# FACTORS INFLUENCING THE RECEPTIVENESS OF HOMEBUILDERS TO COST REDUCING INNOVATIONS IN GREATER LANSING

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ABSTRACT

FACTORS INFLUENCING THE RECEPTIVENESS OF HOMEBUILDERS TO COST REDUCING INNOVATIONS IN GREATER LANSING

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The purpose of this thesis is to develop and test a model describing entrepreneurs' receptiveness to cost reducing innovations in residential housing. The model chosen for testing is a modified version of the profit maximization under conditions of uncertainty approach. The model being tested differs from the usual profit maximization approach because it does not make the adoption decision a function of a tradeoff between expected profits and uncertainty. Instead, it makes the decision a function of estimated profits, with estimated profits being a function of uncertainty, among other things.

The model is tested by multiple regression analysis using data acquired by personal interviews with a sample of twenty homebuilders in the Greater Lansing area. The results of the study suggest that estimated profits are the most important variable affecting the entrepreneur's decision to adopt an innovation. The entrepreneur's estimate of profit is affected by whether he is producing custom built homes or

homes for the mass market, by whether the innovation changes the appearance of the product, by the uncertainty of the innovation, and by prices in the input markets. Uncertainty did not affect adoption through the mechanism of a tradeoff with expected profits. Uncertainty affected the probability of adoption by affecting the entrepreneur's estimates of profit.

Entrepreneurs in this industry did not adopt all innovations that they judged profitable. Where estimated profits were small, and the personal effort required by adoption was considerable, entrepreneurs were unwilling to give up their leisure time to innovate.

The size of the firm, the number of years of formal education of the entrepreneur, and his experience in the industry, did not appear to be correlated with his receptiveness to innovations. They also did not appear to be correlated with his ability to perceive profitable innovations.

Entrepreneurs in the homebuilding industry adopted cost reducing innovations primarily to increase profits. Competition from new entrants into the industry and from currently existing firms does not appear to have a major influence on entrepreneurs' receptiveness to innovations.

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# CHAPTER I

## INTRODUCTION

The purpose of this study is to develop and test a model which describes entrepreneurs' receptiveness to innovations in residential housing and to test the influence of certain variables upon this receptiveness. The variables chosen for testing are the innovation's profitability, its uncertainty, the size of the firm, and the education and experience of the manager. The model and these variables are tested by multiple regression analysis with data obtained by personal interviews with a sample of homebuilders in the Greater Lansing Area in 1969.

Studying homebuilders' receptiveness to innovations is important for two reasons: (1) home ownership cannot be expanded beyond present levels unless costs decline or home purchasers are subsidized, and (2) the present national administration has chosen to seek cost reduction through technological change.

The National Commission on Urban Problems, after making an intensive study of the nation's housing problems, has concluded that the cost of socially acceptable housing has placed home ownership beyond the reach of the poor and lower middle class.[1] They believe that an expansion of home ownership requires a reduction in housing costs or some form of subsidy to home purchasers.[2] Since input costs are unlikely to decline, the choice lies between government subsidy and stimulating technological change.

Society believes the expansion of home ownership is a worthwhile goal. In part, it is viewed as a merit want. The importance with which society views home ownership can be seen in the statements of national leaders prior to the establishment of the Federal Housing Administration and in the changes that have taken place in F.H.A. since its founding. President Hoover, addressing the President's Conference on Home Building and Home Ownership in 1931 stated:

> Every one of you here is impelled by the high ideal and aspiration that each family may pass their days in a home which they own . . . . This aspiration penetrates the heart of our national well being. It makes for happier married life, it makes for confidence and security, it makes for the courage to meet the battles of life, it makes for better citizenship. There can be no fear for a democracy or self government or for liberty or freedom from home owners, no matter how humble they may be.[3]

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[1]National Commission on Urban Problems, Rebuilding the American City (Washington: National Commission on Urban Problems, 1968), pp. 10-11.

[2]*Ibid.*, p. 11.

[3]President's Conference on Home Building and Home Ownership, Housing Objectives and Programs (Washington: President's Conference on Home Building and Home Ownership, 1932), p. 2.

The Commission, in making its report, enunciated substantially the same sentiments:

> There has been a very startling trend in recent years in America away from the private house to a larger multiple dwelling. This tendency is an unfortunate one. In the minds of many, it threatens American institutions.
>
> The social consequences of the passing of the home are already readily apparent. The lack of space, order, privacy and comfort may be traced many tendencies in present day existence in America.
>
> The great majority of the homes that are being built in America today are not worthy of the American people.[4]

Initially, programs to expand home ownership sought to reduce the risk of lending for home purchases. Reducing the risk of lending made it possible for the lender to accept lower down payments, lower monthly payments, and lower interest charges. Risk was reduced by insuring mortgages.

There have been two government sponsored mortgage insurance programs: the Federal Housing Administration Program (F.H.A.), and the Veterans Administration Program (V.A.).

The first government insurance program for home mortgages was the F.H.A., established in 1934. Originally, F.H.A. insured mortgages for 80% of the value of the property, with the length of the mortgage set at 20 years. Over the next 32 years the percentage of value insured increased until, in 1966, it reached 100% of the first $15,000 and 90% of the

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[4] _Ibid._, p. 150.

next $5000. During the same length of time, the length of the mortgage increased, reaching 30 years in 1948, declining to 25 years in 1950, returning to 30 years in 1954, and increasing to 35 years in 1961.[5]

F.H.A. has been bolstered by V.A. The V.A. program was established in 1944. Like F.H.A., it insures the lenders mortgage. When it was founded, V.A. differed from F.H.A. in two important respects: (1) It insured mortgages for 100% of the value of the property, and (2) the length of the mortgage was set at 30 years.[6] The 100% guarantee eliminated the requirement for down payments, and the 30 year length of mortgage reduced monthly payments, making it possible for lower income families to become home owners.

With the establishment of these programs, home ownership began to expand. As can be seen from Table 1, the percentage of occupied units that are owner occupied has increased from forty-plus percent before World War II to 61.9% in 1960.

The Nixon administration has chosen to further expand home ownership by reducing costs through technological change. Secretary of Housing and Urban Development George Romney recently announced that the federal government was awarding

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[5]National Commission on Urban Problems, _op. cit._, pp. 94-96.

[6]_Ibid._, pp. 103-104.

TABLE 1.--The Growth of Home Ownership.

| Year | Total Number of Occupied Housing Units (in thousands) | Percentage of Housing Units That Are Owner Occupied |
|---|---|---|
| 1920 | 24,352 | 45.6% |
| 1930 | 29,905 | 47.8% |
| 1940 | 34,855 | 43.6% |
| 1950 | 42,826 | 55.0% |
| 1960 | 54,352 | 61.9% |

Source: Bureau of the Census; Census of Housing.

several contracts for the development of new cost reducing techniques for residential construction.[7]

Unfortunately, the discovery of new techniques will not, of itself, reduce housing costs. Before new techniques can result in a general reduction in costs they must be used by firms in the homebuilding industry. Little is known about the factors that make entreprensurs relatively willing or unwilling to adopt innovations. A search of the diffusion literature reveals a variety of theories which attempt to explain the entrepreneur's relative willingness to adopt innovations. Empirical research has not been able to reconcile these theories for the empirical results have been contradictory.

[7]Lansing State Journal, May 9, 1969, p. 1.

# CHAPTER II

## ADOPTION OF INNOVATIONS

### Terminology

Technology is knowledge about the productive arts. Technological change is a change in this knowledge and in the extent of its application. Technological change manifests itself in the form of new products, new processes, and new methods of organization.[1]

Changes in technology involve scientific discoveries, inventions, innovations, and imitation. A scientific discovery is an addition to knowledge. An invention is a tested combination of existing knowledge. An innovation is the first practical application of an invention. An innovation is either accepted or rejected for use. Economists concern themselves with those innovations that are applicable to commercial production.

An innovation is defined in the context of a social system. It does not matter if an innovation has already been applied to economic production in one social system.

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[1] Edwin Mansfield, The Economics of Technological Change (New York: W. W. Norton Inc., 1968), pp. 10-11.

If another social system has not applied the invention, then doing so constitutes innovation.

Diffusion is the process by which an innovation spreads. Diffusion cannot take place unless entrepreneurs adopt the innovation. Consequently, the adoption of innovations has been studied mainly by diffusion investigators.

## The Diffusion Literature to 1962

Diffusion has been studied by many academic disciplines. In 1962, Everett Rogers published a book called The Diffusion of Innovations, in which he synthesized and evaluated the available research findings up to that date. In pursuing his goal, he examined 506 research reports. Rogers discusses six separate research traditions: (1) anthropology, (2) early sociology, (3) rural sociology, (4) medical sociology, (5) education, and (6) industrial.[2]

### Sociologists, Anthropologists, and Educators

The research done by anthropoligists has not been concerned with the adoption process as such. Instead, they have been concerned with the consequences of adoption. Not surprisingly, given the subject matter of anthropology, the consequences they have chosen to investigate are the social consequences of innovation.

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[2]Everett Rogers, The Diffusion of Innovations (New York: Glencoe Free Press, 1962), pp. 25-46.

Sociologists have stressed the distribution assumed by the population of adopters and the relationship that exists between adopters and their social environment. The environmental factors that are analyzed are sociological variables, such as the social status of the adopters and their contact with individuals outside of the immediate social system. In analyzing the diffusion process, some attention is paid to economic variables, such as the profitability of the innovation and the size of the firm, but, not surprisingly, these factors have not received much attention from sociologists.

Early sociologists focused their attentions on innovations that promised to result in major social changes. Rural Sociology has concentrated on developing correlates of innovativeness and analyzing the effects of information sources, opinion leadership, social system norms, characteristics of innovations, and the role of change agents. Medical sociology has directed its attention to the influence of opinion leadership upon the diffusion of drugs among medical doctors.

Educational diffusion studies have been concerned with the diffusion of new educational techniques. The studies done by educators have led to three general conclusions: (1) The percentage of a population utilizing an innovation grows rapidly at first and then more slowly as time passes.

When the percentage of the population using the innovation is plotted on a cumulative basis with respect to time, the resulting curve is S shaped. (2) A considerable time lag is required for the widespread adoption of new ideas. (3) The best single predictor of innovativeness is education expenditure per pupil, perhaps because this indicates an ability to invest in new ideas. Although educational diffusion studies do give some attention to economic factors, they are concerned with the diffusion of educational innovations, and hence, have not stressed these factors.

Profitability and Uncertainty

The research orientation with the strongest economic orientation is the industrial research tradition. Rogers argues that the economics of innovation has been analyzed more thoroughly in the industrial tradition than in any other tradition. Several researchers in this tradition have concentrated on the characteristics of the firm that are associated with innovativeness. In general, these characteristics are access to new knowledge, high quality and ingenious personnel, relatively long planning horizons, and a respect for science. Other researchers in this tradition, such as Mansfield and Enos, have stressed the effect of the profitability of the innovation upon its adoption. In addition to pointing out the role played by profitability, Enos presented the concept of the "learning curve."[3,4] Still other industrial diffusion researchers have stressed the part played by uncertainty. One contribution in this area has been made by Strassmann, who argued that the adoption of an innovation requires decision making under conditions of uncertainty. Strassmann reinterpeted nineteenth century American manufacturing history, arguing that the rapid innovation that took place during this period was, in part, due to the exceptionally low risks attached to innovative activity.[5]

The importance of profitability in the diffusion process has not gone unchallenged. The authors mentioned thus far imply that entrepreneurs respond to the stimuli of expected profits in a predictable manner. Carter and Williams hold a different view. They maintain that even if the potential gains and risks were identical for all innovations, that entrepreneurs may respond differently to each innovation because they may put other goals ahead of profit maximization.[6] Galbraith also questions the paramount importance of profitability, arguing that the separation of ownership from

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[3]A learning curve is a graphical representation of the reduction in operating costs that occur when the workers of a firm become familiar with an innovation.

[4]John Enos, "A Measure of the Rate of Technological Progress in the Petroleum Refining Industry," Journal of Industrial Economics (June, 1958), pp. 90-91.

[5]W. Paul Strassmann, Risk and Technological Innovation (Ithaca: Cornell University Press, 1959).

[6]C. F. Carter and B. R. Williams, Investment in Innovation (London: Oxford University Press, 1958), p. 40.

management that has occurred in recent years makes the profit maximization assumption questionable.[7]

Carter, Williams, and Galbraith do not argue that the profitability of an innovation does not affect its diffusion, but that firms do not respond consistently to this influence. This influence is important mainly because it affects the firm's long run survival prospects.[8] Thus, in the Carter-Williams-Galbraith scheme, these factors appear as constraints upon entrepreneurial behavior rather than primary determinants of behavior. The degree to which a firm's response to an innovation differs from the response predicted by the profit maximization model of behavior is a function, among other things, of the degree of competition in the industry.[9]

Responses to Uncertainty

Economists also differ about the role played by uncertainty in entrepreneurial decision making. Uncertainty can have two consequences: (1) entrepreneurs can misjudge the innovation's profitability, and (2) entrepreneurs may hesitate before adopting an innovation that they think might be profitable because they do not like the risk of losses that might result if they should misjudge its profitability.

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[7] J. K. Galbraith, The New Industrial State (Boston: Houghton Miflin Co., 1967), p. 117.

[8] Carter and Williams, op. cit., pp. 42-43.

[9] Ibid., p. 46.

Point (1) is universally accepted. Point (2) is the center of some controversy.

The predominate view is presented by Mansfield. He argues that entrepreneurs react to uncertainty by assuming a probability distribution of payoffs and then trading off the expected return of the innovation against the risks of utilization.[10]

Shackle presents a different point of view. He argues that decision making based upon a probability distribution of payoffs is not rational behavior because (a) for many kinds of decision making it is impossible to establish any meaningful probability distribution of outcomes because one cannot find a sufficient number of past instances which took place under similar conditions, and (b) many decisions are made on a once only basis and are not repeated an infinite number of times. As an alternate explanation, Shackle suggests that the entrepreneur concentrates his attention on only two of the possible outcomes, that which offers him the keenest joy, and that which offers the maximum distress. Both joy and distress are functions of the probability of achieving the payoff in question, and of the utility or disutility that would result if the payoff were actually received. The entrepreneur's choice depends upon his utility function.[11]

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[10] Mansfield, op. cit., pp. 69-70, 104-105.

[11] G. L. S. Shackle, Expectations in Economics (Cambridge: The University Press, 1949), pp. 16-17, 24, 30, 109-110.

Other economists make decision making under conditions of uncertainty less subjective in nature. Boulding suggests that entrepreneurs use a form of linear programming to respond to situations involving uncertainty. A field of choice is surveyed and limiting conditions are noted, which eliminate many possible decisions, until only one decision is left. If it is not possible to limit the possible decisions to one decision, marginal analysis is used to select the final decision from the limited subset.[12]

March and Simon give a somewhat less exotic view of entrepreneurial response to uncertainty. They argue that the cognitive limits on rational decision making lead to the establishment of procedural rules designed to achieve a "satisfactory" rather than a maximum level of profit.[13]

## The Diffusion Literature to 1962: Summary

In synthesizing the diffusion literature up to 1962, Rogers came to the following conclusions about the adoption of innovations in the United States: (1) The adoption of an innovation is not simply a matter of economic advantages, although these are important in many circumstances. The

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[12] K. E. Boulding and W. A. Spivey, Linear Programming and the Theory of the Firm (New York: The MacMillan Co., 1960), pp. 8-9.

[13] James March and Herbert Simons, Organizations (New York: John Wiley and Sons, 1958), pp. 136-172.

innovation's compatability with previous practices, its complexity, divisibility,[14] and communicability also affect its diffusion.[15] (2) The adoption of an innovation approximates a bell shaped curve when plotted over time.[16] This type of curve is essentially S shaped when plotted on a cumulative basis. (3) Adopter distributions are normal.[17] (4) Pre-requisites for successful adoption include the ability to understand and apply complex technical knowledge and the control of substantial financial resources.[18] (5) Earlier adopters are younger, have a higher social status, a more favorable financial situation, and a more specialized operation than late adopters.[19]

## The Diffusion Literature Since 1962

Since 1962, diffusion researchers have concentrated on building and testing models of entrepreneurial decision making, investigating the effects of the size of the firm on its receptiveness to new techniques, and making case studies of the diffusion of innovations in various industries. The results have been sufficiently contradictory so that it is impossible to predict from the experience of other

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[14] Divisibility refers to the degree with which an innovation can be tried on a small scale.

[15] Rogers, *op. cit.*, p. 124.

[16] *Ibid.*, p. 152.

[17] *Ibid.*, p. 152.

[18] *Ibid.*, p. 169.

[19] *Ibid.*, pp. 172-178.

industries which variables are likely to have an important influence on the adoption of new techniques in residential housing.

## Models of Diffusion

Nelson has published an article in which he attributes the productivity differences among developed and developing countries to differences in technology.[20] He argues that the development process is really a diffusion process, and that the relative position of a country in the diffusion hierarchy depends upon the technical and managerial capabilities of its entrepreneurs.

