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Regulatory barriers to the diffusion of innovation: some evidence from building codes

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Previous studies, including the reports of the Douglas and Kaiser Commission, have suggested that outmoded local regulation of residential construction has impeded technical progress in the industry. In this paper, we try to identify the determinants of differences across communities in these regulations. The permissibility of four particular innovations in a cross section of jurisdictions in 1970 and the timing of these innovations are explained by attributes of local firms, labor unions, building officials, and housing demand. Our results suggest that the educational level of the chief building official, the extent of unionization, and the relative size of housebuilding firms in an area affect the diffusion of innovations in residential construction.

1. Introduction

It is widely alleged that housebuilding in the United States is a “backward industry” as compared with other sectors of the economy or with residential construction abroad. Precise measures of the “backwardness” of the residential construction industry are unavailable: little data are available which distinguish between housebuilding and other contract construction activities, such as road building (see Sims, 1976). Nevertheless, estimates made in the 1950s and 1960s suggest that by either measure of sectoral performance—reduced input requirements for the same output (i.e., trends in real costs) or increased output for the same inputs (i.e., trends in input

We are indebted to Charles Field and Francis Ventré for making available to us the raw data from a survey they conducted in 1970 and for several useful conversations during the past year. Ventré’s unpublished dissertation (1973) was extremely helpful in explaining the technical characteristics of the building code provisions explored in this paper. We also acknowledge the helpful comments of colleagues at the Micro Economic Workshop at Yale University and the research assistance of Gail Trask and Robbe Burnstine. We are especially grateful to Randall Olson, Jon K. Peck, and the Editorial Board for thoughtful comments on a previous draft of this paper. This research has been supported by a grant from the Sloan Foundation.

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productivity)—the construction industry has lagged behind other branches of the economy throughout this century.

Grebler, Blank, and Winnick (1956), for example, concluded that productivity remained constant from about the turn of the century to the mid-fifties, while Denison (1962) found an absolute decline in input productivity from the Depression onwards. Similarly, Meyer-son, Terrett, and Wheaton (1962) found that the average consumer was able to purchase more housing services in 1929 than in 1955 despite the real increase in general purchasing power during the period. Finally, crude evidence presented by Nelson, Peck, and Kalacheck (1967, pp. 192–195) suggests that the scale of research and development in the contract construction industry is very small; the ratio of R & D expenditures to value added is three and a half times as large for the economy as a whole as for the construction industry.

The lagging productivity of the residential construction industry and its low level of R & D expenditures, coupled with the importance of housing in the consumer budget, have been cited as a rationale for public intervention to improve efficiency—by the Brookings Institution study (Nelson et al., 1967) and by two federal commissions, the National Commission on Urban Problems (Douglas Commission) in 1968 and the President’s Committee on Urban Housing (Kaiser Com-mission) in 1968. The much publicized experimental program, “Operation Breakthrough,” sponsored by HUD in the late 1960s was inten-tended to facilitate rapid efficiency gains.

Although the precise “cause” of backwardness in the industry is difficult to identify, there are four peculiar characteristics of residential construction activity which may contribute to its relatively low rate of technical progress.

First, effective demand for housing is subject to wide fluctuations, produced in part by the vagaries of the credit market. These demand fluctuations may inhibit the adoption of cost-reducing innovations, especially those which would make the production process more capital-intensive and thus more vulnerable to instability in demand. Further, these cyclical fluctuations may bias the research and development process itself, to discourage the exploration of labor-saving innovations which have been the source of much of the observed productivity increases in other sectors of the economy.

Second, the small scale of firms in the construction industry may also reduce the incentives for private research and development. Small scale may be particularly problematic if many of the potential innovations in the industry are in organization, systems design, and in the integration of housing components. Here the minimum efficient scale for R & D activity is presumably rather large, and, more importantly, the returns to R & D are not easily capturable by a single firm.

Third, the merits of a particular idea or potential innovation in housing may be especially hard to evaluate because the performance of any particular innovation in materials, design, or construction method depends upon a complex interaction with other parts of the structure. Since the industry is highly fragmented, it may be espe-cially hard for suppliers to judge the potential of an innovation. This, too, will inhibit the search for innovation.

Finally, the fragmentation of the market is reflected, not merely in a large number of small firms operating in local housing markets, but also in a cumbersome regulatory process which relies upon local
political divisions to set standards and to enforce regulations in the materials, design, performance, and safety characteristics of residential structures. The bewildering variation in local regulations may very well mean that potentially profitable innovations are also illegal in many geographical areas. This reduces both the scale at which an innovation can be marketed and its profitability, and may further discourage R & D investment. In particular, the variation in regulation may greatly inhibit research and development by suppliers of building materials and capital equipment (even if the supplying firms are themselves large), since the potential market of a successful innovation is often restricted.

