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One of the most studied organizational innovations has been the introduction of the divisional form. In a remarkable history, Chandler (1962) chronicled the impact of organizational change at Du Pont, and the imitation of its innovative divisional structure by other firms. Subsequent histories for other countries have shown that the divisional form arose indigenously in Germany, France and even Japan.[1] Yet, even if the initial innovation was often indigenous, the historical record indicates that the process of diffusion was influenced by the imitation of leading corporate models.

Chandler is emphatic that the adoption of the divisional form was motivated by reasons of profitability, even if the adoption process was influenced by imitation. Given the importance of these organizational innovations, it is surprising that recent studies have found that the diffusion of the multidivisional structure appears to be random, or poorly explained by imitation effects. Mahajan *et al.* (1988) estimated a random-walk specification of the diffusion of the multidivisional structure among 127 firms in Rumelt's (1974) sample and concluded the adoption was influenced by neither imitation, nor innovation effects. Venkatraman *et al.* (1994) replicated this analysis under an altered specification to joint ventures, as well as to the divisional structure. Using a non-linear specification, they rejected the random-walk model for the diffusion of the divisional structure, finding that unspecified external influences mattered; there was no imitation effect.

These results are counter-intuitive and are contrary to the findings on technological innovations, on adoption of new practices in the institutional sociology literature, and to the history put forth by Chandler. The divisional structure, it stands to reason, should be appropriate for diversified firms who have reached a particular size threshold; size and diversification should generate systematic patterns in adoption. Imitation effects should feed partly through industry competitive dynamics, i.e. firms should be more likely to imitate competitors than a firm randomly selected from the general population.

Studies of the adoption of new technologies have routinely found that diffusion can be explained by expected profitability, position in a communication network, and the capabilities of firms.[2] The economic debate has often been focused on the relative importance of market pull (i.e. profitability) and technological push (i.e. the research competence of the firm).[3] Randomness in adoption, or in technological expenditure, has largely

[1] See Kocka's (1969) history of Siemens, Levy-Leboyer's (1980) short comment on St Gobain and the qualifying commentary of Daviet (1989), and Fruin's (1993) description of Matsushita.

[2] The classic text on technological adoption is Rogers (1983), who reduces the broad literature to a few factors regarding the economic value and ease of communication and use of the innovation .

[3] The technological adoption literature, and the distinction between push and pull, is concisely summarized by Mowery and Rosenberg (1979).

been ignored, because the importance and significance of explanatory variables have been found to be persuasive.

Nevertheless, a number of studies belonging to the 'new institutionalism' in organizational theory have questioned the economic motivations behind the adoption of the multidivisional structure. Fligstein (1985, 1990) has argued that the adoption of the divisional structure is determined by the prevailing conception of control in a society and the power of top management. Other studies (e.g. Palmer *et al.*, 1993) have pointed to the influence of legitimation on adoption, namely that an innovation diffuses because others have adopted it, not because it is profitable to the adopter. In all, these studies leave ambiguous an important claim in the institutional sociology literature, namely that adoptions are determined by efficiency early in the process and by imitation later on (see e.g. Meyer and Rowan, 1977; Tolbert and Zucker, 1983; Baron *et al.*, 1986).

It is somewhat jarring that Chandler's detailed historical study has received such short shrift in the marketing and organizational sociology literatures. In the following study, we show that many of these differences arise largely through a misreading of Chandler's history. While Chandler clearly viewed the multidivisional structure as a Schumpeterian radical innovation that increased the efficiency of firms, he also described, *sotto vocce*, the process of diffusion as governed by the industrial proximity of other large firms to the innovating firm. However, the conjoint influence of the propensity of large firms with diversified business to adopt the structure and the competitive incentive to imitate neighboring firms has not been studied statistically for the chronological period corresponding to Chandler's history.

To address these issues of imitation and propensity, we analyze the hazard of adopting the divisional structure for a sample of 62 firms during the period 1917–1980. We shift the analysis from diffusion in a population to the likelihood that a firm, given a set of time-varying characteristics such as size, will adopt the divisional structure. We use these estimates to partition the sample into two groups of high- and low-risk adopters. (Risk is used here in the sense of the likelihood of adopting.) Applying an inverse Gaussian hazard specification, we estimate the means to a random-walk process for the two samples. The results indicate significant differences in the means of the random processes. Adoption rates are clearly predicted by firm characteristics, leading us to reject the Mahajan *et al.* findings. Moreover, imitation as measured by the cumulative adopters in the industry have the most significant effect, contrary to the Venkatraman *et al.* results. These findings are confirmed even when the observation period is re-examined for the shorter period used in the Mahajan *et al.* study. However, while the results are also contrary to the legitimacy view of the new institutionalists, they also do not confirm Chandler's emphasis on diversification as a driver of adoption during the early history of diffusion.[4]

2. *Organizational Innovations*

Because the history by Chandler preceded the statistical work on the adoption of multidivisional structure, it is important to establish why some might believe that adoption decisions are random and, at the same time, what Chandler claimed about the history of these decisions. Abstractly, organizational innovations might be expected to be random due to two considerations. The first is that they may be less observable and harder to codify than technological innovations. Consequently, managers are less certain that a decision to adopt will succeed. Second, since new ways of organizing change the assignment of authority and compensation, managers and workers may exercise individual or collective power to impede adoption of innovations. Whereas such resistance has been historically also important in regard to new technologies, it is arguably the case that technologies, when they do upset the organization of rank and skill, are viewed more neutrally.