March and Simon also stress the quality of management in their explanation of the receptiveness of a firm to new ideas. They argue that the aspiration level of management tends to adjust to its achievement level, but that awareness that a change in behavior will yield substantially better results will lead to revisions in the standards of satisfaction.[21]

Mansfield has developed and tested a model in which the probability that a firm will introduce a new technique is an increasing function of the number of firms already using the technique and a decreasing function of the size

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[20] R. R. Nelson, "International Productivity Differences," *American Economic Review* (December, 1968), pp. 1219-1248.

[21] March and Simons, *op. cit.*, pp. 182-183.

of investment required.[22] Mansfield views the diffusion process as a learning process. As more firms adopt an innovation, the risk of adopting the innovation decreases. This decline in risk is the result of the availability of additional knowledge about the innovation. Mansfield makes the firm's adoption decision a case of profit maximization under conditions of uncertainty. With this model, the probability that an innovation will be adopted is a function of its profitability and riskiness. This model of entrepreneurial decision making was tested to see how well it explained the intra-firm rates of diffusion[23] of diesal locomotives.[24] The independent variables in the analysis were the profitability of the innovation, the length of time the firm waited to adopt the innovation after it had first been introduced into the industry (a measure of risk), the size of the firm, and its liquidity position at the time it first introduced the innovation. The resulting regression equation explained over seventy percent of the variance in the observations, and all the regression coefficients, except the coefficient of the variable measuring size, were

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[22] Edwin Mansfield, "Technical Change and the Rate of Imitation," Econometrica (October, 1964), pp. 741-763.

[23] An intra firm rate of diffusion measures how rapidly an innovation becomes fully utilized once a firm has successfully used it.

[24] Edwin Mansfield, Industrial Research and Technological Innovation (New York: W. W. Norton Inc., 1968), p. 185.

significant at the five percent level. Mansfield concludes that the model is consistent with the facts.

## Inconsistent Response to Profits

Results of other studies undertaken by Mansfield are not consistent with the results of the previously mentioned study. In other studies that he has done, the variable measuring the profitability of the innovation has been, depending upon the industry being studied, both important and unimportant. One of these studies regressed the size of the firm, the profitability of the innovation, the growth rate of the firm, and the age of the president against the number of years that the firm waited to adopt the innovation after its first introduction into the industry.[25] The industries studied were the mining, railroad, and steel industries. In the mining and railroad industries, the profitability coefficient was statistically insignificant while in the steel industry it was statistically significant. The insignificance of the profitability coefficient in railroads and mining may have been because the entrepreneurs expectations of profit did not coincide closely with the actual profitability of the innovation, or it may have been because the innovations studied were

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[25]Edwin Mansfield, "The Speed of Response of Firms to New Techniques," Quarterly Journal of Economics (May, 1963), pp. 290-311.

exceptionally risky (no attempt was made to measure the effect of risk), so that diffusion was a function more of risk reduction than of the profitability of the innovation. Whatever the reason, the applicability of the profit maximization model of decision making under conditions of uncertainty is still not clear.

Firm Size

The effect of firm size on the adoption of new techniques has been a much debated subject among economists. Mansfield argues that larger firms are more likely to adopt new techniques more quickly than small firms because: (a) the costs and risks of innovations are lower for larger firms than smaller firms, (b) larger firms encompass a wider range of operating conditions than smaller firms and therefore have a better chance of containing those conditions for which the innovation is applicable, and (c) larger firms have more units of equipment and therefore are more likely to have some equipment that must be replaced at any point in time.[26] The empirical studies discussed earlier have, at various times, been consistent and inconsistent with this position. In the study of the diesal locomotive, firm size appeared to play no important role. In Mansfield's studies of the mining, railroad, and steel industries, firm size played a significant role. In addition to these studies.

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[26]*Ibid.*, p. 302.

Mansfield has undertaken another investigation, this time in the petroleum refining, bituminous coal, and steel industries.[27] The results of the study established that the larger firms had introduced a disproportionate share of the important innovations in the coal and petroleum industries between 1918 and 1958, but a disproportionately smaller share in the steel industry. The unimportence of firm size in the steel industry was further documented by Adams and Dirlam in their study of the diffusion of the oxygen converter.[28]

Firm size appears to influence the diffusion process in an inconsistent manner. Studies of the mining, coal, and petroleum industries indicate that firm size has an influence on a firm's response to innovations. Some studies of the railroad and steel industries reinforce this conclusion and some do not. This inconsistency of results may reflect differences in the quality of management or the presence or lack of economies of scale in the innovations being studied. Without further information, reconciliation of the different results is not possible.

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[27] Edwin Mansfield, "Size of Firm, Market Structure, and Innovation," Journal of Political Economy (Dec., 1963), pp. 556-576.

[28] W. Adams and J. B. Dirlam, "Big Steel, Invention, and Innovation," Quarterly Journal of Economics (May, 1966), pp. 167-189.

Competition

Many economists believe that competition, not firm size, plays a crucial role in the diffusion process. Dirlam and Adams stressed competition rather than size in explaining the diffusion of the oxygen converter. A. D. Little Inc., a research organization based in Cambridge, Massachusetts, investigated the diffusion of innovations in mature industries.[29] They discovered that innovations usually came from outside the industry and were introduced into the industry in one of three ways: (1) existing firms borrowed or bought the new technology, (2) the new industry invaded the old, or (3) the product of the new industry eliminated the product of the old.[30] A. D. Little demonstrates that obstacles to innovation in three traditional industries were overcome by traditional neo-classical competition from (1) foreign firms, (2) independent inventors, (3) new small periphery firms, and (4) technically progressive firms from another area.[31]

The importance of competition is also stressed by Maddala and Knight who examined the international diffusion of the oxygen steel making process discussed earlier. They came to the conclusion that the slow rate of diffusion of

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[29] Mature industries are industries that are over thirty years old.

[30] R. E. Johnston, "Technical Progress and Innovation," Oxford Economic Papers (July, 1966), p. 162.

[31] Ibid., p. 162.

this process is best explained by defects in national economic plans and by barriers to international competition.[32]

One study that does not reinforce the claim that competition has an important influence on diffusion is a study undertaken by Stekler of the aerospace industry.[33] Stekler concludes that the technical progress that had occurred in the industry was the result of improved government procurement practices and protection of the industry.

### The Diffusion Literature Since 1962: Summary

Economists are generally agreed that the probability that an innovation will be adopted at a given point in time is a function of its profitability and riskiness. There is disagreement, however, over the manner in which they influence the adoption decision. One school of thought holds that these factors serve as constraints upon entrepreneurial behavior. The other school of thought maintain that these factors are important because they directly influence entrepreneurial receptiveness to innovations. Attempts to establish empirically the existence of a relationship between the profitability and riskiness of the innovation and its pattern of diffusion have had mixed results.

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[32] G. S. Maddala and P. T. Knight, "International Diffusion of Technical Change," Economic Journal (September, 1967), p. 558.

[33] H. O. Stekler, "Technological Progress in the Aerospace Industry," Journal of Industrial Economics (July, 1967), pp. 226-236.

Economists are divided over whether firm size or competition is a more important influence on receptiveness to innovations. Attempts to establish a general relationship have been inconclusive. The mixed results that have been achieved may be the result of economies of scale in some of the innovations being studied or of differences in the general quality of top management.

## Adoption of New Techniques in Residential Housing

With respect to residential housing, most writing about the adoption of new techniques has stressed obstacles rather than the factors that might make entrepreneurs more receptive. Little statistical analysis has been done and most of the conclusions of various writers seem to represent an intuitive judgement or a tentative hypothesis. If their conclusions lie on an extensive data base, the authors neglect to inform their readers of this fact.

The diffusion of new techniques in residential housing has been analyzed both by economists and by members of the industry. There are many areas of common agreement.

### The Views of Economists

Herzog stresses the role played by the relative advantage of the new technique. Innovations are adopted by home builders if they do a better job than the existing technique. Entrepreneurs' choices, however, are constrained by building codes and consumer preferences.[34]

Myrdal writes about negative influences on entrepreneurial receptiveness to new techniques. He describes two influences: (1) the organization of the industry, and (2) lack of international competition in housing. In Myrdal's view, the housing industry is extremely fragmented, with many different firms responsible for producing the many components that compose a house. The result is that firms take the existing framework as given, and tries to maximize profit within this framework, rather than seeking to increase its profits by altering the framework. Modern innovations exist, especially in Europe, but the lack of international competition prevents European builders from exporting to the United States and competing with American contractors.[35]

Bowley is in agreement with Myrdal's comments about the organization of the industry. She argues that the spread of some innovations has been delayed because design is divorced from responsibility for construction, leaving the builder no say about the opportunities or occasions for making use of many innovations. The adoption of other innovations has been delayed because of the conservatism of local governing bodies which prohibited their use.

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[34] John P. Herzog, The Dynamics of Large Scale House Building (Berkeley: Institute of Business and Economic Research, 1964), p. 73.

[35] Gunnar Myrdal, "Realizing the Promise of Industrial Housing," Journal of Industrial Housing (September, 1967), pp. 428-431.

Some of the innovations that have been adopted were helped by an expansion in the demand for housing which made it possible to pass on learning costs to consumers.[36]

Needleman also stresses the role played by the organization of the industry, but he feels that it influences the diffusion process in a different manner from the views of Myrdal and Bowley. Needleman argues that the building industry produces differentiated products in local markets and that this results in weak competition. The lack of competition slows down the spread of new techniques. In addition to organization, Needleman also stresses complexity. He states that some techniques would be profitable if the whole building process were reorganized around them, but that they would only add to building costs if introduced piecemeal. Because of uncertainty, entrepreneurs are wary of reorganizing their entire operation.[37] Like Myrdal, Needeleman offers no statistical support for his observations.

The Views of Non-Economists

The trade publications of the housing industry mention many of the barriers to adoption cited by economists. One feature article about housing technology cites the unprofitability of many new innovations, the lack of consumer acceptance, the obstacles of building codes, the expenses of

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[36] Marian Bowley, The British Building Industry (Cambridge: The University Press, 1966), pp. 147, 196-198, 444.

[37] Lionel Needleman, The Economics of Housing (London: Staples Press, 1965), p. 106.

retraining labor, the lack of flexibility characteristic of many new techniques, and labor union opposition as major reasons why many innovations have been slow to spread. Those that have won rapid acceptance have been profitable, required no reorganization of the building process, and did not visibly alter the product.[38] Unfortunately, no statistical analysis was offered in support of these generalizations.

O'Neill offers a different explanation for the slow spread of new technology in residential construction. The industry is highly decentralized, with thousands of firms producing the product. This means that the diffusion of a new technique requires thousands of decisions by thousands of entrepreneurs, unlike the situation that exists in oligopolistic industries where only two or three decisions are required.[39]

Rothenstein stresses the quality of individuals making decisions. He offers the following reasons for the slow utilization of European building building techniques: (1) lack of interest in developments abroad, (2) conservatism of management, (3) conservatism of bankers, (4) consumer resistance, and (5) labor opposition.[40]

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[38] "Housing Technology: It's Time for a Realistic Reappraisal," House and Home (November, 1963), p. 114.

[39] Richard O'Neill, "Technology Roadblocks and How They Can be Broken," House and Home (November, 1963), p. 114.

[40] Guy P. Rothstein, "European Pre-Fab Techniques," Journal of Housing (August-September, 1966), p. 438.

The National Committee on Urban Problems argues that the size of the firms in the building industry is an important obstacle to the rapid diffusion of new techniques. They argue that some innovations have economies of scale and therefore are more readily adopted by large firms than by small firms. In addition, large firms can more readily absorb the learning costs involved in innovation, because they have a larger volume over which to amortize these costs. A small firm, by choosing a longer amortization period than a large firm, can spread these learning costs over an identical volume of output. However, the industry is reluctant to project these costs too far into the future because of the uncertainty that future designs will use these innovations.[41] Unfortunately, as is the case with most of the diffusion literature in housing, no attempt was made to test these propositions empirically.

## Adoption of Innovations in Residential Housing: Summary

Publications concerning the adoption of new techniques in residential housing have offered many generalizations about the adoption of innovations in this industry, but have not tested whether these generalizations are consistent with the available industry data. In general, writings

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[41] National Commission on Urban Problems, op. cit., pp. 440, 443.

about the adoption of new techniques in residential building have stressed the same factors that are stressed by the literature in other industries: the relative advantage of the new technique, its riskiness, the size of the typical firm, the organization of the industry, competition, and the quality of entrepreneurs and managers. In addition they have argued that entrepreneurial decision making in this industry is subject to two additional constraints that either seem to be absent in other industries, or neglected in the various diffusion analyses: legal prohibitions in the form of building codes, and labor union opposition.

CHAPTER III

# THE TECHNOLOGY OF RESIDENTIAL HOUSING

## Introduction

The most common form of housing currently being built in the United States is the single story wood framed building. It averages 1100 square feet in area, excluding the garage. It consists of a living room, kitchen, three bedrooms, a bath and a half, and a garage.[1]

The average size of the firm producing this housing is quite small. In 1963, 17% of the new housing was constructed by builders who built one house at a time.[2] Most of these were built by people building their own homes. There were also carpenters who used their homes as offices and built three or four houses per year.[3] In 1963, only one percent of the builders built over 100 houses per year.

Most writers identify two types of housing technology: on-site construction and prefabrication. Such a distinction

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[1]Pat Tindale, Homebuilding in the U.S.A. (London: Ministry of Housing and Local Government, 1966), p. 12.

[2]*Ibid.*, pp. 7-8.

[3]*Ibid.*, p. 8.

oversimplifies the technology. On-site construction and prefabrication are merely two separate methods of organizing the production process. While methods of organization are one component of technology, they are not the only component. Technology also includes products and processes. Therefore, a discussion of present day housing technology should include some mention of the various components and processes which go into making up the final product.

## Housing Components and Processes

All housing requires a site for the finished product. Consequently, the initial step in erection of a structure is site preparation. Site preparation involves changing the contours of the land, making arrangements for utilities, laying out the exact position of the building on the site, and testing the earth for its load bearing qualities.

After the site has been prepared, a base must be laid for the superstructure of the building. This base is called the foundation. The construction of the foundation requires the removal of varying quantities of earth, depending upon the type of foundation used. There are four general types of foundations: full basement foundations, surface foundations, slab foundation, and pier foundation.[4] These four types of foundations are illustrated by Figure 1.

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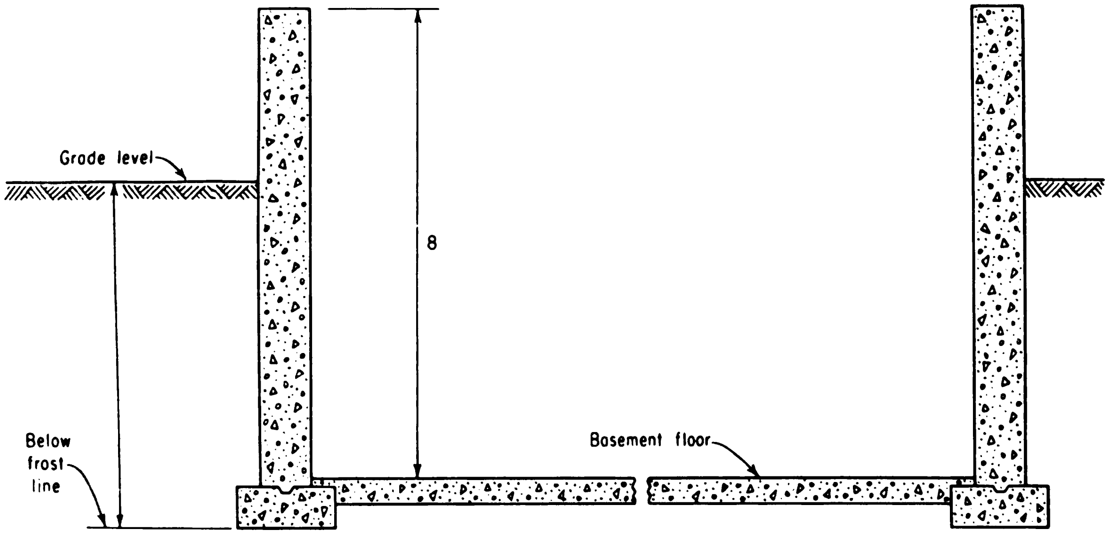
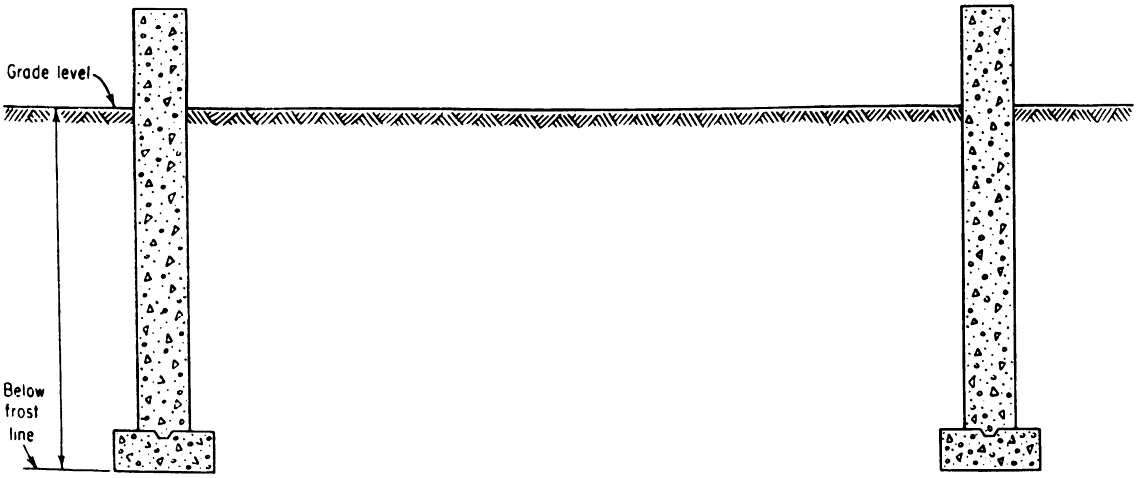
[4] Ronald C. Smith, Principles and Practices of Light Construction (Englewood Cliffs: Prentice Hall Corporation, 1963), p. 44.

