A list of Working Papers on the last pages

No. 108

Entry, Industry Growth and the Micro-dynamics of Industry Supply

by

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December, 1983

ABSTRACT

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Entry is widely discussed, but rarely subjected to empirical study. This study develops a competitive theory of entry, with primary focus on the relationship between entry and industry growth. The main ingredients are adjustment costs to firms already in the industry and the distribution of fixed entry costs to potential entrants. The theory suggests sufficient conditions under which the entry rate is an increasing, convex function of industry growth rate. A regression model is applied to data from Swedish manufacturing industries. The results are consistent with the theoretical prediction for growth and other key variables expected to influence entry significantly.

Entry, Industry Growth, and the Microdynamics of Industry Supply

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I. INTRODUCTION

Recognition of the central role of entry in the theory of supply is at least as old as Adam.[1] Oddly enough, the subsequent theoretical and empirical elaboration of entry has been like Moby Dick without the whale. The main line of development has followed J. B. Clark's doctrine of "potential competition" (1887), recently resurrected and dressed in formal attire by Baumol, Panzar, and Willig (1982). Clark was concerned with understanding how competitive forces would operate if the atomistic structural competition that characterized agriculture and precorporate manufacturing were replaced by industrial markets dominated by a few large firms. He concluded that even a formal monopolist may well charge a "normal" price, reflecting only his costs of production, if there are potential entrants who could and would appear if price rose above this level because of monopolistic restriction of output. Clark believed that recognition of this potential competition was an important constraint on the behavior of formal monopolists and trusts. Over time, he became increasingly skeptical of the adequacy of this control of monopoly power, unless policies were adopted to prevent predatory behavior that might otherwise discourage entry.[2]

The past 25 years have seen the development of a related literature on "barriers to entry," stemming from papers by Bain (1949) and Modigliani (1958). This work attempted to characterize theoretically conditions under which significant long-run departures from Clark's "normal price" might occur. And it attempted to measure empirically the size of such departures, in terms of rates of return or price-cost differentials. It would seem natural for a much more systematic investigation of actual entry to complement this work. Although several empirical studies of actual entry have been carried out, very limited attention has been given to this topic.[3]

There are several reasons why realized entry deserves more attention. (1) Economic theory says almost nothing about where the output comes from when an industry expands. Under what conditions will it come almost exclusively from the firms already in the industry? When will entry play an important role in such expansion? Our inability to answer such questions adequately indicates a major lacuna in the theory of competitive supply. (2) The importance of potential competition in generating competitive outcomes depends on the sensitivity of entry to changes in the returns to or costs of entry. Past attempts to measure barriers to entry have not utilized information on differential entry rates to address this issue. Some of the variables determining entry rates can be interpreted as costs. The sensitivity of entry to variations in such costs is useful evidence on the potential importance of potential competition.

This study is focussed primarily on entry by new firms. In part II we provide a quantitative summary of this entry for a 15-year period (1954-1968) for most of the plastics, primary metals, and engineering manufacturing industries in Sweden. We also consider entry by established firms, which diversify by building a plant in a new industry (for them). In Part III, we develop a simple theory of the relationship between entry and the growth rate of a competitive industry. It is important to understand the mechanism of entry in a competitive context before claiming a serious understanding of the role of strategic behavior to influence entry in markets with monopoly power. Several other variables that affect entry rates are briefly discussed. Part IV presents some econometric evidence on determinants of entry, with particular emphasis on the industry growth rate. This evidence suggests that entry is an increasing, convex function of industry growth rates, a result consistent with the theoretical argument in part III. This empirical work makes use of a recently developed extension of the usual regression model to deal with severe heteroscedasticity, an important statistical problem in many cross-section industry studies.

II. Market Shares of New and Diversifying Firm Entrants

A natural way to characterize the direct impact of entry over a period of time is by the end-of-period market share of the entrants. Market shares are measured by employment, an imperfect, but adequate surrogate for product market shares. Table 1 reports the entrant shares for 39 Swedish manufacturing industries for the 15-year period ending in 1968. The share of new firms ranges from 0 to 26%, while the share of firms that have diversified into new industries ranges from 0 to 20.7%. We denote these two types of entry by E_n and E_d in the following discussion. The share of entry from both sources ranges from .3 to 30.7%. At a more aggregate level, E_n amounts to 5.8% for the 39 industries, while E_d is 1.7%.[4]

(Insert Table 1 about here.)

If entry is measured instead by the fraction of existing firms in 1968 that entered the industry as new or diversifying firms over the preceding 15 years, E_n ranges from 0 to 46% for the 39 industries. E_d entry measured the same way ranges from 0 to 20%.

The first impressions from these data are that entry usually accounts for a rather modest share of an industry's activity, even after a 15-year period, although there is a large variance across industries. Entrants do account for 20% or more of industry employment for five industries in our sample, although these industries are rather small ones. Entry measured by relative numbers of firms exaggerates the direct impact of entry by new firms, since new firms tend to be much smaller than established firms.

Most economists would probably agree that high rates of entry can be regarded as _prima facie_ evidence that long-term monopoly is not sustainable, even if attainable. Based on the 7.5% aggregate employment share of E_n and E_d, some observers might conclude that entry is not a very important mechanism for enforcing competitive behavior in industries. We disagree with this inference. The potential competition literature makes the important point that a high observed entry rate is not a necessary condition for obtaining approximately competitive levels of output and price even with substantial industrial concentration. The sensitivity of entry to changes in the costs or returns to entry is more important than the level of entry as an indicator of the importance of potential competition. Some evidence on this sensitivity is provided in Part IV.

III. The Relationship Between Entry and Industry Growth-Theory

This section develops a simple competitive theory of the qualitative relationship between entry and industry growth. It concludes with a brief, informal discussion of several other important determinants of entry, and defines the empirical counterparts to the theoretical variables.

Our theory has two ingredients, (1) costs of adjustment to existing firms in altering their capital stock and (2) the distribution of fixed costs of entry among potential entrants. The discussion initially omits the possibility of firm exit from the industry. The analysis leads to sufficient conditions under which entry is an increasing, convex function of the industry growth rate.

Consider an industry producing a single homogeneous product X with two factors of production, capital K and labor L. All firms are competitive (price takers) in the product and factor markets. Firms have rational expectations about future values of the product price P(s), and factor prices G(s) and W(s) (for gross investment and wages), where s is any future point in time. These expectations are consistent with the firm decisions to maximize discounted net receipts. The discount rate r and the depreciation rate of capital m are constants.

Firms have identical homogeneous of degree one production functions:

$$X(K,L,I) = F(L,K) - KC(I/K), \tag{1}$$

where gross investment $I=dK/dt + mK$, the sum of net investment dK/dt, and the constant depreciation rate of the capital stock, mK. This specification of adjustment costs as part of the production function follows Lucas (1967). F is twice continuously differentiable and satisfies the usual production function restrictions that both factors of production have positive marginal products ($F_K>0$, $F_L>0$) and generate the usual convex isoquants. The adjustment cost is additive and it is assumed that C is twice continuously differentiable and possesses a piecewise continuous third order derivative. The range of I is restricted by the condition $I \geq 0$, so that net investment has a lower (negative) bound equal to the depreciation rate. It is also assumed that $C(0)=0$, $C'>0$, $C''>0$, and $C'''>0$. These assumptions state that the marginal adjustment cost function is positive, increasing, and convex. The convexity assumption is discussed below. Measuring firm size by its capital stock, the growth rate of a firm is $g=(dK/dt)/K$. Therefore, the argument of the C function can be rewritten $I/K=(g+m)$ when convenient. Since the depreciation rate of the capital stock is constant and exogenous, optimal choice of the gross investment rate I(s) by the firm is equivalent to optimal choice of its growth rate g(s).

