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INNOVATION DIFFUSION AMONG FIRMS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
Edward John Malecki, Jr., B.A., M.A.

* * * * *

The Ohio State University
1975

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ACKNOWLEDGMENTS

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"Examining Change in Rank-Size Systems of Cities," The Professional Geographer, Volume 27 (February 1975), pp. 43-47.

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Chapter 1

INTRODUCTION

This research provides a link between two traditions of research on the diffusion of innovation. One of these focuses upon household or consumer innovations, which are used by individuals, where characteristics of consumers and aggregate market factors related to adoption have been the primary explanatory variables. The second tradition of research focuses upon adoption of innovations which are used by firms themselves, or firm innovations. These have been primarily explained in terms of the economic costs and advantages of adoption and firm characteristics, such as size, which facilitate adoption. Because consumer innovations often involve prior adoption by firms distributing or supplying the innovation, a linkage between these two previously disparate traditions appears to exist. The present research proposes and tests a common framework which embodies this linkage.

The framework consists of a model which posits that adoption time is a function of firm characteristics, such as firm size and management innovativeness and aggressiveness; innovation characteristics, such as its cost and relative economic advantage; information to firms about the innovation; local competition; and market factors, such as market potential. For consumer innovations, all of these factors are expected to be relevant, whereas for firm innovations, only the first four are
expected to operate.

The question of the diffusion of both consumer and firm innovations in urban systems also is considered, and the model is extended to include this focus. This builds on the fact that firm characteristics and market factors are systematically related to urban area size.

The models are tested with data obtained from the Federal Reserve System and from a mailed questionnaire. The former set of data describes the adoption of credit card services by commercial banks in the United States, including Ohio, through 1972. The questionnaire data pertain to the adoption of computer processing by banks in Ohio. Since the credit card is a consumer innovation and the computer is a firm innovation, a comparison of the two types of innovation within the model framework is possible.

The research proceeds first (Chapter 2) by a review of the role of firms in innovation diffusion. This includes a discussion of the firm-related processes behind the diffusion of both consumer and firm innovations, as well as a consideration of the way these processes relate to the empirical regularities of diffusion.

Chapter 3 presents a derivation of the model of innovation adoption among a set of firms. Analysis of spatial diffusion patterns is made possible by the relationship between the number and sizes of firms in a given city and the size of that city. Finally, integration of firm size, city size, competition, interfirm information flow, and market factors provides the basis for a general framework for the diffusion
among firms in an urban system.

The empirical context in which the models are tested is presented in Chapter 4. This includes a brief description of the American banking industry, a discussion of the two innovations, and an outline of the research design.

Chapters 5 and 6 contain the results of the empirical analyses of computer processing and bank credit card diffusion, respectively. Comments on the general applicability of the models are then offered.

Implications of the study for diffusion research are found in Chapter 7. In particular, models by economists and geographers are shown to be integrated in spatial models of firm adoption behavior. A discussion of the link between diffusion and urban and regional growth concludes the research.
Chapter 2

FIRMS IN THE DIFFUSION OF INNOVATION

This chapter presents a review of the existing literature concerning innovation diffusion as it pertains to the role of firms in the diffusion process. The first section discusses firms in the diffusion of consumer innovations; this is followed by a treatment of the literature on the adoption of innovations by firms for their own use. Finally, the spatial and temporal diffusion patterns resultant from each case are discussed, with an emphasis on diffusion in urban systems.

The Role of Firms in the Diffusion of Consumer Innovations

Previous research on the diffusion of innovation has largely focused on adoption by consumers or households (Rogers and Shoemaker, 1971). However, for consumer innovations adoption is actually the last of three stages in the diffusion process (Brown, 1974). The first stage is the establishment of diffusion agencies, entities through which the innovation is made available to the population of potential adopters. Each agency then implements a strategy to induce adoption by the consumers in its service area, which comprises the innovation establishment stage. The final stage, then, is adoption by consumers or households. This final step, which involves consumer behavior, may be seen as the demand side of diffusion. Agency establishment and innovation establishment, on the other hand, largely involve firm or entrepreneurial behavior...
and comprise the supply side of diffusion.

The possible settings for diffusion agency establishment include two distinct, ideal situations. In a mononuclear setting, a single propagator entity determines the location of each agency and the time at which it is established. This is done by evaluating and ranking alternative locations, employing such criteria as market potential for the innovation, and then, subject to budget constraints, choosing the most favorable as diffusion agency sites. Thus, a single propagator determines the structure of the system of diffusion agencies, and consequently, the general pattern of diffusion (Brown, 1974).

In a polynuclear setting, agency establishment is itself an adoption process, involving firms or entrepreneurs who independently of one another decide to establish an agency. Each agency generally is established by a different firm, and the agency's location commonly corresponds with that of its founder. Such factors as market potential appear to operate only as threshold conditions, in the presence of which establishment is primarily dependent upon exposure to the innovation. Exposure includes both awareness of the innovation and information regarding how an agency may be established and the potential profitability of doing so. Thus, the aggregation of individual actions gives rise to the structure of the diffusion agency system and the general pattern of diffusion (Brown, 1974; Malecki and Brown, 1975).

An important aspect of agency establishment is the degree to which there is central propagator support of the innovation. Such support may involve the provision of information about the innovation, support
in establishing an agency, and assistance in the promotion of the innovation by providing the agency with integrated promotional packages and by training agency personnel. This support is intended to facilitate the successful establishment of diffusion agencies and propagation of the innovation. However, the support is usually selective, reflecting a strategy on the part of the central propagator. This will lend direction to the spatial pattern of diffusion, but since the establishment decision ultimately rests with the local entrepreneur instead of with the central propagator, the effect of that direction will always be less than in the mononuclear case (Brown, 1974; Malecki and Brown, 1975; Meyer, 1975; Semple and Brown, 1974).

In diffusion of innovation without central propagator support, on the other hand, local firms and entrepreneurs decide to establish diffusion agencies without the prompting or assistance of a central propagator, so that direction to the diffusion is absent. Information must be transferred through individual channels to a greater extent, and contact with prior adopters and their experience is particularly significant (Brown, Malecki, Gross, Shrestha, and Semple, 1974; Cohen, 1972; Gibson, 1968; Pedersen, 1970; Semple and Brown, 1974).

Consideration of diffusion agency establishment, especially in a polynuclear setting, underlines the importance of firms in the diffusion of consumer innovations. To date, however, research has primarily focused upon the individual potential adopter. That research on consumer innovations which does examine the firm (e.g., Brown, 1974; Brown, Malecki, Gross, Shrestha, and Semple, 1974; Malecki and Brown,
1975) has considered exposure to or information about the innovation and its market potential as major factors in agency establishment. An additional set of factors, however, is the set of characteristics of entrepreneurs or firms themselves. This is one of the topics of the next section.

The Adoption of Innovations by Firms for Their Own Use

Research concerning the adoption of firm innovations, those employed by firms themselves, focuses upon a considerably different set of factors than research on consumer innovations. Market considerations are given almost no attention, and firm adoption decisions are seen as a reaction to competitive pressures among firms (Gold, Pierce, and Rosegger, 1970; Parker, 1974).¹ Three particular sets of factors have been seen as critical to diffusion among firms: innovation characteristics, firm characteristics, competition, and information effects. These are treated in turn below.

Innovation Characteristics

The cost and relative economic advantage of an innovation are indices by which each firm may evaluate the gain from its adoption (Kennedy and Thirlwall, 1972; Nabseth and Ray, 1974). Because of limits on capital availability, the cost of an innovation, in terms

¹A related body of research concerns invention and research and development (R&D) by firms. For examples, see Kamien and Schwartz (1975), Kennedy and Thirlwall (1972), Mansfield (1968), Mansfield, Rapoport, Schnee, Wagner, and Hamburger (1971), Nordhaus (1969), and Sahal (1974).
of both initial investment and operating expenses, acts as a constraint on adoption. The cost of adoption may vary among firms depending upon the degree to which the innovation is congruent with the firm's present and planned activities. For example, an innovation which involves operations similar to a firm's present or contemplated activities is less expensive than one which involves considerable other changes in operation as part of adoption (Mansfield, 1971, p. 94).

Risk is an additional factor which may be considered a cost of adoption. The risk of an innovation's failure in the early stages of diffusion adds to the cost of adoption to firms for which such failure would be especially disastrous or harmful (Nabseth and Ray, p. 307). In addition, especially for early adopters, cost estimates are frequently inaccurate due to the unproven nature of the innovation, and higher costs than expected are possible (Twiss, 1974, pp. 160-163).

The set of potential adopters in a set of firms is determined by the overall cost of adoption. Firms above a threshold size are able to meet the outlay required for adoption, whereas smaller firms are excluded from early adoption by the cost constraint (Mansfield, 1973). Partly because of this threshold, a low cost (and low risk) innovation will diffuse through a set of firms more rapidly than one with high cost and risk associated with it.

Relative economic advantage of an innovation includes the long-run cost savings (or increase in profits) it may induce in comparison to alternative techniques (Nabseth and Ray, 1974, pp. 3-13). This factor characteristically involves subjective judgements by the firm,
including assessment of the risks and uncertainties, as well as the benefits to be gained from adoption (Nabseth and Ray, 1974, pp. 302-303; Parker, 1974, p. 109). The subjective nature of relative economic advantage increases the difficulty of obtaining adequate measurements in empirical situations. In general, an innovation with a large relative advantage will be adopted more rapidly than one which is only slightly different from current practices.

Firm Characteristics

The attributes of firms which influence the incidence of adoption and the overall speed of diffusion are firm size and the qualities of its management. Large firms have several advantages over smaller firms in the adoption of innovations. First, large firms generally have greater ability to raise capital; similarly, the risk of innovation failure is borne more easily. An additional aspect of firm size is that large firms can afford the managerial and technical specialists often necessary to make an innovation successful; small firms usually

---

2 Measurement of relative economic advantage or profitability generally takes one of two forms. The first is the vintage approach, and employs the age of the firm's existing capital equipment or qualitative measures of the activities of the firm prior to adoption as an indication of the urgency of replacement (Lacci, Davies, and Smith, 1974; Schenk, 1974, pp. 242-244). This method has the advantage of employing pre-adoption data to indicate the considerations involved in the firm's adoption decision. The other, and much more common approach is to employ post-adoption benefits of the innovation to represent pre-adoption decision variables (Hakanson, 1974; Hsia, 1973; Mansfield, 1968, p. 182; Nabseth, 1973, p. 265). However, neither of the two approaches has yet successfully incorporated the subjective elements involved in the assessment of relative economic advantage.
must wait for the experience of other firms (Nabseth and Ray, 1974, p. 307; Parker, 1974). Firm size also appears to be closely related to relative economic advantage. Large firms are more able to make use of an innovation, thus increasing its potential advantage over that which small firms can expect (Nabseth and Ray, 1974, p. 308).

Firm size tends to be directly related to early adoption of innovations, and the overall pattern is an adoption sequence which corresponds with decreasing firm size. This decreasing firm size adoption pattern is especially true for high cost innovations, which initially can be afforded only by the largest firms. Lower cost innovations, including most consumer innovations, are more likely to be adopted by large and small firms without a strict size sequence (Myers and Marquis, 1969).

The qualities of a firm's management also affect the incidence of adoption among firms. Aggressive firms with an incentive to grow and improve their competitive position in the industry tend to be more receptive to innovations. This quality is more likely to be found in small firms, whose managements tend to be flexible and more willing to adapt to new procedures necessary for an innovation's success (Nabseth and Ray, 1974, p. 310; Waite, 1973). 3 However, the concept of management innovativeness, because of measurement problems, has remained

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3The term "small firm," which is that used in the literature, generally means "not large" and comprises three major characteristics. First, each firm has only a small market share and hence no individual market power. Second, ownership and management functions are closely associated. Finally, small firms enjoy autonomy in decision-making (Waite, 1973, pp. 154-155).

Competition and Information Effects

Competition among firms constitutes a basic cause of diffusion among firms. Early adoption takes place because certain firms wish to gain an advantage over their competitors. Later adopters either are forced to adopt to remain competitive or do so to take advantage of the innovation's success (Parker, 1974, pp. 99-117). The latter is one of the causes of the so-called bandwagon effect frequently found in empirical studies of interfirm diffusion.

Information creates awareness and reduces uncertainty with respect to innovations, including how they may be implemented. As some firms adopt, more information about the applicability of the innovation is available to nonadopters. This experiential information also results in the bandwagon effect of adoption (Lacci, Davies, and Smith, 1974, pp. 123-124). Information also is essential to each firm's appraisal of the cost and relative advantage of an innovation.

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4 Measurement of management innovativeness or aggressiveness, which should indicate receptivity toward innovations, has proved quite difficult. An early and rather simple measure, the age of the firm's president, was unsuccessful in a study of innovation adoption in several industries (Mansfield, 1968, pp. 155-172). A more rigorous measure of management aggressiveness, involving factor analysis of financial and productivity variables, was found to be useful in the explanation of investment behavior, but was insignificant in accounting for diffusion patterns of basic oxygen steel (Meyer and Herregat, 1974).
Information flows among firms appear to exhibit no clear relationship with distance, since neither distance bias nor gravity model relationships fit actual patterns of entrepreneurial contacts (Lasuen, 1973; Pred, 1973, 1974; Thorngren, 1970; Westaway, 1974a, 1974b). One reason this occurs is that within each industry, ubiquitous trade journals and propagator communications provide information to all firms. Probably more important than such information are institutional arrangements and specialized connections among firms (Brown, 1974; Malecki and Brown, 1975).