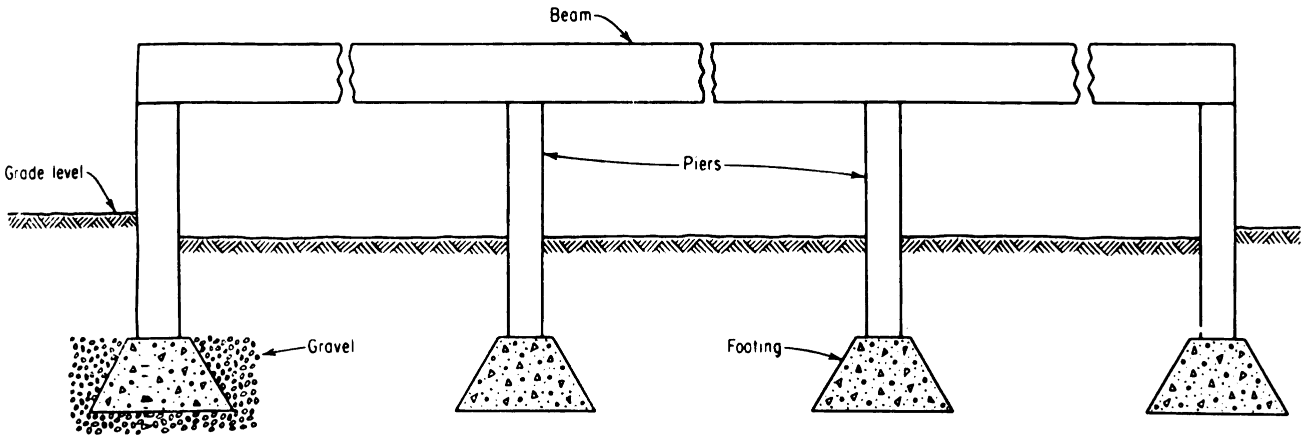



Full Basement

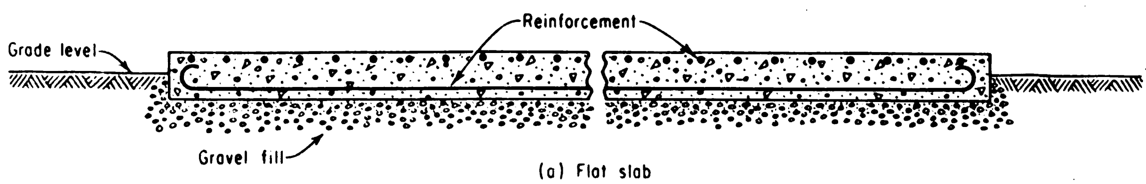



Surface Foundation

Figure 1.--Full Basement, Surface, Pier, and Slab Foundations




Pier Foundation




Slab Foundation

Figure 1.--Continued

A full basement foundation provides liveable, useable space. The walls are constructed of some masonry material, usually concrete, and carry the load of the building. The load is spread over large areas of earth by means of footings. When the full basement foundation is used, there will be a crack between the concrete floor and walls of the foundation that could allow water to seep in. This crack must be sealed with asphalt caulking.

The surface foundation, like the full basement foundation, has masonry walls. However, the walls usually extend into the earth only far enough to reach below the frost line, and are not generally low enough so that they encompass liveable space. The walls rest upon footings, as do the walls of the full basement foundation. However, no concrete floor is poured.

A slab foundation consists of a layer of concrete extending over the entire area to be occupied by the house. It may or may not rest upon footings. Because it is above the frost line, the layer of concrete rests upon a well drained gravel pad. The pad prevents moisture accumulation and freezing, and consequently, movement of the foundation is kept to a minimum.

A pier foundation carries the weight of the house on a series of individual columns of masonry. The piers are topped by beams of concrete, wood, or steel, upon which the house rests.

The strength of the foundation depends upon the quality of concrete. The quality of concrete depends on a number of factors: (1) the aggregates must be clean and well graded. (2) The course and fine aggregate must be properly proportioned. (3) The water used must be clean. Water fit for human consumption is best. (4) Water must be added in the right amounts. The less water used, within limits, the stronger will be the concrete. (5) The concrete must be properly cured. Temperature and moisture conditions control curing. Concrete cures best at about 70 degrees Fahrenheit and very slowly, if at all, below 40 degrees. Moist conditions are required for good curing.[5]

After the foundation has been laid, a floor frame is constructed. This is the part of the structure that carries the floor and the interior walls. The frame consists of bearing posts, the girder they support, the floor joists carried by the girder, the bridging between the joists, and the subfloor. The joists are usually 2 inches wide and are set 16 inches apart. The girders are formed by joining several pieces of wood together. They may be nailed, bolted, or glued and nailed together. Gluing and nailing provide the most rigid unit. The most common method of attaching the floor frame to the foundation is to nail it to a mudsill

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[5] Ibid., pp. 65-66.

which is anchored to the foundation wall by anchor bolts. A typical floor frame is shown in Figures 2 and 3.

The mudsill is a piece of wood (usually 2 inches wide and 8 inches long) that is set on top of the foundation walls in a layer of wet mortar. This is done because it is impossible to finish the foundation wall smoothly enough for the mudsill to set tightly on it after it drys. The anchor bolts used to attach the mudsill to the foundation are 3/4 inches in diameter and 14 inches long.

The building of the wall frame follows the completion of the floor frame. Assembly of the wall frame is simpler if the pieces are cut accurately prior to the assembly. There are three general types of frames: load bearing frames, western frames and balloon frames. These various types of frames are illustrated in Figures 4 through 6.

The load bearing wall frame assumes the role of the posts and girders in the floor frame as the main support of the building. The load bearing wall is supported by a continuous footing having a raised center portion to which the wall studs are anchored. Girths are fitted between the studs halfway between the top and bottom of the wall.

The western frame begins on the subfloor. A sole plate is attached to the subfloor and the wall studs are attached to the sole plate. On top of the studs is a top plate, and over the top plate is a cap plate.

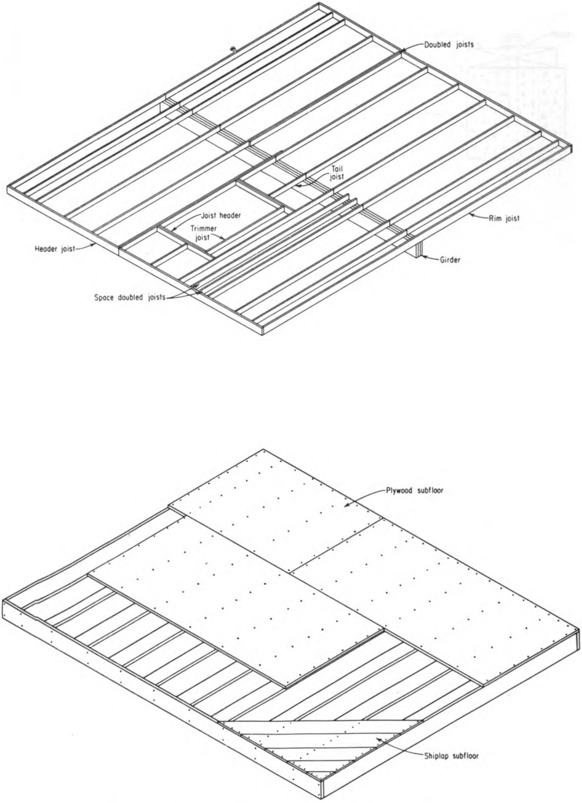


Figure 2.--Floor Frame and Subfloor

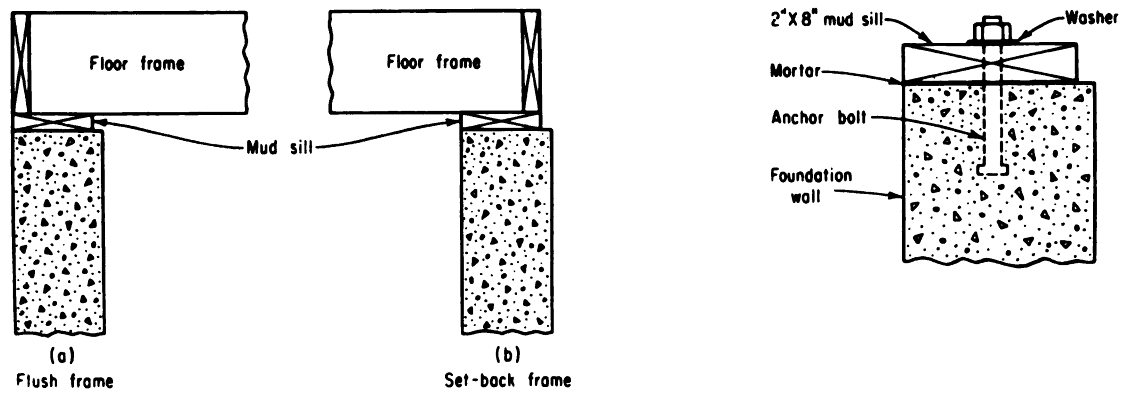


Figure 3.--Floor Frame and Mudsill

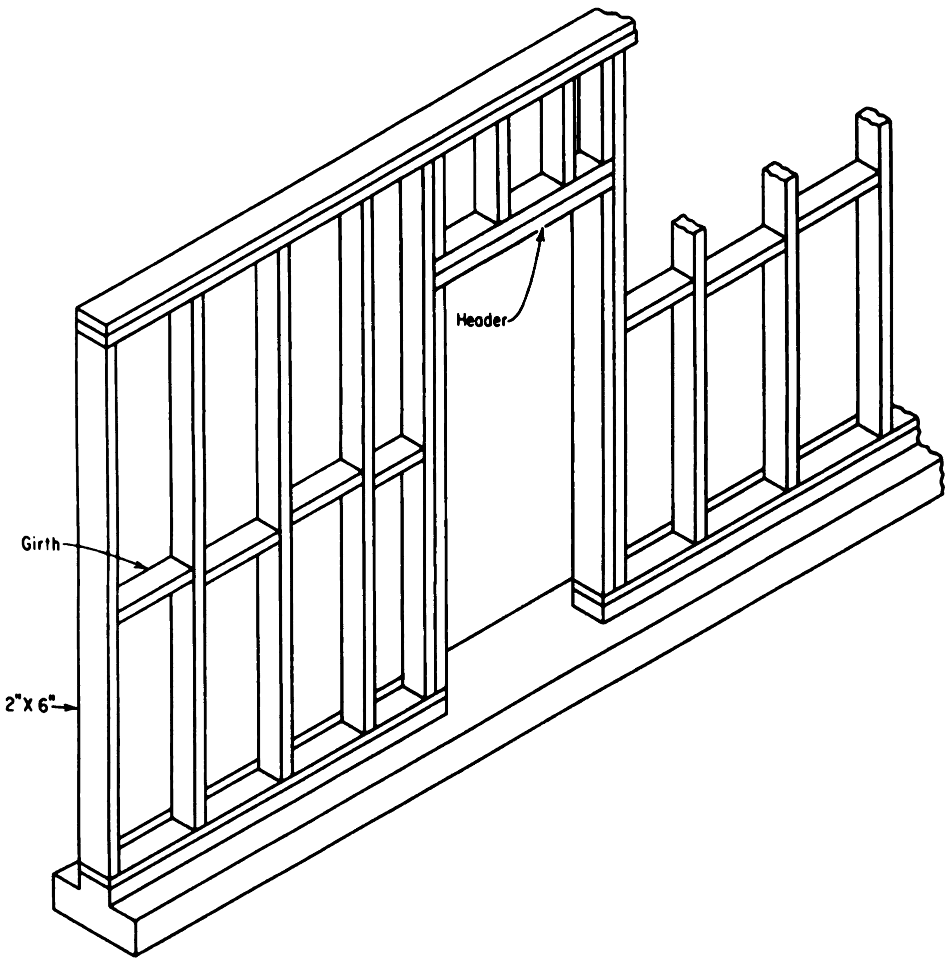


Figure 4.--Load Bearing Frame

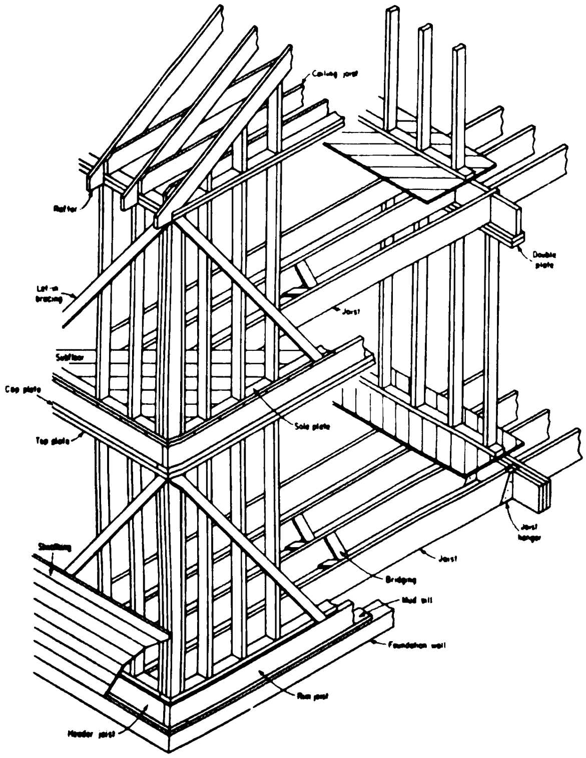


Figure 5.--Western Frame

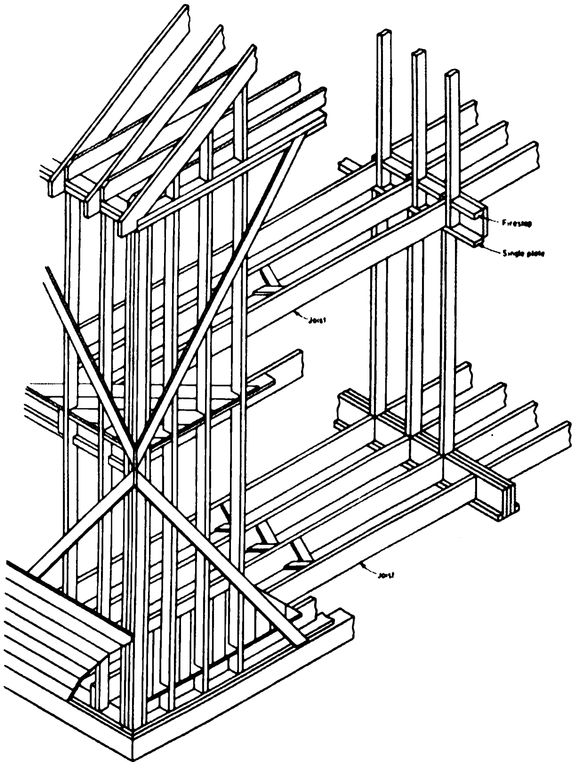


Figure 6.--Balloon Frame

A balloon frame begins at the mudsill. Full length regular studs and corner posts are attached to the sill. They are capped on the top by a top plate and a cap plate. A 1 inch by 4 inch piece of wood is nailed at angles to the studs to brace the frame.[6]

If a one story house is being constructed, the wall frame is not constructed on the floor frame. It is built separately, raised by hand, and attached to the floor frame by nailing two 4 inch nails between each pair of studs. Partitions are laid out, assembled, and erected in the same manner as walls.[7]

Sheathing completes the wall frame. A variety of materials are used for sheathing. Among the materials used are common board, plywood, exterior fiberboard, and gypsum board. Sheathing is nailed onto the studs. If 6 inch boards are used for sheathing, two 2 1/2 inch nails per board are used. If wider material is used, three nails per board are used. When plywood, fiberboard, or gypsum sheathing is used, the verticle joints should be offset, as shown in Figure 7.[8]

Assuming that a one story house is being constructed, the next step is to construct the ceiling frame. The ceiling

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[6] Ibid., p. 88.

[7] Ibid., p. 98.

[8] Ibid., p. 95.