A firm's objective is maximization of the discounted net cash flow from producing X (or exiting from the industry, if that increases its net worth). The formal problem is to choose I(s) (or g(s)) and L(s) for $t \leq s \leq \infty$ to maximize

$$\int_t^\infty [P(F(K,L) - KC(I/K)) - WL - GI]\exp(-rs)ds. \qquad (2)$$

Part A of the Appendix derives the marginal conditions for an interior optimum:

$$PF_L = W \text{ and} \qquad (3a)$$

$$\int_t^\infty PX_K(s)\exp[-(r+m)(s-t)]ds = PC' + G. \qquad (3b)$$

Equation (3a) states that the value of the marginal product of the costlessly variable factor must be equal to its price for a competitive firm. Equation (3b) equates the discounted value of a marginal unit of gross investment at the current point in time t to the current cost of an additional unit of gross investment. The latter is the sum of two components, (1) the current market price of X times the reduction of current output because of the marginal adjustment cost and (2) the market price of a unit of gross investment, G. We follow Mussa in calling the left hand side of (3b) $P_K(t)$, the shadow (demand) price of capital, while we call the right hand side the marginal cost of capital. From the preceding assumptions about C, it immediately follows that the marginal cost of capital is an increasing, convex function of gross investment I (equivalently, of the firm growth rate g). Since the firms in this model are scale replicas of each other (depending on when they entered the industry and on entry size) and the firms have identical rational price expectations, all firms in the industry have the same $P_K(t)$ and the same optimal growth rate $g^*(t)$. Hence, the marginal cost of capital for the "old" firms already in the industry is a function of the equilibrium growth rate of these firms, $j_o(g_o)$.

Before analyzing entry, we pause to consider more closely the assumption that the marginal adjustment cost function is increasing and convex. To our knowledge, there is no discussion in the literature whether it is convex or concave, although a recent diagram by Mussa (1977, p. 166) implicitly assumes that it is convex.[5]

In the analysis of entry, the shape of the marginal adjustment cost function plays an important role in determining the behavior of entry as industry growth becomes large. The standard assumptions of production theory are not restrictive enough to answer this question, although the hypothesis of positive, increasing, and weakly (if not strictly) convex adjustment costs (or costs of financial capital) seems plausible to us, at least for high firm growth rates. There are two dimensions to be distinguished in firm capacity expansion, (1) the relative size of the increment of capacity (at completion) to initial capacity and (2) the length of time over which the expansion takes place. Holding the first component constant, casual observation provides support for the adage "haste makes waste." The construction of oil refineries, paper mills, and steel plants are examples of complex projects that are commonly staged over substantial time. The decision of firms to assume the interest costs accumulated in such undertakings before output is available can only be explained by the expectation that the cost would be still greater if the firm attempted to reduce the construction period.[6] Experience with crash programs to expand production capacity or to achieve some technological feat demonstrates costs that again seem to support the view of accelerating costs as the project construction time is shortened. Simple queuing models can be constructed yielding the conclusion in a more formal way. Thus we consider weak convexity of the marginal cost function a reasonable hypothesis for high firm growth rates.

We next consider potential entrants and formal conditions that must be satisfied to induce entry to the industry. There is a pool of potential entrants to the industry, consisting of new firms that would be formed if profitable and of existing firms that would enter if entry would increase their present value. These potential entrants have the same price expectations and production function (1) as firms in the industry. Entrants are distinguished from other firms by fixed costs of entry, which are a function of the capital stock with which the firm enters, K_i. $Z_i(K_i)$ denotes these fixed costs for the ith potential firm. $Z_i(0)=0$, $Z_i'>0$, and $Z_i''>0$, at least in the neighborhood of the optimum entry size. The ith potential firm enters with initial capital stock K_i* and planned growth rate that maximizes the difference between equation (2) and $Z_i(K_i)$ if the difference is positive.

The Z_i for potential entrants captures both differential opportunity costs of entry associated with differences in specialized resources and differences in learning costs of becoming an efficient firm in the industry. The condition for profitable entry is given by a critical price of capital for the ith firm, $P_{Ki}*$, such that entry of the firm occurs if the calculated shadow price is greater than or equal to this value. In this circumstance, the firm brings in K_i* units of capital. It seems plausible that the density function of capital that will be brought into the industry by potential firms is a unimodal function of the price of capital, and furthermore, that only rarely (if ever) will the shadow price of capital be so high that the mode of the entrant density function of capital is observed.[7] To obtain conclusions about the effect of industry growth rates on entry, we use discrete time language and consider the density function of industry growth from entrants ($g_e=K_{eT}/K_0$) as a function of P_K, the shadow price of capital. Here K_{eT} is the amount of capital introduced by entrants in the time interval from 0 to T. K_0 is the total industry stock of capital at the beginning of the period. We denote this density function by $\phi(P_K)$. Presumably $\phi(P_K)=0$ for $P_K \leq G$, the market price of gross investment. Then the industry growth from entry is

$$g_e=h_e(P_K) = \int_G^{P_K} \phi(x)dx. \tag{4}$$

Assuming that $\phi(P_K)$ is unimodal and that the P_K that occur are less than the modal P_K, it immediately follows that g_e is an increasing convex function of P_K and that the inverse function of g_e, $j_e(g_e)$ is an increasing, concave function of g_e. See Figure 1.

(Insert Figure 1 about here.)

Since the shadow price of capital, $P_K(t)$ is the same function of time for all old and potential firms in this model, the horizontal sum of the graphs of $j_o(g_o)$ and $j_e(g_e)$ for the old and new firms is the graph of the equilibrium shadow price of capital for the firms as a function of the industry growth rate $g_x=g_o+g_e$. Hence both g_x and g_e are functions of the parameter P_K. From the last panel of Figure 1, g_e is an increasing, convex function of g_x, i.e., if $g_e=u(g_x)$, then $u'>0$ and $u''>0$. The last panel shows two equal-sized increments of industry growth on the horizontal axis at a low and a high industry growth rate. It projects these two increments back onto the entry curve and down to the entry axis, showing the size of the entry component in these two increments of industry growth. Given the curvature of the entry curve and the growth curve for old firms, it is obvious that the entry component of the industry growth increment must be larger for the growth increment at the higher growth rate. This establishes the convexity of g_e as a function of g_x. The conditions that $j_o(g_o)$ be an increasing, strictly convex function and that $j_e(g_e)$ be an increasing, strictly concave function are obviously sufficient, but not necessary to assure that g_e is an increasing, convex function of g_x.[8]

A slight modification of the model allows for firm exit from the industry. Each firm can sell its assets and dissolve, or can exit from the industry and enter another if its present value from remaining in the industry (given by equation (2)) falls below some critical value. An analogous argument about the distribution function of capital that will be withdrawn from the industry if the shadow price of capital falls below a critical level preserves sufficient conditions for the conclusion that g_e is an increasing, convex function of g_x.[9]

The assumption of identical cost structure for all firms in the industry (1) is convenient for theoretical analysis, since P_K is then a common parameter for all firms. If the cost of adjustment functions differ between firms, it would be necessary to relate the individual adjustment costs to the disturbance generating a change in the industry's capital stock.[10]

The preceding analysis of the entry-industry growth relationship tacitly assumes a positive industry growth rate. If the industry is contracting, one still expects some new firm entry will occur, replacing some old firms that die or exit to other industries. This "turnover" entry is discussed in Hause (1962). To allow for its presence in the empirical analysis of section IV, we define two industry growth rate variables. X_1 is the instantaneous (employment) growth rate of the industry over a period if growth is positive, otherwise 0.[11] X_2 is the absolute value of the instantaneous growth rate of the industry over a period if growth is strictly negative, otherwise 0. These two growth variables are entered as explanatory variables in the regression equation for entry in the form $b_1 x_1^{a_1} + b_2 x_2^{a_2}$, where the a's and b's are parameters to be estimated. Our theory implies that entry is an increasing function of positive growth, and suggests that this function is convex. Hence we expect $b_1 > 0$ and the exponent $a_1 > 1$. We also expect $b_2 < 0$, since a high negative growth rate of the industry (i.e., industrial contraction) indicates low profitability and should discourage entry. We have no hypothesis about the exponent a_2 beyond $a_2 > 0$.