There is evidence that such considerations influence the adoption rates of the divisional structure. Teece (1980) estimated a Mansfield diffusion model, and found that speed of diffusion was significantly slower for the adoption of the divisional structure than for the adoption of new technologies. The difficulty of observing and implementing the divisional structure might be linked to the mixed findings on its profitability. Though published US studies show that adopting the divisional structure increases the profits of early adopters, the results for other countries are largely negative.[5] Moreover, in a study of the adoption of the multidivisional structure in the largest 200 firms, Bhargava (1973) found that 49% of the adoptions were crisis induced. Crises are required to break impediments posed by powerful groups to divisionalization.

The historical accounts often point to the difficulty of adoption. For the first pioneers, there were no blueprints. In 1920, Alfred Sloan at General Motors

[4] Chandler (personal communication) views diversification, whether product or geography, as an indication of complexity; the divisional structure is a solution to manage this complexity. In this paper, we focus only on product diversification.

[5] See Armour and Teece (1978) for the results on early versus late adopters. Mahajan *et al.* (1988) provide a concise review of the overall findings. Even the UK study of Steer and Cable (1978) that found a profitable relationship did not examine directly the divisional structure, but looked at relationship between firms that were coded 'optimal' and 'non-optimal' and profitability. Of course, part of the explanation for the non-American results may be institutional differences among countries.

(GM) relied largely on his own experiences in the company, even though the Du Pont Corporation, which held control in GM, was undergoing similar change. Chandler (1962, pp. 132–133) writes:

> Nor could Sloan have received early in 1920 much help outside of the corporation. the Du Pont executives, for example, could have provided little meaningful advice. . . . Any books, and probably any expert, on management would have advocated the same type of functionally departmentalized structure. . . . For this reason, General Motor's own experience was probably the most valuable source of ideas for Sloan.

Moreover, attempts to reorganize often faced considerable internal opposition. Of Standard Oil Company of New Jersey, Chandler (1962, p. 200) describes the clash between the innovators around Walter Teagle, the President, and the powerful old guard in production:

> Teagle and the Board were less likely to change top personnel in the Manufacturing than in the Marketing Department, because the senior refining executives had long held positions of responsibility. The entrenched and powerful Manufacturing Committee could not be summarily dismissed or reshaped without either depriving the company of able men or causing a breakdown in morale. This was particularly true because, in this oldest of the Jersey departments, length of service was of greater importance for prestige and promotion than in the rest of the Company. . . . The older refiners . . . were not only skeptical of the new scientific ways but they also resented the placing of outsiders to senior positions.

For the early innovators, the knowledge of how to organize the new corporation was poorly understood, and efforts to experiment faced internal resistance to change.

3. *Internal and External Effects on Diffusion*

It would be wrong, however, to conclude that these impediments should generate a random diffusion of adoption. Impediments influence the rate of diffusion, not necessarily the ordering among firms as predicted by a set of explanatory factors. If impediments do not explain randomization, why then should the random-walk model be accepted by Mahajan *et al.*?

One reason is that the samples are flawed in two ways. First, the results apply to a particular strata of the overall population of firms, namely large and publicly listed corporations. Effects of size and diversification would certainly be more likely to be important predictors if the sample included small firms.[6] Second, the diffusion histories start in 1950. In the sample of Rumelt (a subset of which was used by Mahajan *et al.* and Venkatraman *et al.*), 20.2% of the 246 firms in the sample had already adopted by this date. Even if the random-walk process is a correct specification, the results should be understood to be restricted to a particular sample.

There is good reason to believe that the early history is important for understanding the influence of the industry on adoption, a point stressed emphatically by Chandler. Efforts to reorganize by firms located in unrelated industries were ignored by managers deciding to innovate. 'While the senior executives at the electrical company', writes Chandler (1962, p. 366) of Westinghouse, 'were undoubtedly aware of the multidivisional structures that Du Pont and General Motors had devised, they probably believed that the organizational form used in a chemical or automobile company had little relevance to their business.'

However, the experiences from other competitors were noticed, and sometimes exploited through hiring their employees. Chandler (1962, p. 373) notes that both Ford and Chrysler after World War II adopted the multidivisional structure by observing General Motors' experience, with Ford hiring GM executives 'to clap the GM organization garment onto the Ford manufacturing frame'.[7] Similarly, Chandler (1962, p. 379) observes that Montgomery Ward 'quickly copied the structure that had been developed at Sears, just as Ford adopted the one created by General Motors'. Industry experience, not the cumulative adopters in a cross-section of industries, played a formative role in the diffusion of the multidivisional structure.