More important, in contrast to adoption of innovations by consumers, adoption by firms often lags years behind receipt of information. This delay or bottleneck is the result of cost constraints and, initially, the uncertain results of adoption. Cost especially causes adoption lags among firms which are quite willing to adopt but which do not have the resources available when the innovation first appears (Nabseth and Ray, 1974, pp. 299-301).

**Diffusion Patterns and the Urban System**

This section outlines the major empirical regularities found from diffusion research. Temporal regularities are discussed first, followed by a discussion of the spatial regularities of innovation diffusion. The section concludes with a brief discussion of models for diffusion through urban systems.
Temporal Regularities

The most prevalent temporal regularity of diffusion, for both consumer and firm innovations, is that through time the cumulative trend of adoption depicts an $S$-curve (Brown and Cox, 1971; Mansfield, 1968; Rogers and Shoemaker, 1971). The logistic function has commonly been employed to replicate this observed pattern. It can be generated from the assumption that diffusion results from information passed from previous adopters to nonadopters (Dodd, 1956), but frequently other factors also have been employed, such as resistance to change (Casetti, 1969), the interest of potential adopters (Gray and von Broembsen, 1974), the cost of adoption (Mansfield, 1968), and the profitability of the innovation (Griliches, 1957).

An alternative pattern of cumulative adoption is one which is characterized by an initially rapid adoption rate followed by a leveling off. Exponential functions are employed to represent this pattern. Some situations in which this has been noted include where propagators provide the bulk of information and direction to the diffusion (Lekvall and Wahlbin, 1973), where there is latent demand for the innovation before it is available (Brown, 1968), where the advantages of the innovation are obvious and immediate (Brown, 1974), and where the innovation is merely a minor improvement of an accepted product (Parker, 1974, p. 103).
Spatial Regularities

A second empirical regularity observed primarily in the diffusion of consumer innovations is the neighborhood effect, a pattern of adoption outward from an initial adopter or diffusion source (Hägerstrand, 1967). This operates most clearly in diffusion among consumers on a local scale where interpersonal communication is significant (Brown and Cox, 1971, p. 553). On a larger scale, diffusion agency establishment may take on a neighborhood pattern as a result of information flows (Brown, Malecki, Gross, Shrestha, and Semple, 1974), the distribution of market potential (Brown, 1974; Griliches, 1957), or the importance of logistical costs (Brown, 1974, pp. 8-9; Meyer, 1975).

The hierarchy effect is a diffusion pattern in which early adoptions take place in the highest order centers of the urban system, and later adoptions occur in the lower levels of the system (Brown and Cox, 1971; Hägerstrand, 1966). This regularity has been primarily associated with consumer innovations, although similar patterns have been discussed in the context of firm innovations by Lasuen (1973), Pedersen (1970), Pred (1973), and Robson (1973). One rationale for this effect has been the information flow patterns among urban centers (Hägerstrand, 1966; Hudson, 1972). More convincing, however, is the argument that

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5Studies of firm innovations generally have not considered spatial patterns in their diffusion, but instead tend to emphasize differences in diffusion rates from country to country. For example, see Maddala and Knight (1967), Nabseth and Ray (1974), Ray (1969), Swan (1973), and Tilton (1971). An exception is the work of Griliches (1957), which can be given an explicitly spatial interpretation (Casetti and Semple, 1969).
this pattern is the result of the variation in market potential or prof-
itability among urban areas (Brown, 1974; Brown and Cox, 1971, pp. 556-
559).

**Models of Diffusion in Urban Systems**

The general framework underlying models of diffusion through an urban system consists of a single dominant center and smaller subordinate towns. One type of model within this framework posits a diffusion pattern with a city size sequence beginning with the largest city. This pattern results from models based on both a central place system (Hudson, 1969, 1972) and a rank-size hierarchy (Berry, 1972; Pedersen, 1970).

In a second type of model, usually implemented with a gravity model formulation, both neighborhood and hierarchy effects operate to determine the diffusion pattern. This results in diffusion to small centers located near large cities as well as to other large cities (Berry, 1972; Hanham and Brown, 1972; Pedersen, 1970; Pred, 1973; Robson, 1973). This type of model also assumes that the diffusion process begins in the largest city of the urban system, despite recent evidence that diffusion may begin in medium-size cities (Cohen, 1972; Malecki and Brown, 1975; Pred, 1973). The present study develops a model which accounts for the latter pattern.

**Implications**

This review of the innovation diffusion literature suggests that the diffusion of consumer innovations through the establishment of
diffusion agencies and the diffusion of firm innovations involve the same factors. Research on the latter has emphasized firm and innovation characteristics, whereas research on the former has emphasized information flow and market characteristics. Because these two bodies of research have been conducted separately, they have been previously seen as unrelated. However, the fact that both involve entrepreneurial decision-making clearly demonstrates that they may be treated by a similar conceptualization.

The view taken in the present research, therefore, is that the diffusion of both types of innovation should be studied with a basic framework that includes all factors relevant in firm adoption decisions. For firm innovations, innovation characteristics, firm characteristics, competition, and information are expected to operate. These same factors, with the addition of market potential, are expected to be relevant to the diffusion of consumer innovations. Such an integrated framework for innovation diffusion among firms is presented in the following chapter.
Chapter 3

A MODEL OF INNOVATION DIFFUSION AMONG FIRMS

The objective of this chapter is to construct a general framework for firm adoption of both consumer and firm innovations that also accounts for patterns of diffusion in an urban system. In an initial model, time of adoption is a function of firm size, where size is a surrogate for the adoption propensity of firms, taking into account cost and risk constraints and management aggressiveness and innovativeness. Through the relationship between firm size and city size, the firm adoption process is related to city size diffusion patterns. By integrating urban area characteristics with regard to the distribution of firm sizes and those pertaining to competition, information, and market potential, a more general model for diffusion among urban areas is developed.

The Firm Adoption Model

Existing models of firm adoption emphasize the influence of firm size on diffusion. Because large firms are more able to afford the risk and cost of innovation adoption, they are expected to be the

1Consistent with the polynuclear setting for diffusion agency establishment, the general framework for the model is one of interfirm competition, especially on a local scale. Thus, the presence of several potential adopters in each urban area is assumed.
first adopters, followed by smaller firms (Hakanson, 1974; Mansfield, 1968; Nabseth, 1973; Smith, 1974). The size distribution of firms conforms to a mathematical form which is useful for depicting the relationship between firm size and adoption time. \(^2\) The simplest such form is the Pareto distribution,

\[ y = gx^{-q} \]  

(1)

where \( y \) is the number of firms greater than or equal to size \( x \), and \( g \) and \( q \) are parameters. The intercept, \( g \), indicates the number of firms in the set, and \( q \), the slope, measures the range of firm sizes. In its logarithmic form,

\[ \log y = \log g - q \log x \]  

(2)

the distribution is a straight line sloping downward to the right from the intercept value, \( \log g \).

Given the strong relationship between firm size and adoption time, the Pareto distribution also may serve to express the latter. Thus,

\[ A = dx^{-k} \]  

(3)

and

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\(^2\) There is a sizable literature on the topic of firm size distributions. For example, see Collins (1973), Engwall (1973), Hjalmarsson (1974), Ijiri and Simon (1971, 1974), Simon and Bonini (1958), Steindl (1965), and Wedervang (1965).
\[ \log A = \log d - k \log x. \] (4)

By direct analogy to (1) and (2), A is the date by which firms of size x or larger will adopt or the date of adoption by a firm of size x. Likewise, d is the date of adoption by the smallest firm or the latest adoption date, and k indicates the range of adoption times among the set of firms (Figure 1). That is, the smaller the value of k, the more rapid is the diffusion through the set, and the more similar are the adoption times for firms of all sizes. Alternatively, in a slow diffusion process, k is larger and reflects a greater range in adoption times.

There is, however, a consideration other than the greater ability of large firms to bear the cost and risk associated with adoption. Qualities such as management aggressiveness and innovativeness tend to be more common among small firms, which are anxious to grow and increase their industry share (Mueller, 1972; Waite, 1973). These characteristics, in turn, tend to increase the propensity toward early adoption by small firms, but this propensity toward early adoption is constrained by the cost and risk factors, which constrain small firms more than large firms (Figure 2).

The propensity toward early adoption is greatest among large (but not the largest) firms if the constraint of cost and risk is more important to adoption propensity than is the effect of management aggressiveness
Figure 1

Relationship between Firm Size and Date of Adoption
(Linear Pareto Function, Equations 3 and 4)
Figure 2

Conceptual Representations of Firm Size Effects on Propensity to Adopt Innovations

C = Cost  M = Management Aggressiveness and Innovativeness
R = Risk  T = Overall Effect (assumes effects are additive)
and innovativeness (Figure 2 A). Adoption propensity is greatest among small firms if the effect of management qualities increases adoption propensity more than the constraint of cost and risk (Figure 2 B). In this situation, management aggressiveness and innovativeness among small firms results in their high adoption propensity. If the effect of management qualities is constant for all firms sizes, and the effect of cost and risk is most important, then the largest firms have the highest adoption propensities (Figure 2 C). Finally, if the effect of the two sets of factors are equal, the overall effect is that medium-size firms have the highest propensities to adopt (Figure 2 D). The latter situation is suggested by the results of several empirical studies (Hakanson, 1974; Maddala and Knight, 1967; Mansfield, 1968; Myers and Marquis, 1969; Nabseth, 1973; Ray, 1969).

The overall advantage of medium-size firms in innovation diffusion can be incorporated into a formal model by an expansion of the linear Pareto model of Equation (4). This states that the date of adoption varies inversely with firm size at a constant rate, $k$. However, the rate at which the date of adoption declines actually is not constant, but changes to account for later adoption by large firms. By setting $k$ equal to $(a - b \log x)$, i.e.,

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3This reasoning assumes that, although adoption propensities and management aggressiveness and innovativeness are conceptual notions, are not easily measured, and do not have common units with cost and risk, they may be represented on the same axes to illustrate the effects of both sets of factors.
\[ \log A = \log d - ((a - b \log x) \log x) \]

\[ = \log d - a \log x + b (\log x)^2 \quad (5) \]

beginning with small firms, the date of adoption varies inversely with firm size at a decreasing rate until size \( \hat{x} \), whereupon the relationship is reversed. Thus, there is a firm size beyond which larger size is associated with later, rather than earlier, adoption (Figure 3).\(^4\)

For the remainder of this paper, the quadratic function of Equation (5) will be referred to as the \textit{basic model}. If its parameters are estimated with data from a diffusion process in which the first adoptions are \textit{not} by the largest firms, the value of \( a \) will be negative and the value of \( b \) will be positive. If, however, this tendency is not present and the first adoptions are by the largest firms, the value of \( b \) will be zero, leaving the linear relationship of Equation (4). Thus, the significance of the \( b \) value in Equation (5) indicates whether the quadratic or linear relationship is more appropriate in a given diffusion.

The size of firm which adopts earliest, or the \textit{turning point firm size}, \( \hat{x} \), may be estimated by differentiating Equation (5) with respect to \( \log x \), i.e.,

\(^4\)When adoption time is plotted on the abscissa and firm size along the ordinate, the quadratic model's pattern is similar in functional form and appearance to the "crater" function employed by Newling (1969).
Figure 3

Proposed Quadratic Relationship between Firm Size and Date of Adoption (Equation 5)
(ln A)' = -a/x + (2b ln x)/x

= (-a + 2b ln x)/x

(6)

Setting (ln A)' equal to zero and solving for ln x yields

ln x = a/2b

(7)

and

\[ \hat{x} = e^{(a/2b)} \]

(8)

where \( \hat{x} \) is the turning point firm size.

**Firm Adoption in an Urban Area Context**

A spatial component to the diffusion of innovation among firms is provided by the fact that the range of firm sizes, the size of the largest firm, and the number of firms will vary with the size of the urban area. In general, whether the earlier adopters are large or medium-size firms, the range of firm sizes in small, medium, and large cities (Figure 4) suggests that large cities are most-likely to contain the earlier adopters, since they will have more firms of every size. Given this, the Pareto distribution again is appropriate, now expressed as

\[ T = mp^{-s} \]

(9)

where \( T \) is the date of *first adoption* in the urban area, and \( p \) is its population. The parameter \( m \) in Equation (9) represents the latest
Figure 4

General Relationship between Firm Sizes and Frequencies with City Size
date of adoption among all urban areas, or that date at which adoption occurs in the smallest town. The parameter $s$ represents the rate of progression to earlier adoption as a function of population which in turn is representative of the range of firm sizes and the number of firms.

