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Adoption of Innovations in Tradition-bound Industries: Uncertainty and Competitive Rivalry Effects on Adoption of Wood Products

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ABSTRACT

A common perception of tradition-bound industries is that they are less inclined to adopt new product and process innovations. The residential construction industry is commonly described as one such tradition-bound industry in that the methods and materials that this industry utilizes have been perceived as remaining comparatively static over the past several decades relative to other industrial sectors. The residential construction industry, however, represents one of the largest industrial sectors in the U.S. economy. The importance of the residential construction industry to the overall economy is well understood, as its activity significantly affects the performance of supplier and allied industries. The importance of residential construction as a driver of the domestic forest resources and wood products industries is quite clear; approximately 35 to 45 percent of all softwood structural lumber and structural panel products manufactured in the United States is utilized in the construction of residential buildings. The literature associated with the residential construction industry arrives at a consensus that the fragmented structure of the industry has led builders to be more cautious in adopting proven innovations that would enhance firm, industry, and finished product performance. Some researchers contend that the competitive nature of the industry is a root cause of builders' risk aversion with regard to innovative building products. This study explores the linkage between builders' perceptions of uncertainty and competition within the residential construction industry and firm adoption of innovative wood-based building materials. Hypotheses are developed and tested using data collected from 130 residential construction firms located in three states along the Pacific Coast. Study results strongly suggest that builders' perceptions of uncertainty and competition do not significantly affect firm adoption of innovative wood-based building materials. Implications of the study's results on product innovation within the forest products industry are discussed.

Keywords: diffusion, engineered wood products, innovation adoption, purchasing behavior, residential construction

Introduction

Residential construction represents one of the largest and most important sectors of the United States economy (Lutzenhiser and Janda 1999). The importance of residential construction to domestic forest resources and wood products industries is readily apparent; approximately 35 to 45 percent of all softwood structural lumber and structural panel products manufactured in the United States is utilized in the construction of new residential buildings (Wood Products Promotion Council 1996). Residential construction is also perceived as representing one of the United States' most intensely competitive, tradition-bound, and risk averse industries (e.g., Goldberg and Shepard 1989). One strategy that can increase the residential construction industry's productivity is to adopt proven innovative technologies, such as engineered wood products. The United States residential construction industry, however, has reportedly been habitually slow at adopting cost saving and productivity enhancing innovations (e.g., Dibner and Lemer 1992; Stokes 1981). It can take anywhere from 10 to 15 years before one-half of the industry adopts a proven product or process innovation, and up to 30 years for full industry-wide diffusion (Industry Canada 1999; Goldberg and Shepard 1989). Upstream, the innovativeness of industries that supply materials to the residential construction industry can be constrained owing to the economic situations arising from the long time frame required to recover the costs of developing, manufacturing, and marketing an innovation (Goldberg and Shepard 1989).

Many of the technological advances in residential construction have been qualitative, indirect, and somewhat abstract; new innovative fasteners, for example, are representative of indirect and abstract technologies in residential construction. These advances are often incorporated into component manufacturing and fabrication, making them difficult to quantify (Strassman 1978). Furthermore, the industry has become highly specialized, resulting in the evolution of a number of different subcontracted industries. These subcontracted industries are often monopolistic in nature and use innovative techniques to add value and lower costs only for their particular service or trade (Ventre 1979). While lower costs may result from the adoption of an innovation in one subcontracted industry (e.g., electric), it can either inadvertently or surreptitiously add to costs of construction in another subcontracted industry by reducing compatability (e.g., heating, venting, and air conditioning).

Nationally, construction related costs constitute about one-half to three-fourths of the total cost of a new home; other major costs include land, financing, and brokerage fees.[1] Innovative products and processes in the residential construction industry, therefore, are seen as an opportunity for reducing housing costs by increasing building efficiency and effectiveness. More importantly, innovations can bring housing affordability for new homebuyers within reach (Lutzenhiser and Janda 1999; Goldberg and Shepard 1989; U.S. Congress – Office of Technology Assessment 1986; Oster and Quigley 1977; Spall 1971).

(1) Note that "total costs" does not refer to the market or sale price of the home, which would presumably include an additional margin for the builder, realty fees, etc.