This paper is concerned with the latter two characteristics—in particular, with the operation of local building codes. If local variation in codes is indeed a serious obstacle to technical progress in residential construction, then it is of some interest to consider what factors are responsible for such diversity, as well as what other interests may be served by such local regulation. After a cursory review of the evidence on the relationship between efficiency and regulation in home building, we present empirical evidence suggesting some reasons for the observed variation in local building codes. In particular, we examine four specific cost-saving innovations in residential construction, and we investigate the factors associated with their permissibility in local jurisdictions.

The regulation of residential construction is typically delegated by states to local jurisdictions which, in turn, enforce standards and specifications governing the erection and construction of buildings. Clearly the enforcement of minimum standards restricts consumer sovereignty in the consumption of housing services. As with other forms of regulation (e.g., drugs and pharmaceuticals), these codes are rationalized in a variety of ways. A major argument for these codes is that they help protect consumers from the consequences of their own ignorance. It seems reasonable to presume that few housing consumers (or drug consumers) are technically trained to evaluate fully the potential hazards of consuming such complex commodities. The existence of a market for the information provided by ‘‘building experts’’ (who for a fee will inspect a prospective property and provide a confidential assessment of its structural integrity) does not completely eliminate this rationale for regulation. This information service might solve the problem for the individual consumer, but the results will be inefficient from society’s viewpoint. Homes are typically viewed by several prospective purchasers. If each of these prospects arranges for an inspection of the property, resources have been wasted. On the other hand, if the seller arranges for a single inspection, duplication of effort is avoided, but the possibility of collusion between seller and inspector will reduce the value of the information.

Alternatively, a well-functioning insurance market could eliminate this rationale for public regulation by making optional insurance policies available to the seller or purchaser of used housing—in much the same way as warranties are often written on the components of new homes. The major obstacle to the development of this market is the ignorance on the part of consumers (and potential insurers) about the
relative incidence of infrequent, but nevertheless real, injury and damage from structural deficiencies. An insurance market for these components of used housing has, in fact, existed for some time, but only a tiny fraction of sales is actually covered.\(^1\) This may indicate that the costs of gathering information necessary to write the terms of the warranty or insurance contract are large, or that the risks cannot be estimated with much confidence at this time.\(^2\)

A second rationale for regulation may be found in its external benefits. A home which is structurally unsound or is a fire hazard imposes some costs on surrounding properties. Communities may use building codes in the same way they have used zoning powers: to internalize neighborhood externalities.\(^3\)

Neither of these arguments, based on consumer protection or externalities, is fully convincing, at least as a justification for detailed code provisions relating to private dwellings currently in force in different communities. In addition, there are indications that the fragmented regulatory process acts as a barrier to improved efficiency in housebuilding. The most direct complaint against the operation of building codes is that the system results in unneeded provisions and restrictions which add significantly to the cost of housing—by delaying construction of dwelling units and by preventing the use of the most up-to-date and modern materials. Further, it has been alleged that the procedures for modernizing and amending such codes are slow and laborious, lacking in any objective standards, and dominated by a very small group of local interests.\(^4\)

There is conflicting evidence on the magnitude of excess costs attributable to variations in building codes. Several studies have suggested that the direct effect of building codes upon construction costs is small. For example, Maisel’s early study (1953) of the San Francisco housing market concluded that an increase of less than one percent in the costs of newly constructed housing was attributable to “known code inefficiencies” (pp. 249–250). Muth’s 1968 econometric analysis of single detached housing suggested that locally modified building codes increased average cost by about two percent (as reported in Stockfisch (1968, p. 8)).

Burns and Mittelback (1968), in their report to the Kaiser Commission, analyzed a survey conducted by House and Home (the leading trade journal) in 1958, and suggested that if the 10 most “wasteful practices” required by building codes were eliminated, the average cost saving for single family housing would be from 5 to 7.5

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\(^1\) However it has been reported that at least one “major” real estate broker in one large city, Baltimore, now routinely requires each buyer and seller to sign a statement acknowledging the availability of such warranty and insurance protection. See Leger (1976).

\(^2\) To eliminate the costs of inspection and other information gathering without encountering the problems of adverse selection, one of the three firms currently providing such coverage insists that any participating broker place such contracts on all home listings (at the seller’s expense). This apparently meets some resistance on the part of sellers. (Indeed, it may well affect the sample of listings supplied to such a broker.) A recent newspaper article discussing this small insurance or warranty market notes several other problems, but quotes several industry sources who predict an expansion of this market in the next few years. See Leger (1976).

\(^3\) Indeed, as we note below, fiscal incentives may motivate building codes just as they may motivate zoning ordinances.

\(^4\) These issues are discussed in some detail in the report of the Douglas Commission (1968).
percent. "By assuming the provisions [of building codes] are randomly distributed and by taking account of their varying role in communities," the authors conclude that "...the estimates represent from 1.5 to 3 percent of the price of an average house" (p. 102).

