R & D AND THE DIRECTIONS OF DIVERSIFICATION

James M. MacDonald*

_abstract—_The patterns of diversification within U.S. manufacturing between 1963 and 1977 are examined. Firms didn’t diversify at random; they were more likely to enter rapidly growing industries, and industries that were related to their primary activities through supply relationships or marketing similarities. Research and development (R & D) expenditures also influence the observed patterns. R & D intensive industries generate outbound diversification and attract inbound diversification. However, the strongest influence is directional; R & D intensive firms channel their diversification toward R & D intensive industries. Much diversification reflects the transfer of sharable organization capital among related activities.

I. Introduction

A NALYSES of product diversification typically concentrate on measurement, sources of firm and industry differences in the extent of diversification, and the effects of diversification on profits and concentration. The research reported in this paper takes a different approach: the analysis is directed at the industrial directions in which firms diversify. That is, the aim is to identify factors which influence the choice of industries that firms with given characteristics diversify into. A second, more specific, issue also arises. Previous empirical studies have found statistical links between diversification and Research and Development (R & D) activity, but there is considerable disagreement over the reasons for the link. Three different hypotheses are identified, and the data developed here allow for statistical tests which distinguish among the hypotheses.

The analytical approach used here and elsewhere can be categorized according to the following general specification:

\[ D_{ij} = F(X_i, Y_j, g(X_i, Y_j)) \] (1)

where \( D_{ij} \) is a measure of diversification from the \( i^{th} \) origin, industry to the \( j^{th} \) destination industry, \( X_i \) is a vector of origin industry characteristics, \( Y_j \) is a vector of destination industry characteristics, and \( g(X_i, Y_j) \) is a vector of measures of similarity between origin and destination industries. Some analyses investigate only the total volume of diversification inbound to industry \( j \); that is, the \( D_{ij} \) are summed over the \( i \) origin industries and only the vector \( Y_j \) is used in analysis. Others assess outbound diversification, from industry \( i \), by summing the \( D_{ij} \) across the \( j \) destination industries and retaining only the vector \( X_i \) as independent variables. Those choices depend in part upon the object of analysis and in part upon data restrictions.

This paper takes an alternative, disaggregated approach, using information in all three vectors on the right-hand-side of equation (1), in order to investigate the factors that influence the directions of diversification, the vector \( g(X_i, Y_j) \), as well as the factors that influence levels of diversification, the \( X_i \) and \( Y_j \) vectors.

The specific variables included in (1), drawn from the theoretical literature on diversification, have been used in past analyses. They encompass measures of the relative attractiveness of investment in an industry, and measures of the “organizational capital” that firms can commit to diversification. Organizational capital is the term applied to the collection of assets specific to the firm and transferable across industries, whose interfirr reallocation via markets may be costly relative to internal reallocation (Prescott and Visscher, 1980). Such assets are embodied in the firm’s research, marketing, and production organizations. I will investigate the influence of each; the influence of R & D on diversification is of particular interest, and I shall now turn to several hypotheses of that relationship.

II. R & D and Diversification

Two hypotheses concern observed statistical linkages between R & D and the amount of diversification into or out of an industry. The first asserts that investments in R & D induce later outbound diversification by the firm. Proposed by Penrose (1959), it receives strong emphasis in Chandler’s historical analyses. The reasoning is

1 "It was natural, then, that enterprises which had the greatest resources invested in research and development were the first to diversify and the ones to grow most rapidly by a continuing strategy of diversification" (Chandler, 1978, p. 421)
that the output of an R & D program is new knowledge, and markets for the exchange of new knowledge are subject to a variety of well-known problems which cause market exchange to be a relatively costly way of appropriating the returns to knowledge; as a result, firms will often have to diversify into the new industry in order to apply the new knowledge and gain the returns to it.

The second hypothesis, based on Scherer's empirical work, asserts that destination industry R & D attracts diversification. Scherer initially found no association between diversification and measures of either R & D intensity or patenting at the firm level (Scherer, 1965, p. 1115). However, with the sample restricted to industries that were not R & D intensive, diversification was positively associated with R & D intensity, an association attributed to diversification into R & D intensive industries (Scherer, 1965, p. 1116). McGowan (1971) offered a reason: R & D intensive industries are often populated by rapidly growing firms that find themselves short of skilled managerial, financial, and marketing personnel, and merger with a diversifying firm serves to remedy the problem.