Recent empirical evidence regarding diffusion in systems of cities, however, indicates that the earliest adopters for many innovations are often found in medium-size cities. Examples include the establishment of cable television systems (Brown, Malecki, Gross, Shrestha, and Semple, 1974) and of planned regional shopping centers (Cohen, 1972), where early adoption in the largest cities was prevented by the presence of broadcasting television stations and major downtown department stores, respectively. Likewise, institutional factors and the presence of large established banks in Ohio's major cities resulted in the later establishment of diffusion agencies for BankAmericard and Master Charge in those cities (Malecki and Brown, 1975). Firm innovations which were adopted first in medium-size cities include building societies in eighteenth- and nineteenth-century Britain, where interurban communication patterns resulted in many adoption located near the early adopters before adoption in London (Robson, 1973, pp. 143-154), and several innovations in the United States iron and steel industry, which began among medium-size firms located in medium-size cities (Mansfield, 1968, pp. 86-87). Thus, medium-size cities appear to often provide better environments for innovative firms than do larger cities.
Just as this regularity was built into the firm adoption model, the linear form of Equation (9),

\[ \ln T = \ln m - s \ln p \]  \hspace{1cm} (10)

may be expanded to

\[ \ln T = \ln m - c \ln p + r (\ln p)^2 \]  \hspace{1cm} (11)

by setting \( s = (c - r \ln p) \). In Equation (11), the date of first adoption in the urban area, beginning with small cities, varies inversely with city population until the turning point city size, \( \hat{p} \), where the relationship is reversed. Beyond \( \hat{p} \), larger city size is associated with later, rather than earlier, adoption.

If the parameters of the city size diffusion model (Equation 11) are estimated with data from a diffusion process in which the early adoptions take place in medium-size cities, the value of \( c \) will be negative and the value of \( r \) will be positive. If, on the other hand, the first adoptions are in the largest cities, the value of \( r \) will be zero, leaving the linear relationship of Equation (10). Again, the significance of the \( r \) value indicates whether the quadratic or the linear relationship is more appropriate in a given diffusion through an urban system.

The size of city in which the first adoption occurs, or the turning point city size, \( \hat{p} \), may be estimated as in Equation (8), using the parameter values derived from Equation (11). Thus, \( \hat{p} = e^{(c/2r)} \).
A General Urban Area Model of Innovation Diffusion

Although the linear and quadratic relationships described above provide descriptive statements for the diffusion of innovation among firms and urban areas, for empirical analysis it also is desirable to clearly separate the various factors that underlie the diffusion process. To accomplish this, the basic city size diffusion model, Equation (11), may first be expressed in functional form as

$$T_j = f(p_j, p_j^2)$$  \hspace{1cm} (12)

where $T_j$ is the date of first adoption in urban area $j$, and $p_j$ is its population.

This model was derived under the assumption that population could be a surrogate for firm size, competition, and information effects. While this is true, explicit statement of these factors, together with the population factors from Equation (12), comprise a more general model for the diffusion of firm innovations in a system of urban areas, i.e.,

$$T_j = f(p_j, p_j^2, F_j, C_j, I_j)$$  \hspace{1cm} (13)

In (13), $T_j$ is the date of first adoption in the urban area, $p_j$ is its population, $F_j$ is firm size, $C_j$ is local competition, and $I_j$ is inter-firm information flow in the urban system.

For the diffusion of consumer innovations among firms, market characteristics also influence diffusion through the urban system. Market factors are indirectly included in the population variables in
Equation (12), but population alone does not indicate the probable retail success of a new good or service. Thus, the addition of a city's market potential, $M_j$, to the set of variables in Equation (13) accounts for those factors which operate in consumer innovation diffusion,

$$T_j = f(p_j, p_j^2, F_j, C_j, I_j, M_j)$$

(14)

where $T_j$, $p_j$, $F_j$, $C_j$, and $I_j$ are as above, and $M_j$ is the market potential of urban area $j$. Thus, the same set of factors is expected to operate as in the diffusion of firm innovations, with the addition of market potential as an indication of the innovation's commercial success.

Summary

This chapter has presented a model for the diffusion of an innovation through a set of firms. The model relies primarily upon relationships between firm size and the propensity toward early adoption.

Spatial diffusion patterns are incorporated in terms of the relationships between firm sizes and city size. The spatial pattern of firm adoption, in terms of urban area location, is accounted for by a model which allows for the possibility of large cities not being the location of the earliest adopters. A more general model of diffusion among urban areas takes into account firm size, local competition, and interfirm information flow in the urban system in the case of firm innovations, and these plus market potential for the case of consumer innovations. The specific means of implementing these models are considered in the following chapter.
Chapter 4

EMPIRICAL SETTING AND RESEARCH METHODOLOGY

In the previous chapter, two basic models for the diffusion of innovation among firms were presented. The firm adoption model (Equation 5) provides a general mathematical form for diffusion through a set of firms, where firm size represents the cost, risk, and management aggressiveness and innovativeness components of adoption decisions. Regularities in the location of firms in the urban system provide a city size diffusion model (Equation 11) similar in form to the firm adoption model, but with city population as the major variable. An extension of the city size diffusion model, the general urban area model, incorporates urban size, firm size, location competition, information, and market potential in a more general formulation. In this last model, the diffusion of firm innovations depends on the first four factors (Equation 13), whereas market potential also is relevant in the diffusion of consumer innovations (Equation 14).

This chapter discusses methods of empirically testing these models with data pertaining to two recent innovations in the United States banking industry, one a firm innovation and the other a consumer innovation. First, a brief presentation of the structure of American commercial banking sets the context for the analyses. Next, attention turns to the firm innovation of computer processing for internal record-
keeping and preparation of account statements and the source of data on its diffusion in Ohio. The bank credit card, a consumer innovation, is then introduced. Its diffusion in Ohio provides a comparison with adoption patterns of computer processing, and diffusion in the United States as a whole gives a larger scale perspective to diffusion processes in urban systems. The methodology by which these data sets are analyzed comprises the final section.

Commercial Banking in the United States

American banking, regulated by both federal and state statutes, is generally characterized by a large number of firms, intense competition, and high receptivity to innovations (Candilis, 1975; Fischer, 1968). State legislation determines the number of banks which, in turn, affects the competition among them as well as their relative sizes. In fifteen states, unit banking laws prohibit banks from operating more than one office, although several of these states allow partial service facilities. Statewide branch banking is permitted in nineteen states; sixteen states allow branches only within limited areas. For these 35 states, the head office location is employed as the banking firm's location in the empirical analyses presented here.

1 The most common provisions are to permit branches only within the city and county of the head office, or within that county and contiguous counties (Fischer, 1968, p. 69). The present research has employed the classification of states by branching status in 1972 (Brown, 1975, p. 19; see also Federal Deposit Insurance Corporation, 1970, pp. 8-11). A more recent classification is found in Wrocklage (1975).
The implication of branch banking regulations relevant to the research reported here is that the three groups of states are characterized by different sizes and numbers of banks. In general, dominance by large banks, in terms of concentration of deposits and other assets, is greater in states with statewide branching than in those with limited-branching and unit banking. Statewide branch banking states have fewer and larger banks; unit banking states have a large number of relatively small banking firms (Brown, 1975).

Recent Innovations in Banking

Two innovations in the American banking industry since 1950 are now discussed. The first, computer processing for internal record-keeping and preparation of account statements, is used by banks themselves, in contrast to the bank credit card, which is marketed to the banks' customers.

Computer Processing: A Firm Innovation

Computer processing for internal record-keeping and account statement preparation is now an accepted aspect of banking operation. The use of computers for data processing and storage may be divided into three general types or levels: the use of computer facilities operated by the bank itself; the use of a computer owned by another bank; and the use of a computer owned by a non-banking firm. The first category (Level 1) includes computer facilities owned in joint ventures by two or more banks, and is the most costly of the three types (Longbrake, 1973; Stutts, 1972). The second category (Level 2) results from large
correspondent banks providing data processing for banks in their correspondent networks, thereby adding to the set of services typically furnished by large, big-city banks. Level 2 adoption differs from Level 1 in that it is less expensive and does not involve selection of hardware and software. Level 3, the purchase of data processing services from a non-banking firm, generally is more costly than purchase from a correspondent (Longbrake, 1973).

Computer processing as an innovation in banking appeared in the early 1960's, and by 1963 was to be found in seven percent of all banks. By 1972, thirteen percent of all banks in the United States were Level 1 adopters, and provided services for about thirty-four percent of all other banks (Level 2 adopters). About six percent of all banks were Level 3 adopters, purchasing data processing services from non-banking firms (American Bankers Association, 1972).

The data concerning bank adoption of computer processing employed in this research were obtained from a questionnaire sent to all 495

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2Correspondent banking is the practice of a small respondent "country bank" keeping deposits in a large correspondent "city bank" in return for services provided by the latter, such as check clearing, participation in loans, and management and investment advice. Specific charges rather than minimum account balances are made for other services, such as data processing. See Federal Reserve Bank of Kansas City (1965a, 1965b), Fischer (1968, pp. 110-121), Linneman and Meinster (1970), Nadler (1966), Sullivan (1972), Waller (1961), White (1972), and Wrocklage (1975). Correspondent banking networks primarily emphasize dominance by large city banks (Borchert, 1972; Lawrence and Lougee, 1970). An example of a relatively small bank providing data processing for its respondent banks is found in Hoffman (1971). Within a bank holding company, the parent bank generally operates computer facilities, and correspondent ties are maintained among the member banks (Wrocklage, 1975).
commercial banks in Ohio in March, 1975. The questionnaire asked if and at what date each bank began the use of computer facilities for internal record-keeping and account statement preparation (Appendix). It also asked whether the bank used its own facilities, those of another bank, or those of a non-banking firm. Five of the banks were eliminated from consideration because they had been formed since 1973, leaving 490 banks for further analysis. Of these, 445 (90.8%) replied to the questionnaire.

Of the respondents, 88 (19.8%) were Level 1 adopters, operating a computer either solely or jointly with other banks, 225 (50.6%) were Level 2 adopters, employing the facilities of another bank, and 52 (11.7%) purchased such services from a non-banking firm, and are Level 3 adopters. These percentages are all higher than the national averages for each level. Eighty banks (17.9%) replied that they did not make any use of computer facilities, although two of these indicated that they had plans to adopt in the near future. Subsequent

Ohio permits branch banking within the county and counties contiguous to that of the head office. Thus, it is intermediate between statewide branch banking and unit banking and reflects the average case for the United States.

Discriminant analysis showed that the respondents and non-respondents to the questionnaire were not significantly different from each other. The discriminant analysis yielded an overall F value of 1.7311 on the basis of total assets, loan/deposit ratio, and the composition of the loan portfolio, a value which is not significant at the .05 level.

Two Level 1 adopters and eleven Level 2 adopters failed to provide adoption dates with their returned questionnaires.
The temporal trends of bank adoption of computer processing show that Level 1 adoptions first occurred in Ohio in January, 1961 (Figure 5). Level 2 adoptions obviously required the prior adoption by another bank, and began in June, 1962. Level 3 adoption began in June, 1960. All three diffusion patterns are fairly S-shaped; the rapid rise in Level 2 adoption is consistent with the fact that lower cost innovation adoption tends to take place at a more rapid rate (Hsia, 1973).

Observation of the spatial pattern of computer processing diffusion suggests that population is an important component of the diffusion process (Figure 6). The earliest adoptions took place in five of the most populous counties in the state. Adoptions through 1966 emphasize an east-west corridor in northern Ohio and a north-south corridor in western Ohio; central Ohio adoptions mainly took place after these. Late adoptions occurred primarily in the southeastern portion of the state.

The Bank Credit Card: A Consumer Innovation

The bank credit card is an innovation in banking that depends upon consumer and merchant acceptance. This dependence resulted in the

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Discriminant analysis results showed that adopters of computer processing were significantly different from nonadopters on the basis of total assets ($F = 6.1043$). The distinction was even more clear on the basis of loan/deposit ratio and the proportion of commercial loans ($F = 23.1560$, significant at the .01 level). Thus, adopter banks were larger, had higher loan/deposit ratios, and a higher proportion of commercial loans. They also tended to be located in larger towns.
Figure 5

Cumulative Adoption of Computer Processing by Banks in Ohio through March 1975\textsuperscript{a}

\textsuperscript{a}Source: Questionnaire (Appendix).
Figure 6

Spatial Pattern of First Adoption of Computer Processing by Banks in Ohio Counties through Selected Years

@ = Counties with Adopters
O = Counties without Adopters
failure of several credit card plans in the 1950's, when such plans were operated independently by each bank, which bore the cost and risk of adoption alone (Federal Reserve System, 1968, p. 7; Gibson, 1968, pp. 19-63). In 1966, however, BankAmericard and Master Charge plans were developed as national credit card systems, and changed the nature of the innovation's diffusion by providing central propagator support, coordinated promotion, and national availability for consumers (Abouchar, 1969; Adams, 1974; Johnston, 1972). The diffusion agency establishment process for the bank credit card before 1966 did not include propagator support.

