
<i>CVINPUT</i>	-0.09	4.61	3.82	5.3	11.2

^a This table uses the estimated model reported in column 2 of Table 4 to find the marginal effects of changes in the independent variables on the predicted probability of abandonment. There are 728 decisions represented, and are restricted to "abandon" and "not-abandon", excluding the decisions "reduce capacity", "expand capacity" and "entry". The variables listed in the table are defined as: *DEBT*= long-term debt / total assets for the corporation that operates the chemical plant in year t, *LIQUIDITY*= Emery and Cogger (1982) liquidity measure. Let the probability of negative net cash flow be given by $\xi = \Phi(-\lambda)$ where ξ = probability of default, $\Phi(\bullet)$ = the standard normal distribution function, $\lambda = (\text{cash} + \text{marketable securities} + \mu) / \sigma$, μ = average cash flow over previous five years, σ = standard deviation of cash flow over previous five years. Then the probability of positive net cash flow is given by $L = 1 - \xi$. The variable *L* is scaled so that it measures the firm's liquidity relative to their closest competitors: $LIQUIDITY_{j(i),t} = L_{j(i),t} / (\text{median } L)_{q(i),t}$, where (median *L*) is the median value of *L* for companies operating plants manufacturing the same product q as plant i in year t, and the notation j(i) associates the measure *L* for owner firm j with plant i, *CAPACITY*= plant capacity / median plant capacity for plants

manufacturing the same chemical in the same year, *CVOUTPUT*= coefficient of variation of product price, *CVINPUT*= coefficient of variation of input good price. Sample means and standard deviations of the independent variables are reported in columns 2 and 3. Predicted probabilities of abandonment after increasing the respective variable's value by one standard deviation above the mean are reported in column 4 as P+1. Predicted probabilities of abandonment after decreasing the respective variable's value by one standard deviation below the mean are reported in column 5 as P-1. The expected probability of abandonment 7.7% is found by setting all variables equal to their means. When all variables are set to one standard deviation above their respective means the probability of abandonment is 2.4%; when all are set to one standard deviation below their respective means the probability of abandonment increases to 28.0%.

Table 5. Correlations among the explanatory variables^a

	<i>LIQUIDITY</i>	<i>DEBT</i>	<i>CAPACITY</i>	<i>CVOUTPUT</i>	<i>CVINPUT</i>
<i>DEBT</i>	1	-0.01	-0.03	-0.08*	.07*
<i>LIQUIDITY</i>		1	-0.00	-0.06	.01
<i>CAPACITY</i>			1	-0.01	-0.03
<i>CVOUTPUT</i>				1	-0.03
<i>CVINPUT</i>					1

*Correlations of ± .07 to .09 in absolute value are significant at the 5% level.

^a The variables listed in the table are defined as: *DEBT*= long-term debt / total assets for the corporation that operates the chemical plant in year t, *LIQUIDITY*= Emery and Cogger (1982) liquidity measure. Let the probability of negative net cash flow be given by $\xi = \Phi(-\lambda)$ where ξ = probability of default, $\Phi(\bullet)$ = the standard normal distribution function, $\lambda = (\text{cash} + \text{marketable securities} + \mu) / \sigma$, μ = average cash flow over previous five years, σ = standard deviation of cash flow over previous five years. Then the probability of positive net cash flow is given by $L = 1 - \xi$. The variable *L* is scaled so that it measures the firm's liquidity relative to their closest competitors: $LIQUIDITY_{j(i),t} = L_{j(i),t} / (\text{median } L)_{q(i),t}$, where (median *L*) is the median value of *L* for companies operating plants manufacturing the same product q as plant i in year t, and the notation j(i) associates the measure *L* for owner firm j with plant i, *CAPACITY*= plant capacity / median plant capacity for plants manufacturing the same chemical in the same year, *CVOUTPUT*= coefficient of variation of product price, *CVINPUT*= coefficient of variation of input good price.