In addition to imitative effects, Chandler has placed considerable emphasis on the influence of diversification on the adoption decision. In reviewing adoption patterns across industries, Chandler (1962, pp. 342–343) notes:

> The experience of the leading enterprise in the metals and materials industries reinforces the proposition drawn from that of all four of the case studies, namely, that one basic task of a rationally defined structure must be to relate and coordinate the work of the enterprise's different functional activities to market needs and demands. It further indicates that the fewer the markets and the simpler the marketing process, the easier will be the administration and coordination of functional departments. Thus, those companies that sold semi-finished products to a relatively few large industrial customers required a comparatively simple type of structure. Those that sold a larger variety of *one major line*

[6] Whereas we employ data drawn from the population of large firms in the 1960s, our methodology traces the origins of these firms back to 1917 when they were much smaller.

[7] Chandler cites *Fortune*, 35, p. 88 (May 1947).

> of products in much higher volume to a greater number of industries and business have consistently centralized the control of their activities through developing and rationalizing their functionally departmentalized structures; while only those making and selling quite *different lines* for increasingly differentiated groups of customers turned to the new multidivisional form.

Thus, size alone did not lead a firm to adopt the multidivisional structure.[8] Diversification across distinctly different product lines was, Chandler claims, an important determinant of the adoption decision.

The influence of imitation is called an 'internal' effect in the diffusion literature. The firm-level factors of size and diversification are examples of 'external' effects, namely firm heterogeneity that results in different adoption thresholds. The findings of Mahajan *et al.* state that there are neither internal nor external effects; Venkatraman *et al.* find only evidence for external effects. Both of these findings are contrary to the rich history of Chandler that points to imitation and efficiency as motives for adoption.

4. *Effects of Power and Control on Adoption*

Chandler's history has been given a particularly tough reading by the institutional school in organizational theory, largely due to the objection to the prominence played by a strong efficiency argument. In contrast, Fligstein (1985, 1990) has related these adoption decisions to the type of managerial control that dominates during a particular historical epoch. He describes his argument in the following (Fligstein, 1985, p. 380):

> Fligstein has argued that in different historical periods, different departments are likely to control large firms for different reasons. In the early part of this century, entrepreneurs and manufacturing personnel controlled large firms because they were capable of coordinating large-scale production processes. . . . Once production is routinized, power shifts to sales and marketing personnel as the key issue for the organization becomes growth. . . . The dominance of sales personnel in large firms was undermined by two phenomena: (1) government concern with increasing concentration in product lines, which resulted in the Celler–Kefauver Act of 1950 . . . and (2) a shift to product unrelated and merger strategies for growth (i.e. conglomerates). The emergence of conglomerates and the possibility of enormous growth through mergers further affected business strategies in the early 1960s. Finance

[8] Williamson (1975, pp. 132ff.) sees scale as directly influencing the adoption of the divisional form as a solution to the complexity of size; Chandler argues that the effect of size is mediated by diversification and its impact on growth.

> departments are natural heirs to power in this kind of situation because investment decisions are made primarily on financial criteria. . . . From the power perspective, the MDF [multidivisional form] would result from the acts of certain key actors whose strategic bases of power are consistent with the MDF. Since the MDF could be viewed as a mechanism which allows for growth through product-related and -unrelated strategies, its implementation would be favored by those who stood to gain the most from those strategies, i.e., sales and marketing and finance personnel.

The empirical evidence for the correlation of adoption and control is the finding that firms with chief executive officers (CEOs) with marketing backgrounds adopted (with statistical significance) the multidivisional form (MDF) in the 1930s, and firms with finance CEOs did so also in this period but also in later periods.

This argument is not distant from Chandler's summary of the historical process of the diffusion of the divisional form, though few would quibble with the claim that Chandler relegated the role of the state and anti-trust legislation to minor importance. Chandler surely recognizes that the adoption of the multidivisional form is strongly influenced by the historical maturation of the firm, and that this maturation was closely connected to the growth in the US economy. His proposed four historical phases in the growth of the US firm coincide with Fligstein's observations, referring to them as periods of resource acquisition focused on production, of functional rationalization, of the seeking of new markets due to the 'the threatened decline of existing demand', and of the diversification of product lines leading to reorganization. He locates these overlapping phases, respectively, as prior to World War I, first two decades of this century, the 1920s and 1930s, and the 1940s and 1950s. The parallel to the periods of Fligstein, who is writing more than 20 years later than Chandler and who can observe the later decades, is imperfect, and yet striking.

Yet, Fligstein (1985, p. 388) concludes that

> Chandler underestimated the role of actors who were committed to a certain view of how large organizations should have grown. The power perspective suggests that key actors with certain interests . . . would choose to implement the MDF (multidivisional form) net of strategy . . . Chandler also has very little feel for the fact that these large organizations operate in similar environments and hence watch one another independent of considerations of strategy.