Data pertaining to bank adoption of credit card plans were obtained from a survey of the Board of Governors of the Federal Reserve System conducted in December, 1972. The data, covering all commercial banks in the United States, show that 96 banks which had credit card plans at the end of 1972 had adopted prior to 1966. Nearly all the 6117 adopters since 1966 became affiliated with either the BankAmericard or Master Charge systems.

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7 The survey was a supplement to the December, 1972 Report of Condition (Call Report), Number 206. The Report of Condition is a financial report required quarterly of all commercial banks in the United States.

8 The number of adopters here (6213) differs from that reported in the summary report of the Board of Governors' survey (Seiders, 1973). This is due to the fact that the Board obtained its data on nonrespondents from the national credit card associations on a strictly confidential basis, and these data were not made available to the author. The number of banks with credit card plans in that report (8574) indicates that this nondisclosure applied to 27.5% of all adopters. It is assumed hereafter that the responding majority are representative of bank credit card adopters.
A distinction in the level of adoption occurs again in the case of bank credit cards. A relatively small number of banks act as principals (Class A adopters), holding account balances receivable and, frequently, providing services for the more numerous agents (Class B adopters). The latter therefore avoid the risk and liability of holding credit accounts, transferring them instead to the principal banks through which they offer the card service. Because of this arrangement, Class A banks market the service to a greater number of customers, and small banks are able to provide the banking service at minimal cost (Johnston, 1972, p. 6; McLeary, 1968). The fact that Class A banks usually offer their plan to their respondent banks at cost adds to the ease of Class B adoption (Federal Reserve Bank of Chicago, 1972; Gibson, 1968). Thus, the two levels of adoption are considered separately in this research.

The temporal trend of bank credit card adoption in the United States shows the two phases of diffusion clearly: adoption since 1966 took place much more rapidly than prior to that date (Figure 7). A period of

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9 The distinction employed in this research is to include banks which hold only part of their own receivables with Class A banks. This group, termed "participating agent banks," comprises only about five percent of all credit card adopters (Seiders, 1973, p. 646). Thus, Class B banks as defined here include only those which held no accounts receivable at the end of 1972.

10 Class A and Class B adopter groups nationally are significantly different from each other in terms of total assets, based on a discriminant analysis of the two groups (F = 12.1654, significant at the .05 level). Ohio Class A and Class B banks are even more distinct. Discriminant analysis of these resulted in an overall F value of 23.6953 on the basis of the proportion of commercial loans. The loan portfolio variables were not available at the national scale.
Figure 7

Cumulative Adoption of the Credit Card by Banks in the United States through December 1972

Source: Board of Governors of the Federal Reserve System.
very rapid diffusion took place in 1969, especially in Class B adoptions, suggesting that the entry of Master Charge with its predominance of Class B banks took place primarily during that year (Malecki and Brown, 1975).

The diffusion of the credit card among Ohio banks occurred somewhat differently (Figure 8). Adoption did not begin until 1966, and all adopters are members of either of the two nationally propagated systems. Because of a vigorous promotion by the BankAmericard licensee in the state, adoption of the credit card by banks occurred more rapidly in Ohio. The effect of the early BankAmericard presence also is seen in the relative imbalance of Class A and Class B adopters as compared to the United States adopters. The BankAmericard system is structured to include relatively more account-holding banks, so that the number of Class B adopters in Ohio has remained comparatively small (Malecki and Brown, 1975).

Observation of the spatial pattern of bank credit card adoption in Ohio (Figure 9) clearly shows the contrast between this diffusion and

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11 The Federal Reserve data were employed for Ohio with two exceptions: any banks which were no longer in business at the end of 1973 were eliminated, and adoptions more recent than 1972 were added to the set of bank adopters. Thus, the results reported here differ slightly from those reported in Malecki and Brown (1975). This comprehensive data for Ohio permitted analysis of adopters and nonadopters. These were significantly different from each other on the basis of loan/deposit ratio and the proportion of commercial loans ($F = 29.3073$, significant at the .01 level). A less significant discrimination resulted on the basis of total assets ($F = 14.9910$, significant at the .05 level).
Cumulative Adoption of the Credit Card by Banks in Ohio through June 1974\textsuperscript{a}

\textsuperscript{a}Sources: Board of Governors of the Federal Reserve System and Malecki and Brown (1975).
Figure 9

Spatial Pattern of First Adoption of the Bank Credit Card by Banks in Ohio Counties through Selected Dates

θ = Counties with Adopters
0 = Counties without Adopters
that of computer processing (Figure 6). The early adoption generally avoided the major population centers, and concentrated on east central Ohio, with some adoption in the northwest, northeast, and southern extremes of the state. Adoption in the large cities did not occur until late 1968 and early 1969. Adoptions after mid-1969 occurred mainly in the west central and southern portions of the state.

**Methodology for Empirical Analysis**

This section discusses specific procedures for testing the diffusion models of the preceding chapter. The models for firm adoption and urban system diffusion are discussed in turn.

**Firm Adoption**

The *firm adoption model* (Equation 5) takes the form of a second-degree (quadratic) polynomial in the logarithm of firm size. Stepwise multiple regression with \( \ln \) month and year of adoption as the dependent variable and \( \ln \) total assets and \( (\ln \text{total assets})^2 \) as independent variables permits assessment of the significance of the firm size variables in the diffusion of the bank credit card and of computer processing among banks.\(^{12}\) This analysis is performed on each of the three levels

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\(^{12}\)The dependent variable is constructed by dividing the month number (e.g., January = 1, February = 2, etc.) by 12.0 and adding it to the year of adoption. Thus, an adoption date of September, 1969 becomes 1969.75. The independent variable, firm size, should indicate the ability of firms to bear the risk and cost of adoption. Although many measures of firm size are possible, they are highly intercorrelated; therefore, total assets, the most available measure for banks, is employed in this research. See Engwall (1973) for a discussion of empirical firm size measures.
of adoption of computer processing, on pre-1966 bank credit card adoption in the United States, and on Class A and Class B bank credit card adoption in Ohio from 1966 to 1974 and in the United States as a whole from 1966 to 1972.\textsuperscript{13}

In each analysis, the statistical significance of the regression coefficients indicates whether the linear or the quadratic form of the firm adoption model best fits the empirical diffusion situation. The linear function is characterized by a significant negative coefficient of the linear term, $\ln$ \textit{total assets}, and a coefficient of the quadratic term, $(\ln \textit{total assets})^2$, which is not significant. The quadratic function is characterized by a significant negative linear term coefficient and a significant positive coefficient of the quadratic term. The quadratic relationship can occur from either of two situations -- when the largest firms adopt later than smaller firms, and when the set of largest firms adopts at about the same time as each other but earlier than smaller firms. Which of these situations in fact exists can be determined by calculating the turning point firm size, thereby establishing the size of the earliest adopter firm (Equation 8). If the calculated size is within the range of actual firm sizes, then the early adopters were medium-size firms. If the computed size is equal to or greater than that of the largest firm in the set, then adoption

\textsuperscript{13}Analyses of all bank credit card adopters together and of all levels of computer processing adoption together were also performed. The results were uniformly poor in comparison with those of the groups separately.
began among the largest firms, but took place among them very rapidly. The second situation indicates that, even though the best fit is a quadratic function, diffusion occurred by the same strict firm size dependency that is embodied in the linear function of Equation (4).

In addition to the test of the relationship between firm size and date of adoption, other characteristics of banking firms which measure bank aggressiveness are added to the firm adoption model for analyses of the diffusion of the two innovations in Ohio. The total loans/total deposits ratio (L/D) and the proportion of commercial loans to total loans (% CL) indicate general aggressiveness of banks in terms of their willingness to extend credit. The proportion of automobile loans to total loans (% AL) relates to both aggressiveness and to the consumer orientation of a bank (Snider, 1973). The coefficients of all three variables are expected to be negative, denoting early adoption by more aggressive banks and by those with consumer orientation.

Two of the empirical situations also permit analysis of the importance of interfirm communications in diffusion among firms. Level 2 computer processing adoption and Class B credit card adoption are dependent upon prior adoption by other banks. To implement this, the earliest Level 1 and Class A adoption date among the Ohio correspondents of each Level 2 and Class B adopter was determined (Rand McNally, 1975). This was added as an independent variable to the firm size and aggressiveness variables. The coefficient of the earliest correspondent adoption date (ECA) term is expected to be positive, denoting early adoption by banks with early adopting correspondents.
The second situation also permits analysis of the importance of interfirm communications in diffusion among firms, but specifically as regards contact from the propagator of the innovation. If a bank had a correspondent link with the single Ohio propagator of BankAmericard, it should have adopted the bank credit card earlier than other banks. To implement this, PROP is given a value of one when an adopter had a correspondent relationship with this propagator, and zero otherwise. Propagator contact influencing early adoption is indicated by a significant negative coefficient of PROP.

Thus, the basic firm adoption model, \( A = f(x, x^2) \), where \( x \) is bank total assets, is applied to each of the three levels of adoption of computer processing in Ohio from 1960 to 1975, to pre-1966 adopters of the bank credit card in the United States, to Class A and Class B adopter groups in the United States for the years 1966 to 1972, and to Class A and Class B credit card adopters in Ohio from 1966 to 1974. The basic model is then expanded to \( A = f(x, x^2, L/D, \% CL, \% AL) \), where \( L/D \) is the loan/deposit ratio, \( \% CL \) is the proportion of commercial loans to total loans, and \( \% AL \) is the proportion of automobile loans to total loans, and applied to the three levels of computer processing adoption and both classes of bank credit card adoption in Ohio. The earliest correspondent adoption date (ECA) is added for analysis of Level 2 adoption of computer processing in Ohio, expanding the model to \( A = f(x, x^2, L/D, \% CL, \% AL, ECA) \). The role of propagator contact is considered by adding PROP. In the analysis of credit card diffusion in Ohio, this results in the model \( A = f(x, x^2, L/D, \% CL, \% AL, PROP) \).
For Class A credit card diffusion in Ohio, which did not depend on prior adoption by other banks with the exception of the BankAmericard propagator, the model is \( A = f(x, x^2, L/D, \% CL, \% AL, PROP) \). Each of the empirical applications employs stepwise multiple regression; the results are presented in Chapter 5 and 6.

Diffusion among Urban Areas

The city size diffusion model (Equation 11) takes the form of a second-degree (quadratic) polynomial in the logarithm of city population. Stepwise multiple regression with \( \ln \) month and year of first adoption of the innovation (any level or class) in the urban area as the dependent variable and \( \ln \) population and \( (\ln \) population\(^2 \) as independent variables in the spatial diffusion of the bank credit card and of computer processing.\(^{14} \) This analysis is performed on diffusion of computer processing among banks in Ohio from 1960 to 1975, on diffusion of the bank credit card among banks in Ohio from 1966 to 1974, and on diffusion of the bank credit card in the United States from 1953 to 1965 and from 1966 to 1972.

\(^{14}\) For analysis of diffusion in Ohio, counties are employed as urban areas, consistent with the practice of branch banking in the state. For analysis of diffusion in the United States, Standard Metropolitan Statistical Areas (SMSA's) are treated as urban areas. The 265 SMSA's utilized are primarily those identified as of August, 1973 (National Bureau of Standards, 1973), with a few definitional changes through December, 1973 (U.S. Bureau of the Census, 1973c). Eight of the SMSA's did not contain a bank adopter of the credit card in December, 1972; 46 SMSA's had adoptions prior to 1966, and 211 had first adoptions from 1966 to 1972.
In each analysis, the statistical significance of the regression coefficients indicates whether the linear function or the quadratic function best fits the empirical diffusion situation. The linear relationship is characterized by a significant negative coefficient of the linear term, \( \ln \text{population} \), and a coefficient of the quadratic term, \( (\ln \text{population})^2 \), which is not significant. The quadratic function is characterized by a significant negative linear term coefficient and a significant positive coefficient of the quadratic term. The quadratic relationship can occur from either of two situations -- when the adoption occurs later in the largest cities than in smaller cities, and when adoption occurs in the set of largest cities at about the same time as each other but earlier than in smaller cities. Which of these situations in fact exists can be determined by calculating the turning point city size, thereby establishing the size of the city of earliest adoption (Equation 8). If the calculated size is within the range of actual city populations, then the earliest adoption locations were medium-size cities. If the computed size is equal to or greater than that of the largest city in the set, then adoption began among the largest urban areas, but took place among them very rapidly. The second situation indicates that, even though the better fit is a quadratic function, diffusion occurred by the same strict city size dependency that is embodied in the linear function of Equation (10).

In addition to the test of the relationship between city size and date of first adoption, other characteristics of urban areas which measure competition, firm size, and information flow were added as
independent variables to the basic city size diffusion model for analysis of the diffusion of both computer processing and the bank credit card in Ohio and of the bank credit card in the United States as a whole.