Several other analysts have come to different conclusions, however. In expert testimony presented to the Kaiser Commission, Johnson concludes that "...in large urban areas, it may be possible to achieve on the order of a 10 to 15 percent reduction in direct construction costs [or 5 to 8.25 percent of selling price by Johnson's calculations] ...if the constraints of codes and restrictive labor practices are removed and if the industry is allowed to produce as efficiently as it knows how" (1968, p. 57). Survey evidence gathered by the Douglas Commission indicated some real cost reductions achievable by mass production under more uniform building codes (1968, p. 262). The estimates indicated that if 21 ""excessive requirements"—not all of which are necessarily in effect in any particular jurisdiction—were eliminated, $1838 would be cut from a typical $12,000 FHA insured house. This represents a 15.3 percent reduction in construction cost (or roughly 13 percent in sales price, if one-fifth of selling price is the land component). The commission report also notes the problems of one home manufacturer who estimated that producing a standard product acceptable to the jurisdictions within his six-state market area would increase costs by $2492 or almost 21 percent.

More important than any increased costs directly attributable to the intrinsic aspects of building codes are the production inefficiencies attributable to their lack of uniformity. As noted by Stockfrisch (1968, p. xiii):

The absence of such consistency [in building code provisions] has the effect of constituting subtle but real barriers to trade. As such they stifle specialization and the division of labor which is the principle [sic] source of efficiency and cost saving. The problem, as it afflicts the construction industry, may be viewed as either a housing problem (insofar as it impacts upon housing alternatives available to poor people), or as an "antitrust" problem which exerts a special incidence upon poor people insofar as it is responsible both for higher cost housing and reduced employment opportunities for low-skilled individuals who would find employment in an expanded manufacturing center.

In summary, the analysis suggests that greater uniformity in building codes would lower the costs of construction without compromising housing quality and safety, would facilitate the mass production of housing components, and would provide stronger incentives for research and development. In the following sections, we consider why code revision to achieve uniformity across communities has not occurred more rapidly.

Although local building regulation is the political responsibility of local government—and regulations are thus formally enacted and enforced by elected representatives—the technical complexity of such standards suggests that local building officials exercise considerable influence in proposing and evaluating alternative sets of standards. Thus, we are interested in identifying those factors which determine the willingness of local officials to permit the use of particular construction methods in their jurisdictions.

3. A simple model of the regulatory process

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Ideally, construction standards would be a codification of performance specifications for newly constructed dwellings. In practice, however, standards are typically stated in terms of input requirements. To judge the acceptability of an innovation, then, the local building official must first evaluate the results of performance tests conducted by a wide variety of other agencies (e.g., Underwriters' Laboratory) on particular materials and designs. Based upon these evaluations, specific standards or input requirements are proposed and promulgated. Thus it appears that the progressiveness of local building codes should be directly related to the professional attributes of the local officials: the amount and type of their professional contact, their backgrounds, and their education.

The development of a new product or process in construction, even if it unambiguously reduces costs without affecting quality, will not invariably be welcomed by all interested parties. In particular, we might expect firms to be anxious to adopt the innovation to lower costs, especially since it appears that the demand for housing by consumers is price elastic (see Muth, 1968). The response of organized labor, presumably interested in local jobs rather than profits, may be less than enthusiastic if the innovation reduces labor input requirements, reduces required skill levels, or replaces local labor with other labor (as with innovations in preassembled components). In principle, we should also expect housing consumers to respond favorably to innovations which would reduce final costs. One can picture the local building official, then, as being buffeted about by three interest groups: firms, labor and consumers.

In common with other bureaucratic regulatory agencies charged with adopting standards in some poorly defined "public interest," it is natural to assume that local building departments have a self-interest in minimizing conflict (see, for example, Joskow, 1973). Thus the responsiveness of the local official to proposals for change in building codes is likely to depend on the relative strength in his jurisdiction of construction firms, labor unions, and the conditions of housing demand.

This discussion suggests a simple model of the local regulatory process:

\[ P = f(B; Pc) = g(B; I_F, I_L, I_H), \]  \hspace{1cm} (1)

where \( P \), the permissibility of some innovation in material, design, or organization in the local building code, is a function of the professional background of the chief building official \((B)\) and the perceived level of conflict \((Pc)\) caused by permitting the proposed change. This conflict is, in turn, dependent upon the actual or potential interference by firms \((I_F)\), organized labor \((I_L)\), or housing consumers \((I_H)\).

These interest groups will engage in informational or persuasion activities if the expected benefits of the activity exceed its costs. For firms, the benefits will be larger for innovations which have a larger impact on unit costs. Also, since the costs of lobbying activity are independent of output, we should expect larger firms, producing more units of output, to make greater efforts to secure the adoption of

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5 Fields and Rivkin's review (1975, p. 37) indicates: "In almost all codes, standards are expressed in specifications indicating how and/or what the content of an item should be."
cost-reducing code changes. As the cost of lobbying activity increases, the profitability level required for intervention will increase.