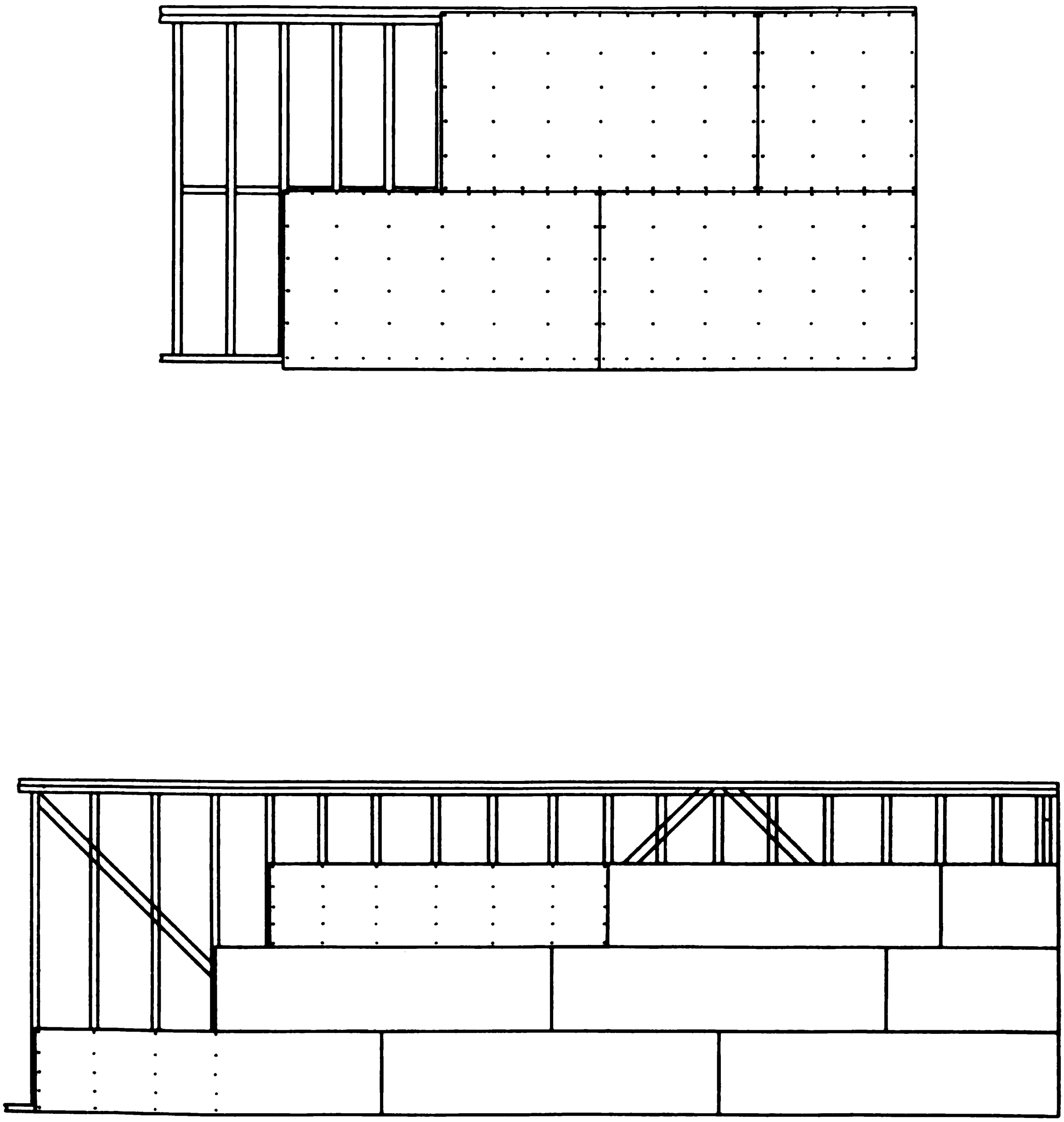

Figure 7.--Plywood and Gypsum Sheathing

frame merely consists of a number of joists attached to the cap plate. The ceiling materials are then attached to the joists. A typical ceiling frame is shown in Figure 8.

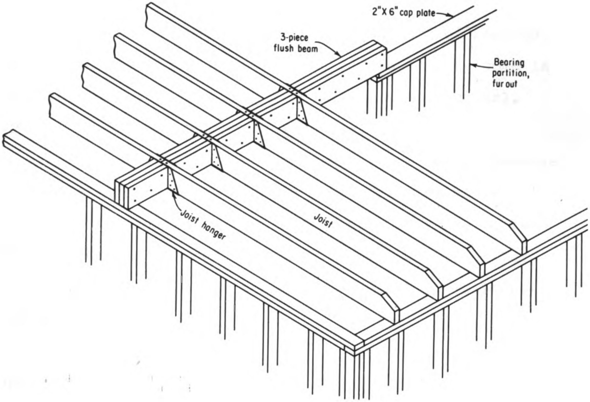


Figure 8.--Ceiling Frame

Upon completion of the ceiling frame, the roof is constructed. The roof may be one of several designs, but the traditional methods of building roofs are, with few exceptions, quite similar. A long wooden member is run the entire length of the building (or section of the roof to be covered) above the ceiling frame. Rafters are nailed to this member and the sole plate. Sheathing (usually plywood) is attached to the rafters. The conventional roof frame is illustrated by Figure 9.

Attached to the sheathing is some sort of roofing. Shingles are most commonly used for roofing. They come in a variety of materials, including wood (usually cedar), asphalt, cement asbestos, and aluminum.

Wood shingles are commonly made from cedar, because it changes very little with atmospheric changes and withstands weathering better than most wood. Only two nails are used for each shingle, regardless of its width. The joints of the shingles on top must be offset 1 1/2 inches from those underneath.[9]

Asphalt shingles are made by impregnating heavy paper with hot asphalt and covering the upper surface with finely crushed color slate. Laying starts at the center of the roof and a chalk line is drawn down the center as a guide.

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[9] Ibid., p. 204.

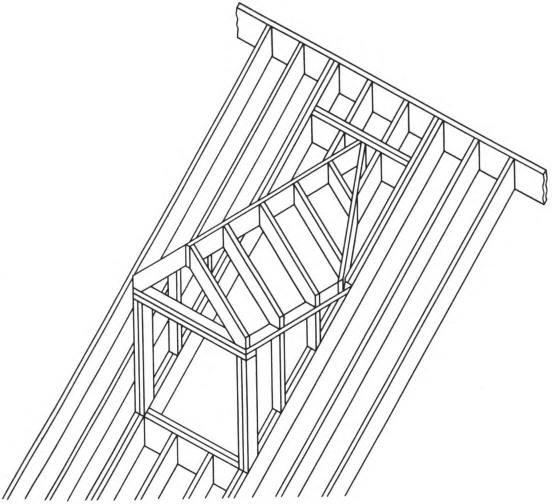

Figure 9.--Roof Frame

To support the projection of the asphalt shingles over the eaves, a row of wood shingles is laid around the edge of the roof prior to laying the asphalt shingles. The top of the asphalt shingles are nailed down, and the bottom flap is attached to the roof with asphalt roofing gum.

Asbestos cement shingles have preformed nail holes. Care must be taken in nailing these shingles to the decking. If nailed too tightly, they crack, and if nailed too loosely, they move.

Aluminum shingles last indefinitely. Usually they are interlocking. Their underlay consists of 15 pounds of saturated felt, and where there are extreme climates, a vapor layer of paper is placed under the felt. Generally, one nail is required for each shingle, and it is placed in the upper corner.[10]

The construction of the roof completes the frame of the house. The next step is to provide the exterior finish. The process, listed in the usual order in which it is done, involves roofing, installing window and door frames, and applying exterior paper, casings, and finish. Exterior finishes include stucco, cedar siding, boards, fiberboard, aluminum, and plywood.

The builder next turns his attention to the interior. First, he installs wiring, plumbing, heating, and air conditioning. Then he places insulation in the wall and

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[10] *Ibid.*, p. 208.

ceiling. Two types of insulation are required: one to guard against heat loss by radiation, and the other to guard against heat loss by conduction. To guard against heat loss by radiation, requires insulation with a smooth shiny surface. Preventing heat loss by conduction requires materials that have many trapped air pockets. If there is considerable difference between inside and outside humidity, a vapor barrier must be constructed to maintain the effectiveness of the insulation. Commonly used materials include wax paper, polyethelene film, and aluminum and copper foil.

Next comes the interior finish. In the past, plaster was the most common finishing material, for walls and ceilings. Today, finishing materials such as drywall, plywood, hard-board, insulating fiberboard, plastic laminate, and tile finishings are common.

The final flooring materials are laid on top of the subfloor. Flooring materials include hardwood, linoleum, and resilient tiles. Often times, carpeting is used as the final finish.

When the flooring has been installed, the final finishing is done. First the baseboard and carpet strip are laid. Then such features as kitchen cabinets and closet shelves are installed. Upon completion of this phase, the house is ready for occupancy.

## Post and Beam Construction

A different system of framing from the one described in the previous pages is post and beam construction. The advantage of the post and beam method is that it adds additional variety to housing designs. Instead of completely flat ceilings, for example, the contractor can let the beams be seen, giving the appearance of a medieval manor house.

In post and beam construction, the various components of the frame are separated by greater distances than they are in conventional framing. This results in larger members being used, and the frame consists of posts and beams rather than studs, joists, and rafters.[11] The difference between conventional construction and post and beam construction is shown by Figure 10.

## Organization of Production

The first page of this chapter mentioned the two main types of organization: (1) on site production, and (2) prefabrication.

In actuality, the organization of the production process is more of a continuum than a dichotomy. No builder fabricates on site all of the components that go into the structure. There are various degrees of utilization of

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[11] Ibid., p. 271.

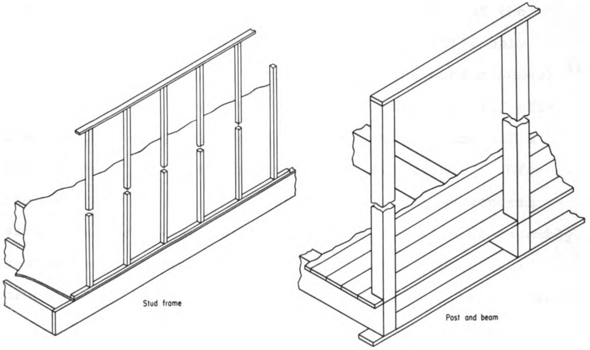


Figure 10.--Post and Beam Construction and Conventional Framing

prefabricated components, which give rise to the continuum that was mentioned. Nevertheless, it does no harm to dichotomize the process for the purposes of discussion, as long as no economic significance is attached to the dichotomy.

Prefabrication has only captured a small part of the total market for permanent residential housing. Of the 1.3 million non-farm family homes started in 1967, only 18.5% were manufactured homes (not including mobile homes).[12]

There are three types of prefabrication: (1) off-site manufacturing, (2) on-site manufacturing, and (3) a combination of off-site or on-site manufacturing.[13] Off-site manufacturing involves manufacturing all structural parts in a factory and shipping them to the site of assembly. On-site manufacturing refers to the construction of all structural parts in a portable factory at the site of assembly.

Reduction in unit costs is the major advantage of prefabrication. This reduction in costs has four sources: (1) the substitution of relatively inexpensive factors of production for relatively expensive factors, (2) simplification of the building process, (3) reduction of construction time, and (4) improvement of working conditions.[14]

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[12]National Commission on Urban Problems, _op. cit._, p. 435.

[13]Guy P. Rothstein, _op. cit._, p. 439.

[14]National Commission on Urban Problems, _op. cit._, pp. 435-436.

Prefabrication permits the substitution of unskilled workers for skilled workers. Since unskilled workers generally have a lower wage structure than skilled workers, a reduction in unit costs usually results. In addition, greater use can be made of power driven machinery, increasing the productivity of the labor force.

The factory type of organization makes possible repetitive operations. Repetitive operations permit a greater specialization of labor than is possible under the craft system of construction. The increased specialization makes possible an increase in labor productivity.

Building time is reduced with prefabrication because a larger percentage of the work is done under shelter, reducing the delays caused by weather, as well as reducing the costs of interim financing. In addition, placing the production process under shelter improves the working conditions of the labor force. Men are less productive when they are chilly and wet, and consequently, improving their working conditions improves their productivity.

The savings from prefabrication can be considerable. The National Commission on Urban Problems estimates that, on the average, prefabrication can reduce the selling price of a $20,000 home by 16.5 percent. The areas in which costs can be reduced are shown in Table 2.

TABLE II.--Estimated Development Costs for Comparable Single-Family Houses of Conventional Construction and Total Prefabrication.

| Cost Components | Conventional Construction | Total Prefabrication (Sectionalized) |
|---|---|---|
| Land Acquisition and Preparation | $3364 | $3364 |
| Framing Material | $3100 | $7707 |
| Field Carpentry | 1560 | 260 |
| Roofing | 228 | Included in Framing |
| Siding | 338 | " |
| Floor | 530 | " |
| Drywall | 571 | " |
| Painting | 600 | " |
| Ceramic tile around tub | 108 | " |
| Heating | 580 | 95 |
| Electrical Work | 530 | Included in Framing |
| Plumbing (one bath) | 1050 | 175 |
| Kitchen Cabinets | 500 | Included in Framing |
| Appliances | 160 | " |
| Interim Financing | 800 | Not Needed |
| Sales Commission | 1000 | 850 |
| Mortgage Points | 1000 | 580 |
| Closing Costs | 500 | 425 |
| Builder's Profit | 1800 | 1530 |
| Other Components | 1836 | 1836 |
| Selling Price | 20,155 | 16,822 |
| Savings vs. Conventional Construction | | 3,333 |
| Percentage Reduction in Selling Price | | 16.5% |

Source: National Commission on Urban Problems

In spite of the potential savings of prefabrication, over 4/5 of the housing starts in the United States are being built with the use of conventional techniques. There are five obstacles to the spread of prefabrication: Consumer resistance, local building codes, transportation costs,[15] adaptation by local material suppliers,[16] and labor union opposition.[17]

Many potential home buyers believe that pre-manufactured houses are aesthetically undesirable and structurally unsound. Consumers believe that manufactured homes come in standardized styles, and that aesthetic variety cannot be maintained. In actuality, their belief is mistaken. Thirty-three percent of the home manufacturers offer at least 25 designs; 21% offer between 25 and 50 designs; 14% offer between 50 and 100 designs, and 17% make 100 or more designs.[18] Likewise, the belief in structural unsoundness is a misconception, or so concludes the National Commission on Urban Problems.[19]

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[15] Ibid., pp. 436-437.

[16] Tindale, op. cit., p. 36.

[17] Rothstein, op. cit., p. 438.

[18] National Commission on Urban Problems, op. cit., p. 436.

[19] Ibid., p. 431.

However, buyers believe that prefabricated homes are structurally unsound and it is they who purchase the house.

Building codes prohibit many assemblies outright, and some that aren't explicitly prohibited, are in effect forbidden by inspection procedures. Examples include electric assemblies that must be disassembled and assembled by local labor, and inspectors that require the disassembly of wall panels to permit inspection of the wiring.

Transportation costs are an important barrier to the spread of prefabricated homes. Prefabricated housing is heavy and bulky and most home manufacturers do not attempt to market their product at distances of over 300 miles from the plant. This makes large volumes of output impossible to achieve in many areas. This offsets some of the economies of prefabrication that are derived from the use of relatively greater numbers of machines, many of which require large volumes of output if they are actually to result in a net cost savings.

The spread of prefabrication has been countered by the activities of local material suppliers. Local suppliers have begun manufacturing assorted building components, such as roof trusses and prehung doors. The components that suppliers have undertaken to manufacture usually use materials normally stocked by the supplier, and require little additional equipment. By utilizing some of these components, the traditional builder can narrow the cost differential between himself and the prefabricator.

## Prospects for Future Cost Reductions Through Technological Change

Despite the emphasis given prefabrication by many writers, it is already apparent that this is not the only change that has the potential of achieving significant cost reductions. Two additional changes may prove to be significant: simplification and mechanization.[20]

Simplification aims at reducing the variety of sizes and types of building components. By reducing the variety of components, greater scope is given to specialization, with its beneficial effects on labor productivity.

Mechanization offers potential costs savings by speeding up the production process and by serving as a substitute for relatively expensive labor. However, machines are less flexible than human beings, and must be fully employed if they are to be profitable. Human beings can be transferred between tasks with relative ease, but machines cannot. Consequently, increased mechanization of homebuilding may require an increase in the scale of operations of the typical firm so that machinery can be fully employed. An increase in size, of course, would not be needed to utilize some of the smaller power tools, such as drills and saws.

Simplification, prefabrication, and mechanization are not pananceas. There is an unfortunate tendency in the

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[20]Needleman, op. cit., p. 105.

popular press to assume that if only the housing industry would concentrate on making major changes along these lines that costs of production could be reduced. However, major changes in productivity are not usually the result of major innovations, but rather the cumulative result of many small improvements.[21]

Because of the peculiar nature of the cost functions in housing, small reductions in costs tend to be multiplied. One type of costs is often a function of other types of costs, and a decrease in one type of cost can often set up a chain reaction that results in a decline in selling price that exceeds the original decrease in costs. For example, architects fees, engineering fees, real estate commissions, and the entrepreneur's mark up for profit are usually calculated as percentages of construction costs. Any reduction in construction costs automatically reduces these costs.[22] The same can be said about the costs of interim financing. The lower the cost of the house, the less the loan needed for interim financing, and the lower the interest cost will be. The results of these interrelationships is that a one dollar reduction in one type of costs may well cause a reduction in selling price in excess of one dollar. This fact should make one cautious in rejecting out of hand the

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[21] Mansfield, op. cit., p. 18.