In our theoretical framework, entry rates may also be influenced by interindustry differences in the characteristics of the pool of potential entrants and/or in the implicit costs of entry (relative to the costs of expansion by old firms). We consider briefly several categories of such interindustry differences, how they would affect entry, and the variables used as empirical counterparts.

(1) The minimum size of plant required for efficient entry has been widely discussed. There are several reasons why major economies of scale are likely to retard entry. First, the number of potential entrepreneurs possessing the capital requirements presumably declines as the capital requirements increase, and the supply curve of capital to them is not perfectly elastic. This consideration is especially relevant for new-firm entry. Second, it is plausible that larger plants incorporate relatively more specialized capital resources, and therefore the pool of pre-existing resources that can be elastically transferred to such industries is smaller.[12]

The minimum efficient size of plant is also a relevant component of the well-known Modigliani-Sylos Labini limit price model, e.g., in Modigliani (1958). In this model, a limit price substantially above the competitive level can arise without attracting entry if economies of scale are so great that an efficient size plant is large relative to size of the industry. Studies of entry and industry profits frequently include an explanatory variable indicating the size of an efficient plant or firm relative to the industry, based on this line of argument.

In our empirical work, we include variables x_3 and x_4 as measures of the absolute and relative size of efficient new plants in an industry. The variable x_3 is the logarithm of the average size of new establishments built by new, diversifying, and old firms already established in the industry. Size is measured by employment at the end of the subperiod in which the establishment was built. However, an average is taken of the three subperiods of data, to reduce the sampling variation. This variable is intended as a crude proxy for the optimum size of new establishments. In previous studies, a number of unconvincing and extremely ad hoc proxies have been used e.g., average size of all firms or plants in the industry, or size of plant such that 50% of industry output comes from larger plants. Since entrepreneurs building new establishments have nontrivial incentives to build economically viable plants, our proxy has some appeal.[13] We expect this variable to be negatively correlated with entry. X_4 measures the size of an efficient new plant relative to 1968 industry employment. It is measured by the logarithm of the ratio of an efficient sized new plant (as defined in the preceding paragraph) to 1968 industry employment. Large values of this variable indicate that an industry is not large enough to contain many optimum size new plants. If Modigliani's argument is relevant for our data, one expects a negative relationship between entry and x_4.

(2) Our model of the entry-growth relationship is essentially competitive, and abstracts from strategic firm behavior when significant long-term monopoly power exists in the industry. Since monopoly power implies the ability to restrict industry output, the existence of long-term monopoly power will presumably be associated with less entry almost by definition. An unusual variable is available as an indicator of monopoly for this study. X_5 is a dummy variable with value 1 if the industry has a significant registered cartel agreement, otherwise 0. This classification of industries is reported in Carling (1968). With one exception these cartel agreements were made well before the

beginning of the sample period in 1954. Consequently we interpret this variable as an indicator of a durable noncompetitive element in the market, and expect it to be negatively associated with entry. The appropriate causal interpretation of this variable (or of any variable indicating monopoly power) is unclear. The presence of a durable cartel agreement might indicate deliberate cartel policies to retard entry. But it could also be a proxy indicating the presence of other unmeasured obstacles to entry, and these obstacles might be a necessary condition for the long term viability of the cartel.

Several other variables intended to capture the effects of technical change and product change on entry, and their empirical effects have been examined. These variables are not readily included in a theoretically satisfactory way, and it is difficult to obtain convincing proxy variables for them. They are discussed briefly in appendix C, and seem to yield reasonable results.

IV. ECONOMETRIC SPECIFICATION AND ESTIMATION OF NEW-FIRM ENTRY

The empirical analysis is restricted to a single equation reduced form. We discuss the specification of this equation, the data used in the analysis, and the results from estimating homoscedastic and heteroscedastic versions of the equation.

Entry is measured empirically by the ratio of employment in new firms at the end of a period to total industry employment at the beginning of the period, unless otherwise stated.[14] Our single equation regression model is:

$$y = b_0 + b_1 x_1^{a_1} + b_2 x_2^{a_2} + \sum_{i=3}^{5} b_i x_i + u. \tag{5}$$

In this equation, y is the vector of 117 observations from 39 manufacturing industries (most of the plastics, basic metals, and engineering industries in Sweden) for the three periods 1954-58, 1959-63, and 1964-68. The independent variables have been defined in the preceding section. They include positive industry growth rates of employment x_1, absolute value of negative industry growth rates of employment x_2, log of average employment of newly constructed plants (indicator of efficient size of new plants) x_3, log of ratio of x_3 to 1968 industry employment (indicator of relative size of efficient new plant) x_4, and a dummy variable for industries with significant cartel agreements (indicator of monopoly power) x_5.

The disturbance term, u, in equation (5) is assumed independently and normally distributed. Two alternative specifications are considered. In the first, the variance of u is assumed constant.

In the second, we adopt the model of multiplicative heteroscedasticity proposed by Harvey (1976). This model assumes the variance of each observation is:

$$\sigma_{ii}=\exp(\mathbf{z}_i'\mathbf{c}). \tag{6}$$

In (6), z_i is a vector of observed variables related to the ith observation, and $\mathbf{c}$ is a corresponding vector of parameters to be estimated. In cross sectional industry studies, outlying observations which greatly affect the least squares fitting are often observed. The residuals from these outliers are often so large that they make the distributional assumptions of independently and identically distributed normal errors untenable. Harvey's model is an appealing specification that assumes the intrinsic variability of the dependent variable is a function of observable characteristics of each observation. Furthermore, those characteristics associated with high variability may be of substantive economic interest. In this study, we consider for $\mathbf{z}$ a two-variable subset of the $\mathbf{x}$ variables that explain the mean part of the model. These variables include positive industry growth, x_1, and new-plant optimum size, x_3. Industries experiencing high growth rates are plausibly associated with stochastically noisier environments than those with low growth. Our entry measure has a lower bound of 0, and we expect the variance of entry will be positively correlated with its level. The optimum size of new plants should be negatively correlated with new firm entry, and so small values for x_3 are likely to be associated with both high entry and high variance. The specification of the variance in Harvey's model has some pitfalls for the unwary, and is discussed further in appendix C.

The results of the first two regression equations are reported in Table 2. They indicate that OLS and the Harvey heteroscedastic model yield qualitatively similar results, since variable parameters have identical signs in both regressions.[15] All regression coefficients have the theoretically expected signs. A positive industry growth rate (x_1) is associated with higher entry rates. A negative industry growth rate (x_2), an increase in the minimum efficient size of new establishments (x_3), and the existence of a significant registered cartel agreement (x_5) are all associated with a lower rate of entry. X_4 (minimum efficient size of new plant relative to industry employment) has the predicted negative sign, but it is trivial in size and statistical significance. Hence these data provide no support for the Modigliani-Sylos Labini model of relative plant size barriers to entry.

(Insert Table 2 about here.)

Both regressions (1) and (2) qualitatively support the hypothesis that entry is an increasing, convex function of the industry growth, since the point estimates of $b_1>0$ and the point estimates of the exponential parameter $a_1>1$. The asymptotic t-value for the null hypothesis that $a_1=1$ is 2.3 in the OLS regression (1), while the corresponding t-value in the heteroscedastic regression (2) is more modest, 1.22, just short of the 10% significance level for a one-tail test. Three comments should be made on these statistical results. First, the data strongly reject the OLS hypothesis of homoscedasticity and so statistical inference should be based on regression (2), not regression (1). This issue is discussed below. Second, the lower t-value for the null hypothesis $a_1=1$ in regression (2) is probably a consequence of using industry growth (x_1) as an explanatory variable of the heteroscedasticity in the Harvey model. Third, it is difficult to obtain a sharp test of the convexity of the entry function because of the extremely high sampling correlation (-.990) between the linear growth parameter b_1 and the exponential growth parameter a_1. This correlation is a consequence of trying to allocate the effect of x_1 on entry through two distinct parameters and is analogous to severe multicollinearity. Given this statistical problem, we consider that regression (2) provides reasonable, if modest support for the convexity hypothesis. The small t-value for b_1 also stems from this correlation, and does not imply that x_1 is a statistically insignificant explanatory variable.[16]

Although the signs of estimated parameters are identical in regressions (1) and (2), there are substantial discrepencies in both the magnitudes of some parameters and in their calculated t-values. The parameter estimates often differ by a factor of 1.5, The cartel dummy x_5 has a significant negative relationship with entry by conventional standards in the Harvey model, but not OLS, and the OLS t value for the exponential coefficient, a_1, exaggerates the statistical importance of this parameter. More extreme differences between OLS and Harvey parameter estimates and their calculated t-values are reported in Appendix C, where additional explanatory variables are included in the regression.