For labor, the benefits of intervention to promote adoption of a code change should be greater for innovations which have a larger impact on unit costs (again, assuming price elastic demand for housing output). The benefits of intervention to oppose code changes will be greater for those innovations which are labor saving—at least those which reduce the demand for local labor. Again, the strength of the incentive to undertake persuasional activity will vary directly with the size of the interest group—the relative strength of organized labor.

Housing consumers, the least organized of the three interest groups, may be unlikely to undertake direct persuasion of local officials on matters of local building codes. However, we may expect that, in areas where housing demand is increasing rapidly, construction firms may push more vigorously for the adoption of innovations. Thus, even in the absence of organized consumer lobbies, increased housing demand should encourage the adoption of innovation.

This simple model suggests, then, that the permissibility of a particular innovation in material, design, or organization will increase with firm size, with the demand for housing, and with the magnitude of its reduction in unit cost, and will decrease with the unionization of the local labor market and the labor-savingness of the innovation. Holding these factors constant, localities with more professional building officials should be more likely to permit the innovation.

This simple model of the regulatory process can be tested somewhat crudely by utilizing a special survey of local building departments conducted by Fields and Ventre (1971). Tabulations and analysis of these survey data appear in Fields and Rivkin (1975) and Ventre (1973). This survey gathered information about the characteristics of building officials in a cross section of U.S. jurisdictions, as well as about the specific provisions of the local building codes in force in those communities. Our analysis concentrates on survey data collected from 608 jurisdictions located in metropolitan areas.

We have chosen four of these code provisions, which reflect the permissibility of particular materials and techniques and which are generally agreed to be “progressive,” for analysis. A brief description of these “innovations” in residential construction is followed by an analysis of the factors affecting the “diffusion” of these techniques—as measured by their permissibility under local building ordinances.

The dependent variables. Each of these code provisions is somewhat technical and narrowly defined. Broadly speaking, the first two “innovations” represent the removal of redundancies in residential construction; these innovations arise from increased knowledge about material stress in construction materials. The third code provision represents the preassembly of housing components, an innovation in organization, and the fourth is the substitution of cheaper and more flexible construction material.

Specifically, the first innovation is the provision for using 2 × 3 inch studs instead of 2 × 4 inch studs in nonload-bearing interior
partitions; the second is the provision for placing studs 24 inches apart instead of 16 inches apart in such partitions. The use of 2 × 3 inch studs involves a reduction of 25 percent in the wood required in nonload-bearing partitions. The wider placement of studs reduces the wood required in such partitions by 33 percent and simultaneously reduces the labor required for such partitions. According to the report of the Douglas Commission, each of these relaxed standards is, in the light of current engineering knowledge, as effective as the more restrictive provision:

Any objective standard or test indicates that the requirement for the use of 2 by 4's every 16 inches in nonload-bearing partitions is an excessive one. They are not required to bear the stress and weight of the building or ceiling. Experts agree that 2 by 3's can be used just as effectively in interior partitions and in nonload-bearing walls, and that 2 by 4's spaced every 24 inches would be just as safe. There seems to be no expert or scientific data to refute these facts. The requirement for 2 by 4's every 16 inches in non-load-bearing walls clearly adds to both material costs and labor costs. (1968, p. 258)

The third innovation is the use of preassembled drain, waste, and ventilating systems instead of the assembly on-site of these components. This typically involves the substitution of a factory assembled plumbing wall (or "wet wall") with bathroom fixtures in-place instead of conventional on-site assembly of plumbing components. This innovation has the effect of reducing the demand for local labor, since on-site assembly time is reduced substantially. Again, the evidence presented by the Douglas Commission suggests that this innovation is highly economical:

Among the more important methods of reducing building costs is the prefabrication or offsite assembly of plumbing or electrical units. This makes the use of mass production and assembly line techniques possible; work can be done more efficiently through specialization and the division of labor; and much of the work is freed from the added costs due to time lost because of inclement weather because it is done indoors. (1968, p. 258)

The fourth innovation is the use of nonmetallic (chiefly plastic) sheathed cable for electrical wiring systems instead of metal conduit. This makes wiring systems somewhat cheaper and easier to install. More importantly, use of this technique may reduce the skill requirement for electricians and thus labor inputs.

Estimates of the cost savings in construction attributable to any one of these code provisions are, as noted above, imprecise. Published estimates, as of 1968, suggest that for a $12,000 house the removal of redundant standards for studs would reduce costs by $100 (removal of other redundant standards for wood stress would reduce costs by $343). Removal of prohibitions on preassembled water fixtures would reduce costs by $135 to $250, and permission to use nonmetallic cable by another $50 to $300 (National Commission on Urban Problems, pp. 263–266). None of these potential cost savings is dramatic, but each is significant.

The survey responses indicate that in 1970, 71 percent of the sampled jurisdictions permitted the substitution of 2×3 inch studs for 2×4's in nonload-bearing partitions. Fifty-three percent of the jurisdictions permitted wider placement of studs. Preassembled plumbing components were permitted in 55 percent of the jurisdictions, and nonmetallic cable in 69 percent of the localities.