Four measures of local competition were employed. The intercept and slope parameters of each local firm size distribution (the size distribution of all banks in each urban area j), estimated by Equation (2), provide two such measures. The intercept value \( g_j \) indicates the number of firms in the urban area; a large value of \( g_j \) should be related to early adoption. The slope value \( q_j \) represents the range of firm sizes in the urban area; a large value of \( q_j \) designates that firm sizes in the area are similar and that therefore local competition among the firms is enhanced. The number of firms in the urban area \( n_j \) also serves as a simple measure of local competition, and is similar to \( g_j \) except that it is an exact measurement rather than a statistical estimate. The ratio of the mean firm size to the largest firm size in the urban area \( M/L_j \) is a size range measure similar to \( q_j \); its value will be large when firm sizes in the area are similar and competition is therefore greater. The coefficients of \( g_j \), \( q_j \), \( M/L_j \), and \( n_j \) should be negative, denoting early adoption in urban areas where there is local competition among banks, as measured by similarity of firm sizes, as well as a larger number of banks.

Firm size for the urban area is measured by the size of its largest firm \( L_j \). A large value of \( L_j \) indicates the presence of at least one large firm, suggesting that early adoption should occur. This is
indicated by a significant negative coefficient of \( L_j \).

Interurban information flow among firms is examined only for the analysis of both innovations in Ohio. This is measured by an information potential component similar to that employed by Pedersen (1970). Both a total information potential \( (TP_j) \) and an average information potential variable \( (AP_j) \) were computed for each county in Ohio for each innovation by

\[
TP_j = \sum_{i=1}^{z} \left( \frac{P_i}{D_{ij}} \right)
\]

and

\[
AP_j = \frac{TP_j}{z}
\]

where \( P_i \) is the population of places adopting computer processing earliest (seven in the period from 1960 to 1962) or of places adopting the bank credit card earliest (six in the period from 1966 to 1967), \( D_{ij} \) is the distance from each county \( j \) to each of the early adopter counties \( i \), and \( z \) is the number of such places adopting previous to place \( j \). Those urban areas with high information potential should be the sites of early adoption of innovations, indicated by significant negative coefficients of \( TP_j \) and \( AP_j \).

Market potential \( (M_j) \) of urban areas should be a significant factor in the diffusion of consumer innovations in urban systems. For analysis of bank credit card diffusion in Ohio and in the United States, therefore, median income for the urban area is employed. High income areas should contain diffusion agencies that are established earlier owing to
the higher profits attainable in such locations. This would be indicated by a significant negative coefficient of the $M_j$ term.

Thus, the basic city size diffusion model, $T_j = f(p_j, p_j^2)$, where $p$ is urban area population, is applied to diffusion of computer processing in Ohio from 1960 to 1975, to pre-1966 and 1966-1972 diffusion of the bank credit card in the United States, and to diffusion of the bank credit card in Ohio from 1966 to 1974. The basic model is then expanded to $T_j = f(p_j, p_j^2, g_j, q_j, M/L_j, n_j, L_j, M_j)$, where $g_j$ and $q_j$ are the intercept and slope, respectively, of the local firm size distribution in the urban area, $M/L_j$ is the ratio of the mean bank size to the largest bank size in the area, $n_j$ is the number of firms, $L_j$ is the size of the largest bank in the urban area, and $M_j$ is the median income of urban area $j$. This is applied to the diffusion of the bank credit card in the United States for two time periods: pre-1966 and 1966-1972.

Information potential is added to the model for the analysis of the diffusion of the bank credit card in Ohio from 1966 to 1972, resulting in $T_j = f(p_j, p_j^2, g_j, q_j, M/L_j, n_j, L_j, M_j, TP_j, AP_j)$, where $TP_j$ and $AP_j$ are total and average information potential for area $j$. Computer processing, a firm innovation, is not influenced by the market potential of urban areas, leaving the model $T_j = f(p_j, p_j^2, g_j, q_j, M/L_j, n_j, L_j, TP_j, AP_j)$, which is applied to the diffusion of computer processing in Ohio from 1960 to 1975.
Summary

This chapter has presented the empirical contexts in which analyses of innovation diffusion among firms are conducted. The adoption of two innovations in banking -- computer processing for internal record-keeping and preparation of account statements and the bank credit card -- are analyzed to test the firm adoption model and the city size diffusion model. The basic firm adoption model is expanded to include measures of firm aggressiveness and consumer orientation and is applied to analyses of both innovations, and interfirm communications and propagator contact are added for analyses of the bank credit card in Ohio. The basic city size diffusion model is expanded to include measures of local competition, firm size, interfirm information flow for analyses of the diffusion of computer processing in Ohio, and market potential is added for application to the diffusion of the bank credit card in Ohio. The results of the empirical analyses are presented in Chapters 5 and 6.
DIFFUSION OF A FIRM INNOVATION AMONG BANKING FIRMS

The results of the application of the models of firm adoption and diffusion in an urban system in an empirical setting are now presented. The diffusion of computer processing, a firm innovation, is discussed in this chapter. Analysis of the diffusion of the bank credit card, a consumer innovation, is presented in Chapter 6. The tables in this chapter present only statistically significant results; other results are discussed in the text.

Firm Characteristics and Innovation Adoption

Stepwise multiple regression was employed with Equation (5) to determine the relationship between date of adoption and firm size for the 86 Level 1 adopters, 211 Level 2 adopters, and 52 Level 3 adopters in Ohio. Firm size, measured here by bank total assets, indicates the ability to bear the cost and risk of adoption associated with large firms, as well as the qualities of management aggressiveness and innovativeness associated with small firms. Only the linear term was significant for Level 2 and Level 3 adoption, and both the linear and quadratic terms were significant for Level 1 adoption (Table 1). However, when the turning point firm size was calculated for Level 1 adoption, employing Equation (8) and the parameters of the quadratic relationship from Table 1, the value, 32,547.6 (in millions of dollars of total assets),
Table 1. Regression Analysis of Ohio Computer Processing Adoption on Firm Size

<table>
<thead>
<tr>
<th>Level 1 Adoption (N = 88)</th>
<th>Intercept</th>
<th>ln Total Assets</th>
<th>(ln Total Assets)^2</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.40784*</td>
<td>-0.05881*</td>
<td>0.00283*</td>
<td>.6843*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.70)</td>
<td>(2.12)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 2 Adoption (N = 211)</th>
<th>Intercept</th>
<th>ln Total Assets</th>
<th>(ln Total Assets)^2</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.31180*</td>
<td>-0.02348*</td>
<td></td>
<td>.1987*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level 3 Adoption (N = 52)</th>
<th>Intercept</th>
<th>ln Total Assets</th>
<th>(ln Total Assets)^2</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.34477*</td>
<td>-0.03279*</td>
<td></td>
<td>.3456*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*a Dependent variable is ln (Month and Year of Adoption). Data sources: Board of Governors of the Federal Reserve System and questionnaire (Appendix). Values in parentheses are t-values (* = significant at the .05 level). Firm size is measured by total assets (in millions of dollars) at the end of 1973. The results for the linear function applied to Level 1 adoption were ln (Month and Year of Adoption) = 4.35411 - 0.03282 ln total assets. (r^2 = .6672; t-value of slope coefficient = 12.98, significant at the .05 level).
was ten times greater than Ohio's largest bank. The significance of the quadratic function, then, occurred because diffusion among the large firms took place more rapidly than would be predicted by the linear function, and not because adoption began among medium-size firms. Thus, it was concluded that for all three levels of computer adoption that date of adoption followed a strict firm size relationship.

The $r^2$ values of the regression equations, which are .6672 for Level 1 adoption, .1987 for Level 2 adoption, and .3456 for Level 3 adoption, clearly illustrate the importance of firm size in the process of diffusion among firms. This progression of explained variance ($r^2$ values) is consistent with the degree to which adoption on the three levels was independent. Level 1 adoption was independent of other firms, Level 3 adoption required the computer processing facilities of a non-banking firm, and Level 2 adoption required a prior adoption by another (Level 1 adopter) bank. Thus, it was also concluded that dependence on factors external to the firm is associated with a reduction in the relative role of firm size in the diffusion process.

The predicted adoption dates for the average size bank of each level revealed the same progression (Table 2). Level 1 adoption was predicted to occur earliest, followed by Level 3 and Level 2 adoption. For other representative firm sizes, the progression is different, suggesting that firm size plays a role in determining the type of adoption as well as the time of adoption. For example, for banks of size 10 million dollars of total assets (the size of the 362nd ranked bank of
Table 2. Predicted Adoption Dates for Selected Firm Sizes and Mean Size, All Three Levels of Adoption of Computer Processing\(^a\)

<table>
<thead>
<tr>
<th>Total Assets</th>
<th>Level 1 (Linear)</th>
<th>Level 2 (Linear)</th>
<th>Level 3 (Linear)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1972.135 (February)</td>
<td>1970.163 (February)</td>
<td>1971.469 (June)</td>
</tr>
<tr>
<td>25</td>
<td>1969.998 (December)</td>
<td>1969.146 (February)</td>
<td>1969.354 (May)</td>
</tr>
<tr>
<td>50</td>
<td>1968.424 (June)</td>
<td>1968.030 (January)</td>
<td>1967.795 (October)</td>
</tr>
<tr>
<td>100</td>
<td>1966.885 (November)</td>
<td>1966.932 (December)</td>
<td>1966.272 (April)</td>
</tr>
<tr>
<td>500</td>
<td>1963.443 (June)</td>
<td>1964.449 (June)</td>
<td>1962.865 (November)</td>
</tr>
<tr>
<td>Mean Total Assets</td>
<td>241.8</td>
<td>27.2</td>
<td>40.4</td>
</tr>
<tr>
<td></td>
<td>1964.980 (December)</td>
<td>1969.013 (January)</td>
<td>1968.269 (April)</td>
</tr>
</tbody>
</table>

\(^a\)Calculated from results in Table 1. Total assets is in millions of dollars at the end of 1973.
the 49th in Ohio), Level 2 adoption is earliest, followed by Level 3 and Level 1. At a bank size of 50 million dollars of total assets (the size of the 104th largest Ohio bank), the progression becomes Level 3-2-1 and changes to the sequence Level 3-1-2 at a size of 500 million dollars in total assets (between the fourteenth and fifteenth largest banks in the state). In summary, among small banks (e.g., total assets of 10-25 million dollars), Level 1 adoption was predicted to occur later, consistent with the greater cost and risk involved in implementing computer processing in a small operation and the lesser need for that type of adoption. Among large banks, on the other hand (e.g., total assets above 500 million dollars), the more costly adoption levels, Level 1 and Level 3, occurred earlier than Level 2 adoption.

Other banking firm characteristics — total loans/total deposits ratio (L/D), proportion of commercial loans to total loans (% CL), and proportion of automobile loans to total loans (% AL) — representing aggressiveness of banks in terms of their willingness to extend credit, were added to the basic model. These characteristics were insignificant for all three levels of computer processing adoption when analyzed along with ln total assets and (ln total assets)^2. However, regression analysis of the month and year of adoption on the proportion of commercial loans without the firm size terms indicated that adoption time was inversely related to the proportion of commercial loans (Table 3). The level of explanation was much higher for Level 1 adoption (r^2 = .3126) than for Level 2 adoption (r^2 = .0282), but both were considerably lower than the explanation of the firm size functions.
Table 3. Regression Analysis of Ohio Computer Processing Adoption on Firm Aggressiveness$^a$

<table>
<thead>
<tr>
<th></th>
<th>Intercept</th>
<th>Proportion of Commercial Loans to Total Loans</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1 Adoption</td>
<td>4.27754*</td>
<td>-0.31149*</td>
<td>.3126*</td>
</tr>
<tr>
<td>(N = 86)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 2 Adoption</td>
<td>4.25103*</td>
<td>-0.06804*</td>
<td>.0282*</td>
</tr>
<tr>
<td>(N = 211)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^a$Dependent variable is ln (Month and Year of Adoption). Data sources: Board of Governors of the Federal Reserve System and questionnaire (Appendix). Values in parentheses are t-values (* = significant at the .05 level). Proportion of commercial loans to total loans was computed from data for the end of 1973.
Firm adoptions which are not independent, but which require a prior adoption by other firms, are represented by Level 2 adoption, where the adopter employs the computer facilities of another bank. For a Level 2 adoption to occur, a bank which is willing to provide such services for other banks on a correspondent basis must have previously adopted its own (Level 1) facilities. Regression analysis of the month and year of Level 2 adoption on ln total assets and ln ECA (a measure of interfirm communications) provided slight improvement in explanation ($r^2 = .2136$) over the firm size variable alone ($r^2 = .1987$) (Table 4). However, the sign of the coefficient of ECA was negative, the opposite of that which would indicate early adoption by banks whose correspondent adopted early. Thus, interfirm communications appear to not have been significant in the adoption of computer processing.