The data overwhelmingly reject the assumption of homoscedasticity, the hypothesis underlying the OLS calculation of regression (1). The log of the likelihood ratio of the restricted regression (1) to the unrestricted regression (2) times (-2) is 40. This statistic has a chi-square distribution with 2 degrees of freedom under the null hypothesis, and hence the null hypothesis is decisively rejected. This implies that the estimates, and statistical inferences based on the OLS regression

(1) are completely unacceptable.

The relationship between regressions (1) and (2) can best be understood by recalling that the mean part of the Harvey model is equivalent to a weighted regression. The weights are equal to the reciprocal of the estimated standard deviation for each observation, using the parameters obtained for the variance part of the model. The coefficient of variation of the weights is .62, and the ratio of the largest to smallest weight is about 24. These summary statistics on the weights indicate that the appropriate heteroscedastic weights depart substantially from the uniform weighting of OLS regression, and explain why these regressions differ. Closer inspection of regression (2) reveals that the signs of the parameters of each variable that appears in both the mean and variance part of the regression are the same. This implies that the variance of entry is positively correlated with the level of entry. The correlation of the weights with the expected value of the entry rate is -.68, while the correlation of the weights with actual entry is -.42. These large correlations confirm the anticipated effect of the Harvey model in reducing the importance of the high entry rate observations in the regression.

These results indicate that inference based on OLS with cross sectional industry data is hazardous, and can be extremely misleading, in the absence of a proper test of homoscedasticity. Failure to correct for severe heteroscedasticity can thoroughly vitiate the statistical results of an otherwise well-executed empirical study.

We therefore restrict further quantitative discussion of the parameter estimates to the Harvey regression (2). The size of the effect of optimum new plant size on entry implied by the parameter of x_3 is substantial. Since the log of this variable was used in the regression, the coefficient indicates that a doubling of the size leads to an expected reduction in the annual entry rate of about -1.3 percentage points. The t value for this coefficient is rather high, about 4. The presence of a strong cartel agreement (x_5) is associated with a reduction of the entry rate by .7%, an empirically modest amount, but statistically significant (5% level). The proper causal interpretation of this correlation is unclear. Do cartels make entry more difficult, or does the lack of entry facilitate cartels?

What happens if entry is measured by the ratio of new to initial numbers of firms instead of the ratio of new firm employment to initial industry employment? Regressions (4) and (5) are the counterparts of regressions (1) and (2) in Table II, using this alternative measure of entry. This entry measure behaves somewhat erratically, and has a larger coefficient of variation than the employee entry measure. Even so, there is qualitative similarity of these new regressions with (1) and (2). Homoscedasticity is again emphatically rejected, since (-2) times the log likelihood ratio has a value of 40, and the statistic is asymptotically chi-square with two degrees of freedom under the hypothesis of homoscedasticity. We therefore limit our discussion to a comparison of the heteroscedastic regressions (5) and (2).

All parameters in these two regressions have the same sign, except the trivially small and statisticantly insignificant coefficient of x_4. The magnitude of the convexity (exponential) parameter a_1 is about 25% smaller, but gives slightly more statistical support to the hypothesis that $a_1>1$. The statistical support for the significance of x_3 is much weaker, but the statistical significance of the negative association of cartel agreements and entry is much stronger. These differences are partially accounted for by the smaller effect that x_3 has in determining the heteroscedasticity in (5), which in turn alters the observation weights in determining the mean part of the regression. Although both definitions of entry lead to similar patterns of results, we have greater confidence in the former, based on employment of new firms.

In summary, these results certainly suggest responsiveness of new firm entrants to changes in costs and returns, which provides some evidence supporting belief in the importance of potential competition. There is strong statistical evidence that new firm entry is positively related to industry growth. There is more modest statistical support for the conclusion that entry is a convex function of growth in this sample.

The average size of new plants built in an industry seems to be a sensible indicator of the size of resource commitment required for entry. This variable has a strong negative association with new firm entry. There is also significant support for concluding that monopoly power (as indicated by cartel agreements) has a negative association with entry. The causal basis of this relationship is undetermined.

Finally, our statistical work indicates the great importance of examining cross section industry data for heteroscedasticity and taking it into account before attempting statistical inference (or estimation). Otherwise, one is likely to draw ill-founded conclusions. We have far more confidence in the results from Harvey's heteroscedastic model than from the OLS calculations. However, our experience suggests that Harvey's model is a delicate one, requiring careful specification. The development of more robust models for dealing with heteroscedasticity will be important for more reliable empirical conclusions.

Appendix

A. Dynamic Optimization by a Competitive Firm[17]

The firm's objective is maximization of the present value of its cash flow:

$$\int_t^{\infty}[PX(K,L,I) - WL - G\dot{I}]e^{-rs}ds. \qquad (1a)$$

The production function incorporates costs of adjustment of the capital stock as given by (3) in the main text, $X(K,L,I)=F(L,K)-KC(I/K)$. The firm has rational expectations about the product price P, and factor prices W and G. These prices may vary with time. The constraints are the firm's capital stock at t ($K(t)=K_t$), the gross and net investment identity ($\dot{K}=I-mK$, where m is the exogenous depreciation rate), and the boundary conditions ($K,L>0$). The firm chooses L(s) and I(s) ($t<s<\infty$) to maximize (1a). We adopt the Hamiltonian approach for solving this problem.

The current value Hamiltonian is

$$H(K,L) = P[F(K,L) - KC(I/K)] - WL - GI + \lambda[I - mK]. \qquad (2a)$$

Necessary conditions for a maximum include:

$$\partial H/\partial I = 0 \quad , \text{ so } [-PC' - G + \lambda] = 0, \qquad (i)$$

$$\partial H/\partial L = 0 \quad , \text{ so } [PF_L - W] = 0, \qquad (ii)$$

$$\dot{\lambda} = -\partial H/\partial K + r\lambda \; , \text{ so } \dot{\lambda} = (r+m)\lambda - P[F_K + C'/K - C] \qquad (iii)$$

$$\lim_{T\to\infty} \lambda(T)e^{-rT} = 0 \text{ (transversality condition with } \infty \text{ horizon)} \qquad (iv)$$

$$\dot{K} = I - mK \qquad (v)$$

The costate equation is

$$\dot{\lambda} - (r + m)\lambda = f(t) = -P[F_K + C' - C]$$
$$= -PX_K. \qquad (3a)$$

The formal solution to the costate equation is

$$d[\lambda e^{-(r+m)t}]/dt = f(t)e^{-(r+m)t} \qquad (4a)$$

Integrating (4a) from t to T, letting T approach ∞, and using the transversality condition (iv) yields

$$\lambda(t) = \int_t^\infty PX_K e^{-(r+m)(s-t)} ds$$

(5a)

$$= pC' + G \text{ (from the necessary marginal condition (i)).}$$

The last pair of equations and equation (ii) are the marginal conditions for the optimum cited in the text.

If one adopted the calculus of variations approach, and used K(s) as a control variable instead of I(s), one obtains the marginal condition

$$\int_t^\infty [PX_K - Gm] e^{-r(s-t)} ds = PC' + G. \qquad (6a)$$

Equations (5a) and (6a) look slightly different, but are both correct and make economic sense when one considers the difference between gross and net investment. But the interpretation of (5a) is perhaps more immediately obvious.