The diffusion of these improved techniques over time is depicted
in Figure 1, which indicates the proportion of localities permitting their use in each year. The figure indicates that the diffusion of the two methods which most directly reduce the demand for local labor has been much slower than for the other two.

6 A number of jurisdictions permitting these innovations in 1970 did not indicate the year in which their regulations were amended to permit their use. Consequently, the data reported in Figure 1 (and in Table 3 below) exclude them. These jurisdictions are, however, included in the cross-sectional analysis reported in Tables 1 and 2.

7 A cumulative logistic function, \( \log \left( \frac{\bar{p}}{1 - \bar{p}} \right) = a_0 + a_1 t \), fits the diffusion pattern of these techniques rather well, with \( R^2 \)'s of 0.96–0.98—much better than the cumulative exponential decay, \( \log (1 - p) = a_0 + a_1 t \). This is consistent with the “chain reaction” or “snowball” diffusion pattern of the adoption of innovation reported among physicians as compared with the pattern resulting from “isolated individual” adoption (see Coleman et al., 1966). It should be noted, however, that the cumulative normal, \( \log p = a_0 + a_1 t^2 \), fits these data equally well (as measured by the transformed \( R^2 \)’s).
The independent variables. Since the evidence indicates that none of these four innovations interferes with public health or safety, the model developed in Section 3 suggests that jurisdictions with better educated building officials with wider professional contacts will be more likely to permit the innovations. Similarly, we expect that jurisdictions where local labor unions are more powerful will be less likely to permit these innovations (with the possible exception of the provision for 2 × 3 inch studs); we also expect that jurisdictions where firms are relatively larger will be more likely to permit these innovations. In addition, however, we may expect organized labor to be less resistant to the adoption of any of these innovations in markets where housing demand (and hence the demand for labor) is increasing anyway. Finally, the potential gain to firms from a particular innovation varies directly with housing demand and inversely with the per unit cost of inputs. Thus, we expect that jurisdictions with increasing demand for housing and higher prices for construction inputs will be more likely to permit these innovations.

In measuring these influences, we use ten variables. Many of these variables are quite crudely estimated; the specific details of their computation appear as footnotes.

Four variables are used to characterize local building officials: the education of the chief building official (in years); the background of the chief building inspector, noted as a dummy variable with the value of 1 if his prior experience is in the union building trades and 0 otherwise; a measure of the amount of contact the chief building official reported with building professionals (material producers, other building officials, etc.); and a measure of the proportion of the building official’s professional contact which is with representatives of organized labor.8

Pressure by firms and labor for the adoption of these innovations is measured by five variables. It is our hypothesis, as noted earlier, that larger firms have stronger incentives to lobby for code changes, and, secondly, that there may be some economies to scale in persuasion. We measure these influences by an estimate of the average size of construction firms in the local (SMSA) housing market and by the proportion of building trade workers who are unionized. Housing demand, a second determinant of the incentive for firms and labor to exert pressure for change, is measured by the change in the vacancy rate in the SMSA between 1960 and 1970 and by the population growth in the jurisdiction during the same period. Finally, since these innovations are labor saving (with the exception of 2 × 3 inch studs) we use an index of labor input prices (real hourly wages in construction) to measure differences across housing markets in the cost sav-

8 These four variables were taken from the original sample of jurisdictions reported in Fields and Ventre (1971).

The variable measuring the amount of professional contact of the chief building inspector was computed from responses to two questions asking how frequently the chief building inspector had official business and personal contact with each of five classes of professionals. Responses were obtained in four classes (e.g., “often, occasionally, rarely, never”). Responses to these questions were assigned values from 1 to 4 and aggregated. This resulted in a somewhat crude measure of the amount and intensity of contact with other professionals with a range between 0 and 40. The variable measuring the proportion of contact with union personnel is the ratio of the computed measure for union contact to the measure for total contact with professionals.
nings expected by the adoption of an innovation. This, of course, assumes that the price of materials is constant for the nation as a whole (i.e., that materials are traded in a national market).  

In addition to these nine measures, we include one additional variable to represent fiscal incentives for resistance to lower cost housing. Given the property tax financing of local public services, jurisdictions have an incentive to insure that the marginal house is more expensive than the average. We measure the relative exclusivity of jurisdictions, and their fiscal incentive to use building codes to ration entry, by the ratio of the median income in the jurisdiction to the median income in the Standard Metropolitan Statistical Areas (SMSA).

We investigate the diffusion pattern of these techniques in several ways. First we investigate the diffusion pattern observed cross sectionally, by reporting estimates of univariate and multivariate logistic models of diffusion. Then we examine the diffusion of these more progressive building standards over time by estimating the probability of adoption separately for the 1960–1970 decade.  