In a more favorable evaluation of Chandler, Palmer *et al.* (1987) argue that

Chandler nevertheless neglected the effect of family and bank interests on adopting the divisional structure.[9]

One suspects that the pithy quality of the structure follows strategy argumentation has worked to obscure Chandler's emphasis on individual authority. Chandler not only noted explicitly the role of imitation, as documented above, but was emphatic on the importance of leadership and control. At the conclusion of a survey of 70 large firms, he concludes that 'expansion did cause administrative problems which led, in time, to organization change and readjustment, but it further suggests that the essential reshaping of administrative structure nearly always had to wait for a change in the top command'. A few lines later, he notes that 'the few firms among those studied here that remained family held have tended to be slower in changing both structure and strategy than the others' (Chandler, 1962, p. 380).

Chandler's thesis of the efficiency properties of the MDF receives a more favorable but still critical audience among the new sociological institutionalists. In this view, the diffusion of an innovation is frequently motivated by efficiency reasons early in the process, but, as the innovation becomes institutionalized, by imitation later on. Tolbert and Zucker (1983) demonstrate this pattern for the diffusion of civil service reform, and Baron *et al.* (1986) find a similar pattern for the adoption of personnel administration offices.[10] We will return to an investigation of this pattern later in the paper.

5. *History Meets Management Studies*

The criticism of Chandler's thesis in management studies appears, in summary, to be derived from three sources. The first is an incomplete reading of the history; there is less disagreement than meets the eye. Second, in a number of articles, method seems to have prevailed over common sense. It is a fairly radical thesis, especially given the qualitative evidence, that adoptions occurred randomly, or without imitation of other large and prominent firms.

Finally, there is a difference in emphasis and, less obviously, in theory. Chandler clearly ascribes a powerful role to the rational search for better ways

[9] Palmer *et al.* (1987, p. 38) found that 'the results support the economic explanation of the MDF, especially Chandler's (1962) version, in almost every respect.'

[10] Chandler himself appears as an endogenous agent in the diffusion of the multidivisional form. Palmer *et al.* (1993, p. 107) note that 'Chandler's (1962) pro-decentralization ethos that permeated management thinking in the 1960s, was written at Harvard University immediately prior to the period covered by our study. . . . It was probably well known to this school's alumni as well as their faculty from Harvard. Thus firms whose CEOs had degrees from elite graduate schools of business should have been more likely than other firms to adopt the MDF.' The variable was estimated significantly to predict multidivisional adoption in the 1960s.

by which to organize economic activities. It is not clear what explanation Mahajan *et al.* offer other than the difficulty of detecting causal relations between adopting an innovation and performance. Given that Armour and Teece (1978) estimate that petroleum firms increased their return on assets by 2% by adopting the multidivisional structure, some investment in inference from the experience of other firms should be expected, and, more importantly, was observed in the historical record.

Fligstein's argument does not contradict clearly Chandler's emphasis on the rational search for better practices, but simply questions its agency. He more strongly stresses the role of powerful agents who strive to adopt structures to increase their authority. But since he does not deny that their success is linked to their ability to persuade others of the economic merits of adoption, his explanation rests upon many of the same elements as Chandler, namely the evolving complexity of the firm as it grows and seeks new opportunities. The only argument, besides random adoption times, that clearly contradicts the thesis of Chandler is the institutional claim that imitation dominates economic motives for adoption over time.

Whereas a statistical analysis cannot supplant the rich textual history, it can serve to cast doubt or support articulated interpretations. It is hard to avoid the limitations placed on generating a representative sample of firms. Archival data are notoriously difficult to find for a large sample of firms, and the difficulty increases with decrements in firm size. In the analysis below, we work with the subsample of firms identified by Bhargava for which we can find data extending back to 1917 (prior to the original innovation of the divisional structure by Du Pont). As explained in the next section, we specify a research design that examines the random-walk hypothesis at the firm level, as opposed to the population, and also allows for a direct testing of some of the alternative interpretations.

6. *Model Considerations*

Let us assume that the firm's choice of structure is determined by its evaluation of an unobserved index, Y_i. At a critical value, Y^*, the firm chooses to adopt the multidivisional structure. Thus, we observe Y_i only latently through the revealed choice to stay with the current structure, or to adopt the new one.

The approach of Mahajan *et al.* and Venkatraman *et al.* has been to analyze this problem as a diffusion process among a population of potential adopters. Given a population of m firms at risk at time T, integrating over previous and current adopters gives the cumulative distribution of adopters. By specifying a differential or difference equation governing the process, the estimation extracts values for microbehavioral parameters, such as imitation and innovation effects.

The Teece (1980) study applied a Mansfield imitation specification to multidivisional adoptions and found they diffused more slowly than technological innovations. Mahajan *et al.* (1988) fitted several diffusion specifications to data on adoption times of the multidivisional structure of 127 firms. They tested standard diffusion models against a baseline which they called a white-noise specification. For certain parameter values, they showed the white-noise specification is a special case of the Bass model.[11] They found that their white-noise specification proved to be a superior fit to the Bass, Coleman and quadratic models. The Venkatraman *et al.* study allowed for non-linearities and rejected the white-noise specification in favor of a model showing external effects.