B. A Note on Correcting Heteroscedasticity with Harvey's Model

Harvey's (1976) modifies the standard normal linear regression model:

$$y_i = \mathbf{x}_i'\mathbf{b} + u_i \tag{7a}$$

by assuming that the variance of the ith disturbance, u_i, is given by

$$\sigma_{ii} = \exp(\mathbf{z}_i'\mathbf{c}). \tag{8a}$$

In these equations, $\mathbf{x}_i$ and $\mathbf{z}_i$ are mx1 and px1 vectors of observed variables for the ith observation, which may be identical, overlapping, or distinct sets of variables. The u's are independently, and normally distributed, with 0 mean. Additional properties of the model have been discussed by Breusch and Pagan (1979), Godfrey (1978), and Kao (1983). The model is appealing, since in many studies, it is plausible that economic agents are making choices in environments of differing variability (and risk). If so, the differing variability should be allowed for in the econometric model, for two reasons. First, efficient estimation and proper inference on the parameters in (7a) require heteroscedasticity to be taken into account. Second, the variables associated with more risky environments, and the size of their parameters in (8a) may be a matter of substantive interest. We describe briefly implementation of the model and a few potential pitfalls in its use, since we have not seen it applied before.

First order equations are readily derived for maximum likelihood estimation. The equations for the **b** parameters of the mean part of the model are the usual weighted least squares equations, with weights given by the reciprocal of the standard deviation from (8a). The equations for the **c** parameters of the variance part of the model are nonlinear, and essentially say that the weighted sum of the deviations of the ratio of the squared residual to the variance for each observation is equal to 0. Kao (1983) argues that the MLE has higher second-order asymptotic efficiency than other estimates, and provides Monte Carlo evidence on the superiority of the MLE for moderate sized samples. The estimates in this study are MLE, using the Goldfeld and Quandt nonlinear optimization program. The best strategy for estimating the model is unresolved, since Carroll and Ruppert (1982) present some theoretical and Monte Carlo evidence that the MLE estimate in a heteroscedastic model is sensitive to the distributional assumption of normality and to small errors in specification of the functional form for the variances. They find that robust weighted estimators they proposed in another paper were less sensitive to the variance specification than MLE.

Under fairly weak assumptions, a solution to the first-order likelihood equations exists. But uniqueness of this solution is not assured. Thus, it is desirable to begin iteration of the likelihood equations from a consistent starting value. A consistent estimate of **b** is obviously obtained from OLS estimation of (7a). A consistent estimate of **c** (except for the constant term) is obtained by running an OLS regression of the logarithm of the squared residual from the previous regression on the linear function **c**'z.

The information matrix is calculated from the second derivative of the log likelihood function, and the asymptotic covariance matrix for the parameter estimates is obtained from its inverse. The results are in Harvey (1976). The information matrix (and thus the asymptotic covariance matrix) is block diagonal, since the true covariances between the **b** and **c** parameters are 0. Hence, we use 0 covariances for these elements of the information matrix instead of the values calculated by the Goldfeld-Quandt program. It would probably be desirable to calculate and report the Goldfeld-Quandt values as a descriptive statistic, to verify whether the Harvey assumptions are consistent with the data.

It turns out that the covariance matrix for the **b** parameters is the usual weighted least squares result, with weights equal to the reciprocals of the standard deviations obtained from (8a). The covariance matrix for the **c** parameters is twice the inverse of the (**zz'**) matrix.

One defect of Harvey's model is that it assumes the specification of the individual variances in (8a) is exactly correct. In OLS, we assume that the residual subsumes misspecification, and the size of the variance is another parameter to be estimated. There is no room in Harvey's model for a scale parameter in the variance part of the model (8a), to allow for similar misspecification. This defect may be a significant issue when inference on specific parameters of **c** is substantively important. We are unaware of any comment on this problem in the published literature on Harvey's model.

There is a pitfall in using Harvey's model analogous to a problem that arises when severely heteroscedastic data are uncorrected in an OLS regression analysis. With small or moderate size samples, the parameter estimates and their standard errors, can be unduly influenced by a few extreme observations, with very large residuals. With heteroscedasticity, the residuals of certain observations may be close to 0 for two reasons. A small residual can occur by chance, or because it belongs to an observation class with intrinsically small variance.

Very small residuals will tend to have a large effect in estimating c, especially in modest size samples. In turn, the estimated variance of such an observation, from (8a) may be very small. Since the weights in the regression for estimating b in Harvey's model are $(1/\ \sigma_{ii})^{1/2}$, the use of Harvey's model may again yield estimates of b unduly influenced by a few observations, this time, by those with small residuals.

In our original calculations, we included the variable x_2 (negative industry growth rates) as a z covariate in the variance part of the model. This variable is strongly associated with industries with 0 or very low entry rates. Its inclusion yields an absurdly large asymptotic t-value (-16!) for its c parameter in the variance part of the model, and an implausibly large asymptotic t-value (-7.3) for its b parameter in the mean part of the model. These extremely large t-values are a diagnostic hint of the exceptionally large weight given to industries with large, negative growth rates.

Given the possible influence of "outliers" in the weights from Harvey model estimates, wild results may be obtained if attention is not paid to the distribution of the estimated weights $(1/\ \sigma_{ii})^{1/2}$. We recommend routine reporting of the largest, smallest, mean weight, and the standard deviation of the weights. This enables the reader to assess the adequacy of the model.

Despite this potential delicacy of the Harvey model, we believe it can be a major improvement over OLS calculations with no test for heteroscedasticity. The likelihood ratio test for comparing the homoscedastic and heteroscedastic alternatives decisively rejects homoscedasticity in this study, and we find large differences in the estimates of the **b** (mean) parameters and their nominal statistical significance. It seems likely that heteroscedasticity will be a serious problem in many cross-sectional industry studies. Failure to recognize the problem or to take it appropriately into account leaves all statistical estimates and hypothesis testing at serious risk.

C. The Relationship between Entry, Technological, and Product Change

This appendix discusses three more categories of variables plausibly related to entry, and the statistical results of entering them in the reduced form entry equation (5) in the main text. The results are tentative, since these variables have not been built into the model in a theoretically satisfactory way, and because adequate empirical proxies for these variables are not readily obtained. But economists have speculated about entry and technological change, and these preliminary findings may be of interest.

(1) The relationship between entry and technological change seems ambiguous without further specification. Adoption of the new technology will presumably be associated with higher rates of gross investment and therefore, with higher adjustment costs. This factor should facilitate entry. But if the technological change is largely endogenous, e.g., because of large research and development expenditures in the industry, potential entrants may be at an informational disadvantage, at least, in the short run.

Lacking a good measure of R and D expenditures, we use x_6, the logarithm of the ratio of technical employees to all employees (as measured in 1959), as a proxy for "endogenous technical change," With this interpretation, we expect it to be negatively correlated with entry. A good measure of "exogenous technical change" is even more elusive, and it is represented by x_7, the annual rate of change of labor productivity, as measured by the difference in the log of value added per employee in 1968 and 1954, divided by 14 years. Since we assume existing firms in the industry have no informational advantage over potential entrants for the technological change reflected in this variable, we expect the higher adjustment cost from greater gross investment by the insiders will induce a positive correlation of entry and x_7.

(2) An exogenous change (relative to the industry) in the mix of demands for an industry's products is likely to have a positive correlation with entry. This is a consequence of the higher adjustment costs to firms in the industry because of the higher level of gross investment required to meet this changed pattern of demand. Furthermore, customer experience and rational brand loyality to old firms is likely to be less for new than for old products. The proxy variable for this industry characteristic is x_8, an index of the importance of "new" commodities in the output mix of an industry. "New" commodities are defined empirically by those goods with Brussels commodity code numbers assigned after 1946, or goods that were assigned under old numbers, but are regarded as essentially new goods since 1946. The index is calculated by the change in total sales of "new" commodities between 1954 and 1968 (price adjusted to 1954) divided by total industry sales in 1968. With our interpretation of this variable, it should be positively associated with entry.