[22] National Commission on Urban Problems, op. cit., pp. 428, 431.

importance of minor changes in the building process. If one also takes into account the fact that the cumulative effect of many minor changes need not be minor, he may well agree with the National Council on Urban Problems who concluded, "Housing costs can be reduced if none of the many avenues for savings are dismissed as inconsequential. Add them all up and they promise to be substantial."[23]

[23]National Commission on Urban Problems, op. cit., p. 16.

CHAPTER IV

# ENTREPRENEURS' RECEPTIVENESS TO INNOVATIONS IN RESIDENTIAL HOUSING: A MODEL

## Introduction

An entrepreneur's receptiveness to innovations can be measured by the percentage of innovations that he has adopted out of a given population of innovations. If $R_i$ represents the receptiveness of the ith entrepreneur, n the number of innovations in the population, and $A_i$ the number of innovations he has adopted, then his receptiveness can be defined by the equation

$$(1)\quad R_i = \frac{A_i}{n}$$

Different economists stress different influences on an entrepreneur's receptiveness to innovations. Five influences are usually discussed: (1) the relative advantage of the new technique over the old, (2) the uncertainty of the new technique, (3) the technical and managerial skill of the entrepreneur, (4) the size of the firm, and (5) the degree of competition in the industry. This chapter discusses whether these views provide a good description of entrepreneurial receptiveness to innovations in residential housing. Out of this discussion will emerge a model that attempts to provide a good explanation of entrepreneurs' receptiveness to innovations in this industry.

## Profits

In general, what a firm seeks from an innovation depends upon its goals. Economists differ about the primary goals of business firms. The usual assumption is that firms attempt to maximize profits. Different economists have taken issue with this assumption. Some argue that the cognitive limits on rationality lead to satisficing rather than maximizing behavior.[1] Others maintain that the separation of ownership and management makes the maximization assumption questionable.[2] Still others hold that firms exist to satisfy the needs of their owners, that the owners may have goals that are more important than profit maximization, and that expected profits do not influence the decisions of the entrepreneur in a consistent manner.

Profits are a necessary condition for the long run survival of the firm. Consequently, owners and managers must pay close attention to the impact of an innovation on

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[1] March and Simons, op. cit., pp. 136-172.

[2] Galbraith, op. cit., p. 117.

the firm's profits, even if they have other goals they consider important. Owners and managers cannot use the firms to satisfy their goals if the firm ceases to exist. Consequently, we shall hypothesize that the decision to adopt an innovation is a function of its estimated profitability. If P represents the estimated profitability of the nth innovation, the second equation in the system becomes

$$(2)\quad A_i=f(P_1,P_2,\ldots,P_n)\ \frac{\partial A}{\partial P}>0$$

<u>Uncertainty</u>

Decision making can take place under three states of knowledge: certainty, risk, and uncertainty. Under conditions of certainty, the entrepreneur has full and accurate knowledge of the consequences of his actions. Under conditions of risk, the entrepreneur has accurate knowledge only of the probability distribution of the consequences of his actions. Under conditions of uncertainty, the entrepreneur does not have accurate knowledge of the probability distribution of the consequences of his actions.

The decisions to adopt an innovation is made under conditions of uncertainty. An innovation, by definition, is a new way of doing things, and as such, may have unforeseen consequences. Economists usually assume that entrepreneurs react to situations of uncertainty be estimating a probability distribution of possible outcomes and by choosing that course of action that maximizes expected utility.

If the probability distribution of possible outcomes is the distribution generated by a random variable, then the law of large numbers will ensure that the individual will maximize his utility in the long run by choosing the course of action which offers the highest expected utility. Unfortunately, the results from utilizing an innovation are not a random variable. If the results were a random variable, then repeated use of the innovation under similar circumstances would yield a variety of results. However, the repeated use of an innovation under similar circumstances will repeatedly yield similar results. This means that the entrepreneur can only imagine that he can take refuge in the law of large numbers. If the innovation has a negative payoff when it is tried under one set of circumstances, it will have a negative payoff if it is tried again under the same set of circumstances. There is no hope of a positive payoff unless the circumstances change under which the innovation is used. The payoff of an innovation is unpredictable, but it is not a random variable.

If the payoff of an innovation cannot be considered a random variable, then the usual rules of utility maximization are not applicable. But if the usual rules of utility maximization are inapplicable, how does the entrepreneur make his decision?

We begin by assuming that the entrepreneur uses his knowledge of the innovation to estimate a probability distribution of possible outcomes. (This probability distribution is not the distribution of a random variable.) He concludes that the innovation will be profitable if the sum of the probability weights attached to the positive payoffs is greater than 50%. This is a better measure of the likely results of utilizing an innovation than the expected payoff of the distribution, because the expected payoff can be greater than zero when there is a greater than 50% probability of achieving a loss.

If the entrepreneur estimates that the innovation is likely to be profitable, he must then estimate how profitable it is likely to be. We assume that he chooses the positive payoff with the highest probability weight as the payoff he estimates he will receive if he utilizes the innovation. In future pages, this measure of profitability will be called "estimated profitability."

The concept of estimated profitability results in a restriction upon the second equation of the model. Let k represent positive probability weights. Then

$$(2)\ A_i = f(P_1, P_2, \ldots, P_n)\ \frac{\partial A}{\partial P} > 0; P > 0 \text{ if } k > .5$$

At this point in the analysis, most economists would argue that the entrepreneur's next step is to decide whether the estimated profitability of the innovation is enough to justify the risks of adoption. In the generally accepted analysis, the entrepreneur trades off the estimated profitability of the innovation against the subjective risks, and makes his decision to adopt or reject the innovation. The exact terms of the tradeoff depends upon the entrepreneur's utility function.

The justification for this process is that the entrepreneur must compensate for his uncertain state of knowledge about the innovation. We might reasonably ask whether the entrepreneur does not compensate for uncertainty when he estimates the probability distribution of payoffs from utilizing the innovation. What danger does the entrepreneur face that is not expressed by the probability distribution?

Only one danger appears to be ignored by the entrepreneur's estimated probability distribution: the danger that the distribution is not a good reflection of reality. The distribution can be inaccurate in three respects: (1) The probability of achieving a negative payoff can be understated, (2) The estimated distribution does not contain the actual outcome of utilizing the innovation, and (3) some combination of the first two inaccuracies.

Suppose that the entrepreneur is worried that he has given the negative payoffs too low of a probability weight. What is the simplest solution for him? Will he trade off the estimated profits of the innovation against some indicator of risk, or will he simply adjust the negative probability weights until he no longer worries about this possibility. Adjusting the negative probability weights appears the most logical thing to do.

Suppose however that the entrepreneur is worried that his assumed probability distribution does not contain the actual payoff that will result if he adopts the innovation. He can, as before, tradeoff estimated profits against subjective risks, or he can expand the range of possible payoffs in his probability distribution until he is no longer worried about this possibility. If he expands the range of possible outcomes far enough, there must certainly come a point at which he no longer worries whether the actual payoff from using the innovation is contained in his probability distribution. For example, an entrepreneur considering the use of a new hand saw with a price tag of $5.00 might conceivably worry whether he ought to consider a loss of $4.00 or $5.00 to be the worst possible result that might occur from utilizing the saw, but he would hardly worry about a loss of $1,000,000.00.

Once the entrepreneur has expanded the range of his probability distribution and has satisfied himself that it corresponds to reality, he must consider the problem of adjusting his probability weights. This problem has already been considered earlier in this chapter.

The analysis just developed suggests that the entrepreneur may compensate for the degree of uncertainty possessed by an innovation when he estimates the probability distribution of payoffs. If he does so, there is no reason for him to trade off estimated profits against subjective risks.

In both models (the traditional model and the model being developed) the uncertainty of an innovation affects the likelihood that it will be adopted. However the mechanisms involved are different. In the traditional model, there is a tradeoff between expected profits and risks. In our model, uncertainty affects adoption because it affects the entrepreneur's estimate of profits. In our model, estimated profits are a function of uncertainty, among other things. The third equation in the model becomes

$$(3)\quad P_n = g(F, T_n, U_n)$$

where $P_n$ represents the estimated profitability of the nth innovation, $T_n$ represents the entrepreneurs understanding of the technical properties of the innovation, $U_n$ represents the uncertainty of the innovation, and F represents relative factor prices. All of these factors are determined exogenously.

$$(4)\quad F = \bar{F}$$

$$(5)\quad T_n = \bar{T}_n$$

$$(6)\quad U_n = \bar{U}_n$$

The model is now complete except for the equilibrium condition. Assume that all innovations in the population are profitable. (This is a simplifying assumption and not crucial to the analysis.) Equilibrium will occur when

(7) A=n

This model is a modified version of the traditional model of profit maximization under conditions of uncertainty. No role is allowed for factors such as the skill of individual entrepreneurs or the size of the firm. In the remaining sections of this chapter, the influence of these variables will be discussed.

## The Skill of the Entrepreneur

Does the technical and managerial skill of the entrepreneur affect his receptiveness to innovations? On the surface, it appears difficult to deny such a proposition. We have argued that receptiveness to innovations is a function of whether the innovation appears profitable. If this proposition is correct, an entrepreneur's long run receptiveness to innovations will depend on his ability to recognize an exploit profitable innovations. The qualifying term "long run" is a necessary part of this sentence. An entrepreneur can be temporarily highly receptive to innovations because he is unable to distinguish between profitable and unprofitable innovations. But if his firm is to survive in the long run, his receptiveness to innovations must be constrained by his ability to recognize and exploit profitable opportunities.

In the long run, the entrepreneur's receptiveness to innovations must depend upon his skill.

Arguing in this fashion does not result in many meaningful conclusions. It does, however, suggests a meaningful question. What determines an entrepreneur's ability to recognize and exploit profitable opportunities?

Answering this question could take us far beyond the scope of economics. Rather than roaming far afield however, we shall restrict ourselves to examining the influence of three variables that would be of primary concern to economists studying technological change: the entrepreneur's education, his experience as a manager, and his experience as a worker.

Education

Education may influence an entrepreneur's receptiveness to innovations in a variety of ways. One of the less obvious ways is by making an individual more receptive to new ideas. Education, according to educators, makes men more questioning about their environment and less willing to accept the status quo.

Another possible benefit of education is the transmission of technical knowledge. An individual who is well versed in the technology of his industry may be able to make more accurate judgments about the possible outcomes that might occur if he were to adopt the innovation. The ability to make accurate judgments about the possible outcomes of adoption increases the probability that a profitable innovation will be judged profitable and decreases the probability that an unprofitable innovation will be judged profitable, thereby reducing the risks of adopting the innovation.

There is some question whether education has the beneficial effect previously described. In addition to teaching inquisitiveness and methods of problem solving, education also imparts the accepted doctrine of the physical and social sciences. Some academic settings reinforce closed minded individuals who resist change because they fear that it is theoretically unsound. These individuals imagine that certain types of change are disapproved by scientific or engineering "authorities."

In addition, there is some question whether the technical knowledge imparted by education is an aid in judging the potential benefits of an innovation. It may not be possible to pass on detailed technical knowledge about housebuilding in school. The manner in which each firm attacks the problem of housing construction may be peculiar to itself, and education may be able to do little more than impart the general principles upon which the industry's technology is based. If only general principles of technology are taught, education may be of little aid in judging the benefits and risks of an innovation. Accurate judgments of profitablity and risk may require talent and experience in applying the principles learned in school.

There appears to be no compelling reason for assuming education increases an entrepreneur's receptiveness to new techniques. Education can teach inquisitiveness or passive memorizing of "principles of technology." Not everyone is equally adept at applying general principles. Education can be different things and therefore may not instill a consistant response in its recipients. Whether education influences entrepreneurial receptiveness must be decided by empirical investigation. Either a positive relationship or no relationship between the two variables would not be surprising, but since education may not instill a consistent response in its recipients, our hypothesis is no consistent relationship exists between the level of educational achievement and entrepreneurial receptiveness.

## Managerial Experience

Managerial experience may make an entrepreneur more receptive to innovations because (1) experience allows him to acquire a detailed knowledge of the industry's technology, and (2) it gives him a certain business sense that cannot be acquired elsewhere.

Detailed knowledge about the technology of the industry can increase receptiveness to profitable innovations in a variety of ways. To begin with, a detailed knowledge of existing techniques will aid the entrepreneur in visualizing where and how an innovation can fit into his operation. In addition it aids him in visualizing the actual results of utilizing the innovation. Finally, it may give him confidence in his judgment. The interplay of these three factors makes it less likely that a profitable innovation will be judged unprofitable and be rejected by the entrepreneur.

In addition to providing the opportunity to acquire technical knowledge, experience can also provide entrepreneurs with a business sense that can be acquired in no other manner. Education can teach him some of the tricks of the trade, such as record keeping and job layout, but it cannot teach him what to sell, or what prices to pay or charge.[5] This requires a certain "sense of business" that only experience can provide, though, of course, experience does not provide it for all. An entrepreneur's business sense can be an important factor affecting his receptiveness to new techniques. The costs of acquiring and installing an innovation (hence profits) can also be affected by his business sense.

There are several factors which might offset the positive attributes provided by managerial experience. To begin with, the experienced manager may learn that innovations have results that cannot be foreseen with accuracy, no matter what his level of technical sophistication. This may cause him to weigh the negative payoffs in the probability distribution higher than his less experienced competitor. Secondly, he might resist change because it is different from the

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[5] W. Authur Lewis, The Theory of Economic Growth (Homewood: Richard D. Irwin, Inc., 1955) pp. 196-197.

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accepted way of doing things. Lastly, he might grow complacent after many years of success in the industry and feel no need to search out new ideas or to adopt new ways of doing things; or perhaps he may merely feel that the personal effort of innovation is not worthwhile.

Any conclusion about the net effect of managerial experience myst be tentative unless there is an appeal to empirical evidence. For the time being, we shall hypothesize that managerial experience does not affect the mass of entrepreneurs in any consistent manner.

Non-Managerial Experience

Non-managerial experience can be defined as experience in a non-supervisory capacity. If detailed knowledge about the technology of the industry makes entrepreneurs more receptive to new techniques, then perhaps the most receptive entrepreneur is an individual who has had non-managerial experience in the industry. The employees of a firm are in closer contact with the technology of housebuilding than the managers and owners and may thus acquire a more detailed knowledge of the technology than their supervisors. For this reason, entrepreneurs who have had experience in a non-managerial capacity in the industry may be more receptive to new techniques than those who lack this experience. One should not make too much of this point, however. While detailed knowledge of the technology of one particular operation may be an aid in estimating the profitability of a given innovation, it is not an aid in estimating the profitability of all innovations. Non-managerial experience in residential building may give an individual a detailed knowledge of one job, but entrepreneurs must make decisions about innovations in several phases of building, and it is doubtful whether detailed knowledge of one or two jobs will significantly improve the average receptiveness of entrepreneurs. Moreover, an entrepreneur must judge the potential benefits of an innovation in the context of the entire building process and not just in the context of a single job. An innovation can be profitable in one phase of the process and unprofitable in another. An individual with non-managerial experience may find it difficult to look at an innovation in the context of the entire production process. Non-managerial experience could increase entrepreneurial receptiveness or it could have no affect. Any statements about the affect of non-managerial experience must be tentative without investigation. Our tentative hypothesis is that no relationship exists between non-managerial experience and receptiveness to innovations.

## The Question of Size

The term "size of the firm" can mean many different things. For example, it can refer to the number of employees a firm hires, the value of its capital assets, the value of the firm's sales, or its volume of output. For the purposes of this study, size will be measured by the number of houses built by a contractor in a typical year.

Economists are generally agreed that an innovation will appear more profitable to a large firm than to a small firm if there are economies of scale involved. Beyond this, there is disagreement about whether a firm's size influences its receptiveness to new techniques.

Lower learning costs per unit of output is the primary reason that large firms might be expected to be more receptive to new techniques than smaller firms. It takes time to learn how to utilize an innovation correctly. During this time, the firm may not realize the full benefits of an innovation, and may even suffer losses. The larger the output of the firm, the less is the learning cost per unit of output. Therefore, other things being equal, learning costs are less likely to make an innovation unprofitable if the firm is "large."

Offsetting the advantage of smaller unit learning costs are the demands made upon the time of the large scale entrepreneur. The large scale entrepreneur may have to spend so much of his time coordinating the various activities of his firm that he has little time to consider the merits and demerits of any given innovation. He may not have time to search for innovations that will improve this firm's efficiency, and he may not have time to weigh the advantages and disadvantages of innovations that are brought to his attention.