A less frequented route has been to analyze adoptions at the individual firm or consumer level. In this framework, adoption can be modeled as analogous to conditional waiting times or hazard rates. As is well known, the survival function, p.d.f., and hazard are interrelated; from any two, we can derive the third. Thus, knowing the duration time and the timing (or order) of adoption events is sufficient to estimate the hazard rates.

$$h(t) = \frac{f(t)}{1 - F(T)} \quad \text{or} \quad h(t) = \frac{f(t)}{\bar{F}(t)} \tag{1}$$

That is, where the hazard rate is defined as equal to the p.d.f. divided by the survival rate (i.e. 1 – the cumulative density function of deaths). Palmer *et al.* (1993) applied a partial likelihood model to multidivisional data, though the time series was rather short (i.e. for the period 1963–1968).

There has been some interest in understanding the correspondence between the hazard rate which describes the microbehavior of individuals, and the diffusion rates that characterize the population dynamics. Schmittlein and Mahajan (1982) showed that the well-established Bass model does not arise from common hazard functions. Chatterjee and Eliashberg (1990) derive several aggregate diffusion specifications from the micromodeling approach on the assumption of a constant information rate, i.e. the rate does not change over time.

[11] They specified a white-noise model as $x(t) = \beta_1 x(t-1) + \varepsilon(t)$, where $x(t)$ is the number of adoptions at time as predicted by the lag value of previous year's adoptions plus an error term. In the special case that $\beta = p - q$ (the usual Bass parameters), then $\beta = 0$ is the white-noise null specification. Clearly, this nesting is not general.

We can think of $Y(t)$ as a random variable representing the perceived benefits to the firm of adopting a divisional structure at time t. Changes in $Y(t)$ are distributed normally and are independent of each other. Moreover, we assume that there is a steady tendency to adopt the multidivisional structure over time. These conditions are sufficient to describe the diffusion as a Wiener process

$$dY(t) = \mu dt + u(t)\sigma\sqrt{dt}$$

where μdt is the drift rate, $u(t)$ is distributed $N(0,1)$ and σ is the standard deviation. Given this formulation, we can reinterpret Y^* as an absorbing barrier; for ease of exposition, we work with the constant case where $Y^* = \alpha$. [Lancaster (1990) shows that the more general linear barrier can be studied as the case of a constant barrier, $Y^* = \alpha$, resulting in a Wiener process of drift $\mu - \beta$ and variance σ.][12] Solving for the first passage time and setting the conditions such that $Y(0) = 0$, the cumulative function is the standard inverse Gaussian, with the p.d.f. of

$$f(t) = \frac{\alpha}{\sigma\sqrt{2\pi t^3}} \exp\left(-\frac{(\alpha - \mu t)^2}{2\sigma^2 t}\right) \tag{2}$$

As can be expected, the barrier, α, effectively shifts the p.d.f. in space. The survival function is:

$$\bar{F}(t) = \Phi\left(\frac{\alpha - \mu t}{\sigma\sqrt{t}}\right) - \exp\left(\frac{2\mu\alpha}{\sigma^2}\right)\phi\left(\frac{-\alpha - \mu t}{\sigma\sqrt{t}}\right) \tag{3}$$

The hazard rate can be written following equation (1). The hazard rate reaches a maximum at a value of t in the range of $[1/3\sigma^2, 2/3\sigma^2]$. If the random walk is drifting toward the absorbing barrier, then the firm will eventually adopt an MDF structure because, the cumulative probability of adoption $F(t)$ tends toward 1 as time approaches infinity. If the random walk is drifting away from the absorbing barrier, then there is some positive probability that the firm will never adopt an MDF structure, no matter how much time elapses. For our purposes, we assume that the drift is toward the barrier.

As we do not observe the values of Y or the absorbing barrier directly, one

[12] Chatterjee and Eliashberg (1990) develop the argument for the stochastic variate under specific initial conditions. We follow their argument heuristically, but redefine the unobserved variate $Y(t)$ as the waiting time to adoption with an initial condition of $Y(0) = 0$, as standard in Lancaster (1990, p. 11). See also Cox and Miller (1964, pp. 220–221).

approach is to find reasonable instruments. A common solution is to reparameterize the distribution by setting $\alpha = 1$ with no loss of generality (Folks and Chhikara, 1978, p. 266; see Lancaster, 1972, for an application). Individuals that are at the boundary initially adopt (or innovate) immediately. It is tempting to set m equal to a sum of weighted and known covariates, such as firm size or degree of diversification. There are, however, important technical problems with proceeding in this fashion. Given the specification, the attributes should be time-varying. As measurements were only made for particular intervals, the covariates are fixed within intervals. It is possible to estimate the fixed covariate hazard for each interval, and then work out a weighting scheme for the piecewise integration. Not only is this technically difficult, it does not satisfactorily address the problem of fitting covariates measured at discrete times to a continuous process.

We therefore designed a two-stage process.[13] First, we estimated the effects of time-varying (but discretely measured) covariates on the hazard rate by specifying a partial likelihood model. Partial likelihood, by acting on the ordinal ranking of events, is less sensitive to data, measured at discrete intervals. While a 'true' discrete-time hazard model, e.g. Allison's stacked logit model, does not converge to the Cox partial likelihood, the differences between the models have usually been found to be small (Allison,1984; Cox and Oakes, 1984, p.101).