(3) If there are scale diseconomies to growth for very large firms in an industry, they will presumably generate greater opportunities for entry if there is an exogenous increase in demand. The proxy used to

represent such diseconomies is x_9, the difference between the annual growth rate of the largest firms in the industry (as of 1954) and all firms in the industry, averaged over the three subperiods. The "largest" firms include only enough firms to account for at least 25 per cent of industry employment. Systematically lower growth rates by the largest firms may reflect adjustment costs that increase more than proportionally with firm size, for any given growth rate. If such "diseconomies to growth" exist, they should give greater opportunity for entry. Hence x_9 and entry would have a negative association.

Regressions (1a), (2a), (4a), and (5a) in Table 1a include these additional explanatory variables as well as the ones used in the main text, and may be contrasted with the corresponding regressions in Table 2. The first two regressions measure entry by number of employees, while the last two measure entry by number of new firms. Regressions (1a) and (4a) are OLS, while (2a) and (5a) are the Harvey model. The variables used to explain the heteroscedastic part of the Harvey model include x_1 (positive industry growth and x_3 (new-plant minimum optimum size) which were also used in the main text models in Table 2. From the set of new variables, the two technical change variables, x_6 and x_7, and the new products variable, x_8, were added as determinants of the heteroscedasticity. These new variables were included in the heteroscedastic part because they are plausibly associated with stochastically noisier industry environments.

(Insert Table 1a about here)

Once again, the likelihood ratio test strongly supports the conclusion that the data are heteroscedastic, so the Harvey regressions are more relevant for parameter estimates and inference. Comparison of the Harvey and OLS regressions, (2a) and (1a) indicates larger discrepencies in the parameter point estimates and in the parameter t-values then observed in Table 2 in the main text. This may due in part to the fact that the coefficient of variation of the weights and the ratio of the largest to smallest weight are .7 and 42, respectively. Thus the weights are considerably less equal for computing the Harvey model b-parameters for the mean in regression (2a), Table 1a, than in regression (2), Table 2.

The parameters of the two technological change variables, x_6 and x_7, and the new product variable, x_8 all have the predicted signs, and are significant at conventional levels in regression (2a). The scale diseconomies of growth parameter, x_9, has the wrong sign in (2a).

A comparison of parameter estimates for those variables appearing in the original regression (2) and the expanded regression equation (2a) shows that they have the same signs except for the statistical trivial parameter on x_4. The cartel dummy parameter on x_5 is statistically insignificant in the expanded regression. The magnitude of the exponential parameter on x_1 is about 30% smaller, and has a somewhat lower t-value in (2a).

Regression (3) in Table 1a tests the adequacy of the additive form assumed for the regression model. It seems plausible that for any positive industry growth rate, x_1, the slope of the entry function, dy/dx_1 will be greater in industries that are easy to enter. For example, if the pool of potential new firm entrants because of high capital costs of building an efficient size plant, a modest increase in profitability of the industry due to growth in industry demand will not draw many new firms into the industry, and most expansion will come from established firms. Yet the additive specification in equation (5) denies this possibility. To test this conjecture, define "ease of entry" to an industry by the entry predicted by the regression equation when the industry growth rate is 0. Define a dummy variable d, which takes the value of 1 for half of the observations in the sample for which the "ease of entry" is largest, using the parameter estimates for regression (2a). Otherwise, let d=0. Then define variable x_{10} to be the product of d and x_1, raised to the same power as x_1. Our conjecture is that x_{10} should have a positive multiplicative parameter if it is included in the regression. The t value of the coefficient of x_{10} supports this conjecture. We conclude that for our sample, high ease of entry has a positive interaction with the industry growth rate in affecting entry.

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FOOTNOTES

*Hause's work on this study has received support at various stages from the Industriens Utredningsinstitut, from a visiting fellowship at the Hoover Institution, and from NSF Grant SES-7927217. He is indebted to G. J. Stigler for initial interest in this topic, to Ken Hendricks, and to an unknown referee for constructive comments. H. C. Yeh carried out most of the calculations reported in part IV of the study. Only the authors are liable for the analysis and conclusions which follow.

[1]"When by an increase in the effectual demand, the market price of some particular commodity happens to rise a good deal above the natural price, those who employ their stocks in supplying that market are generally careful to conceal this change. If it was commonly known, their great profit would tempt so many new rivals to employ their stocks in the same way, that, the effectual demand being fully supplied, the market price would soon be reduced to the natural price, and perhaps for some time even below it. If the market is at a great distance from the residence of those who supply it, they may sometimes be able to keep the secret for several years together, and may so long enjoy their extraordinary profits without any new rivals. Secrets of this kind, however, it must be acknowledged, can seldom be long kept; and the extraordinary profit can last very little longer than they are kept." (Adam Smith, The Wealth of Nations, page 60.)

[2]See Stigler (1968) for several interesting comments on potential competition.

[3]Previous cross-sectional studies of entry include Duetsch (1975), Du Rietz (1975, 1980), Gorecki (1975), Hause (1962), Mansfield (1962), McGuckin (1972), Orr (1974), Wedervang (1964). This study is a major refinement and extension of work reported in Du Rietz (1975, 1980).

[4]The entry data are from establishment statistics. Each establishment is assigned to one industry even for multi-product establishments. Data were also collected on entry when an establishment (or entire firm) is reclassified into a new industry, but are not analyzed in this paper. Such "entry" is small relative to new firm and diversification entry, and contains large measurement errors. See Du Rietz (1975, 1980) for further information.

[5]The large literature on adjustment costs of firm growth (see, e.g., Holt, Modigliani, Muth, Simon ((1960) and Gould (1968)) generally assumes that the marginal adjustment cost is an increasing function of gross or net investment. See Rothschild (1971) and Nickell (1978, pp. 35-40, 256-71) for a more critical view. None of the published literature appears to consider the convexity or concavity of the marginal adjustment function.

[6]Strictly speaking, the production function in (1) doesn't really capture investment processes that go on for more than one time period before the new capacity is completed and able to deliver output.

[7]This conjecture stems from the following intuitive line of argument. We expect a positive correlation between P_K and the transitory profits required to offset the fixed entry cost, Z_i, of the ith potential entrant. The Z_i's reflect the learning costs and quasi-rents of specialized resources owned by the potential entrant. Historical episodes of exploration for gold and oil, and wartime expansion of output by entrants illustrate the volume of resources that entrants will bring into an industry when transitory profits are high. But we doubt whether the shadow price of capital in a well-defined industry ever becomes so high that most entrepreneurs in the economy seriously contemplate entry. We expect that the mode occurs at a shadow price of

capital substantially above the usual range of values taken on by this shadow price.

[8]A formal proof that g_e is an increasing convex function of g_x is straightforward, given the assumed properties of $j_o(g_o)$ $[j_o'>0; j_o''>0]$ and of $j_e(g_e)$ $[j_e'>0; j_e''<0]$. By the implicit function theorem, the inverse functions $g_o=h_o(P_K)$ and $g_e=h_e(P_K)$ exist and have derivatives satisfying the conditions $h_o'>0$; $h_o''<0$; $h_e'>0$; and $h_e''>0$. Since $g_x=g_o+g_e$ is an identity (given the assumption of no firm exit), we obtain the identity $g_x=h_x(P_K)=h_o(P_K)+h_e(P_K)$, with $h_x'>0$. Using the chain rule, we obtain:

(a) $dg_e/dg_x=h_e'/h_x'>0$, and

(b) $d^2g_e/dg_x^2=(h_o'h_e''-h_e'h_o'')/(h_x')^3>0$.

Thus g_e is an increasing convex function of g_x.

[9]The extension allowing for exit assumes a density function of capital (P_K) that will be withdrawn by exiting firms, depending on their opportunity cost of remaining in the industry. Then the (negative) component of the industry growth rate due to exit is $g_d=\int_{P_K}^{\infty}\rho(x)dx$. If P_K is always greater than location of the mode of this density function, it follows that the function $g_d=h_d(P_K)$ is a decreasing convex function, i.e., $h_d'<0$ and $h_d''>0$. The assumptions on $h_o(P_K)$ and $h_e(P_K)$ are in footnote 8. We have the identity $g_x=g_o+g_e-g_d=h_x(P_K)$, with $h_x'>0$. By the chain rule,

(a) $dg_e/dg_x=h_e'/(h_o'+h_e'-h_d')>0$, and

(b) $d^2g_e/dg_x^2=[(h_o'-h_d')h_e''-h_e'(h_o''-h_d'')]/(h_x')^3>0$.