Table 6
Analysis of variance results for the full multinomial model of capacity choice

Variable ^a	Df	χ^2	Prob> χ^2
<i>Intercept</i>	4	84.01	<.000
<i>DEBT</i>	4	6.66	.155
<i>LIQUIDITY</i>	4	30.68	<.000
<i>CAPACITY</i>	4	31.68	<.000
<i>CVOUTPUT</i>	4	15.75	.0034
<i>CVINPUT</i>	4	10.00	.0405
Likelihood ratio ^b	3888	1934	1.000

^a Maximum-likelihood analysis-of-variance results from a multinomial logistic regression including each of the capacity decisions as a separate category in the analysis. These tests are run using the full set of 996 observations, accounting for all five possible decisions; abandon, reduce capacity but do not abandon, entry, expand capacity, and do nothing. The explanatory variables are: *DEBT*= long-term debt / total assets for the corporation that operates the chemical plant in year t, *LIQUIDITY*= Emery and Cogger (1982) liquidity measure. Let the probability of negative net cash flow be given by $\xi = \Phi(-\lambda)$ where ξ = probability of default, $\Phi(\bullet)$ = the standard normal distribution function, $\lambda = (\text{cash} + \text{marketable securities} + \mu) / \sigma$, μ = average cash flow over previous five years, σ = standard deviation of cash flow over previous five years. Then the probability of positive net cash flow is given by $L = 1 - \xi$. The variable *L* is scaled so that it measures the firm's liquidity relative to their closest competitors: $LIQUIDITY_{j(i),t} = L_{j(i),t} / (\text{median } L)_{q(i),t}$, where (median *L*) is the median value of *L* for companies operating plants manufacturing the same product q as plant i in year t, and the notation j(i) associates the measure *L* for owner firm j with plant i, *CAPACITY*= plant capacity / median plant capacity for plants

manufacturing the same chemical in the same year, *CVOUTPUT*= coefficient of variation of product price, *CVINPUT*= coefficient of variation of input good price.

^b The null hypothesis for the likelihood ratio test is that the total variability of the dependent variable vector is explained by the system estimated. The likelihood ratio test statistic has a value of 1934 which, with 3888 degrees of freedom is insignificant ($p=1.0$), indicating that the model fits very well.

Table 7. Marginal effects on the probability of abandonment from changes in all explanatory variables: Full multinomial model of capacity choice

	Explanatory Variable Varied ^a					
	None (Base Case)	<i>DEBT</i>	<i>LIQUIDITY</i>	<i>CAPACITY</i>	<i>CVOUTPUT</i>	<i>CVINPUT</i>
Probability of abandonment (%)	5.0	6.1	4.2	3.2	2.8	3.6
% □ Prob relative to Base Case		23.5%	-16.2%	-34.9%	-42.6%	-27.7%

^a This table uses the parameters estimated by a full multinomial logistic regression to find the marginal effects of changes in the independent variables on the predicted probability of abandonment. The model is estimated using the full set of 996 observations, accounting for all five possible decisions; abandon, reduce capacity but do not abandon, entry, expand capacity, and do nothing. Column 1 presents the estimated probability of abandonment when each of the independent variables is set to its sample mean value. Columns 2 through 6 present the probability of abandonment when the mean value of each respective variable is increased by one standard deviation. The second row of the table presents the percentage change in the probability of abandonment. The explanatory variables are: *DEBT*= long-term debt / total assets for the corporation that operates the chemical plant in year *t*, *LIQUIDITY*= Emery and Cogger (1982) liquidity measure. Let the probability of negative net cash flow be given by $\xi = \Phi(-\lambda)$ where ξ = probability of default, $\Phi(\bullet)$ = the standard normal distribution function, $\lambda = (\text{cash} + \text{marketable securities} + \mu) / \sigma$, μ = average cash flow over previous five years, σ = standard deviation of cash flow over previous five years. Then the probability of positive net cash flow is given by $L = 1 - \xi$. The variable *L* is scaled so that it measures the firm's liquidity relative to their closest competitors: $LIQUIDITY_{j(i),t} = L_{j(i),t} / (\text{median } L)_{q(i),t}$, where (median *L*)_{q(i),t} is the median value of *L* for companies operating plants manufacturing the same product *q* as plant *i* in year *t*, and the notation *j*(*i*) associates the measure *L* for owner firm *j* with plant *i*, *CAPACITY*= plant capacity / median plant capacity for plants manufacturing the same chemical in the same year, *CVOUTPUT*= coefficient of variation of product price, *CVINPUT*= coefficient of variation of input good price.