Background and Objectives

Numerous articles and researchers indicate that high levels of uncertainty and competitive rivalry in the residential construction industry play a crucial role in inhibiting the adoption of innovative products and processes (Toole 1998; Shook 1997; Civil Engineering Research Foundation 1996; NAHB Research Center 1991; Goldberg and Shepard 1989; Tatum 1986; U.S. Congress – Office of Technology Assessment 1986). The authors of these studies arrive at anecdotal conclusions by assessing resultant effects of failing to adopt proven technological innovations in the industry.

However, no study has yet attempted to assess whether builders' perceptions of uncertainty and competitive rivalry in the marketplace are correlated with their purchase behavior of innovative products. As a result, the linkages made in residential construction research between builders' perceptions of uncertainty and competitive rivalry and the resulting effects are disjointed and possibly unfounded. The primary objectives of this study are twofold: [1] to empirically determine if residential builders' perceptions of uncertainty affect their adoption for innovative wood-based products and [2] to investigate the association between builders' perceptions of competitive rivalry in the industry and their adoption of innovative wood-based products.

Perceived Environmental Uncertainty

Despite the fact that the terms "risk" and "environmental uncertainty" are often interchangeably used in the literature, they are not, conceptually, identical constructs (van Raaij 1991). Specifically, the probability distribution of an outcome under risk is known. The risk paradigm assumes that choices are made between a sure outcome and a risky outcome, not knowing which is going to occur (MacCrimmon et al. 1986). Under environmental uncertainty, the probability distribution of an outcome is unknown, and one can only attach or exclude some probability to a probability distribution of an uncertain outcome (van Raaij 1991). In extreme cases, no probability distributions for an uncertain outcome can be excluded and all outcomes are still possible. Given the nature of its probability structure, environmental uncertainty has often been referred to as "second-order risk" (van Raaij 1991) and "perceived risk" (Kennedy 1983).

The concept of environmental uncertainty has been investigated at length within the organizational theory literature (e.g., Miller 1993; Jackson et al. 1987; Lawrence and Lorsch 1967; Thompson 1967; March and Simon 1958). Generally, the literature suggests that environmental uncertainty is dysfunctional to maintaining stability and satisfactory firm performance (e.g., Jauch and Kraft 1986; Robertson and Gatignon 1986; Miles and Snow 1978). According to Milliken (1987), three commonly used definitions of environmental uncertainty exist in the organizational theory literature: [1] an inability to assign probabilities as to the likelihood of future events, [2] a lack of information concerning cause-and-effect relationships, and [3] an inability to accurately predict what the outcomes of a decision might be as they relate to the firm.

Milliken (1987) suggests that environmental uncertainty affects the nature of firm strategy development, action, and performance. Milliken defines one particular type of environmental uncertainty as state uncertainty. State uncertainty occurs when a manager perceives the environment, or a particular component of the environment, to be unpredictable. The actions of relevant organizations and constituencies (e.g., competitors, consumers, distributors, regulators, shareholders, suppliers) may be uncertain to a manager. In addition, the manager may be uncertain as to the probability and/or nature of general changes in state of the relevant environment (e.g., demographic shifts, developments in technology, sociocultural trends). It has been hypothesized that as environmental volatility, complexity, and heterogeneity increase, managers' state of uncertainty increases. (Milliken 1987) A manager's inability to understand how components in the state of the environment might be changing leads to his/her inability to predict the future behavior of organizations and constituencies that affect his/her firm. For example, a residential construction firm manager's inability to determine or predict whether a local carpenters or plumbing union goes on strike is a manifestation of state uncertainty, as is the manager's inability to predict the actions of building code regulators.

Shoemaker and Shoaf (1975) and Kennedy (1983) point out that despite the wide recognition that environmental uncertainty can influence innovative behavior, little empirical research has been conducted to determine the magnitude of this influence. However, there have been some studies examining the relationship between environmental uncertainty and innovation adoption. For example, in a study of the adoption of in-house business computers, Peters and Venkatesan (1973) found that environmental uncertainty was one of only two variables that differentiated between early adopter and late adopters. Similarly, Parkinson (1976), in a study of the adoption of an innovation in the earth-moving equipment industry, found that the time difference in adoption of the innovation between late and early adopters could be partially explained by factors directly related to environmental uncertainty.