Hence g_e is still an increasing convex function of g_x under our assumptions even when exit is taken into account. By a similar argument, it can be shown that g_d is a decreasing function of g_x, but its convexity or concavity is undetermined without further assumptions.

[10]Another limitation of the model is its partial equilibrium structure. What is the nature of the pool of potential entrants and their resources? If the shadow price of capital is high enough to produce rapid growth over a number of periods, should one expect a change in the relative shares of internal expansion and entry? It is difficult to pursue these questions without additional empirical evidence on appropriate restrictions that should be imposed.

[11]Let m_s and m_t denote industry employment at times s and t. The variable $x_1=(\log(m_t/m_s))/(t-s)$ if positive, otherwise 0.

[12]There is another explanation why x_3 may be negatively correlated with entry. Hause (1962) argued that the expected life of small, but established firms is shorter than the expected life of large firms. Hence entry may be high in industries where average firm size is small because of turnover of small firms. Since average firm size is probably positively correlated with the minimum optimal entry size, the conclusion follows.

[13]Let A_n, A_d, and A_o be the average size of new establishments built by new firms, diversifying firms, and old firms already established in the industry. For industries where the comparisons can be made, $A_n<A_d$ 23 out of 24 times, and $A_n<A_o$ 30 out of 31 times. But $A_d<A_o$ only 13 out of 22 times.

These findings provide strong evidence that new firm establishments are relatively small. But the comparison of A_d and A_o provides much less evidence of a capital constraint for diversifying firms relative to old firms already in the industry for the construction of new plants.

The following means and standard deviations of the log ratios of these average sizes across industries provides further evidence.

	Mean	Standard Deviation
$\log(A_d/A_n)$	1.20	.71
$\log(A_o/A_n)$	1.48	.88
$\log(A_o/A_d)$	.29	1.04

A rather ingenious way of measuring minimum optimum size, based on multiple establishment data of old firms in the industry was recently proposed by Lyons (1980). This suggestion was discovered too late for consideration in this study.

[14]Input (employment) measures of entry and of the industry growth rate are used, since they reduce the statistical noise from absolute and relative price changes that would occur if nominal output measures, such as sales or value added, were used. Most empirical studies of entry have measured entry by the ratio of new to old firms, except for Hause (1962) and Du Rietz (1975,1980). We prefer our measure as an indicator of the direct quantitative importance of entry, since new firms are on average very much smaller than existing firms.

[15]This similarity of parameter signs for the two regressions is not surprising. The mean part of Harvey's regression model is equivalent to a weighted least squares regression with weights $(1/\sigma_{ii})^{1/2}$,

obtained by using the variance parameter estimates from Harvey's model. Unless the weights are very different, the coefficients obtained by OLS and weighted least squares usually have the same sign.

[16]Regression (3) reports the results if the growth rates are entered linearly. Since no exponential parameter competes with the linear parameter b_1 for transmitting the effect of x_1 on the entry rate, the parameter b_1 is statistically significant in this regression.

Allowing for convexity improves the overall regression fit very little. The log of the likelihood ratio of regressions (3) and (2) times 2 is 1.64, which is asymptotically distributed chi-square with 1 d.f. Hence the hypothesis of a linear relationship of growth on entry is rejected at the 22% level. However the relevant hypothesis is if $a_1 > 1$, not the two-tail test whether $a_1 \neq 1$. Hence, the relevant significance level is about 11%. This result is very close to our direct test of $a_1 > 1$ by its asymptotic t value in regression (2).

[17] Ken Hendricks kindly supplied the details of the following analysis, including the distinction between the Hamiltonian and calculus of variations formulations of the problem.

TABLE 1

Direct Impact of Entry on 39 Swedish Manufacturing Industries

Industry		Entry as % of Total 1968 Employment New Firm	Diversification	Total Employ.
351310	Basic Plastics	3.7	1.5	1892
351320	Semimanufactured Plastic Goods	7.8	20.7	5164
356000	Manufactured Plastic Goods	21.0	9.3	8052
371010	Iron and Steel Mills	0	.3	42000
371030	Iron and Steel Foundaries	1.5	1.4	4733
372030	Nonferrous Metals	2.3	0	7783
372040	Nonferrous Foundaries	6.4	1.6	1969
381100	Cutlery, Hand Tools, and Hardware	12.3	1.2	6756
381200	Metal Furniture	15.1	.8	4139
381300	Structural Metal Products	24.1	3.7	20095
381910	Metal Containers	19.3	2.3	2839
381920	Wire Cloth, Wire, and Cable	1.6	4.0	4675
381930	Nails, Bolts, and Nuts	1.1	2.3	4652
381940	Other Metal Prod. for Construction	3.4	3.7	11486
381950	Household Metalware	3.3	0	4212
381990	Other Metal Products	15.4	2.9	18818
382200	Agricultural Mach. and Equipment	4.1	1.3	8585
382310	Metalworking Machinery	2.6	1.3	7577
382320	Woodworking Machinery	2.7	0	2333
382410	Pulp and Paper Mill Mach.	6.7	0	2955
382420	Construction and Mining Mach.	6.5	0	6369
382490	Industrial Mach. N.E.C.	9.7	.5	13412
382590	Other Office and Accounting Mach.	3.0	5.2	10673
382991	Lifting and Hoisting Mach.	6.1	5.2	11344
382992	Liquid Pump Manufacturing	8.5	0	3329
382993	General Purpose Machine Parts	1.1	.9	9182
382999	Other Machinery and Equipment	4.1	1.0	26073
383100	Electrical Indus. Mach. & Apparat.	2.5	.1	15160
383200	Radio, TV, and Commun. Equip. & Appar.	1.3	.3	28230
283300	Electrical Appliances and Housewares	4.3	.02	11535
383910	Insulated Wires and Cables	3.9	0	4102
383920	Storage Batteries & Accumulators	.2	5.4	2296
383930	Light Bulb and Flourescent Lamps	2.9	0	1621
383990	Other Electrical Equipment	11.4	1.6	5114
384110	Ship Building and Repairing	.6	0	25833
384120	Boat Building and Repairing	26.0	4.7	1834
384310	Motor Vehicles and Chassis	.4	0	15250
384320	Motor Vehicle Engines, Prts, Trailers	7.1	1.3	19676
384400	Motorcycles and Bicycles	1.3	0	1462
TOTAL		5.8	1.7	383210

TABLE 2

OLS and Harvey Regression Parameter Estimates for New Firm Entry

Independent Variable Coefficients[a]

NUMBER	X_0	X_1 linear	X_1 exp	X_2 linear	X_2 exp	X_3	X_4	X_5	R^2	logL
1. OLS	7.83	.055	2.18	-1.07	.440	-1.81	-.0165	-.683	.46	-176
Mean	(2.6)	(.060)	(.46)	(.76)	(.36)	(.43)	(.31)	(.67)		
2. HRVY	6.33	.00300	3.13	-.69	.50[b]	-1.32	-.0228	-.702	.33	-156
Mean	(1.5)	(.011)	(1.7)	(.27)		(.23)	(.19)	(.40)		
Var	6.46	.261				-1.68				
	(.67)	(.050)				(.20)				
3. HRVY	6.04	.201		-.216		-1.33	-.0221	-.731		-157
Mean	(1.5)	(.11)		(.10)		(.26)	(.19)	(.41)		
Var	6.46	.261				-1.68				
	(1.2)	(.053)				(.36)				
4. OLS	12.4	.513	1.55	-1.70	.383	-1.47	-.0581	-3.83	.24	-322
Mean	(9.3)	(.77)	(.64)	(3.1)	(.87)	(1.6)	(1.1)	(2.4)		
5. HRVY	13.7	.0729	2.47	-2.19	.380[b]	-1.36	.0151	-4.76		-302
Mean	(1.9)	(.17)	(1.1)	(1.1)		(1.0)	(.73)	(1.5)		
Var	6.03	.304				-.821				
	(.67)	(.050)				(.20)				

Note__ The R^2 for the Harvey model in regression 2 is for weighted least squares regressions, with weights obtained from the variance estimate from the model. The column "logL" is the log likelihood.