The partial likelihood results are sufficient to reject the hypothesis that the hazard of adoption is a random walk. If the partial likelihood hazard is significantly influenced by the covariates, then these results indicate that the parametric specification of the inverse Gaussian would have a non-zero drift. Moreover, this drift would be shown to be determined by the estimated covariates. We do not test if the restrictions on the variances are satisfied. However, the finding that the covariates matter is sufficient to reject the hypothesis that a pure random process determines the adoption rate, regardless of the values of firm and industry characteristics.

To validate statistically this approach, we use in stage 2 the estimated coefficients to generate predicted hazard rates. We use these predicted values to divide the sample into two groups of slow and fast adopters. We then estimate the inverse Gaussian parameters for each population to show that the mean rate of adoption for fast adopters is significantly larger than that for slow adopters.[14] Of course, a mixed distribution model could also test for

[13] We would like to thank David Schmittlein for his timely intervention in our design.

[14] Stage 2 does not triangulate the results from stage 1, because the tests are not independent. It is more insightful to view the design as consisting of a stage 1 that 'factors' the sample into fast and slow adopting partitions; stage 2 then validates that the samples indeed do differ in the critical parameter, i.e. the drift rate.

significant heterogeneity in the population. The advantage of our approach is that this heterogeneity can be related directly to the now latent covariates.

7. *Model Specification and Estimation*

The specification of the partial likelihood treats the nuisance baseline as non-parametric, but allows it to act multiplicatively on the exponentiated vectors of the coefficients and explanatory variables (i.e. covariates). The sample consists of observations ordered by the *kj* failure times, such that $t(1) < t(2) < \ldots t(k)$. Ignoring ties, this semi-parametric specification reduces to the log likelihood:

$$l_{i,t_i} = h_0(t_i) + \beta X_{j,t_i}$$

Forming the odds ratio cancels the baseline hazard from the estimation:

$$\frac{l_{i,t_i}}{\sum_j l_{j,t_i}} = \beta X_{i,t_i} - \sum_{j \in R(t_i)} \beta X_{j,t_i} \quad \text{for } i \neq j$$

Summing over all the j likelihoods at risk:

$$L = \sum_i^k \frac{l_{i,t_i}}{\sum_j l_{j,t_i}} = \sum_i \left(\beta X_{i,t_i} - \sum_{j \in R(t_i)} \beta X_{j,t_i} \right)$$

Note that $k \# j$ depending on whether any observations are censored. The first term represents the contribution of the ith subject that fails (i.e. adopts) at time t, the second term is the contribution of the subjects whose survival times are censored. (The specification has a clear analogue in the standard Tobit, or truncated distribution.) In the case of ties, the likelihood is formed by taking a weighted average over the likelihoods of the tied events. This method enters a conservative bias into the estimation (Kalbfleisch and Prentice, 1980, p. 96).

To implement stage 2 of the research design, the predicted hazard values are calculated from the estimated coefficients and the covariates, fixing their values at their geometric means. These estimates are used to split the sample into high- and low-risk classes. We label these classes fast and slow adopters. In our model, we use the specifications of the p.d.f. and survival as given in equations (2) and (3). Initializing the values by ordinary least-squares, the estimates are passed to iterative algorithms.[15] From the second derivatives of the likelihood, we can construct the variance–covariance matrix. The likelihood and variance–covariance matrices allow us to derive the standard likelihood and information tests. As both provide similar results, we provide the likelihood test for the overall equation fit and t-tests derived from the variance–covariance matrix for the individual coefficients.

The parameter of interest is the mean, or drift, which determines the central tendency towards adoption. By comparing the means, we determine whether the central tendency differs for the fast and slow samples. Folks and Chhikara (1978) give a means test when the variance is unknown:

$$SL \leq 2(1 - F|T|)$$

where

$$T = \frac{\left[n_1 n_2 (n_1 + n_2 - 1)\right]^{\frac{1}{2}} (\overline{X} - \overline{Y})}{\left[\overline{X}\overline{Y}(n_1 \overline{X} + n_2 \overline{Y})(V_1 + V_2)\right]^{\frac{1}{2}}}$$

n_1 and n_2 are the sample sizes, X and Y are the means, V_1 and V_2 are the estimated variances, and F^*T^* is the distribution of Student's t.[16]

8. *Data*

The time series of the adoption of the MDF used in our study is drawn from Bhargava's (1973) comprehensive examination of the adoption of the multidivisional form among the largest 200 American firms in 1965. Bhargava traces the structural evolution of each of these firms from 1920 to 1970. Further research into the post-1970 history of the non-adopting firms (relying principally on annual reports and other published information) extended this time series forward to 1980. This collection resulted in a final time series of 150 firms.

Covariate data were gathered from several sources for the years 1917, 1930, 1937, 1948, 1958, 1968 and 1978. The diversification variable is a simple count of distinct two-digit product lines as used by Gort (1962). The use of two-digit industries corresponds to Chandler's claim that a firm had to diver-

[15] The program is written in Gauss and is available on request.