The literature examining innovation adoption in the residential construction industry, to date, has produced no studies that have empirically tested the relationship between levels of environmental uncertainty and innovation adoption. There are numerous studies, however, that provide speculative commentary suggesting that high levels of environmental uncertainty in the residential construction industry play a crucial role in inhibiting the adoption of innovative products and processes (e.g., Industry Canada 1999; Civil Engineering Research Foundation 1996; NAHB Research Center 1991; Goldberg and Shepard 1989; Tatum 1989, 1986; U.S. Congress – Office of Technology Assessment 1986). In this study, we empirically test whether builders' perceptions of environmental uncertainty influence their degree of innovation adoption.

Miles and Snow (1978) developed a measure of perceived environmental uncertainty, which they termed the perceived environmental uncertainty scale. Their scale has been shown to be valid, reliable, and consistent with Milliken's conceptual definition of state uncertainty (Buchko 1994). Given the status of measures of environmental uncertainty available, the following hypothesis is proposed in the context of a firm's level of environmental uncertainty:

> H_1: Residential construction firms' adoption of innovative wood-based products is greater for firms that perceive low levels of environmental uncertainty relative to those firms that perceive high levels of environmental uncertainty.

Competitive Rivalry

In the residential construction industry, competition can arise from one of three sources: [1] from firms that produce close substitutes (e.g., mobile home manufacturers), [2] from existing firms within the industry, or [3] from new entrants in the industry. Spall (1971) points out that most Americans consider substitute products for traditionally constructed fixed-foundation residential structures as inferior.(2) These inferior substitutes (e.g., mobile homes) are generally used on a temporary basis until financial resources allow for the purchase of a traditional residential structure. Therefore, competition in the residential construction industry is confined primarily to existing firms within the industry and from new firms entering the industry.

(2) A traditional residential home is defined as a permanent, fixed-foundation structure generally constructed on site.

The impact of competition on innovation and adoption behavior has been studied to some extent, although research is nearly nonexistent within the context of construction and wood-based industries. Collectively, this research has produced rather mixed results, with two competing and diametrically opposed hypotheses being offered to explain empirical findings. One hypothesis supports the monopolistic industry structure as being superior for enhancing firm-level innovation adoption, while the other supports a highly competitive industry structure (Kennedy 1983).

The leading hypothesis suggests that a high level of competition from new or existing firms promotes firm innovativeness and the adoption of novel products, services, and ideas (e.g., Atuahene-Gima 1996; Abrahamson and Rosenkopf 1993; Levin et al. 1992; Porter 1990; Shrivastava and Souder 1987; Robertson and Gatignon 1986). The rationale behind this hypothesis is two-pronged. First, it suggests that firms adopt innovative products when they perceive that the adoption of products by competitors threatens the firm's established strategies (Shrivastava and Souder 1987). Second, increasing rivalry allegedly leads firms to adopt innovative products as quickly as possible to accrue the benefits of early adoption prior to their competitors (Levin et al. 1992). Delaying innovation adoption in a highly competitive setting not only lowers the risks associated with adoption, but also lowers the expected returns or efficiency. Abrahamson and Rosenkopf (1993) provide a framework for this second rationale. They assume a utility schema in which a firm's perceived threat of competitive disadvantage substantially outweighs the firm's perceived value of an equally large competitive advantage (i.e., prospect theory, cf. Kahneman and Tversky 1979). Under this utility schema, firms in highly competitive industries, such as the residential construction sector, are more apt to adopt innovative products than firms within less competitive industries.

The competing hypothesis suggests that increasing industry concentration (i.e., decreasing competition) will maximize the adoption rate of product innovations (e.g., Lutzenhiser 1994; Gatignon and Robertson 1989; Shrieves 1978). Reinganum (1981) concurs, indicating that, under increasingly oligopolistic conditions, firms pay particular attention to the competitive movements that each other make relative to firms in more competitive industry environments. In addition, it is suggested that adoption of innovations can build or maintain barriers to entry, preserve cost advantages, and decrease risk in increasingly oligopolistic industries (Lutzenhiser 1994; Levin 1978). As a result, the benefits of adopting innovative products increase as the number of competitors decrease. It should be noted, however, that this hypothesis is not without controversy. For example, Swan (1970) states that as industry competition decreases, firms become complacent and, therefore, less likely to recognize the value associated with various innovations.