As a result, he may not be aware of many innovations, and he may misjudge the profitability of those that are brought to his attention. He could avoid these difficulties by hiring someone to investigate and make decisions about innovations, but this would increase his costs of adoption and offset the advantage of spreading learning costs over large volumes of output. Whether coordination difficulties offset this advantage is not certain. The costs imposed by coordination problems could be considerable. Empirical investigation is needed before any firm conclusions can be drawn about the effects of firm size on receptiveness to innovation.

## Competition

Competition can come from one of three sources: (1) from firms in another industry that produces a close substitute for the product in question, (2) from other firms in the industry, and (3) from new firms entering the industry.

The homebuilding industry faces competition from builders of mobile homes and multiple rental units. For most Americans, however, these are inferior substitutes for home ownership, and are utilized as a temporary measure until the income level of the family permits them to purchase regular housing. Consequently, it appears that the strongest competition facing homebuilders comes from firms within the homebuilding industry itself, and from new firms entering the industry. How important is competition from existing firms and new entrants into the industry?

The purchase of a home requires a substantial commitment of a family's present and future resources. For most families, it will be the largest single purchase they will ever make. For a large number of families, the purchase of a home is a one time only affair. Some families may sell their first home and purchase a second, but few will sell their second and purchase a third. Since the purchase of a home requires a substantial commitment of resources, and since families expect to enter the housing market infrequently, they are concerned with such matters as the aesthetic value of the house and its quality of construction. The consumer is likely to give factors such as "aesthetic values" and the builder's reputation for quality construction a higher priority than minor price differentials when he decides to purchase a house. There appears to be a strong probability that the demand for housing is quite price inelastic.

An entrepreneur has two incentives to adopt a cost reducing innovation: (1) he can increase his profits if he adopts the innovation; (2) competition will punish him if he does not. The considerations discussed in the previous paragraph suggest that competition does not have a strong influence on the adoption of cost reducing innovations if they offer only small reductions in costs.

As was pointed out in Chapter III, major changes in productivity are usually the result of many small changes rather than of major innovations. If the price elasticity of demand for housing is low, then the potential pressure of price competition will be low and the speed with which new techniques will spread will be reduced. Other things being equal, the diffusion of cost reducing techniques in residential housing will be slower than it will be in other industries with a higher price elasticity of demand.

Whether or not competition influences entrepreneurial receptiveness is an empirical question. Our tentative hypothesis is that competition does not influence receptiveness.

## Summary

A firm's receptiveness to new techniques can be measured by the percentage of a given population of innovations that it has adopted. The percentage that is adopted depends upon how many innovations the entrepreneur judges to be profitable. My theory on this point is that in forming his judgments of profitability, the entrepreneur assumes a probability distribution of possible payoffs. If the sum of the probability weights attached to the positive payoffs are greater than .5, he assumes the innovation is profitable, and the positive payoff with the highest probability weight becomes the estimated payoff of the distribution.

The model outlined in this chapter suggests the entrepreneur does not handle uncertainty by trading off estimated profitability against subjective risk. He compensates for the effect of uncertainty when he estimates his probability distribution. He adjusts the range of the distribution and the probability weights of the possible outcomes until he is satisfied that he can use the distribution to estimate the effects of adopting the innovation.

The education, managerial experience, and non-managerial experience of the entrepreneur, as well as the size of his firm, do not play a role in this model. These variables have certain advantages and disadvantages that may offset one another, resulting in no net effect on the average entrepreneur's receptiveness to new techniques. This conclusion must be tentative until it is substantiated by empirical investigation.

The mechanism leading to the adoption of cost reducing innovations in the model is the profit motive. The reason for the relative unimportance of competition as a mechanism in the model is the relative unresponsiveness of consumers to small changes in the price of housing.

CHAPTER V

# THE DIFFUSION OF NEW TECHNIQUES IN RESIDENTIAL HOUSING: THE APPLICABILITY OF THE MODEL

## Introduction

The model presented in Chapter IV raises some interesting issues: (1) Do entrepreneurs in residential housing consider the return of an innovation when they decide to adopt it? (2) Do entrepreneurs trade off subjective risks against estimated profits, or do they compensate for uncertainty when estimating profitability? (3) Do the education and experience of the entrepreneur affect his receptiveness to new techniques? (4) Are large firms more receptive to innovations than small firms? (5) What role does competition play in the spread of innovations in residential housing?

Multiple regression analysis was used to answer these questions. The data for the analysis was obtained by interviews with the managers of 20 owner-occupied-single-unit homebuilding firms in the Greater Lansing Area.[1] The firms constituted 27.4% of the homebuilders in the Greater

[1]For the purpose of this study, the Greater Lansing Area is defined as the area bounded by, and including Haslett, Okemos, East Lansing, Lansing, and Delta Township.

Lansing area in 1969[2], and their typical volume of construction constituted 21.6% of the building permits issued for the construction of single family dwellings in the area in 1968.[3] A copy of the questionnaire used in the interviews can be found in Appendix A. Managers of the firms were questioned about their volume of output, the percentage of their output that was built for speculative purposes, and their managerial and non-managerial experience in the industry. Through the use of indirect questions, their educational achievements were also ascertained. The managers were then asked whether they were using a list of eight innovations, and their reasons for using or not using them.

The list of innovations represents a sample of eight of the most important innovations that have been introduced in the last 25 years in the industry. In compiling this list, architectural, engineering, and construction trade journals were examined, and talks were held with professors of related disciplines on the Michigan State University campus, with heads of local trade unions, and with a local

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[2]The Lansing Homebuilders' Association has 73 members whose business address is the Greater Lansing Area. This figure was used as an estimate of the number of homebuilders in the area.

[3]The Bureau of the Census estimates that building permits for 2394 single unit family dwellings were issued in the Lansing S.M.S.A. in 1968. This figure was used to calculate the percentage cited above. However the Lansing S.M.S.A. includes all of Ingham, Clinton, and Eaton Counties. Hence, this percentage figure understates the contribution made by the sample firms to total construction in the Greater Lansing Area.

contractor. The list was purposely limited to changes whose primary purpose was cost reduction in order to avoid the question of whether a product change represented a change in form (i.e. a change in appearance) or a change in substance (i.e. a change in the way a task is accomplished). The eight innovations comprising the list were: (1) roof trusses, (2) thin coat plaster, (3) oversized bricks, (4) power nailers, (5) finger jointed wood, (6) prefinished mouldings, (7) prehung doors, and (8) critical path scheduling.

## The Sample Innovations

### Roof Trusses

Roof trusses were introduced into the Greater Lansing Area in 1950. The original method of roofing a house was to run a long heavy wooden rib the entire length of the roof (or section of the house that was being roofed) and nail rafters to the rib and sole plate. Trusses are rafters that have been tied together in pairs along a bottom chord. The chord runs the width of the building. The trusses are hoisted to the roof and nailed in place. A light connecting rod ties them together. The heavy rib running the length of the building disappears.

The manufacturer claims that trusses are stronger than the regular roofing construction, and, in addition, economize on labor, materials, and time. Seventy percent of the sample firms used trusses in their building process. The overwhelming reason given for their use was that they economized on time. Thirty percent of the sample firms did not use trusses. The principal reason given for their rejection was that they could not be used with the roofing designs that these firms were utilizing. The firms that rejected trusses were low volume producers of custom built houses for high income groups. In general, these firms felt that their key to success lay in building houses that have high sales appeal rather than houses that are highly competitive in prices. One manager said, "In this price bracket, people don't worry about what the house costs them." If this viewpoint is typical of the viewpoint of the producers of luxury items, it lends support to the view expressed in some of the literature on technological change that entrepreneurs are not likely to be receptive to cost reducing innovations unless they are producing for a mass market.

Thin Coat Plaster

This innovation was introduced into Greater Lansing in 1959. Thin coat plaster is a substitute for drywall and the regular plaster system. It is called thincoat because less plaster need be applied with this material than with regular plaster. A specially treated paper is required for backing.

The major advantages of thincoat plaster over regular plaster are weight savings, time savings, and material savings. The advantages over drywall are mainly in appearance. Walls made of thin coat lack the seams and nail marks that are present when drywall is used.

Not all entrepreneurs in the sample were asked whether they used the thin coat system, since it was not included in the sample until the interviews had already begun. The individuals contacted prior to choosing the sample innovations had not indicated that alternatives existed to the drywall regular plaster system. In the course of the interviews, this alternative was discovered and added to the sample.

Sixteen entrepreneurs were asked about the innovation. Fifty percent[4] (8 cases) replied that they were using it. Three-fourths of the adopters (6 cases) used the innovation because they felt it reduced their costs.

The main reason for rejecting the innovation was the judgment that it would not be profitable because it cost too much. Sizty-three percent of the rejections (4 cases) fell into this category. The reason that entrepreneurs felt that the cost was excessive was that they often had to repair cracks that developed in the finish. This was a problem when the innovation was introduced, but it was eliminated with subsequent improvement in the product. Evidently many entrepreneurs were not aware of subsequent product improvement.

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[4] Percentages are used in the exposition of the results for convenience and consistency, not to hide the fact that the sample number is small. The actual number of cases are given to the right of the percentage.

<u>Oversized Bricks</u>

This innovation was also introduced into Greater Lansing in 1959. The term "oversized bricks" describes bricks that are longer and wider than regular bricks. Regular bricks are approximately two and one-fourth inches wide and eight inches long. Oversized bricks are approximately three and one-fourth inches wide and nine inches long. The price of oversized bricks is greater than the price of normal bricks, but the percentage increase in volume is greater than the percentage increase in the price of the brick. Thus the cost of laying brick over a given area is lower with oversized bricks than it is with regular bricks. In addition, the use of oversized bricks reduces labor costs since fewer repetitive actions are necessary to brick over a given area.

Ten percent of the firms in the sample (2 firms) left the choice of brick up to the customer. These were builders who built all their homes on order. Because of the type of business these firms were doing, the entrepreneur did not have an opportunity to adopt or reject the innovation. Of those who did have the opportunity to adopt or reject it, 47.1 percent (8) adopted it. Fifty percent of the adopters (4) utilized the innovation because they felt that it enhanced the appearance of their product. Thirty seven and one-half percent (3) of the adopters used the bricks because they felt that the bricks reduced costs. The rest of the adopters used the bricks for miscellaneous reasons. Of those who rejected the innovation, two-thirds (6) did so because they felt that potential customers would not like the bricks' appearance. The rest gave scattered reasons for their rejection.

Power Nailers

This innovation was introduced into the Greater Lansing area in 1949. Power nailers are devices designed to speed up nailing by using compressed air to drive the nail. Nails are loaded into the nailer; the nailer is connected to an air compressor; and the nail is driven by pulling the trigger on the gun. The innovation was not considered by 45 percent (9) of the firms in the sample because they subcontracted their carpentry work. Of those that did their own nailing 54.5% (6) used the nailer. All of the adopters used it because it saved labor time. Of those that rejected the innovation, 40 percent (2) did so because their volume of construction was not large enough to justify its use.

Finger Jointed Wood

Finger jointed wood was introduced into Greater Lansing in 1957. Finger jointed wood are pieces of wood that have a number of tongues and grooves on their ends. By placing glue on the tongues, and inserting tongues into the grooves, long pieces of wood can be made up from shorter pieces. Since exceptionally long pieces of wood are more expensive than the same length made from combining shorter pieces of woods, finger jointing offers a cost savings to the entrepreneur. In addition, it reduces the wastage of materials. If the contractor doesn't use any of the longer lengths of wood, workers have no opportunity to cut the longer lengths into shorter lengths rather than take the trouble to look for the shorter lengths.

Fifty percent (10) of the sample firms used finger jointed wood. Sixty percent (6) of the adopters used it because it was less expensive than regular lumber. The other 40% (4) used it because the lumber yard sent it to them or because they felt unable to obtain anything else. These entrepreneurs seemed to feel that any savings that might be obtained from alternative forms of wood would not be enough to justify the investigative effort required to discover them.

The entrepreneurs who did not use finger jointed wood gave a variety of reasons for their non-use. Forty percent of the non-users (4) did not like its looks, 30 percent (3) did not know of the innovation's existence, and 40 percent (4) did not use it for a variety of reasons. As was the case with adopters, some rejectors felt that the savings that might result from changing materials was not worth the effort involved. One entrepreneur who didn't use the innovation stated, "I've never used it because the lumber yard never sold it to me. I use whatever they recommend."

Prefinished Mouldings

Prefinished mouldings are a substitute for painters' labor. The mouldings are finished at the factory with a stain, vinyl coating, or paint. The innovation was introduced into the Greater Lansing area in 1955.

Forty percent (8) of the sample firms used prefinished mouldings. With one exception, all of the adopters used the innovation because it reduced their costs.

Eighty-eight (7) percent of the adopters used the innovation only when they were installing a prefinished room. They stated that the savings were too small to justify its use unless the entire room was prefinished. The entrepreneurs do not give the impression that they do not attempt to save this small sum because the savings are uncertain, but rather that the savings are so small that they are not worth the additional effort that is required. These replies, in conjunction with some of the reasons given for using or not using fingerjointed wood, imply that probability alone does not insure adoption. Changing a building technique requires an additional expenditure of effort by the entrepreneur. The estimated increase in profits must be large enough to entice him to make this effort.

The most common reason for rejecting the innovation was because the colors or styling that the mouldings were available in did not match the colors and styling of the houses that the contractors were building. Fifty-eight percent of the rejections fell into this category. Many entrepreneurs chose not to change the design of their homes to take advantage of the opportunity offered by this innovation. Evidently the costs of redesigning added to the learning costs of building an unfamiliar structure offset the minor savings offered by the mouldings.

Prehung Doors

This innovation became available in Greater Lansing in 1955. Prehung doors are a substitute for carpenters' labor. When prehung doors are used, only a rough opening in the wall is necessary. The door comes attached to the door frame, and both are inserted into the rough opening. A prehung door can be put into place in a few hours as opposed to the full day it can take to hang a regular door.

Forty-five percent (9) of the sample firms used prehung doors. Seventy-eight percent (7) of the adopters used them because they reduced costs. The rest used them because it was part of their subcontractor's package.

Fifty-five percent (11) of the sample firms did not use the innovation. Thirty-six percent (4) of the rejectors did not use them because they felt the innovation cost too much. The rest of the rejectors gave a variety of reasons for their rejection.

Critical Path Scheduling

This innovation was introduced into the Lansing area in 1961. Critical Path Scheduling is an organizational change designed to achieve better coordination of activities and reduce the time men are idle because of conflicts in scheduling. Critical Path Scheduling consists of finding the chain of events that control the production process (i.e. those stages of the process that must be completed before anything else can be done) and making all other events subordinate to them. Definite periods of time are alloted for the completion of the critical steps. The subordinate steps have adjustable completion plans depending upon what happens in the other phases of the operation.

Twenty-five (5) of the sample firms used the critical path method of management control. Eighty percent (4) of the adopters used the method because it made control and coordination easier, reducing their construction time. The remainder used it because the head foreman had used it.

Eighty percent (15) of the sample firms did not use the innovation. Forty-seven percent of those that did not use it had not heard of the innovation. Thirty-three percent of the non-users (5) felt that their volume of construction was too small to make its use worthwhile. The

rest did not use it because they were not convinced that it would work at any volume.

## Implications of the Survey Replies

The results of the survey are summarized by Table 3. Two implications of the survey repleis have already been mentioned: (1) Entrepreneurs are more receptive to cost reducing innovations if they are producing for a mass market, and (2) Profitability alone does not ensure adoption. The profits must be large enough to justify the additional physical and mental effort required to make the change.

Examination of Table 3 suggests two further generalizations: (1) Entrepreneurs in residential housing are not fully aware of their opportunities to reduce costs and (2) Product differentiation is an important barrier to the diffusion of new cost reducing techniques.

Inadequate knowlege about cost reducing innovations has two dimensions: (a) the entrepreneur may not know the innovation exists, or (b) the entrepreneur may have knowledge of the innovation but may mistakenly conclude that the innovation will not reduce costs. Table 3 indicates that both problems are present in residential housing. Eleven cases of non-utilization occured because the entrepreneur was not aware of the innovation. Another 18 cases resulted because the entrepreneur did not believe that the innovation

TABLE III.--Reasons for Adoption and Rejection of Eight Innovations, Lansing, Michigan, 1969.

| Innovation | Reasons for Adoption: Saves Time | Cost of Substitute | Appear. | Misc. | Tot. |
|---|---|---|---|---|---|
| [a] Trusses | 10 | 1 | | 3 | 14 |
| [b] Thin Coat | 2 | 4 | 1 | 1 | 8 |
| [c] Bricks | | 3 | 4 | 1 | 8 |
| [d] Nailer | 4 | 2 | | | 6 |
| Finger Jointed Wood | | 6 | | 4 | 10 |
| Mouldings | | 7 | 1 | | 8 |
| Doors | 1 | 6 | | 2 | 9 |
| Critical Path | 2 | 2 | | 1 | 5 |
| Total | 19 | 31 | 6 | 12 | 68 |

| Innovation | Reasons for Rejection: Volume of Construction Too Low | Design of House | Appearance | Cost of Substitute | Lack of Knowledge | Misc. | Tot. |
|---|---|---|---|---|---|---|---|
| [a] Trusses | | 4 | | 1 | | | 5 |
| [b] Thin Coat | | | 2 | 5 | | 1 | 8 |
| [c] Bricks | | | 6 | 1 | 1 | 1 | 9 |
| [d] Nailer | 2 | | | 3 | | | 5 |
| Finger Jointed Wood | | | 4 | | 2 | 4 | 10 |
| Mouldings | | 7 | | 1 | | 4 | 12 |
| Doors | | 1 | 1 | 4 | 1 | 4 | 11 |
| Critical Path | 5 | | | 3 | 7 | | 15 |
| Total | 7 | 12 | 13 | 18 | 11 | 15 | 75 |

[a]The number of responses to trusses do not add up to 20 because one entrepreneur who was using trusses was inadverdently not asked why he was using them.