[16] An alternative to our stage 2 design is to mix the inverse gaussian with a gamma-related distribution, as in Bannerjee and Bhattacharyya (1976), Vaupel *et al.* (1979) and Levinthal (1991). But given that we can estimate the effects of the covariates, sorting out heterogeneity through a mixing distribution is less compelling (though there may well be residual heterogeneity after estimating the covariate effects).

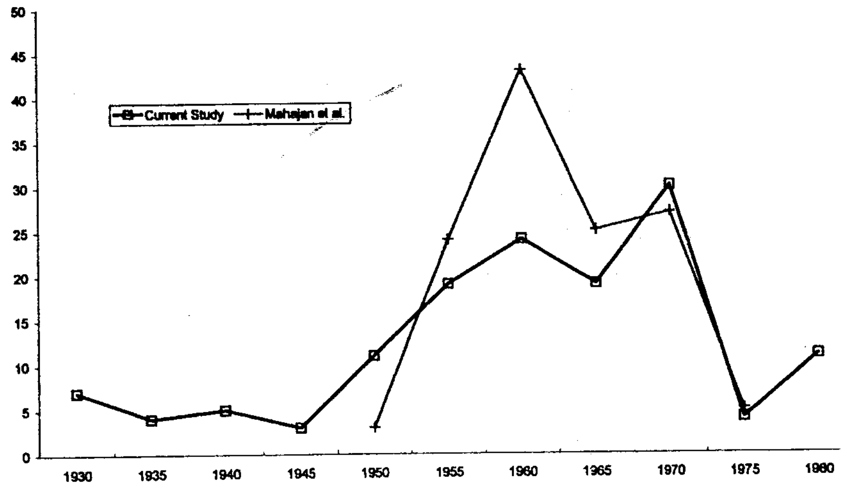

FIGURE 1. Noncumulative adapters.

sify along 'quite *different lines*' (as cited above) before adopting a divisionalized structure.[17] For observations after 1946 these counts were available from *Moody's Industrials*. For observations prior to 1946, annual reports were used as the data source.

The size variable used is number of total assets. Size data were gathered for each firm from the Fortune 500 directory, from 1957 to 1980, and from *Moody's Industrials* for 1954–1956. Prior to 1954, data sources include annual reports, Berle and Means (1932) and Chandler (1990). From these sources, complete data was obtained for 62 firms spanning the time period 1917–1980.

Figure 1 contrasts the non-cumulative adoption of the MDF by the firms in our sample and with the non-cumulative adoption by the 127 firms in Rumelt's (1974) data as reported in Mahajan *et al.* (1988). The two series are similar with each showing a spike in the adoption rate in the mid- to late 1950s and again in the mid-1960s. The similarity is not surprising because Rumelt's total sample of 246 firms and Bhargava's examination of the largest 200 firms come from the same Fortune 500 list. However, our extension of Bhargava's data forward to 1980 shows a third spike in the adoption rate in the late 1970s. This third spike is missed in studies using data which ends earlier, and indicates that the diffusion process was ongoing throughout the 1970s. Figure 2 shows the cumulative adoption for the two samples.

Figure 3 shows the penetration rate by industry of the MDF in the years

[17] Rumelt reports in the second edition of his 1974 book that product counts surprisingly proved the morst attractive measure than other more sophisticated measures.

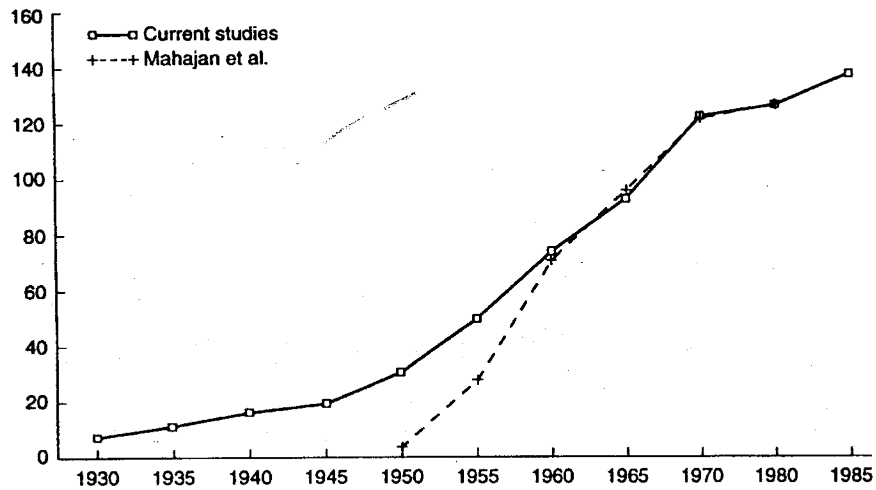

FIGURE 2. Cumulative adapters.