A majority of the empirical research examining the relationship between competition and innovation and adoption across industries utilizes indices of industry concentration, most notably the Herfindahl-Hirschman Index (HHI), as the measure of competitive rivalry (cf. Kamien and Schwartz 1975). The HHI is computed by summing the squares of the percent market shares for all firms within an industry and multiplying that sum by 10,000. For a pure monopoly, HHI equals 10,000, and an industry is considered "concentrated" by the U.S. Department of Justice and the U.S. Federal Trade Commission when the HHI equals 1,000. Concentration ratios can also be calculated using the summed market shares of the top four, eight, or twenty dominant market leaders in relation to the total market. The fact that most firms produce multiple products (i.e., product lines) for multiple markets, however, can make the firm-level computation of a HHI exceedingly complex. Additionally, measures such as the HHI fail to directly account for an assessment of ease of market entrance and the impact of product differentiation. Very few researchers devote their studies to examining the effects of competitive rivalry on innovation and adoption within a specific industry. Generally, intraindustry studies use Likert-type scales to measure respondents' perception of industry competition (e.g., West and Sinclair 1992; Gatignon and Robertson 1989), a convention applied in the current study.

Spall (1971) is one of the only researchers to have explicitly studied the role of competition on innovation and adoption in the residential construction industry, although numerous reviews of the industry's structure have mentioned that competitive rivalry (commonly termed competitive intensity) may significantly influence innovation adoption (e.g., NAHB Research Center 1991; Goldberg and Shepard 1989; Tatum 1987, 1986). Spall (1971) hypothesizes that competition from new entrants in the residential construction industry influences a firm's adoption behavior for new building construction innovations; namely, newer firms in the market are more likely to adopt innovations than older firms. Spall rationalizes that new firms perceive the residential construction industry as more competitive than older, more established firms. Using the age of the responding firms as a proxy for "market newness," Spall found no support for his hypothesis. Spall's results may be spurious, however, given the nature of his sample, which was not randomly selected and consisted of only 20 firms operating within a single local market (Greater Lansing, Michigan, area).

Considering the nature of the two competing hypotheses, it appears that the influence of competition on firm-level innovation and adoption within an industry may be nonlinear (concave). Specifically, the greatest degree of innovativeness or innovation adoption occurs when firms perceive the competitive nature of the industry at either the high or low ends of a linear and unidimensional competitive rivalry scale. Conversely, firms that perceive the competitive nature of the industry to be at a medium level of rivalry will be significantly less innovative and, consequently, adopt fewer innovative products. Note that this reasoning directly opposes that of Kamien and Schwartz (1976), who provide some evidence suggesting that the rate of innovative activity within an industry (measured using industry concentration ratios across industries) increases with competitive rivalry up to a point, measured using industry concentration ratios across industries, then peaks and declines with further industry rivalry (i.e., nonlinear convex). Given the evidence we have outlined, it is hypothesized in this study that:

> H_{2a}: The degree of innovative wood-based product adoption in the residential construction industry is greater for firms that perceive the competitive rivalry of the industry to be either high or low on a unidimensional competitive rivalry scale. Conversely, firms that perceive the competitive nature of the industry to be at a medium level of rivalry are significantly less innovative.

In order to test Spall's (1971) hypothesis that newer firms perceive the residential construction industry to be more competitive than older, more established firms, we propose the following hypothesis:

> H_{2b}: Firm perception of the competitive rivalry in the residential construction industry is greater among newer firms than older, more established firms.

Research Methodology

The specific product category of innovations to be assessed in this study is engineered wood products (e.g., finger-jointed lumber, wood I-beams, structural panels, glulam timbers).(3) The engineered wood products category is selected for investigation since more than 95 percent of residential home builders are directly involved with the framing of homes, while more than 70 percent of masonry, electrical, plumbing, and heating, venting, and air conditioning tasks are subcontracted out (Shook 1997; Anonymous 1996). In other words, wood-based products are considerably more salient products for builders to assess since they tend to have a very high level of familiarity with using them in framing systems.

(3) Wood I-beams are synonymous with wood I-joists in this paper.