**Urban Area Characteristics and Innovation Diffusion**

Stepwise multiple regression was employed with Equation (11) to determine the relationship between date of first adoption in an urban area and city size for the first adoptions of computer processing (at any level) in the 88 Ohio counties. Urban size, as measured by population, indirectly involves firm size, competition, and information effects which together often result in early adoption in medium-size cities. Only the linear term was significant; however, the level of explanation was quite high ($r^2 = .5862$) which clearly illustrates the importance of city size on diffusion patterns in an urban system (Table 5). The significance of the linear function, then, occurred because diffusion
Table 4. Regression Analysis of Ohio Level 2 Computer Processing Adoption on Firm Size and Interfirm Communications $^a$

<table>
<thead>
<tr>
<th>Intercept</th>
<th>In Total Assets</th>
<th>In Earliest Correspondent Adoption Date</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.65404*</td>
<td>-0.02360*</td>
<td>-0.08265*</td>
<td>.2136*</td>
</tr>
<tr>
<td>(7.28)</td>
<td>(1.98)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N = 211

$^a$Dependent variable is ln (Month and Year of Adoption). Data sources: Board of Governors of the Federal Reserve System, Rand McNally (1975), and questionnaire (Appendix). Correspondents employed include only those located within Ohio. Total assets is measured in millions of dollars at the end of 1973. Values in parentheses are t-values (* = significant at the .05 level).
Table 5. Regression Analysis of Computer Processing Adoption on Urban Size for Counties in Ohio\(^a\)

<table>
<thead>
<tr>
<th>Intercept</th>
<th>ln Population</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.58555*</td>
<td>-0.03457*</td>
<td>0.5862*</td>
</tr>
<tr>
<td>(11.04)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(N = 88\)

\(^a\)Dependent variable is ln (Date of First Adoption in County). Data sources: Questionnaire (Appendix) and U.S. Bureau of the Census (1971). Values in parentheses are t-values (* = significant at the .05 level).
began among the large urban areas, and not because diffusion began among medium-size cities. Thus, it was concluded that the diffusion of computer processing followed a strict city size relationship.

Other urban area characteristics -- the parameters of the local firm size distribution ($g_j$ and $q_j$), the mean bank size/largest bank size ratio ($M/L_j$), and the number of banks in the urban area ($n_j$), all of which represent local competition; the size of the largest bank in the urban area ($L_j$), representing firm size; and total and average information potential ($TP_j$ and $AP_j$), representing interfirm information flow in the urban system -- were added to the basic model. Regression analysis of the month and year of first adoption of computer processing in the 88 Ohio counties resulted in the significance of only one urban area characteristic, the largest bank size ($L_j$), in addition to both the linear and quadratic population terms (Table 6). The parameters of the quadratic relationship from Table 6 and Equation (8) were employed to calculate the turning point city size. This population value, 428,052.0, falls between the sixth and seventh largest counties in Ohio, indicating that adoption took place in medium-size counties first, and adoption in the largest counties occurred only after these. Thus, the presence of a large firm in an urban area resulted in earlier adoption in medium-size counties, and urban areas with large banks had adopters of computer processing earlier than areas with only small banks.
Table 6. Regression Analysis of Computer Processing Adoption on Urban Size and Firm Size for Counties in Ohio

<table>
<thead>
<tr>
<th>Intercept</th>
<th>In Population</th>
<th>(In Population)^2</th>
<th>In Largest Firm Size</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.22573*</td>
<td>-0.15042*</td>
<td>0.00580*</td>
<td>-0.01826*</td>
<td>.6215*</td>
</tr>
<tr>
<td>(2.99)</td>
<td>(2.53)</td>
<td></td>
<td>(2.08)</td>
<td></td>
</tr>
</tbody>
</table>

N = 88

*aDependent variable is ln (Month and Year of First Adoption in County). Data sources: Board of Governors of the Federal Reserve System, questionnaire (Appendix), and U.S. Bureau of the Census (1971). Largest firm size is measured by total assets (in millions of dollars) at the end of 1973. Values in parentheses are t-values (* = significant at the .05 level).
Summary of Findings

The empirical analysis of the diffusion of computer processing among Ohio banks showed that firm size was the most important variable in the diffusion. Firm size, measured by \( \ln \text{total assets} \), determined the level of adoption of computer processing, evidenced by the typical firm sizes of each adoption level. The speed with which adoption took place among banks then varied within the level chosen by the bank. Overall, the pattern of adoption at each level followed a strict firm size order.

Because of the relationship between firm size and urban area size, the spatial diffusion in the urban system was explained. The pattern of first adoption of computer processing in an urban area was found to begin with medium-size cities with large banks, followed by both the largest and smaller urban areas.

The only firm characteristic other than size which was related to the date of adoption by banks was the proportion of commerical loans to total loans. Banks with large proportions of commercial loans were early adopters of computer processing. Other urban area characteristics, including local competition and information, at least as measured here, were not related to the spatial diffusion of computer processing among banks.
Chapter 6

DIFFUSION OF A CONSUMER INNOVATION AMONG BANKING FIRMS

The results of the application of the models of firm adoption of the bank credit card and its diffusion in the United States as a whole and in Ohio are now presented. The tables in this chapter generally present only statistically significant results; other results are discussed in the text.

Firm Characteristics and Innovation Adoption: National Scale

Stepwise multiple regression was employed with Equation (5) to determine the relationship between date of adoption and firm size for the 96 pre-1966 adopters, 1510 Class A adopters, and 4607 Class B adopters in the United States. Firm size, as measured here by bank total assets, indicates management aggressiveness and innovativeness associated with small firms, and the ability of a firm to bear the cost and risk of adoption associated with large firms. Both the linear and quadratic terms were significant for all adopter groups (Table 7). The turning point firm sizes for each group were calculated, employing Equation (8) and the parameters of the quadratic relationships from Table 7. The firm size values -- 549.6 for pre-1966 adopters, 7427.9 for Class A adopters, and 230.7 for Class B adopters (in millions of dollars of total assets) -- are all within the range of actual bank
Table 7. Regression Analysis of United States Bank Credit Card Adoption (1953-1972) on Firm Size\textsuperscript{a}

<table>
<thead>
<tr>
<th></th>
<th>Intercept</th>
<th>ln Total Assets</th>
<th>(ln Total Assets\textsuperscript{2})</th>
<th>R\textsuperscript{2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-1966 Adoption (N = 96)</td>
<td>4.36372*</td>
<td>-0.10120*</td>
<td>0.00802*</td>
<td>.3382</td>
</tr>
<tr>
<td></td>
<td>(5.67)</td>
<td></td>
<td>(4.66)</td>
<td></td>
</tr>
<tr>
<td>Class A Adoption (N = 1510)</td>
<td>4.26384*</td>
<td>-0.00713*</td>
<td>0.00040*</td>
<td>.0785*</td>
</tr>
<tr>
<td></td>
<td>(5.05)</td>
<td></td>
<td>(2.65)</td>
<td></td>
</tr>
<tr>
<td>Class B Adoption (N = 4607)</td>
<td>4.25681*</td>
<td>-0.00801*</td>
<td>0.00074*</td>
<td>.0398*</td>
</tr>
<tr>
<td></td>
<td>(7.40)</td>
<td></td>
<td>(4.05)</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a}Dependent variable is ln (Month and Year of Adoption). Data source: Board of Governors of the Federal Reserve System. Values in parentheses are t-values (* = significant at the .05 level). Firm size is measured by total assets (in millions of dollars) at the end of 1972.
sizes nationwide. The significance of the quadratic functions, then, occurred because adoption took place first among medium-size firms. Thus, it was concluded for all three adopter groups of the bank credit card that date of adoption did not follow a strict firm size relationship, but began among medium-size firms followed by both large and small firms.

The $r^2$ value of the quadratic function for pre-1966 adopters ($r^2 = .3382$) was considerably higher than that for Class A ($r^2 = .0785$) and Class B adopters ($r^2 = .0398$). This progression of the importance of firm size, as indicated by the levels of explained variance, conforms to the progression of the cost and risk involved in adoption of the credit card and the amount of management aggressiveness and innovativeness required. Pre-1966 adopters operated their own plans, bearing full cost and risk, thus requiring a considerable amount of management aggressiveness and innovativeness to adopt. Class A adopters (since 1966) bear the risk of default on payments and loans, but have adopted a proven, centrally-supported innovation. Class B adoption involves little or no cost and risk, thus requiring relatively little aggressiveness and innovativeness on the part of the management. This progression also includes the degree to which adoption was independent. Pre-1966 adopters independently began credit card plans with no external support. Class A adopters had the assistance of central propagators; Class B adoption required both propagator support and Class A adoption. Therefore, it was also concluded that independence in adoption, the extent to which cost and risk are borne by the adopter, and the degree
of management innovativeness and aggressiveness required are all associated with the role of firm size in the diffusion process. It appears that management aggressiveness and innovativeness were relatively important in the diffusion of the bank credit card, owing to the generally low cost and risk involved and as evidenced by the fact that adoption began among medium-size banks.

Although data pertaining to other bank characteristics and interfirm communications were not available for the national diffusion of the bank credit card, a division of adopters by type of state banking legislation was informative. The 1510 Class A adopters were partitioned into statewide branch banking state adopters (N = 257), limited branch banking state adopters (N = 847), and unit banking state adopters (N = 406). Regression analysis of the three groups, employing Equation (5), indicated that adoption proceeded differently in the different legal environments (Table 8). The quadratic and linear terms were both significant for limited branch banking state adopters, but only the linear term is significant for the other two groups of adopters. The turning point firm size for limited branch banking state adopters, 2708.1, verified the fact that medium-size banks were the first adopters of the credit card in those states. By contrast, in unit banking and statewide branch banking states, adoption began among the largest banks. In these states, there is a greater number of relatively large banks which were early adopters, and comparatively few medium-size banks. In limited branch banking states, on the other hand, there is a larger number of medium-size banks,
Table 8. Regression Analysis of Class A Bank Credit Card Adoption (1966-1972) on Firm Size by Type of State Branch Banking Legislation

<table>
<thead>
<tr>
<th>Type of State Branch Banking Legislation</th>
<th>Intercept</th>
<th>ln Total Assets</th>
<th>(ln Total Assets)$^2$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statewide Branch Banking State Adopters</td>
<td>4.25235*</td>
<td>-0.00373*</td>
<td></td>
<td>.1077*</td>
</tr>
<tr>
<td>(N = 257)</td>
<td></td>
<td>(5.55)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited Branch Banking State Adopters</td>
<td>4.26312*</td>
<td>-0.00664*</td>
<td>0.00042*</td>
<td>.0533*</td>
</tr>
<tr>
<td>(N = 847)</td>
<td></td>
<td>(3.52)</td>
<td>(2.06)</td>
<td></td>
</tr>
<tr>
<td>Unit Banking State Adopters</td>
<td>4.25750*</td>
<td>-0.00363*</td>
<td></td>
<td>.0745*</td>
</tr>
<tr>
<td>(N = 406)</td>
<td></td>
<td>(5.70)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*aDependent variable is ln (Month and Year of Adoption). Data source: Board of Governors of the Federal Reserve System. Values in parentheses are t-values (* = significant at the .05 level). Firm size is measured by total assets (in millions of dollars) at the end of 1972. The predicted size of the earliest adopter for limited branch banking state adoption is 2708.1, a size which is fairly large nationally, but much smaller than the nation's largest banks.*
many of which adopted early. Thus, the adoption patterns reflect the relative sizes of banks under the three types of legislation.

**Urban Area Characteristics and Innovation Diffusion: National Scale**

Stepwise multiple regression was employed with Equation (11) to determine the relationship between date of first adoption in an urban area and city size for the first adoptions of the bank credit card in the 46 SMSA's which had adopters prior to 1966. Neither the linear nor the quadratic terms were significant for this phase of the diffusion, and local competition and market potential characteristics of these SMSA's also were unable to account for the diffusion pattern. Early adoptions in the 1953-1965 period generally were among small banks, whereas several adoptions in 1964 and 1965 were by very large banks, primarily reflecting a conservatism by most large banks toward the innovation when it first appeared. Therefore, the pattern of adoptions was quite different from that incorporated in the firm adoption model.

Analysis of the date of first adoption in the 211 SMSA's with first adoptions since 1966 indicated that only the linear term was significant for this diffusion (Table 9). The addition of other urban area characteristics failed to improve on the linear model. Thus, the strict city size relationship was followed in the diffusion of the bank credit card in the United States from 1966 to 1972. However, local competition, when measured by the mean bank size/largest bank size ratio, resulted in a slightly higher level of explanation \( r^2 = .0761 \) than urban size \( r^2 = .0730 \) (Table 10). This was further increased \( r^2 = .0950 \) by
Table 9. Regression Analysis of Bank Credit Card Adoption on Urban Size for United States SMSA's (1966-1972)\textsuperscript{a}

<table>
<thead>
<tr>
<th>Intercept</th>
<th>In Population</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.29792*</td>
<td>-0.00533*</td>
<td>.0730*</td>
</tr>
<tr>
<td>(4.06)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$N = 211$

\textsuperscript{a}Dependent variable is $\ln$ (Month and Year of First Adoption in SMSA). Data sources: Board of Governors of the Federal Reserve Systems and U.S. Bureau of the Census (1973a, 1973c). Value in parentheses is t-value (* = significant at the .05 level).
Table 10. Regression Analysis of Bank Credit Card Adoption on Local Competition and on Local Competition and Market Potential for United States SMSA's (1966-1972)a

<table>
<thead>
<tr>
<th>Intercept</th>
<th>Largest Bank Size Ratio</th>
<th>ln Median Income</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.21745*</td>
<td>0.02353*</td>
<td></td>
<td>.0761*</td>
</tr>
<tr>
<td></td>
<td>(4.15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.35475*</td>
<td>0.02200*</td>
<td>-0.01497*</td>
<td>.0950*</td>
</tr>
<tr>
<td></td>
<td>(3.88)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N = 211

---

*aDependent variable is ln (Month and Year of First Adoption in SMSA). Data sources: Board of Governors of the Federal Reserve System and U.S. Bureau of the Census (1973a, 1973c). Values in parentheses are t-values (* = significant at the .05 level). Firm size is measured by total assets (in millions of dollars) at the end of 1972.
the addition of market potential, measured by median family income. However, the coefficient of the local competition factor has the opposite sign from the negative sign associated with greater local competition. Therefore, it was concluded that early adoption occurred in urban areas where market potential was high and where large firms were present.