Cross sectional models of diffusion. Table 1 investigates the diffusion pattern observed cross sectionally in 1970; it presents estimates of univariate logistic models relating the probability that an innovation is permitted by local ordinances to the set of independent variables. The four equations in Table 1 are each interpreted as the independent probability that one of these improved techniques will be permitted, conditional only upon the values of the independent variables.

A likelihood ratio test indicates that each equation is highly significant, three at the 0.01 level and one at the 0.02 level. The educa-


<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLES:</th>
<th>EXPECTED SIGN</th>
<th>INNOVATION</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>NON-METALLIC CABLE</td>
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<tr>
<td>I. PROFESSIONAL BACKGROUND</td>
<td></td>
<td></td>
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<tr>
<td>EDUCATION</td>
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<tr>
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<td>UNION CONTACT</td>
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<td>II. DEMAND PRESSURE</td>
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<tr>
<td>RELATIVE INCOME</td>
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<tr>
<td>III. PRESSURE GROUPS</td>
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<td>IV. PRICE OF INPUTS</td>
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<tr>
<td>INTERCEPT</td>
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<td>−2 LOG L/L₀</td>
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\[ \chi^2(0.01, \text{ 10df}) = 23.21 \]
\[ \chi^2(0.02, \text{ 10df}) = 21.16 \]

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(ASYMPTOTIC t-RATIOS IN PARENTHESES)

The chief building official is highly significant in all four equations. On average, the chief building official has about 14 years of formal education. The coefficient estimates indicate that, holding other factors constant, an additional two years of education (i.e., college graduation) increases the probability that pre-assembled plumbing and wider placement of studs (both of which reduce the demand for local labor) will be permitted by about 5–6 percentage points (from 55 percent to 61 percent and from 53 percent to 58 percent, respectively). Two years of additional education increase the probabilities for the other two techniques by 2–4 percentage points.

In three of the four equations, the unionization of workers significantly reduces the probability of adoption. Since the exception, the utilization of 2 × 3 studs, is the only one of the four which does not affect the demand for labor, these results are precisely according to expectations.

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In nonunionized housing markets, at the means of the other variables, the coefficient estimates imply probabilities of 0.79, 0.58, and 0.61 that plastic cable, preassembled plumbing, and wider placement of studs will be permitted. If these construction markets were completely unionized, these probabilities would be reduced rather substantially to 0.56, 0.51, and 0.45, respectively.

Virtually all of the other coefficients have the anticipated signs, but the level of significance is somewhat lower. For the two code provisions concerning wood studs, the probability of adoption is significantly related to the average size of construction firms in the local housing market. At the point of means, a doubling of the average firm size increases the probability that $2 \times 3$ studs are permitted by about 8 percentage points (from 0.71 to 0.79). The effect of firm size is even larger upon the placement of wood studs—doubling the average firm size increases the probability that fewer studs (and hence less labor) will be permitted by 16 percentage points (from 0.53 to 0.69). In the light of our model, it is somewhat surprising that firm size appears unrelated to the permissibility of preassembled plumbing (which can result in larger cost reductions).

There is also consistent evidence that each of these cost-saving techniques is less likely to be permitted in more affluent jurisdictions. As compared to a jurisdiction where incomes are at the SMSA average, an affluent town with incomes twice the metropolitan average would be less likely to permit these four lower cost techniques by 6–8 percentage points.

Table 2 presents further results on the cross sectional pattern of diffusion derived from the more general estimation method suggested by Nerlove and Press (1973). The table presents the estimated coefficients from the model which postulates that the probabilities of adoption of these four improved techniques are jointly determined. It is assumed that the joint distribution of adoption probabilities is multivariate logistic; the table indicates the probability of adopting each of these innovations, conditional upon the adoption of the other three and the set of independent exogenous variables. Again, a likelihood ratio test indicates that the estimates as a group are highly significant.

The table indicates a strong positive association between the adoption of these innovations, holding the other characteristics of the jurisdictions constant. As might be expected, the association is strongest between the “innovations” in the size and the placement of wood studs, but the other interactions are all highly significant. The results indicate that jurisdictions which permit one of these innovations are more likely to permit the others, even holding constant the effects of the other ten variables.

The statistical significance of the other coefficients is reduced somewhat by the inclusion of the jointly determined endogenous variables; the pattern of results is, however, generally consistent with the simple models. In particular, it appears that the unionization, firm size, and education measures are important, and the other variables have anticipated signs, if not significant $t$-ratios.\[^{11}\]

\[^{11}\] It should be noted that, in this formulation, the overall effect of an independent variable upon the probability of adoption of any innovation includes an indirect effect, through the bivariate interactions, as well as a direct effect. Thus, the overall sig-
## Table 2