Operationalization of Independent Measures

The initial assembly of the survey instrument for this study involved personal interviews with over two dozen residential home builders that assessed various existing and derived scales related to the quantification of uncertainty, competitive rivalry, and innovation adoption/rejection. Perceived environmental uncertainty in this study was assessed using a slightly modified version of Miles and Snow's (1978) perceived environmental uncertainty scale. This scale contained six subscales consisting of a total of 22 scale items to measure major dimensions of an industrial firm's external environment that moderate perceptions of uncertainty. These dimensions included suppliers, competitors, customers, financial markets, government and regulatory agencies, and unions. Survey respondents rated the degree of predictability for various characteristics of these sectors using a five-point interval categorical scale with response categories of "1" representing highly predictable, "3" representing neutral, and "5" representing highly unpredictable. Obtaining the mean item score per subscale and summing the six subscale scores resulted in the perceived environmental uncertainty score. The conceptual definition of Miles and Snow's scale suggests that managers' perceptions of environmental uncertainty are determined by the predictability of various conditions in the organization's environment, which is consistent with Milliken's (1987) conceptualization of perceived environmental uncertainty outlined previously. As a result, the Miles and Snow scale of perceived environmental uncertainty addresses the inconsistencies in operational definitions and inappropriate conceptualizations of uncertainty found in other research (Buchko 1994).

Research utilizing Miles and Snow's perceived environmental uncertainty scale indicates that the scale is reliable (Buchko 1994; Hitt et al. 1982). Research by Buchko (1994), analyzing test-retest correlations with the criterion variable in his study, suggests that Miles and Snow's scale may not be stable over time. Buchko, however, indicates that market dynamics can change sufficiently between the times when measurements are taken to cause instability in the measurement (e.g., changes in financial lending markets).

Competitive rivalry (or competitive intensity) can be operationalized either through objective measures (e.g., geographical concentration ratio) or perceptual measures. Sharfman and Dean (1991) provide a detailed review of the arguments regarding the use of objective versus perceptual measures of competitive rivalry. Their review indicates that several researchers believe that managerial perceptions shape the nature of managerial choices. In fact, their review indicates that many researchers who espouse the use of objective measures of competitive rivalry tend to point out that managers often over-generalize events occurring in the market, thereby biasing the perceptions that form the basis of their decisions. In this study, it is assumed that perceptions of the competitiveness of the market impart a greater impact on a residential construction firm's choice behavior for innovative products than do objective measures. Hence, competitive rivalry is operationalized by perceptual rather than objective measures.

Several existing perceptual measures of competitive rivalry exist in the marketing literature. Lusch and Laczniak (1987), for instance, developed a three-item interval categorical scale (the competitive intensity scale) measuring the degree that an individual believes that firms in a particular industry will experience greater competition in some future time period. Lusch and Laczniak report a coefficient α of 0.71 for their scale, indicating that the scale is fairly reliable (DeVellis 1991). They do not, however, report on the validity of their scale. This scale can be readily modified so that it examines an individual's perception of competitive intensity in the past and/or present state of the market.

Atuahene-Gima (1995) developed a seven-item interval categorical scale measuring what he termed the intensity of market competition. This scale is unique in that it is used in the context of the introduction and use of new products. Atuahene-Gima reports a coefficient α of 0.83 for his scale, providing an indication that the scale is reliable. However, he fails to report on the validity of this scale.

This study uses a multi-item interval categorical competitive rivalry scale based on the survey respondents' perception of the current status of the residential construction market. The scale incorporates various aspects of the Lusch and Laczniak (1987) and Atuahene-Gima (1995) scales, and has been developed in part through consultation with several economists and marketing research experts. Field-testing of the competitive rivalry scale was also conducted prior to the assembly of the final survey instrument. The hypothesis concerning competitive rivalry and innovation adoption in this study indicates a curvilinear relationship. Curvilinearity is explored by employing quadratic transformation measures of the competitive rivalry parameter.

Several other independent variables, most being demographic in nature, are included in the analyses to determine if they have any explanatory effect on the dependent variables. These variables include percent of framing work that is subcontracted, percent of carpentry work that is subcontracted, number of years firm has operated in the residential construction industry, number of full time employees, number of part time employees, percent of revenue generated from single family construction activities, and 1999 sales revenue. Note that these demographic variables have been used in past research examining the residential construction industry, as well as other industries (e.g., Goldberg and Shepard 1989; Spall 1971).

Operationalization of Dependent Measure

As Kotler (1991) indicates, products can be described as product classes (e.g., solid dimension products, wood panel products, engineered wood products), product forms (e.g., wood I-beams, laminated veneer lumber, glulam), and brands (e.g., Louisiana-Pacific Corporation's TechShield™ radiant barrier oriented strandboard sheathing, Trus Joist's Parallam®). This study analyzes innovation with respect to product class and product form within the residential construction industry. The product class is, hereafter, referred to as engineered wood products, while product forms are referred to by their generalized industry vernacular names.