1950, 1960, 1970 and 1980. The plot indicates the dramatic effects of industry membership had on the propensity to adopt. This variation in adoption rates across industries was first noted by both Chandler (1962); Rumelt (1974) links the pattern to the constraining effect of some technologies and products on diversification. The most notable laggard industry is primary metals, a finding that confirms Chandler (1962) and Rumelt (1974). Figure 3 also shows that, by 1980, the diffusion process was virtually complete, with 90% of the firms in the sample adopting the MDF.

To capture the imitation effects, the variable, the proportion of previous adopters, is defined at the industry level in accordance with Chandler's observations. At each time interval, the proportion of previously adopting firms was calculated. This variable then formed the observation for each firm in the industry at that time interval.

9. *Results*

The results from the two-stage design are given in Tables 1 and 2. Table 1, column 1, presents the estimates to the proportional hazard (partial likelihood) model for the 1917–1980 period. Neither size nor diversification is significant at 0.05, though their coefficients are correctly signed. A highly significant result is the number of previous adopters in the industry of the adopting firm. Imitation effects are quite powerful.

To make our results comparable to those of Mahajan *et al.* and Venkatraman *et al.*, we ran the model for the time period of 1950–1980 for 101 firms.

TABLE 3 Proportional Hazard Results (Standard Errors in Parenthesis)

	1917–1980	1950–1980
Imitation	6.69***	2.49
	(1.95)	(1.57)
Firm factors		
Diversification	0.011	0.093**
	(0.077)	(0.044)
Size	0.00016*	0.00002
	(0.00009)	(0.00006)
Metal industry	−1.01*	−0.83*
	(0.567)	(0.45)
Log-likelihood	−181.85	−342.13

Significance: $*P < 0.1$, $**P < 0.05$, $***P < 0.01$.

backgrounds of executives might all lead to faster communication and adoption.[19]

To sort out unobserved industry efforts, we ran the models reported in Table 1 with industry dummies. (Because of convergence problems, the models were run with each industry dummy.) In Table 3, the results are reported for the only industry dummy to be significant. As Chandler's description complies, the coefficient is negative, since the metals industry was very slow to adopt. (US steel and three other companies did not adopt by 1980; however, one firm adopted in 1929, with others doing so in the 1950s and 1960s.) The imitation variable loses significance for the 1950–1980 period. This dramatic difference in the results for the two time periods points to the sensitivity of when history is started.

The late adoption in the metal industry appears to reflect unobserved industry factors. Chandler (1962, pp. 327ff.) points to the slow technological change and the simplicity of the product line and market demands. In this regard, it seems odd that the monopoly control of nickel and the powerful copper oligopoly should not suggest that incentives for change were low in the metal industry, be it technical or organizational. It is particularly in this industry that the consideration of the absence of competition and the failure of government intervention is lacking in Chandler's analysis.

The results regarding the firm factors, i.e. diversification and size, are weak. Again, it should be emphasized that among a population of large firms, size and diversification effects are attenuated. There are also important problems with measurement. Product count is relatively easy to collect compared to Herfindahl or other sales-weighted measures, but it is a troubled measure of

[19] Palmer *et al.* (1993) found, however, complex and mixed effects of interlocking boards on adoption times.

diversification. Though a better measure, accounting values of fixed assets is an imperfect measure of size. Outside of company archives, these data represent, however, the best sources available.

The finding by Venkatraman *et al.* that external, or firm factors, influence diffusion rates is directly supported by our study for the 1950–1980 period. Of course, external effects might include other factors than size and diversification, which do not fully encapsulate the heterogeneity of firm propensities to adopt. A reasonable candidate, suggested by Chandler (1962), Bhargava (1973) and Fligstein (1990) is the internal influence of powerful groups that promote or hinder change.

An intriguing speculation is that the causal relationship between multidivisional adoption and diversification is reversed. Chandler (1962, p. 394) hints at this possibility

> Once the new type of structure became known, as it did during the 1930s, its availability undoubtedly encouraged many enterprises to embark on a strategy of diversification, for the ability to maintain administrative control through such an organizational framework greatly reduced the risks of this new type of expansion.

Imitation, because it is made in reference to economic gain, is difficult to separate from the firm factors, or external effects, that influence the pattern of diffusion. For this reason, the relationship between diversification and divisionalization may have grown in significance, as the knowledge of their efficiency of their pairing became diffused.

The statistical analysis provides no support for the hypothesis of a reversed causality, but does indicate that diversification and multidivisional adoption may have been recognized as linked by the 1960s. Restricting the analysis to a panel of 1960–1970 adopters, we regressed previous multidivisional structure adoption and size on change in diversification. Neither parameter was significant. The correlational analysis is revealing. The variable indicating that a firm had adopted the multidivisional structure by 1960 has only 0.01 correlation with changes in diversification over the decade. However, the correlation of adopting the structure and increasing diversification has a correlation of 0.1, though it is not significant. Taking these correlations at face value, they indicate that it is 10 times more plausible that multidivisional structure adoption and increased diversification come together as a strategic combination than one predicting the other. The inference from these correlations is that managers by the 1960s viewed multidivisionalization and diversification as strategically linked. This result is consistent with Fligstein's account of the trends in the 1960s.

The results in Table 3 lend themselves to an important inference. The