ESTIMATES OF THE JOINT PROBABILITY OF ACCEPTANCE OF FOUR INNOVATIONS INCLUDING BIVARIATE INTERACTION EFFECTS

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLES:</th>
<th>EXPECTED SIGN</th>
<th>INNOVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NON-METALLIC CABLE</td>
</tr>
<tr>
<td>I. PROFESSIONAL BACKGROUND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDUCATION</td>
<td>+</td>
<td>0.051</td>
</tr>
<tr>
<td>UNION BACKGROUND</td>
<td>-</td>
<td>-0.006</td>
</tr>
<tr>
<td>AMOUNT OF CONTACT</td>
<td>+</td>
<td>-0.019</td>
</tr>
<tr>
<td>UNION CONTACT</td>
<td>-</td>
<td>-0.700</td>
</tr>
<tr>
<td>II. DEMAND PRESSURE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ VACANCY RATE</td>
<td>-</td>
<td>0.034</td>
</tr>
<tr>
<td>LOCAL POPULATION GROWTH</td>
<td>+</td>
<td>-0.026</td>
</tr>
<tr>
<td>RELATIVE INCOME</td>
<td>-</td>
<td>-0.085</td>
</tr>
<tr>
<td>III. PRESSURE GROUPS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVERAGE FIRM SIZE</td>
<td>+</td>
<td>0.014</td>
</tr>
<tr>
<td>PROPORTION UNIONIZED</td>
<td>-</td>
<td>-1.070</td>
</tr>
<tr>
<td>IV. PRICE OF INPUTS</td>
<td>+</td>
<td>1.105</td>
</tr>
<tr>
<td>V. BIVARIATE INTERACTIONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLASTIC CABLE</td>
<td></td>
<td>0.234</td>
</tr>
<tr>
<td>PREASSEMBLED PLUMBING</td>
<td></td>
<td>0.234</td>
</tr>
<tr>
<td>TWO BY THREE INCH STUDS</td>
<td></td>
<td>0.158</td>
</tr>
<tr>
<td>24 INCH PLACEMENT OF STUDS</td>
<td></td>
<td>0.145</td>
</tr>
<tr>
<td>INTERCEPT</td>
<td>-0.879</td>
<td>(0.85)</td>
</tr>
</tbody>
</table>

\[-2 \log \ell _{l_0} = 95.11\]

\[\chi^2(0.01, 52 df) = 76.15\]

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For three of the innovations, the estimated effect of unionization is quite large, even compared to the interaction terms. For example, at the means of the other variables, the conditional probability of adop-

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tion of nonmetallic cable is 0.82 in jurisdictions which have nonunionized building trades and which have adopted the other three innovations. The conditional probability in jurisdictions which have not adopted the other three innovations is 0.73. In completely unionized labor markets, however, the conditional probabilities are reduced by 20 percentage points and 31 percentage points—to 0.62 and 0.42—respectively. The relative importance of unionization is even larger for the adoption of 2 × 3 inch studs.

The estimated effect of education upon the adoption probabilities varies. Two additional years of education of the chief building official has little or no effect upon the adoption of 2 × 3 inch studs. However, it increases the probability of adoption of preassembled plumbing by 4 percentage points (from 0.61 to 0.65) conditional upon the adoption of the other three innovations, and it increases the probability by 5 percentage points (from 0.43 to 0.48) conditional upon the nonadoption of the other innovations.

☐ Diffusion of innovation over time. Much of the literature on the diffusion of innovation has been concerned with the time lag between the “discovery” of a better technique and its subsequent adoption by firms (e.g., high intensity presses for paper, basic oxygen processes for steel (Nabseth and Ray, 1974)), by independent professionals (e.g., the drug “gammanym” among physicians (Coleman et al., 1966)), or by the political process (e.g., fluoridation among cities (Crain, 1966)). The data presented in Figure 1 indicate that there are substantial differences in timing among those communities which permitted each of the four improved construction techniques. For example, between 1960 and 1970 the proportion of sampled jurisdictions permitting 2 × 3 inch studs increased by about 17 percentage points.

In Table 3 we investigate the pattern of adoption of these improved techniques during the most recent decade, 1960–1970. Again, the conceptual model hypothesizes that those jurisdictions with more professional building officials, and those housing markets with larger construction firms, less unionization, and higher labor prices are more likely to adopt these improved techniques.

The results reported in Table 3 are based upon the subsample of 143 jurisdictions which had not adopted these innovations by 1960. The table indicates the relationship between the probability that an innovation is adopted during the decade 1960–1970 and the ten independent variables. As in the estimates presented in Table 1, the statistical model postulates that the probabilities of adopting these four innovations are independently logistic. The coefficients reflect the probability of adopting each of these improved techniques, conditional upon the ten independent variables.