The third hypothesis, a comparative advantage theory of the directions of diversification, holds that firms with experience in technological innovation (substantial R & D investments) direct their diversification toward other R & D intensive industries, where their skills are presumably most valuable, when they do diversify. Firms without R & D expertise (which may be relatively skilled in marketing or large-scale production) direct their diversification into low R & D industries. The directions hypothesis holds that R & D investments may still have important influences on diversification decisions, even if no association between R & D and the amount of diversification surfaces.

In the analysis, I shall investigate the likelihood of diversification, in 1963–77, into one industry from another, and test for the effects of origin industry R & D intensity, direction industry R & D, and similarity between industries in R & D.

III. The Diversification Data

The diversification data are drawn from Census Enterprise Statistics. Establishments are assigned to industries (defined at the three digit level), according to standard Census procedure, and companies can own many establishments in a variety of industries. The primary, or origin, industry of a company is that which accounts for the largest share of company payroll, and all other industries of the company are secondary, or destination, industries. The Enterprise Statistics group all companies assigned to a particular origin industry, and present the distribution of their employment across all destination industries. This suggests a simple measure of diversification links between industries:

\[ N_{ij} \text{—employment in the } j^{th} \text{ destination industry by firms assigned to the } i^{th} \text{ origin industry.} \]

Unfortunately, the Census often presents the \( N_{ij} \) as a range (for example, between 1,000 and 2,500 employees), rather than a point value, because of disclosure restrictions. The width of the range expands with higher \( N_{ij} \), so that there is considerable room for measurement error in higher ranges if one uses an estimate such as the range median. In analysis, the measurement error could be large, and systematically related to several explanatory variables. As a result, one cannot use the \( N_{ij} \) as cardinal measures of the extent of diversification into industry \( j \) from industry \( i \).

However, the \( N_{ij} \) can still be useful. The data accurately specify whether any firms from industry \( i \) were active in industry \( j \), that is, the incidence of diversification linkages. Analysis of those factors which make linkage likely will make a considerable addition to current knowledge of the directions of diversification.

Sixty-seven Enterprise Industries were consistently defined in 1963 and 1977. Those 67 form the data set; with 66 observed destination industries for each origin industry there are 4,422 \((67 \times 66)\) observations. Four qualitative diversification measures are used (the \( i-j \) subscripts are dropped for convenience):

\[ 63\text{LINK} — \text{equal to 1 if } N_{ij} \text{ was positive in 1963, and 0 otherwise} \]

\[ 77\text{LINK} — \text{equal to 1 if } N_{ij} \text{ was positive in 1977, and 0 otherwise} \]

---

2 Each hypothesis clearly views firms as collections of specific, rent-yielding assets, which influence the rate and directions of firm growth. The view is widely applied to analysis of foreign direct investment (Caves, 1982). The third, directions, hypothesis surfaces in the Caves volume and in earlier works on corporate growth by Coase (1937), George (1972), Gort (1962), and Penrose (1959).
EXIT — where 63LINK was 1, equal to 1 if 77LINK was 0, and 0 otherwise
ENTRY — where 63LINK was 0, equal to 1 if 77LINK was 1, and 0 otherwise.

The variables capture events of diversified entry and exit over the 1963–77 time period, as well as the incidence of diversification linkage in each of the two years. The interpretation of the entry and exit measures is important; entry occurs if a firm enters an industry in which no other member of its origin industry was active in 1963, while exit occurs if no other member of the origin industry is active in the destination industry in 1977. Thus, the entry and exit measures refer to industries without widespread firm linkages.

IV. Measures and Data Sources

Enterprise industry definitions generally comprise one or more four digit Census industries, Federal Trade Commission (FTC) Lines of Business, and Bureau of Economic Analysis (BEA) Input-Output industries. They provide measures of the characteristics of the origin and destination industries.

R & D: FTC aggregate Line of Business data provide the R & D measures. For constituent Lines of Business in an Enterprise Industry, R & D expenditures and total shipments were summed and the following three measures derived:

ORD — the ratio of R & D to shipments in the origin industry
DRD — the ratio of R & D to shipments in the destination industry
DIFRD — the absolute value of the difference between ORD and DRD.

The Chandler-Penrose hypothesis asserts that ORD should have a positive effect on the probability of diversified entry. The alternative Scherer-McGowan argument posits a positive effect of DRD. Finally, if R & D influences the directions of diversification, such that firms from high R & D industries are more likely to diversify into other high R & D industries rather than into low R & D industries, the DIFRD will have a negative influence on diversification. That is, the greater the difference in R & D ratios, the less likely is diversified entry.