Numbers in ( ) are asymptotic standard errors.

[a]The independent variables are: x_0=1 (for constant term);x_1=positive growth rate of industry; x_2=negative growth rate of industry (absolute value); x_3=proxy for optimum size of new plants (log of average size of new establishments);x_4= ratio of "optimum size new plant" to industry employment;and x_5= dummy variable for significant registered cartel agreement. Linear and exponential parameters are shown for x_1 and x_2. The dependent variable in regressions 1-3 is new firm entry rate measured by employment, in 4-5 it is measured by numbers of firms.

[b]This exponent was treated as a fixed constant in the regression because of difficulty in obtaining convergence.

TABLE 1a
OLS and Harvey Regression Parameter Estimates for New Firm Entry

Independent Variable Coefficients[a]

NUMBER	X_0	X_1 linear	X_1 exp	X_2 linear	X_2 exp	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	R^2	logL
1a OLS	4.19	.0470	2.17	-.456	.772	-2.70	-.581	-.557	-2.86	.277	.00307	.0308		.65	-150
Mean	(2.3)	(.049)	(.43)	(.50)	(.48)	(.67)	(.41)	(.27)	(.40)	(.073)	(.010)	(.14)			
2a HRVY	6.20	.0182	2.22	-.246	.846[b]	-1.180	.100	-.227	-.588	.102	.0129	.129		.40	-127
Mean	(1.1)	(.046)	(1.3)	(.11)		(.23)	(.13)	(.47)	(.33)	(.040)	(.0054)	(.083)			
Var	3.12	.383				-.765			-1.21	.246	-.00839				
	(.75)	(.056)				(.22)			(.22)	(.046)	(.0054)				
3a HRVY		.00642	2.46										.0213		
Mean		(.031)	(2.4)										(.010)		
				*	*	*	*	*	*	*					
4a OLS	11.9	.543	1.44	-1.45	.407	-2.64	-.153	-2.03	.138	.256	.0987	.514		.30	-316
Mean	(9.8)	(.94)	(.72)	(3.2)	(1.0)	(1.8)	(1.2)	(2.9)	(1.7)	(.32)	(.044)	(.61)			
5a HRVY	17.4	.0924	2.30	-1.03	.569[c]	-2.02	-.0555	-5.61	-1.73	.0839	.0260	.528		.36	-266
Mean	(4.0)	(.12)	(.58)	(.51)		(.88)	(.51)	(1.1)	(.86)	(.14)	(.032)	(.27)			
Var	5.57	.126				-1.33			1.01	-.0923	.0377				
	(.75)	(.056)				(.22)			(.22)	(.046)	(.0054)				

Note__ The R^2 for the Harvey model in regressions 2a and 5a is for weighted least squares regressions, with weights obtained from the variance estimate from the model. The column "logL" is the log likelihood.

Numbers in ( ) are asymptotic standard errors.

[a]The independent variables are: $x_0=1$ (for constant term); x_1=positive growth rate of industry; x_2=negative growth rate of industry (absolute value); x_3=proxy for optimum size of new plants (log of average size of new establishments); x_4= ratio of "optimum size new plant" to industry employment; x_5= dummy variable for significant registered cartel agreement; x_6= proxy for endogeneous technical change (log of ratio of technical employees to all employees; x_7= annual rate of change of labor productivity; x_8= proxy for exogeneous demand change (index of increase in importance of new commodities); x_9= proxy for diseconomies of scale of adjustment costs (measured by difference in growth rates of largest firms and all permanent firms; x_{10}= industry growth rate for half sample of industries with lowest impediments to entry. Linear and exponential parameters are shown for x_1 and x_2. The dependent variable in regressions 1-3 is new firm entry rate measured by employment, in 4-5 it is measured by numbers of firms.

[b]This exponent was treated as a fixed constant in the regression because of difficulty inobtaining convergence.

[c]This exponent is the converged value for regression 5.

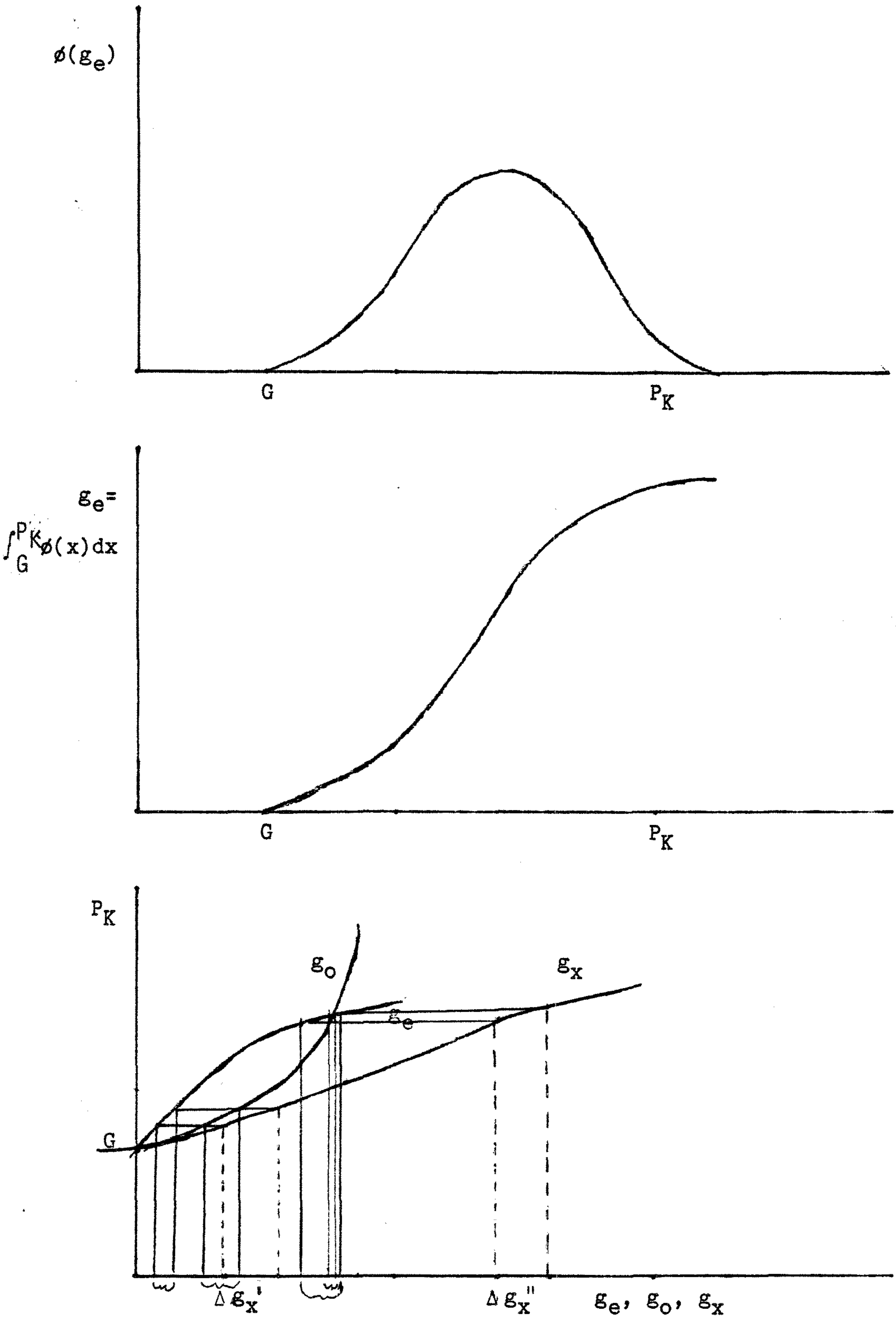

FIG 1—Density Function of Entry; Entry Function; and Old Firm Growth as Functions of P_K (Shadow Price of Capital)

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