**Firm Characteristics and Innovation Adoption: State Scale**

Stepwise multiple regression was employed with Equation (5) to determine the relationship between date of adoption and firm size for 178 Class A adopters and 117 Class B adopters in Ohio. Both the linear and quadratic terms were significant for Class A adoption but were insignificant for Class B adoption (Table 11). The turning point firm size for Class A adoption was calculated, employing Equation (8) and the parameters from Table 11. The firm size value, 280.5 (in millions of dollars of total assets), is about the size of the twenty-second largest bank in Ohio, implying that Class A adoption occurred first among medium-size banks.

Other banking firm characteristics -- total loans/total deposits ratio (L/D), the proportion of commercial loans to total loans (% CL), and the proportion of automobile loans to total loans (% AL) -- representing aggressiveness of banks in terms of their willingness to extend credit, were added to the basic model. The proportion of automobile loans, which measures consumer orientation as well as aggressiveness, added to the explanation of the quadratic model for Class A adoption.
Table 11. Regression Analysis of Ohio Bank Credit Card Adoption on Firm Size

<table>
<thead>
<tr>
<th></th>
<th>Intercept</th>
<th>In Total Assets</th>
<th>(In Total Assets)²</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A Adoption</td>
<td>4.27562*</td>
<td>-0.01364*</td>
<td>0.00121*</td>
<td>0.1068*</td>
</tr>
<tr>
<td>(N = 178)</td>
<td>(3.62)</td>
<td>(1.69)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class B Adoption</td>
<td>4.25920*</td>
<td>-0.01017</td>
<td>0.00161</td>
<td>0.0251</td>
</tr>
<tr>
<td>(N = 117)</td>
<td></td>
<td>(1.69)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dependent variable is ln (Month and Year of Adoption). Data sources: Board of Governors of the Federal Reserve System and Malecki and Brown (1975). Values in parentheses are t-values (* = significant at the .05 level). Firm size is measured by total assets (in millions of dollars) at the end of 1973.
(Table 12). The sign of the coefficient of the proportion of automobile loans, however, was positive rather than the negative sign expected from a consumer orientation variable. This suggests that banks with successful consumer loan programs were at first unwilling to add an unproven loan plan. The turning point firm size for the relationship with % AL was calculated employing Equation (8) and the linear and quadratic terms from Table 12. The firm size value, 184.9 (in millions of dollars of total assets) indicates even more strongly that medium-size banks were the early adopters in Ohio.

Variables measuring propagator contact and support were added to the model to determine the importance of propagators in the diffusion of the bank credit card. When analyzed with in total assets, propagator contact, measured by a one/zero variable indicating the presence (or not) of a correspondent relationship with the BankAmericard propagator in Ohio, provided a higher level of explanation than the quadratic model ($r^2 = .1654$ compared to $r^2 = .1068$) (Table 13). Thus, larger banks and banks having correspondent links with the state propagator of the bank credit card were the earliest adopters of the innovation. Propagator contact was important to early adoption, especially among medium-size banks (Malecki and Brown, 1975).

Class B adoption, which is dependent upon Class A banks as well as on propagator contact, was not significantly accounted for by any of the variables in the firm adoption model. The fact that firm size is insignificant in the Class B adoption process suggests the
Table 12. Regression Analysis of Ohio Class A Bank Credit Card Adoption on Firm Size and Bank Characteristics

<table>
<thead>
<tr>
<th>Intercept</th>
<th>In Total Assets</th>
<th>(In Total Assets)$^2$</th>
<th>Proportion of Automobile Loans to Total Loans</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.27363*</td>
<td>-0.01587*</td>
<td>0.00152*</td>
<td>0.03406*</td>
<td>.1482*</td>
</tr>
<tr>
<td>(4.21)</td>
<td>(3.70)</td>
<td>(2.91)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N = 178

---

aDependent variable is ln (Month and Year of Adoption). Data sources: Board of Governors of the Federal Reserve System and Malecki and Brown (1975). Values in parentheses are t-values (* = significant at the .05 level). Firm size is measured by total assets (in millions of dollars) at the end of 1973.
Table 13. Regression Analysis of Ohio Class A Bank Credit Card Adoption on Propagator Contact and Firm Size$^a$

<table>
<thead>
<tr>
<th>Intercept</th>
<th>Propagator is Correspondent $(1/0)$</th>
<th>In Total Assets</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.25817*</td>
<td>-0.00784* (3.77)</td>
<td>-0.00349* (3.56)</td>
<td>.1654*</td>
</tr>
</tbody>
</table>

$N = 178$

$^a$Dependent variable is $\ln$ (Month and Year of Adoption). Data sources: Board of Governors of the Federal Reserve System, Malecki and Brown (1975), and Rand McNally (1975). Values in parentheses are t-values (* = significant at the .05 level). Firm size is measured by total assets (in millions of dollars) at the end of 1973.
inapplicability of the firm adoption model for innovations where cost and risk constraints do not operate and where little management aggressiveness and innovativeness are required. The appearance of Master Charge in Ohio in early 1969 was met by Class B adoption by banks of all sizes and characteristics, resulting in little that is statistically significant.

Urban Area Characteristics and Innovation Diffusion: Ohio

Stepwise multiple regression was employed with Equation (11) to determine the relationship between date of first adoption of the credit card (either class) in 85 Ohio counties with adopters through March 1974. All Ohio adoptions of the credit card took place after 1965. Only the linear term was significant, indicating a strict city size relationship with date of adoption (Table 14). The level of explanation \( r^2 = .1828 \) was considerably lower than in the diffusion of computer processing, and is most likely due to the lower requirements of cost, risk, and management factors involved in the diffusion of the credit card. In addition, the much shorter time period involved in the credit card's diffusion resulted in adoption in many urban areas of different sizes within a fairly short period.

Other urban area characteristics -- the parameters of the local firm size distribution \((g_j, q_j)\), the mean bank size/largest bank size ratio \((M/L_j)\), and the number of banks in the urban area \((n_j)\), all of which represent local competition; the size of the largest bank in the urban area \((L_j)\), representing firm size; total and average information
Table 14. Regression Analysis of Bank Credit Card Adoption on Urban Size
and on Urban Size and Firm Size for Counties in Ohio

<table>
<thead>
<tr>
<th>Intercept</th>
<th>In Population</th>
<th>(In Population)^2</th>
<th>In Largest Firm Size</th>
<th>R^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.28939*</td>
<td>-0.00489*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4.31)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.57527*</td>
<td>-0.05658*</td>
<td>0.00267*</td>
<td>-0.01053*</td>
<td></td>
</tr>
<tr>
<td>(2.96)</td>
<td>(3.09)</td>
<td>(3.54)</td>
<td></td>
<td>.3164*</td>
</tr>
</tbody>
</table>

N = 85

*Dependent variable is ln (Month and Year of First Adoption in County). Data sources: Board of Governors of the Federal Reserve System, Malecki and Brown (1975), and U.S. Bureau of the Census (1971). Largest firm size is measured by total assets (in millions of dollars) at the end of 1973. Values in parentheses are t-values (* = significant at the .05 level).
potential \((TP_j^* \text{ and } AP_j^*)\), representing interfirm information flow in the urban system; and median household income, representing market potential \((M_j)\) — were added to the basic model. Regression analysis resulted in the significance of only one of these urban area characteristics, the largest bank size, in addition to the linear and quadratic city size terms (Table 14). The level of explanation \((r^2 = .3164)\) was considerably greater than for the linear relationship in Table 14 \((r^2 = .1828)\). The turning point city size, calculated by means of Equation (8) and the quadratic terms from Table 14, is 39,974.6, approximately the population of the fiftieth largest county in Ohio. Thus, it was concluded that medium-size counties were the sites of early adoptions, especially those counties with large banks. Perhaps because of the conservatism of the big-city banks, the largest counties, including those with large banks, had adoptions only after those medium-size areas.

**Summary of Findings**

The empirical analysis of the diffusion of the bank credit card showed that, in general, medium-size banks were the earliest adopters, and that the strict firm size pattern was not followed. Class A adoption in Ohio also was related to propagator contact and the proportion of automobile loans. Class B adoption in Ohio, however, failed to correspond to the firm adoption model, suggesting that such a minor innovation to a firm, involving little cost and no risk, is not adopted in the manner represented by the model.
Early adoption in medium-size cities, especially those with large banks in the urban area, characterized the diffusion pattern of the bank credit card only through the Ohio urban system. At the larger scale of the United States, however, large banks were the first adopters, and diffusion followed the city size hierarchy. At this larger scale, median income proved to be a significant indicator of market potential. These results indicate that it is not clear whether large or medium-size cities are the origins of adoption in the spatial diffusion of consumer innovations. However, the fact that medium-size cities may be the sources of adoption indicates that hierarchical models of diffusion are not necessarily valid in all situations. Firm sizes, represented by the largest firm size in an urban area and by the mean/largest firm size ratio, and median income seem to be major factors in interurban diffusion in some cases.
Chapter 7

IMPLICATIONS OF THE STUDY

This chapter presents a summary of what this study has accomplished and its implications for future diffusion research. Attention first turns to a critical assessment of the study, focusing in particular upon the methodology employed. The focus then turns to the conceptual advances of the firm adoption and city size diffusion models posited and tested here. Next, a summary of the empirical findings of the study is presented. The final section comprises general implications of the study.

A Critique of Research Procedures

A number of issues may be raised in connection with the approaches taken in the present research. The first set of these concerns the structure of industries, of individual firms, and of the imprecise definition of these for both theoretical and empirical research. The second set involves issues of model specification, alternative methods for analysis of diffusion processes, and the surrogates utilized for conceptual variables.

Firms and Industries: Some Unanswered Questions

The definition of a firm in diffusion research or economic theory has never been adequately clarified. A firm is an economic unit which
produces a good or service by means of one or more inputs. Real-world situations, however, pose problems about the applicability of a simplistic notion of the firm. For example, one-person firms such as farmers and professionals have the same function as firms with large employments, but have a single decision-maker who may act differently alone than if he were a member of a larger decision-making body. Innovation adoption decisions in one-person firms may not differ greatly from the individual adoption process of the consumer adopter. In fact, the one-person firm is essentially a hybrid between the individual consumer adopter and the firm adopter, and embodies the characteristics of both. For example, diffusion among farmers and physicians has been treated as diffusion among individuals, emphasizing information sources rather than entrepreneurial characteristics (Rogers and Shoemaker, 1971). Farmers also have been studied as entrepreneurial adopters and firm and innovation characteristics are stressed (Griliches, 1957).

Large conglomerate corporations, with multiple units producing vastly different outputs, represent the other extreme of the firm. Decision-making in a large corporation rarely reflects the impetus of a single individual, but rather a collective process. In such firms, moreover, the resources are divided among its various segments. The commitment which a corporation has made to a particular division will be reflected in the resources made available to that division, and this will affect the ability of that division to bear the cost and risk of innovation adoption. In addition, the importance of a division to the
corporation may be projected into a higher degree of management aggressiveness and innovativeness. Likewise, a division to which the corporation is not strongly committed generally will not exhibit innovativeness. Clearly, then, the division is a more appropriate unit of analysis than the conglomerate itself, but data concerning divisions and subsidiaries of corporations are likely to be quite difficult, if not impossible, to obtain.