Entry and exit occur over the 1963–77 time period. We would therefore prefer a 1963 R & D measure. However, the FTC data, with complete coverage beginning in 1975, are the only available industry-level R & D measures.\(^4\) Fortunately, industry and firm level measures of technological progressivity show little change during the period, and R & D intensities of the mid-1970s should be excellent indicators of industry technological progressivity in the early 1960s.\(^5\)

Marketing: If marketing organizations provide an important basis for diversification in production, then firms engaged in the production of consumer goods should be more likely to diversify into other consumer goods industries, while producer goods manufacturers will generally direct their diversification to producer good destination industries (Chandler, 1978; Penrose, 1959). In order to capture these marketing influences, I calculated the share of domestic industry commodity output (total commodity output minus net exports) directed to consumers, using BEA detailed Input-Output tables. Three measures were constructed:

OCON—final consumer demand share of origin industry output
DCON—final consumer demand share of destination industry output

\(^4\) National Science Foundation R & D data are too highly aggregated. The 1960 Census of Population provides an alternative measure, the ratio of scientists and engineers to total employment. However, the Census industries are also defined at an unacceptably high level of aggregation; 41 Census industries encompass the 67 Enterprise industries of this study. Aggregation to the Census level would sharply reduce sample size, without a clear benefit, and assignment of the aggregated estimate to all constituent industries likely introduces greater measurement error.

\(^5\) Griliches and Lichtenberg (1984), using NSF industry data, report a correlation of 0.92 between 1969–73 average R & D intensity and 1959–63 R & D intensity. Griliches and Mareeas (1984) show high levels of stability over 1966–77 for individual firms. For the 41 Census of Population industries described above (footnote 4), 1980 Scientist and Engineer (S & E) ratios had a correlation coefficient of 0.96 with 1960 S & E ratios. The FTC R & D ratios were highly correlated with 1960 S & E ratios (\(r = 0.89\)) and with 1980 S & E ratios (\(r = 0.94\)). When the 67 Enterprise industries were aggregated to the Population Census level.

---

\(^3\) Lemelin's (1982) interesting article takes a similar approach. The principal differences are that he used Canadian data, derived from Dun and Bradstreet establishment employment and product listings, for the single year 1972 (and thus investigates linkage, but not entry). Specific hypotheses of interest also differ; I shall compare the results later in this report.
DIFCON — the difference between OCON and DCON, in absolute value.

DIFCON should capture major differences between industries in buyer characteristics. If diversification is directed to industries with similar marketing characteristics, DIFCON should have a negative influence on the likelihood of diversified entry. Industry marketing characteristics may have an independent impact on the likelihood of diversification; OCON and DCON will be included in the analysis in order to test for differences between producer and consumer goods industries in the likelihood of diversified entry.6

Supplier Influences: Williamson (1979) argues, on transactions cost considerations, that we are likely to see internalization of transactions, or vertical integration, under certain conditions (concerning the number of buyers and sellers and the nature of information in the transaction). If Williamson's arguments hold, we should be more likely to observe diversification links between industries if one is an important supplier of the other. In order to capture supplier relations, the following two measures were drawn from BEA detailed Input-Output data:

BVR — a dichotomous variable equal to one if the destination industry accounts for at least 1% of intermediate input shipments to the origin industry, and zero otherwise

FVR — a dichotomous variable equal to one if the origin industry accounts for at least 1% of intermediate input shipments to the destination industry, and zero otherwise.

BVR (backward vertical relation) and FVR (forward vertical relation) should each increase the likelihood of diversified entry.7

Other Influences: Firms are expected to redirect their pools of organization capital out of relatively unprofitable activities and into relatively profitable ones. This contention is straightforward, but the difficulty lies in empirical implementation, for we must specify measures of profits and measures of the alternatives available to the firm. I will use industry growth as a measure of expected profits. Demand growth should drive up prices relative to costs, creating short-run profits and entry incentives. More important, rapid growth is often indicative of fundamental shifts in technology or in consumer demand, which would erode incumbents' competitive advantages relative to diversified entrants.

Firms are not equally well disposed to enter a given industry; firms already active in highly profitable industries may get higher investment returns by expanding in those industries. As a result, the measure of profit opportunity of an industry should be its growth, relative to the growth of the firm's existing industries. The following measure reflects that requirement:

DGRE — destination industry 1963–77 employment growth, minus the median growth rate of the industries in which firms from the origin industry were active in 1963.