[b]The number of responses to thin coat do not equal 20 because it was not included in the sample until after the interviews had begun.

[c]The number of responses to oversized bricks do not equal 20 because two entrepreneurs did not make a decision to use or note to use them, leaving the choice up to the customer and because one entrepreneur was inadverdently not questioned about the innovation.

[d]The number of responses to nailers do not equal 20 because 9 firms did not do their own nailing but subcontracted it out, thus leaving the choice of technique up to the subcontractor.

would reduce his costs. In total, the number of cases of non-utilization could have been reduced by about 39 percent if entrepreneurs were better informed about the sample innovations.

In some cases, use of the sample innovations would have necessitated a change in appearance or in the housing design that the entrepreneur was using. It is important to realize that those innovations in the sample that altered the aesthetic qualities of the product did not do so in such a way that it became repugnant to all consumers. The innovations that some firms rejected because of the appearance they gave the product were adopted by other firms precisely to achieve that appearance. A good example of this is oversized bricks. This innovation was adopted by four firms because they felt that the appearance of the brick increased the sales appeal of the house. Six firms rejected the innovation because they felt that the appearance of the brick reduced the sales appeal of the house. These responses imply, other things being equal, that cost reducing innovations which alter the aesthetic qualities of the product are likely to spread less rapidly than those which do not. Unless the new aesthetic properties are universally desired, some entrepreneurs will find it profitable to use the old techniques, even though the old techniques may result in higher costs of production. If entrepreneurs are more receptive to cost reducing techniques that leave the appearance of the product unchanged than they are to cost reducing techniques which change the appearance of the product; then, other things being equal, non-appearance changing innovations will result in a larger shift in resources than appearance changing innovations.

## Regression Analysis

If the diffusion model described in Chapter IV is correct, we would expect to find that different entrepreneurs have adopted different percentages of the sample innovations. We would further expect to find that the different degree of receptiveness were the result of different estimates of profitability with profitability being affected by the uncertainty of the innovations, but not by the mere length of his education or his experience in the industry. The size of his firm is also an uncertain determinant. In addition, we would expect to find that competition is not an important force influencing the diffusion of innovations in this industry.

Multiple linear regression was chosen to test the usefulness of this model. Linear regression was chosen for statistical reasons rather than theoretical reasons. Economic theory provides no reason to suspect a nonlinear relationship among the variables, and scatter diagrams of the residuals and the various variables in the linear equation do not suggest a nonlinear function. These scatter diagrams can be found in Appendix B. In the absence of reasons to seek a more complicated function, statisticians choose the simpler function.[5] Therefore, a linear function was chosen to test the model.

Seven variables entered the first regression equation. These variables were: (1) the percentage of sample innovations adopted by the ith firm (the dependent variable), (2) the percentage of output build on a speculative basis, (3) the volume of construction of the firm, (4) the education of the manager, (5) the managerial experience of the entrepreneur in the homebuilding industry, (6) the non-managerial experience of the entrepreneur in the industry, and (7) the percentage of the sample innovations he thought were profitable. The reasons for including these variables are discussed briefly below.

## Percentage of Houses Built on a Speculative Basis

This variable was included to measure the effects of subjective risks on the entrepreneurs' receptiveness to innovations. If the model outlined in Chapter IV is correct, the subjective risk of an innovation should not directly ffect the entrepreneurs' receptiveness to innovations. ıfortunately it is not possible to test the effects of risk

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[5] Frederick Mills, Statistical Methods (New York: lt, Rhinehart and Winston, 1955), p. 601.

directly because no good objective measurements of the risks of the various sample innovations was available. However it was possible to test for the effects of risk indirectly. If entrepreneurs' decisions are directly influenced by subjective risks, it would seem that their willingness to adopt innovations would vary with their willingness to take risks.

One possible measure of the willingness to take risks is the percentage of the firm's output that is built for speculative purposes. Two schools of thought exist about this measurement. One school of thought argues that building houses on speculation is riskier than building houses on order. If a house is built on order, the probability that it will be sold within a given time period is almost 100 percent. If a house is built on speculation, the probability that it will be sold within a given time period is clearly less than 100 percent.

The second school of thought argues that building houses on order is riskier than building houses on speculation. If costs are rising rapidly, speculative building is less riskier because cost increases can be passed onto consumers in the form of price increases. Under these circumstances, speculative building is less risky than building on order.

Whether speculative building is more or less risky than building on order does not affect the usefulness of speculative building as an indicator of the willingness to bear risks. The argument over whether speculative building is more or less risky than building on order is an argument over the expected sign of the regression coefficient, not an argument over whether the variable is a useful indicator of the willingness to bear risks. If the willingness to take risks varies directly with the percentage of houses built for speculative purposes, then the regression coefficient should have a positive sign. If it varies inversely with the degree of speculation, then the regression coefficient should have a negative sign.

In order to obtain some idea of the expected sign of the regression coefficient, interviews were conducted with the home mortgage managers of the seven home loan institutions in the Greater Lansing area. Three of the managers felt that speculative building was always riskier than building on order because of the danger that the house could not be sold. These managers felt that the danger of rising costs was always less than the danger of being unable to sell the houses. The other four managers felt that the relative risks depended upon conditions of demand and costs. If demand is strong and costs are rising rapidly, then building houses on order is riskier than building on speculation.

Two of the four mortgage managers felt that building on order had been riskier in 1968 and early 1969 because of the rapidly rising costs during this time period. The other two managers felt that building on order was riskier in 1968, but speculative building was riskier in 1969 because tight money reduced demand and cost increases began to subside. On balance, therefore, five out of the seven mortgage managers felt that speculative building was riskier than building on order in 1969.

### Volume of Construction, Education, Managerial Experience, Non-Managerial Experience

These variables were included in the regression equation to test the hypothesis that they did not affect the receptiveness of entrepreneurs in residential housing.

### The Percentage of Sample Innovations Thought Profitable

This variable was included in the equation to test the hypothesis that entrepreneurs' receptiveness to innovations is affected in a consistent manner by estimated profitability.

## Implications of the First Regression Equation

The results of the regression equation are summarized by Table 4. The equation is significant at the 1 percent level of significance and explains over 79 percent of the

TABLE IV.--Results of the 1st Regression Equation.

| Variable | Regression Coefficient | Standard Error | T Value | Significance |
|---|---|---|---|---|
| Speculation | .040 | .098 | .405 | .692 |
| Volume | -.001 | .001 | -1.000 | .396 |
| Education | .007 | .017 | .410 | .688 |
| Managerial Experience | -.001 | .006 | -.172 | .866 |
| Non-Managerial Experience | -.004 | .008 | -.500 | .538 |
| Estimated Profits | 1.315 | .254 | 5.18 | .0005 |

variation in the dependent variable. One variable was significant at the 5 percent level of confidence: the percentage of innovations thought profitable. None of the other variables were found significant at the 5 percent level.

The significance of the variable measuring the effects of estimated profits implies that entrepreneurs respond in a consistent manner to this variable. The regression results showed a partial correlation coefficient of .8208 for the profitability variable. The value of the coefficient, which is less than 1.00 implies that entrepreneurs respond to other influences besides profits. This lends support to the view that entrepreneurs in this industry use their firms to achieve goals other than profit maximization. The survey responses do not indicate any consistent pattern of non-profitable responses. The lack of a consistent pattern of responses to goals other than profit maximization, coupled with the high partial correlation coefficient, suggests that goals other than profit maximization have only a minor influence on entrepreneurs' receptiveness to innovations in this industry.

The insignificance of the variable measuring the effect of the willingness to bear risks indicates that the subjective risks of an innovation does not affect directly the entrepreneur's decision to adopt the innovation. This result is consistent with the hypothesis that subjective risks influence the adoption decision by influencing estimated profits rather than through a trade off between estimated profits and risks.

The insignificance of the variables measuring the influence of firm size, and the entrepreneur's managerial and non-managerial experience imply that these variables do not have a direct influence on the entrepreneur's receptiveness to innovations. The insignificance of the variable measuring the entrepreneur's level of educational achievement implies that mere number of years of schooling cannot directly explain entrepreneurial receptiveness. These results do not prove however that these variables do not have an indirect influence by influencing estimated profits.

## Further Regression Analysis

In order to test the hypothesis that firm size, education, and managerial and non-managerial experience do not influence estimated profits, a second regression equation was estimated. The variables entering the equation were: (1) the percentage of sample innovations the entrepreneur thought were profitable (the dependent variable), (2) the percentage of output build for speculative purposes, (3) the education of the entrepreneur, (4) the managerial experience of the entrepreneur, and (5) the non-managerial experience of the entrepreneur. The reason for including variables three through five has already been explained. The reason for including variable two has not been explained.

The percentage of output built for speculative purposes is a measure of the willingness to take risks. If subjective risks influence entrepreneurial receptiveness to innovations by influencing estimated profits, then we would expect the percentage of innovations thought profitable to vary as the willingness to take risks varies. The entrepreneur is less likely to weight the negative probability weights "highly" if he is willing to take risks. Including the speculation variable in the regression equation permits testing the hypothesis that uncertainty affects adoption by affecting estimated profits.

None of the variables in the second regression equation were significant at the 5 percent level and the equation itself was insignificant at this level. Nevertheless, the results have some interesting implications.

To begin with, the significance level of the speculation coefficient has increased. In the first regression equation, there was a 69 percent probability that the measured relationship between specualtion and the dependent variable occurred by chance. In the second regression equation, there was a 57 percent probability that the relationship occurred by chance. It seems, therefore, that the willingness to bear risks explains estimated profits better than it explains entrepreneurial receptivenss. Detracting from this argument is the fact that neither relationship is statistically significant, but this could result because the data was collected at an inopportune time. The year 1969 appears to have been a transition point during which speculative building changed from being less risky to more risky than building on order. Entrepreneurs may not have fully responded to this change in the economic conditions at the time when the interviews were conducted. If this were the case, the standard errors would increase relative to the regression coefficients and an insignificant relationship would be measured when, in fact, the relationship was significant. The important point is that there is a better relationship between speculation and estimated profits than there is between speculation and entrepreneurial receptiveness. This result implies that subjective risks influence entrepreneurial receptiveness through estimated profits.

Additional information is available from the study which also supports this conclusion. Eighteen of the entrepreneurs in the sample were asked whether they had any doubts that the innovation would "pan out" when they decided to adopt it. These entrepreneurs were responsible for 64 of the 68 adoptions that took place. In only seven cases did the entrepreneurs feel doubts that the innovation would bring about the desired results. In three of the seven cases the entrepreneur originally estimated that the innovation would probably be unprofitable, but changed his mind with the receipt of new information and adopted the innovation as soon as he thought that the probability of achieving the desired results exceeded 50 percent. In four cases, changing economic conditions in the input markets increased the prospective return enough to justify the subjective risks involved. In only 4 of 64 cases was there a tradeoff between estimated profits and subjective risks.

The insignificance of the variable measuring the effects of size implies that large firms are not more receptive to innovations than small firms. A possible explanation of this result is that large scale entrepreneurs are so busy coordinating their various building projects that they have little time to devote to studying the merits and demerits of various innovations. This position is partially supported by examining the type of firms that adopted critical path scheduling. The primary benefit of this innovation is that it eases coordination problems for firms. Four of the five firms adopting this innovation were large firms. In fact, the four large firms adopting this innovation were the four largest firms in the sample, building respectively 38, 40, 45, and 200 houses per year.

The chi square test for differences was used to test the hypothesis that these firms reacted differently from other firms in the sample. The test was significant at the 5 percent level, implying that there was a difference in reactions. This difference in reactions is consistent with the hypothesis that coordination difficulties prevent large firms from being more receptive to innovations than small firms.

The insignificance of the variables measuring the effects of non-managerial experience imply that this variable does not influence entrepreneurial receptiveness towards innovations by influencing estimated profits. The insignificance of the variable measuring the effect of education implies that this variable does not effect receptiveness by affecting estimated profits. This conclusion must be tentative, however. The regression only tested for the affects of a global number: years of education completed. It could be that the school attended, the subjects studied, or performance at school is related to receptiveness. Or, perhaps, being a small Lansing builder is a mark of failure for the college trained engineer so that only the worst ones enter the business, while it is a sign of high success for the junior high dropout. The number of observations does not permit sufficient disaggregation of the data to draw meaningful conclusions about these issues. The data only suggests that the mere number of years of schooling of itself is a poor predictor of entrepreneurial receptiveness to innovations.

The insignificance of the variable measuring the influence of managerial experience implies that this variable does not influence entrepreneurs' receptiveness by influencing estimated profits. Even more important, however, the insignificance of this variable permits us to make some statements about the influence of competition upon entrepreneurs' receptiveness to innovations in the homebuilding industry.

Competition within the homebuilding industry can come from (1) new entrants into the industry, (2) currently existing firms within the industry, or (3) some combination of both.

If competition plays an important role in the diffusion of innovations, and if new entrants into the industry are the most important source of competition, we would expect to find (1) New firms are more receptive to innovations than old firms; and (2) New firms see more innovations as being profitable than old firms. The second condition is a necessary condition if the argument is to be valid. If new firms are more receptive to innovations than old firms, but are not basing their adoption decisions upon profit considerations, they may not survive and provide competition for less receptive firms.

Table 5 shows that the length of managerial experience generally corresponds with the age of the firm. Thus managerial experience can be used as a proxy for the age of the firm. If new firms put competitive pressures on older firms, we would expect managerial experience to be inversely related to receptiveness and to the percentage of sample innovations believed to be profitable. But these hypothesis are not supported by the regression results. The managerial experience variable is insignificant in both equations. Therefore, competition from new firms entering the industry is not an important influence on entrepreneurs' receptiveness to innovations.

Does competition from existing firms influence the diffusion of innovations? If competition from currently existing firms is an important influence, then we would expect the more receptive firms to eliminate the less receptive newcomers and the less receptive currently existing firms. These considerations lead us to expect that (1) Older firms will be more receptive than younger firms, and (2) Older firms will be larger than younger firms. As before, receptiveness must be based on profitability, so a third condition is that older firms believe a larger percentage of the sample innovations to be profitable.

TABLE V.--Age of the Firm and Managerial Experience of the Entrepreneur.

| Age of the Firm | Managerial Experience |
|---|---|
| 1 | 19 |
| 2 | 2 |
| 3 | 7 |
| 4 | 4 |
| 4 | 4 |
| 6 | 6 |
| 6 | 6 |
| 9 | 9 |
| 9 | 9 |
| 15 | 15 |
| 15 | 15 |
| 15 | 15 |
| 17 | 23 |
| 17 | 17 |
| 20 | 20 |
| 20 | 20 |
| 22 | 22 |
| 22 | 22 |
| 24 | 24 |
| 41 | 21 |

The regression results do not support these hypotheses. The variable measuring the effect of managerial experience is insignificant in both regression equations. The simple correlation coefficient between managerial experience and firm size is only .195 and it is insignificant at the 5 percent level of confidence. Thus competition from currently existing firms is not an important influence of entrepreneurial receptiveness.

## Generality of the Results of the Study

The sample firms do not represent a true random sample of all residential building firms in the Greater Lansing Area. An attempt was made to obtain a truly random sample by drawing numbers representing certain firms from a box. However some of the firms associated with these numbers could not be reached at their phonebook address nor at the address provided by the homebuilders' association. Some entrepreneurs that could be located were never at their home nor in their office, and two that were located in their office refused to cooperate. Consequently, the sample firms represent a random sample of those firms which could be located, that could be contacted, and whom were willing to talk, and not a random sample of firms in general. Nevertheless, this is probably not a serious drawback since the sample firms constituted a large percentage of the population and built a large percentage of the new residential housing in the area. For these reasons, it is probably safe to generalize from the sample to the population of contractors in the area.

Caution should be used in generalizing from the Greater Lansing Area to the country as a whole. Caution should be used for two reasons: (1) Homebuilders in the Greater Lansing Area use non-union labor and therefore are not constrained by union work rules. (2) The Greater Lansing Area has a household income that is approximately $2000 per year above the household income of the country as a whole. Consequently, the price elasticity of demand for the average home may be less in the Greater Lansing Area than is most other parts of the country.