Industry structure also affects the behavior of firms in innovation adoption situations. The present research has assumed a (not necessarily perfectly) competitive industry, represented rather well by the American banking industry. Application of the firm adoption model to other industries might therefore be limited. Industries with few firms, or those in which oligopoly and other constraints on firm operation exist, may involve influences on adoption decisions other than cost, risk, relative economic advantage, local competition, information, and management aggressiveness and innovativeness. Local competition may be less relevant than industry-wide competition in industries with few firms. In addition, certain industries, regardless of their structure, seem to foster innovativeness among their firms. It is not clear whether this industry effect on adoption behavior is systematically related to the structure of industries, in terms of competition, oligopoly, and monopoly. These issues cannot be answered here, and await further research on innovation adoption by firms.
Methodology for Diffusion among Firms: Some Considerations

The use of stepwise multiple regression as the method of analysis employed in this study raises some questions for the analysis of innovation diffusion patterns. The fact that several of the predictor variables employed in the firm adoption and city size diffusion models are collinear suggests that alternative techniques might be considered. For example, in the Ohio urban system, \( \ln \) population (city size) is highly correlated with measures of firm size, local competition, and market potential, implying that overidentification may be present in the model (Table 15).\(^1\) The relationship of city size to all of the other urban area characteristics can result in an overestimate of the importance of city size in an ordinary least squares (OLS) model. In this regard, a two-stage least squares (2SLS) model in which city size is endogenous could eliminate the overidentification problem. For example, in the case of consumer innovation in an urban system, the first stage of the model could include the following relationships

\[
M_j = f(p_j)
\]

\[
F_j = f(M_j) = f(p_j)
\]

\[
C_j = f(F_j, M_j) = f(p_j)
\]

\(^1\)Overidentification of a model occurs when there are more predictor variables included than is necessary.
Table 15. Intercorrelations of Variables Employed in Ohio Urban Area Analysis

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) In Date of Computer Processing Adoption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) In Date of Bank Credit Card Adoption</td>
<td>.455</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3) In Population</td>
<td>-.766</td>
<td>-.415</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4) (In Population)^2</td>
<td>-.756</td>
<td>-.407</td>
<td>.998</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5) Number of Banks</td>
<td>-.443</td>
<td>-.134</td>
<td>.548</td>
<td>.545</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6) Mean Bank Size/Largest Bank Size Ratio</td>
<td>.470</td>
<td>.288</td>
<td>-.519</td>
<td>-.509</td>
<td>-.712</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7) In Median Income</td>
<td>-.575</td>
<td>-.386</td>
<td>.643</td>
<td>.623</td>
<td>.361</td>
<td>.454</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8) In Largest Bank Size</td>
<td>-.743</td>
<td>-.469</td>
<td>.933</td>
<td>.940</td>
<td>.455</td>
<td>-.563</td>
<td>.543</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9) In Total Information Potential (Computer Processing)</td>
<td>.233</td>
<td>.002</td>
<td>-.252</td>
<td>-.271</td>
<td>-.053</td>
<td>.075</td>
<td>.015</td>
<td>-.295</td>
<td></td>
</tr>
<tr>
<td>10) In Total Information Potential (Bank Credit Card)</td>
<td>.260</td>
<td>.364</td>
<td>-.361</td>
<td>-.374</td>
<td>-.172</td>
<td>.213</td>
<td>-.157</td>
<td>-.383</td>
<td>.128</td>
</tr>
</tbody>
</table>
\[ I_j = f(F_j, p_j) = f(p_j) \]

where \( M_j \) is market potential, \( p_j \) is urban area population, \( F_j \) is a measure of firm size in the urban area, \( C_j \) is local competition, and \( I_j \) is information flow in the urban system which affects firms in \( j \). The second stage of the model could then consist of

\[ T_j = f(M_j, F_j, C_j, I_j) \]

where \( T_j \) is the date of first adoption of the innovation in urban area \( j \). Thus, the predicted time of first adoption only indirectly would involve city size through its influence on the four endogenous variables. A similar approach has been taken in the context of migration analysis by Willis (1974, pp. 121-141).

Two major drawbacks to the two-stage least squares model are present. First, the multicollinearity between the endogenous variables (firm size, local competition, market potential, and information) will not be eliminated; the variables remain intercorrelated through their common relationship with city size. More important, however, is the inability of such a model to include the quadratic city size formulation for diffusion in the urban system. Thus, the city size pattern, indicating whether adoption begins in medium-size or large cities, is a valuable indicator of urban system diffusion that is lost in a model where city size is exogenous.

A related issue involves the conceptual variables of the study and the surrogates chosen to represent them. It is believed that the
variables employed were sound, but that poor surrogates for these in some cases caused difficulties in empirical analyses. This is a common problem in social science research. Conceptually, the notions of firm size, city size, local competition, information, and market potential appear to embody the major variables operating in diffusion among firms. Of these, firm size and city size were measured adequately by largest firm size (in total assets) and urban area population. However, it was not possible to find a reasonable surrogate for market potential since population also measures this factor. Further, various measures of local competition were employed, but none of these was consistently significant in the analyses. Other measures of local competition need to be developed and tested in a diffusion context. Similarly, information flow among firms in the urban system, which was insignificant as measured here, following Pedersen (1970), may be significant in other analyses under different surrogates.

**Conceptual Contributions**

The study of diffusion agency establishment for consumer innovations, largely carried out by geographers, has shifted the emphasis of diffusion research from individuals or consumers to firms and other diffusion agencies. Until this study, however, the diffusion agency focus had not yet been integrated with the body of research on diffusion of innovation among firms, largely carried out by economists. The present research has also shown that diffusion processes for firm innovations and for consumer innovations may be viewed within a single
In addition to retaining the market potential and information flow factors emphasized in geographical diffusion studies of consumer innovations, the study also has included the factors which firm innovation diffusion studies have found to be critical. Thus, the innovation characteristics of cost, risk, and relative economic advantage are considered to be the primary variables for the firm. The firm's response to these factors is seen through the concept of firm size, which represents the firm's resources for adoption, as well as its management aggressiveness and innovativeness. Thus, the firm adoption model presented here incorporates firm characteristics and innovation characteristics within the firm size context, allowing the major recognized components in firm adoption to be included in a single model. Factors external to the firm, such as information and local competition, also were included. The model provides a common framework for the diffusion of both consumer and firm innovations, integrating the two approaches into a single logical structure. Testable models, in multiple regression form, were constructed from the theoretical framework to fit a variety of empirical contexts.

Furthermore, the conceptual model posited here permits insights into diffusion in an urban system. The location of firms of various sizes, as indicated by urban area population and the relative sizes of firms in the urban area, is seen as the basis for urban system patterns of diffusion. This approach provides an explanation for
urban system diffusion that is different from those previously put forth which include early adoption only in the largest cities (Berry, 1972; Hägerstrand, 1966).

A Summary of Empirical Findings

The diffusion of two innovations in American banking since 1953 comprised the empirical context for the study. The diffusion of computer processing for internal record-keeping and preparation of account statements among banks in Ohio from 1960 to 1975 provided an example of a firm innovation. The diffusion of the bank credit card among banks in the United States from 1953 to 1972 and in Ohio from 1966 to 1974 served as an example of a consumer innovation.

Adoption of computer processing among Ohio banks began with the largest banks in the state, corresponding to a linear or strict firm size sequence of adoption times. The rate of change in date of adoption with firm size, however, varied with the level of computer processing adoption. Large banks tended to install their own computer facilities, and adoption took place rather slowly in this set of adopters. By contrast, smaller banks, on the average, tended to adopt the innovation by means of purchasing the services from other firms, and adoption occurred more rapidly, owing most likely to the lower cost involved in such adoptions.

The diffusion of the bank credit card among United States banks generally began among medium-size firms. Adoption before 1966 nationally took place among medium-size firms beginning in 1953, followed
in the late 1950's and early 1960's by several very large banks. Diffusion of the credit card since 1966, mainly comprising adoption of BankAmericard and Master Charge plans, also generally began among medium-size firms. This was especially true for limited branch banking states, including Ohio, whereas adoption in unit banking and statewide branch banking states tended to begin among large banks. Early adoption by medium-size firms was particularly significant among Ohio adopters of the credit card.

City size regularities in the diffusion of innovations among firms have not previously been studied directly. Patterns of the diffusion of consumer innovations, however, shed some light upon diffusion processes among firms. An expectation of the study was that, in certain situations, medium-size cities are the origins of diffusion in urban systems. This pattern was found in the diffusion of computer processing in Ohio, where medium-size urban areas with large firms were the sites of early adoptions. A similar pattern of diffusion resulted in the spread of the bank credit card in Ohio, where adoption began in medium-size cities. Urban system diffusion in the United States, however, did not conform to the pattern in which medium-size cities are the origins of diffusion. Adoption in the set of SMSA's with adopters from 1953 to 1965 did not fit the model; none of the variables employed provided significant explanation. First adoptions in SMSA's from 1966 to 1972 followed a hierarchical pattern or strict city size sequence.
Other variables employed in the analysis were generally less important than firm size and city size. Only firm aggressiveness, measured by the proportion of commercial loans to total loans was significantly related to the date of adoption of computer processing. In the diffusion of the bank credit card in Ohio, the proportion of automobile loans to total loans, a measure of both firm aggressiveness and consumer orientation, as well as propagator contact were significant predictors of adoption time among banks. Of other urban area characteristics employed in the analyses, market potential and large firm dominance were significant in the diffusion of the credit card among United States SMSA's from 1966 to 1972. Propagator contact was a significant factor in diffusion of the credit card in Ohio. Other variables were not significant in the analyses.

This analysis of the diffusion of both a firm innovation, computer processing, and a consumer innovation, the bank credit card, in the same industry permits a comparison of the two types of diffusion among firms. Computer processing was adopted first by large firms, whereas the bank credit card originated among medium-size banks, a difference which appears to be attributable to the relative cost involved in the adoption of each. The level of explained variance was higher in the case of computer processing adoption, owing to the fact that cost, risk, and management innovativeness and aggressiveness, the principal variables in the models of the study, were more important to that innovation than to the diffusion of the bank credit card.
Analysis of the diffusion of both a firm innovation, computer processing, and a consumer innovation, the bank credit card, in the same industry allows a comparison of the two types of diffusion among firms. Consistent with the findings of Myers and Marquis (1969), it appears that firm or process innovations are adopted by large firms first, primarily because of their generally higher cost. In the diffusion of firm innovations, the effect of cost and risk seems to be more important than management innovativeness. Consumer or product innovations may be adopted by firms of various sizes, depending upon the ability of firms to bear the cost and risk and upon the innovativeness and aggressiveness needed to result in adoption. Because of the generally lower cost and risk involved in consumer innovation adoptions, management factors appear to be more important.

General Implications

The study has expanded the scope of previous approaches to the diffusion of innovation among firms by incorporating a wider range of variables, particularly in the analysis of diffusion in an urban system. Information and market potential, employed in analyses of consumer innovation diffusion, were integrated with competition and firm size, employed in studies of firm innovations. The study of both types of innovation diffusion among firms was made possible through the combination of the concepts and variables of the two approaches.

This integration has also permitted new insights into the process of diffusion in urban systems. The effect of firm size on city size
patterns of diffusion indicates that the traditional hierarchical diffusion pattern does not apply in all contexts. Furthermore, the previous models of diffusion in urban systems have relied upon an information flow framework. The present research, by contrast, builds upon the adoption processes of individual firms. The findings of this study suggest that medium-size cities may be the origins of diffusion for innovations which are adopted by firms; further research will discover to what extent this is true and what situations are applicable.

One principal future application of the models and findings of the present study lies in the area of regional economic growth. Spatial patterns of diffusion among firms have important impacts on urban and regional economic growth. Innovations are necessary in order for firms to remain competitive in regional and national markets. The diffusion of innovation among firms occurs primarily as a result of competitive and survival pressures on individual firms (Kuznets, 1972; Parr, 1974). Without improvements in its production and management, a firm may lose its relative position within the market, and consequently result in a decline in employment in its region. The "technological gap" between firms which employ the best currently available techniques, or best-practice techniques, and the firms which have not yet adopted them is an indicator of the economic growth potential of a region (LeHeron, 1973; Thomas, 1974).

Research on the spatial diffusion of such innovations tends to focus on a strict city size ordered pattern that stems from the concept
of the urban hierarchy as a transmitter for economic growth (Berry, 1972; Pedersen, 1970; Richardson, 1973; Robson, 1973). Thus, regional policies concerning regional growth tend to emphasize the large cities as the points from which growth spreads to other cities and towns in the region (Kuklinski, 1972). The present study, on the other hand, provides evidence that medium-size cities often serve as the centers of adoption. Thus, the fact that early innovation adoption takes place in smaller urban centers lends credence to alternative policies which suggest that such cities can serve as regional growth centers (Hansen, 1971, 1973).

Furthermore, the focus of this research on adoption by firms emphasizes a process which generally only implicitly underlies past work on urban adoption patterns (Pedersen, 1970; Robson, 1973). The role of firms in the spread of economic growth is embodied in the process of spatial diffusion through the concepts of firm size and competition. Innovation diffusion, therefore, may be seen as more intrinsically involved in regional economic growth than has heretofore been recognized.²

²The specific impact of the banking industry on local economic prosperity is considerable. The willingness of banks to undertake financing of new projects and business ventures, especially in small towns and rural areas where development is most needed, often is crucial to local development (Carusone, 1974; Dahl, 1974; Oster, 1972). The adoption behavior of banks, then, may have a significant impact on the economic well-being of regions.
APPENDIX

QUESTIONNAIRE REGARDING BANK ADOPTION OF COMPUTER PROCESSING

1. Does your bank now use computer facilities for internal record-keeping and preparation of account statements?

   YES _____  NO _____

2. If yes to the above, when did your bank first begin such activities?

   (Month, Year) __________________

3. At the present time, does your bank operate its own computer facilities alone, employ the facilities of another bank, or employ the facilities of a non-banking firm?

   Own facilities ____
   Other bank's ____
   Non-bank's _____
LIST OF REFERENCES