The size of an industry, and the size distribution of its firms, should also affect the likelihood of entry. Large industries have more firms and more heterogeneity, and consequently a greater probability of diversification into or out of them. Diversified entry into highly concentrated industries likely requires a substantial commitment of resources in order to reach efficient scale, and also generates the risk of incumbent retaliation. Diversification into such industries should be less likely. Alternatively, for firms wishing to expand, such expansion may be relatively costly in a highly concentrated origin industry, leading to a preference for diversified expansion.

Four variables describe origin and destination industry concentration and size:

OCR — origin industry four firm concentration in 1963

DCR — destination industry four firm concentration in 1963

OSIZE — total origin industry employment in 1963, in thousands

DSIZE — total destination industry employment in 1963, in thousands.

---

6 The Input-Output data are from the 1972 tables. The consumer/producer orientation of industries changes very little over intermediate run periods.

7 The 1% cutoff, which encompasses 12% of the industry pairs (most pairs have less than 0.1%), is an arbitrary choice, but should capture all economically important linkages in the vertically related category. Results were unchanged with a 2% cutoff, but deteriorated (lower coefficient values and t-statistics on BVR and FVR) with a 0.5% cutoff.
The concentration ratios for Enterprise Industries are shipments-weighted averages of those for constituent four digit Census industries, while the size data are taken directly from the Enterprise Statistics.

V. Empirical Analysis

Logit coefficient estimates for analyses of entry and exit are displayed in table 1. Entry probabilities are assessed for the 3,678 industry pairs with no 1963 linkages, while exit probabilities are analyzed for the 744 industry pairs with 1963 linkages. Predicted values of dependent variables are logarithms of the odds ratio \( \frac{P_{ij}}{1 - P_{ij}} \), so transformations must be made to arrive at predicted values of \( P_{ij} \), the probability of diversification from industry \( i \) into industry \( j \).

Consider first equations (1) and (2), the logit analyses of entry. During 1963–77, entry occurred in one-sixth of the industry pairs. The coefficients on the size variables (OSIZE and DSIZE) are positive and significant in each equation. The growth variable, DGRE, is also positive and highly significant, indicating that diversification was likely to be directed toward high growth industries and away from low growth industries.

The concentration coefficients are of opposite signs. High destination industry concentration (DCR) appears to deter entry, since the coefficient is negative and significant; an entry probability of 20% with concentration of 40 falls to 14% as concentration rises to 80 (equation (2)). Origin industry concentration (OCR) has a positive, but relatively low, coefficient that is not quite significant.
Now consider the relatedness measures—supplier relations, the share of consumer demand, and R & D intensity. Firms appear more likely to diversify into vertically related industries, since the supplier dummy variables, BVR (backward vertical relation) and FVR (forward vertical relation), are each positive and highly significant. If we accept Williamson’s transactions cost arguments, then the other factors may not affect the likelihood of linkage between vertically related pairs. In order to investigate that possibility, the sample was stratified according to vertical relatedness and equation (2) excludes observations with a vertical relation; coefficients in (2) are essentially unchanged compared to (1).8

The coefficients on the share of consumer shipments, OCON and DCON, are both negative, with the origin share (OCON) highly significant and much larger than the DCON coefficient. During this period, manufacturer diversification into services and trade increased markedly; I suspect that the OCON coefficient value reflects a tendency for consumer goods firms to direct their diversification toward services and trade, rather than manufacturing. Relatedness in consumer share (DIFCON) has a strong impact on diversified entry, as the coefficient is large and negative. Recall that DIFCON measures the difference between industries in consumer and good orientation, so that a negative coefficient indicates that diversified entry tends to link industries with broadly similar buyer characteristics.9

Now consider the evidence on R & D. In table 1, equation (2), the logit coefficients on origin R & D intensity (ORD) and destination R & D intensity (DRD) are each positive and significant, while that on the difference in industry R & D intensities (DIFRD) is negative and significant. The net effects are displayed in table 2, for alternative R & D intensities and representative values of other variables. Several patterns stand out. First, two high R & D industries are far more likely to be linked than two low R & D industries (moving along the diagonal representing equal R & D intensities). Second, firms are as likely to enter destination industries with higher R & D intensities as they are to enter those with equal intensities, but are clearly less likely to enter industries with lower R & D intensities. Intensive research and development activity in a firm’s primary activity may increase the extent of diversification by the firm, but also channels the diversification toward other R & D intensive industries and away from industries with little orientation towards R & D.

---

8 Vertical relatedness appears to increase the likelihood of entry, but other factors have no statistical effect in such cases. In a separate analysis (not shown), entry was more likely to occur (in 35% of the 282 observations with vertical relations, as opposed to 17% of the 3,396 other observations) However, no other coefficient was significant at a 95% level of confidence, and four (including the growth variable) changed signs.