Some of the results of this study can be safely generalized to other parts of the country. It would seem reasonable to expect that entrepreneurs in all parts of the country will respond to the estimated profits of an innovation. Since there is no reason to expect Lansing entrepreneurs to respond to uncertainty in a different manner from entrepreneurs in other parts of the country, this result can probably be generalized also. Since increasing firm size probably results in coordination difficulties in all parts of the country, the effects of firm size can most likely be generalized. There appears to be no reason to suspect that the lack of influence of education and non-managerial experience was due to particular characteristics peculiar to Lansing entrepreneurs, so these results can probably be generalized also.

# CHAPTER VI

## SUMMARY AND CONCLUSIONS

Society has decided that homeownership is, in part, a merit want. In the past, attempts to stimulate homeownership have taken the form of reducing the uncertainty of mortgage lending so that down payments, monthly payments, and interest payments would be within the "common man's" budget. This policy has been successful in increasing the percentage of owner occupied dwellings from 40% to 60% of all occupied dwellings.

It appears, however, that homeownership cannot be further expanded unless costs decline or some form of subsidy is offered to potential purchasers. The present national administration has chosen to stress cost reduction through technological change. Contracts have been approved for the development of new products and processes which will aid in reducing costs.

The discovery of new cost reducing products and processes will not, of itself, reduce housing costs. Before housing costs can be reduced, the innovation must be adopted by building firms.

Little knowledge exists about the factors that make entrepreneurs receptive towards innovations. A variety of different theories exist. In general, there appear to be four theories. These theories are: (1) theories stressing the profitability and risk of an innovation, (2) theories stressing the qualities of the entrepreneur, (3) theories stressing the size of the firm, and (4) theories stressing the importance of competition.

A model of entrepreneurial receptiveness to cost reducing innovations was tested by using multiple regression analysis. The regression results suggested that entrepreneurs respond to estimated profits in a consistent manner, and that estimated profit is the most important variable affecting entrepreneurial receptiveness. The regression results, coupled with the personal interviews, suggest that the supply of entrepreneurial effort is not infinitely elastic with respect to profits. Replies to the personal interviews also suggest that the entrepreneur's estimate of profitability is affected by the type of market for which he produces, whether the innovation changes the appearance of the product, and by the uncertainty of the innovation. Uncertainty affects adoption by influencing estimated profits, not by a tradeoff between estimated profits and subjective risks.

The size of the firm, the entrepreneur's receptiveness, managerial experience, and non-managerial experience do not affect his receptiveness to innovations.

Entrepreneurs adopt cost reducing innovations primarily to increase profits. Competition from new entrants into the industry and from currently existing firms does not have a major influence on the entrepreneur's receptiveness to innovations.

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APPENDIX A

QUESTIONNAIRE

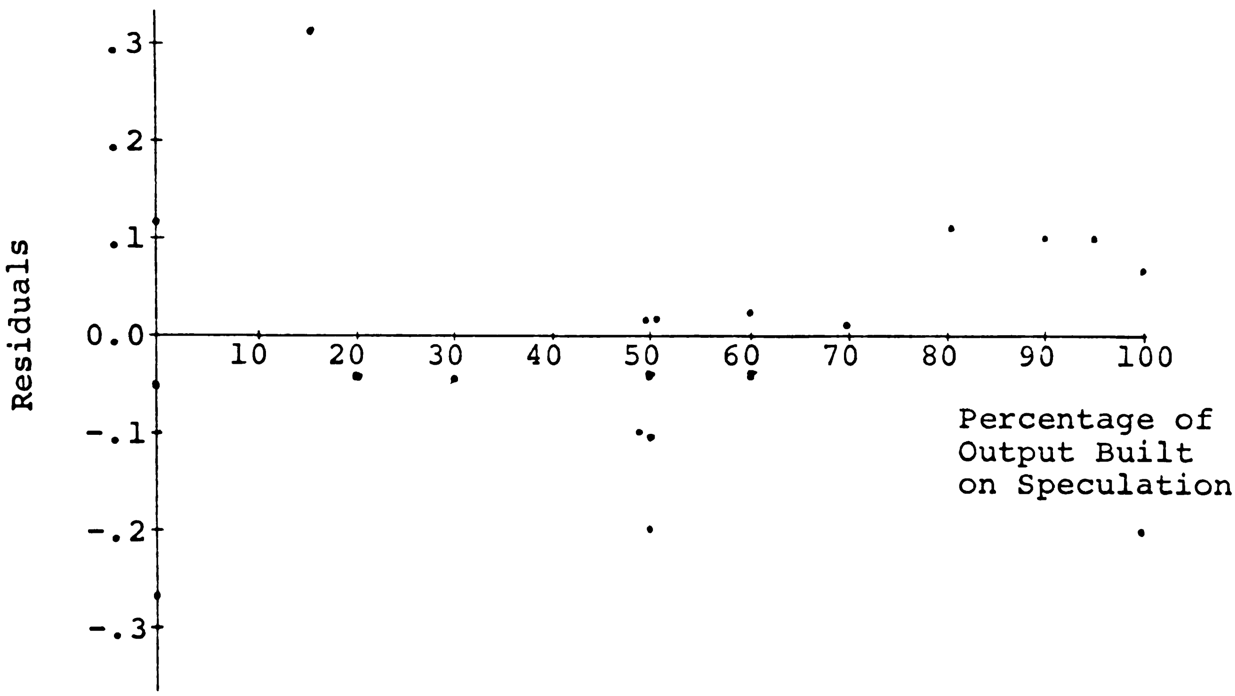
1. When did your firm first begin doing business?
2. Is your firm unionized?
3. How many single-unit houses do you build in a good year?
4. How many years experience do you have as a manager in residential building?
5. How many years experience have you had as a worker in housing construction?
6. How many journals do you subscribe to?
7. Was your formal education relevant to homebuilding?
8. When did you graduate from high school (college)?
9. What percentage of your houses are built on a speculative basis?
10. Do you use innovation X?
11. When did you first begin using X?
12. How long did you wait to use X after first hearing about it?
13. What was your first source of information about X?
14. What advantages does X have?

    or
15. What disadvantages of X make it inadvisable to use it?
16. Are there some jobs you wouldn't use X on?
17. Are labor costs or interest costs your most important savings when you save time?

18. If wages (interest costs) were 50% lower would you still use X?
19. Would your labor force be larger if you did not use X?
20. Did you have to retrain your labor force before you used X?
21. Would X be more profitable if you built twice as many houses as you now build?
22. Did any of the changes I asked you about require you to make any substantial changes in your pattern of operations?
23. Did you have any doubts that X would "pan out" when you decided to use it?

APPENDIX B

APPENDIX B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70
80
90
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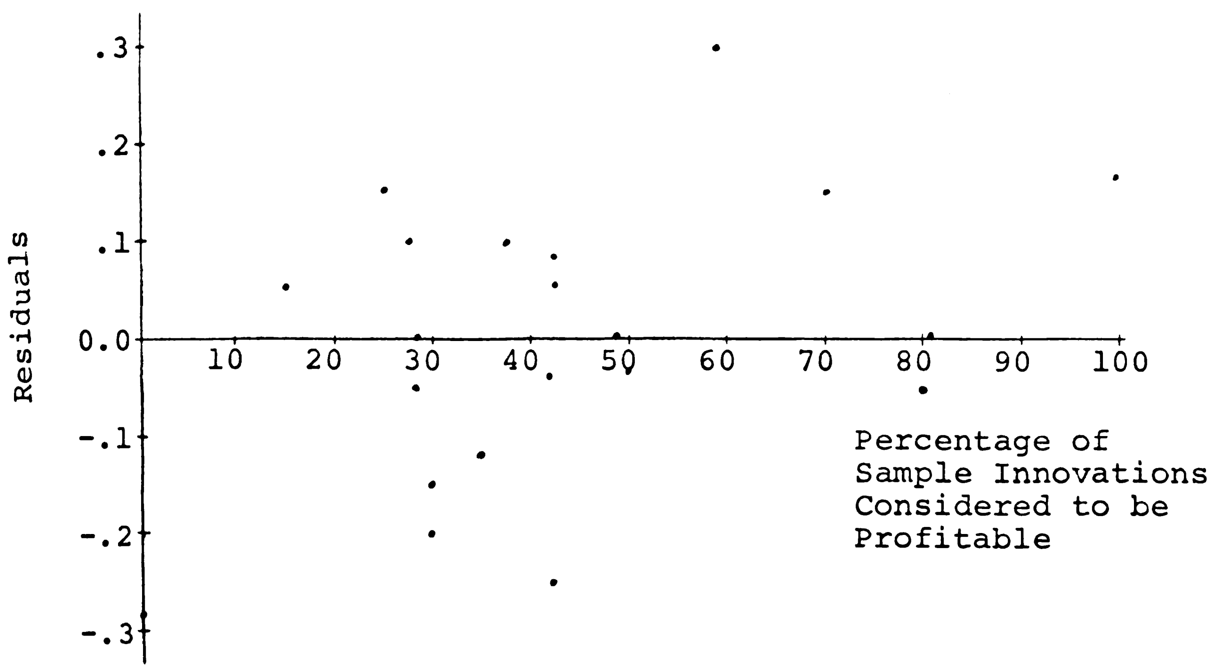
Percentage of
Output Built
on Speculation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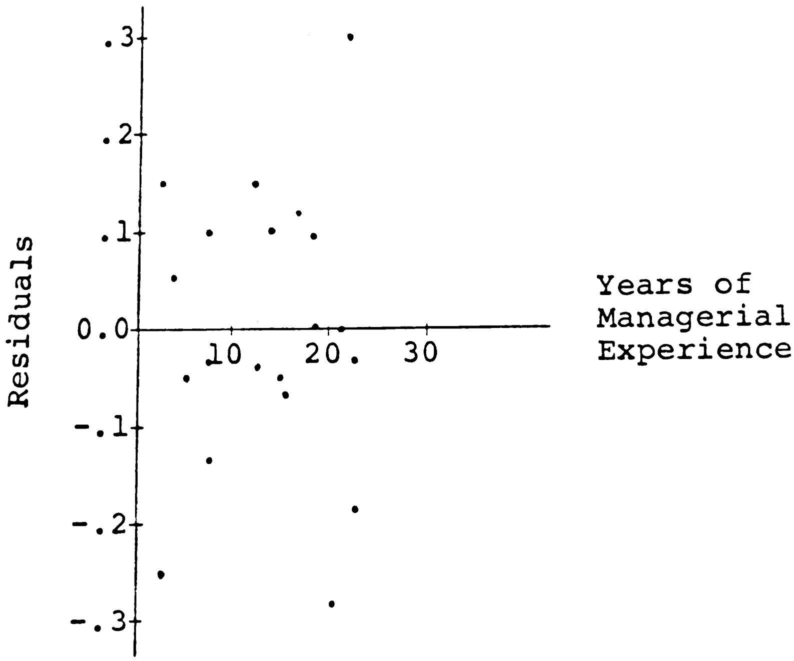
Percentage of
Sample Innovations
Considered to be
Profitable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Years of
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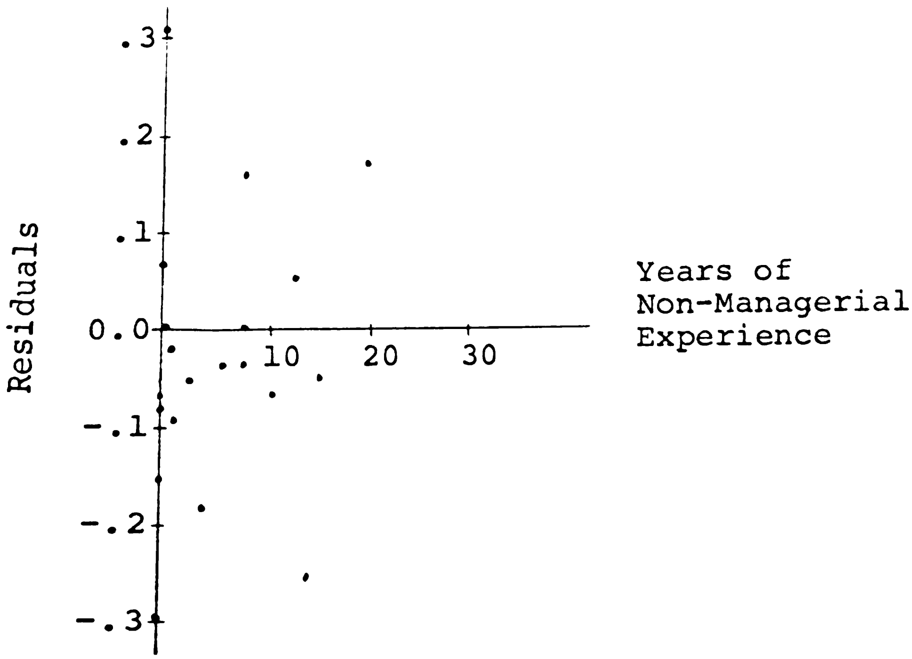
Experience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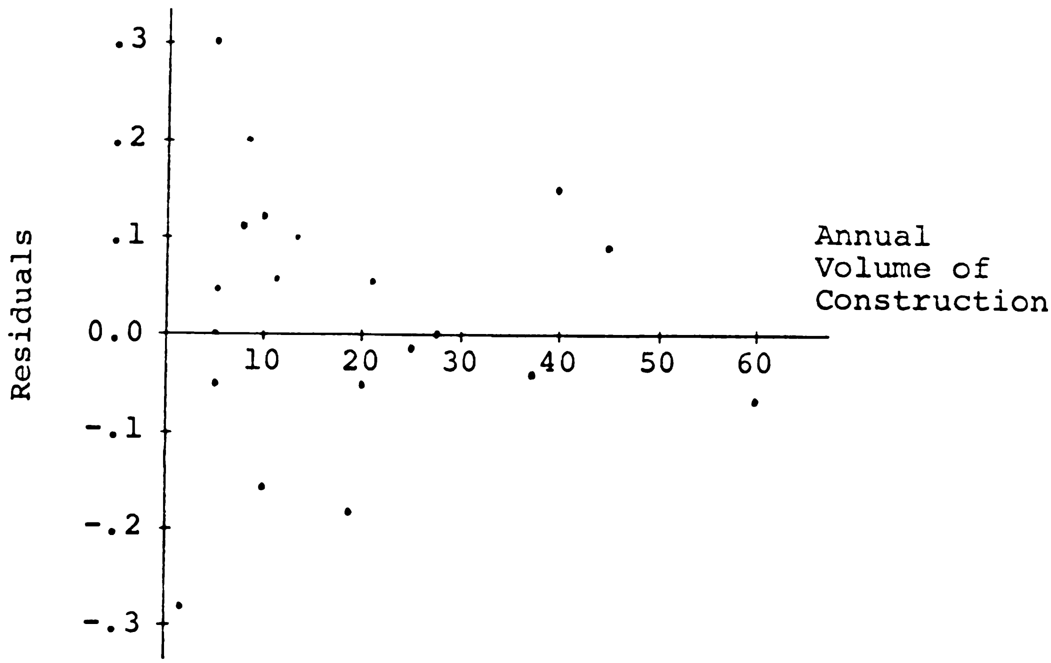
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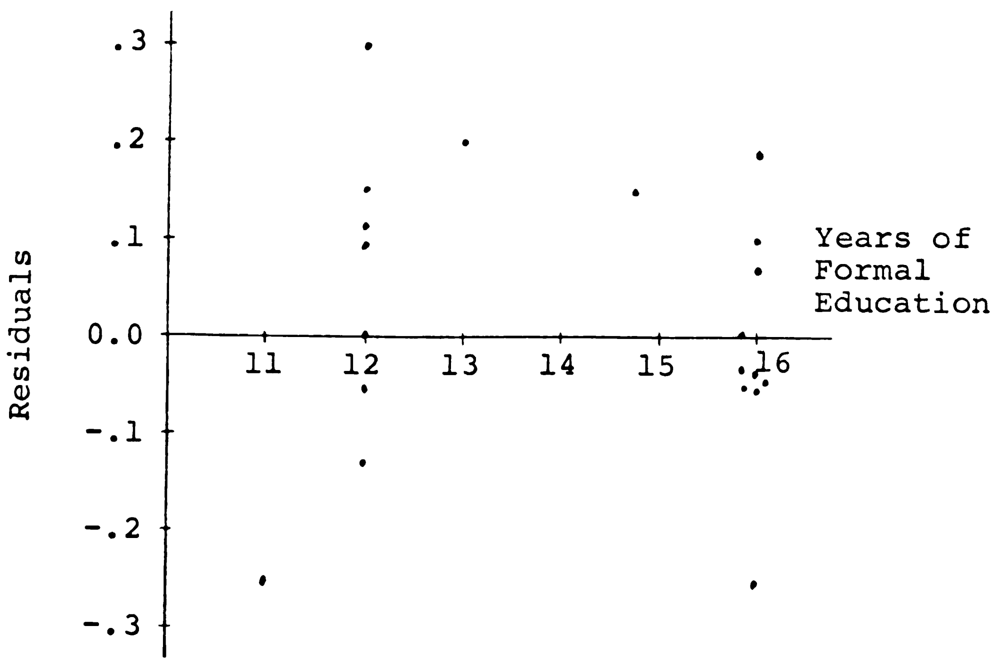
50
60
Annual
Volume of
Construction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Residuals
11
12
13
14
15
16
Years of
Formal
Education