A comparison of Tables 1 and 3 indicates that the cross sectional results are generally confirmed by considering only the “late adopters” of these innovations. Three of the four equations are significant at the 0.10 level. Again, the results indicate the importance of the education of the chief building official, his background and contacts, and the extent of unionization in influencing the adoption of these cost reducing construction techniques.

\[\text{12 The multivariate logistic estimates, not shown, are qualitatively similar to the results presented above, but the levels of significance are much lower.}\]
### TABLE 3
LOGISTIC ESTIMATES OF PROBABILITY OF ACCEPTANCE OF FOUR INNOVATIONS BETWEEN 1960 AND 1970

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLES:</th>
<th>EXPECTED SIGN</th>
<th>NON-METALLIC CABLE</th>
<th>PRE-ASSEMBLED PLUMBING</th>
<th>TWO BY THREE INCH STUDS</th>
<th>24 INCH PLACEMENT OF STUDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. PROFESSIONAL BACKGROUND</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDUCATION</td>
<td>+</td>
<td>0.226</td>
<td>0.217</td>
<td>0.046</td>
<td>0.197</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.181)</td>
<td>(2.937)</td>
<td>(0.912)</td>
<td>(2.699)</td>
</tr>
<tr>
<td>UNION BACKGROUND</td>
<td>-</td>
<td>0.426</td>
<td>0.307</td>
<td>0.004</td>
<td>0.053</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.707)</td>
<td>(1.152)</td>
<td>(0.018)</td>
<td>(0.194)</td>
</tr>
<tr>
<td>AMOUNT OF CONTACT</td>
<td>+</td>
<td>0.032</td>
<td>0.038</td>
<td>0.019</td>
<td>0.019</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.400)</td>
<td>(1.404)</td>
<td>(0.989)</td>
<td>(0.784)</td>
</tr>
<tr>
<td>UNION CONTACT</td>
<td>-</td>
<td>-0.992</td>
<td>-2.224</td>
<td>-0.634</td>
<td>-1.040</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.784)</td>
<td>(2.445)</td>
<td>(1.335)</td>
<td>(1.646)</td>
</tr>
<tr>
<td>II. DEMAND PRESSURE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ VACANCY RATE</td>
<td>-</td>
<td>-0.232</td>
<td>-0.584</td>
<td>0.271</td>
<td>0.569</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.664)</td>
<td>(1.478)</td>
<td>(0.802)</td>
<td>(1.438)</td>
</tr>
<tr>
<td>LOCAL POPULATION GROWTH</td>
<td>+</td>
<td>-0.041</td>
<td>0.163</td>
<td>0.057</td>
<td>0.196</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.378)</td>
<td>(1.034)</td>
<td>(0.536)</td>
<td>(1.095)</td>
</tr>
<tr>
<td>RELATIVE INCOME</td>
<td>-</td>
<td>-0.342</td>
<td>-0.518</td>
<td>-0.521</td>
<td>0.106</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.822)</td>
<td>(1.083)</td>
<td>(1.377)</td>
<td>(0.251)</td>
</tr>
<tr>
<td>III. PRESSURE GROUPS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVERAGE FIRM SIZE</td>
<td>+</td>
<td>0.015</td>
<td>-0.018</td>
<td>-0.001</td>
<td>-0.004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.464)</td>
<td>(0.500)</td>
<td>(0.043)</td>
<td>(0.101)</td>
</tr>
<tr>
<td>PROPORTION UNIONIZED</td>
<td>-</td>
<td>-0.011</td>
<td>-0.004</td>
<td>-0.0002</td>
<td>-0.010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.811)</td>
<td>(0.998)</td>
<td>(0.072)</td>
<td>(2.452)</td>
</tr>
<tr>
<td>IV. PRICE OF INPUTS</td>
<td>+</td>
<td>0.046</td>
<td>-0.001</td>
<td>-0.080</td>
<td>-0.080</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.315)</td>
<td>(0.027)</td>
<td>(1.821)</td>
<td>(1.400)</td>
</tr>
<tr>
<td>INTERCEPT</td>
<td></td>
<td>-7.280</td>
<td>-0.595</td>
<td>10.181</td>
<td>7.683</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.648)</td>
<td>(0.117)</td>
<td>(1.870)</td>
<td>(1.094)</td>
</tr>
<tr>
<td>–2 LOG L/L₀</td>
<td></td>
<td>15.68</td>
<td>16.35</td>
<td>5.43</td>
<td>16.70</td>
</tr>
</tbody>
</table>

χ²(0.10, 10df) = 15.99
χ²(0.20, 10df) = 13.44
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### 5. Conclusions

This paper set out to explore those factors which affect the diffusion of improved techniques in residential construction. By concentrating on four innovations in housebuilding which are generally agreed to be progressive, we investigated the relationship between the provisions of local codes and several characteristics of officials and their local housing markets. Although our results are hardly definitive, they suggest that the educational level of the chief building official, the extent of unionization, and the relative size of housebuilding firms in the local construction industry exert an influence on the probability of acceptance of several cost reducing innovations. The cross-sectional results also suggest that wealthier jurisdictions, presumably more exclusive suburbs, are more likely to prohibit these cost saving techniques. The relative price of labor inputs appears, at best, to be only weakly related to the diffusion of these innovations. As a whole, the analysis provides some support for the conclusion that the organization of the local housing market—as measured by unionization and
firm size—and the professionalism of local regulators—as measured by education, background, and professional contacts—affect the diffusion of technical progress in housebuilding.

References