9 Assume that, with OCON and DCON both equal to zero (pure producer goods industries), the likelihood of entry is 33%. Replacement of the producer origin industry with a consumer origin industry (OCON equal to 80), while holding other variables constant, reduces the entry probability to 10.8%, in equation (2).

The marketing findings have related antecedents in the literature. In an analysis of conglomerate mergers, Stewart, Harris, and Carleton (1984) found that advertising intensive firms directed their acquisition activity toward advertising intensive industries, while low advertising firms were more likely to acquire other low advertising firms. Lemelin’s (1982) analysis of 1972 linkages among Canadian industries assigned industries to categories of producer goods, consumer convenience goods and consumer nonconvenience goods, and found linkage more likely to occur between industries assigned to the same category.
Finally, equations (3) and (4) of table 1 present logit estimates of the likelihood of exit. Exit occurred during 1963–77 in 32% of the linked industry pairs of 1963, a high degree of divestiture that appears consistent with the evidence of Weis (1983) on the incidence of conglomerate divestitures during the period from 1950 to 1975, and also with divestiture trends in the late 1970s. The R & D and DIFCON coefficients are interesting; they are statistically significant, with signs opposite those of the entry equations. Exit was more likely among industries dissimilar in R & D or marketing orientation. That evidence implies that such relatedness influences not only the likelihood of diversified entry, but also the likelihood of remaining in an industry.

Table 3 shows the results of logit analyses of static 1963 and 1977 linkages. The results are quite similar to each other and to those for entry. Size and vertical relations have significant positive effects on the probability of linkage. Since DIFRD and DIFCON may not influence linkage probabilities in vertically related industries, those industries are excluded in columns (2) and (4).

The pattern of R & D coefficients mirrors the entry equations; all are significant, with ORD and DRD positive, while DIFRD is negative and important. High R & D intensity increases the likelihood of linkage, while also directing diversification toward industries with similar R & D commitments.\footnote{Stewart, Harris and Carleton (1984) find a similar “directional” influence for R & D. Lemelin (1982) finds linkage to be significantly more likely, if both industries are “science-based” and, among producer good industries, if one is an important supplier of another.}

The consumer shipments variables show an interesting pattern. The coefficient on OCON is small and not significant; firms from consumer goods industries are no less likely to be linked to other industries. However, that on DCON is negative and quite significant with lower values in 1977.
than in 1963. Consumer goods industries were less likely to be diversified into, and the lower 1977 coefficient value likely reflects the effects of conglomerate mergers in the late sixties. The DIFCON coefficient remains negative and large. In the static 1963 and 1977 pictures, the producer/consumer orientation of industries had a strong influence on the directions of diversification.

VI. Conclusions

Between 1963 and 1977 there was a 50% increase in the proportion of industry pairs with diversification links. However, firms did not diversify at random, but rather were more likely to diversify into industries with characteristics similar to their primary industries. Several measures of similarity were devised, and each had significant effects on the directions of diversification. Firms were more likely to diversify into vertically related industries, and other measures of similarity did not affect the likelihood of diversification linkages among vertically related pairs. Firms were also significantly more likely to diversify among marketing related industries, and they were less likely to exit those industries.

The evidence on statistical associations between R & D and diversification suggests a more complex interrelationship than previous empirical and theoretical work has found. The results provided support for the Chandler-Penrose hypothesis and for the Scherer-McGowan hypothesis, in that origin industry R & D had a significant, positive, effect on the probability of diversification, and DRD also had a positive, significant, coefficient—high destination industry R & D attracted diversification. However, R & D also channels diversification in certain directions. Although firms from higher R & D industries are more likely to enter an industry than firms from lower R & D industries, the higher R & D firms are most likely to enter other high R & D industries; that is, firms diversify among industries with similarities in R & D orientation. The observed effects of R & D, marketing, and supply influences on the likelihood and directions of diversification, as reported here and in other research (Lemelin, 1982; Stewart, Harris, and Carleton, 1984), suggest that some part of product diversification reflects attempts to transfer the organization’s intangible capital among related activities. Future research into the nature and sources of such intangible capital, and its influence on the growth and resource allocation decisions of firms, seems warranted.

REFERENCES

Caves, Richard E., Multinational Enterprise and Economic Analysis (Cambridge: Cambridge University Press, 1982).


Lemelin, André, “Relatedness in the Patterns of Interindustry Diversification,” this REVIEW 64 (Nov. 1982), 646–657.