Researchers investigating innovation adoption are often criticized for utilizing analysis methods that focus on either single or multiple innovative products or processes (Bigoness and Perreault 1981). Critics of research focusing on the adoption of a single innovation cite that the adoption of the innovation may be idiosyncratic. As a result, the single innovation may not be a valid or reliable measure of innovativeness that can be generalized to a larger set of innovations or potential class of adopters. Critics of research involving the adoption of multiple innovations, which traditionally employ dependent measures based on summated indices of adopter innovativeness, argue that innovations should not be implicitly assumed to be homogeneous. In other words, multiple innovation studies are criticized because they implicitly assume that factors that affect the adoption of the innovations being studied are homogeneous.

Each of the preceding criticisms concerning the use of single or multiple innovation parameters is valid, but not necessarily in all research situations. As Bigoness and Perreault (1981, p. 73) point out, “a single product criterion of innovativeness is appropriate if one is concerned with identifying innovativeness only with respect to that highly specified content area. Alternatively, if a more general aspect of innovativeness is the subject of investigation, it is better to sample adoptions of multiple products or activities potentially representative of that content domain so that the reliability and validity of the innovativeness measure may be evaluated, and so that the homogeneity and representativeness of the items sampled may be appraised.”

Downs and Mohr (1976) criticize the use of summated indices of innovativeness based on the adoption of multiple products. They argue that summated indices ignore the variations in the characteristics of particular innovations and the influence that these variations may have on the adoption decision. Downs and Mohr’s point is well taken in the context of their particular study, which was a microanalysis focused on internal change within a specific organization. However, its validity is questionable in research that seeks to determine the factors influencing innovativeness within various industries or product classes (Bigoness and Perreault 1981). Industry studies of innovation are typically based on external reference sets and general content domains. Use of summated indices in this context provides a stronger basis to make deductive statements concerning the differences between innovation adopters and nonadopters.

This study follows Tornatzky and Klein’s (1982) recommendation concerning the use of a continuous dependent measure of product form innovativeness that, to some extent, accounts for the depth of innovation usage and time of adoption. The measure used in this study is a single-item ordinal scale composed of seven response categories first developed by Shook (1997). This scale, termed the product form innovativeness index, or PFII, provides for a continuous measure explaining the degree of implementation of the innovation that accounts for post adoption behavior. **Table 1** presents a representation of the PFII measure that is used in this study.

Table 1. Example of the product form innovativeness index (PFII) used in study.

Telephone Interviewer: *The following questions will ask you to define your company’s use of six different building products. These questions only apply to your product usage for single family construction.*	
Index Value	**Product Use Phrases**
1	Your company is not familiar with (product[a]) at all
2	Your company is familiar with (product) but has never considered using it
3	Your company has considered using (product) but has never used it
4	Your company has made a decision not to use (product)
5	Your company has used (product) but later stopped using it altogether
6	Your company is currently using (product) but only on a trial basi
7	Your company routinely uses (product)
[a] Products assessed included finger-jointed lumber, glue laminated beams, laminated veneer lumber, oriented strandboard, wood I-beams, and laminated strand lumber.	

In order to make an assessment of the general adoption for engineered wood products as a product category within the residential construction industry, a composite measure of the individual products is created. This composite measure utilizes the PFII measure described earlier. Specifically, the PFII measure for each product form is summed into a total engineered wood products product class innovativeness index, or PCII, which measures the breadth of engineered wood product use within residential construction firms. Use of a composite measure for assessing product category adoption in various industries is common. For example, Kimberly and Evanisko (1981) and West and Sinclair (1992) use summated indices of individual product adoption measures in their research covering the hospital furniture and wooden household furniture industries, respectively. The composite measure devised for this study, however, diverges from past innovation adoption research in that it is a composite of an ordinal scale; past studies using a composite measure to analyze product categories have simply summed the scores of dichotomous product adoption and nonadoption/rejection measures, which results in significantly less variance in the data relative to ordinal composites.

Model Types and Hypothesis Testing

Hypotheses are tested within the context of each of six engineered wood products as product forms (i.e., PFII analyses). In addition, the hypotheses are tested within the context of engineered wood products as a product class (i.e., PCII analysis). In order to test the hypotheses using an ordinal-scaled dependent measure of innovativeness that takes into account the implementation of the innovation being examined, a second-order multiple regression model is employed. Second-order multiple regression models are appropriate models to use in this study since they can model both the linear and quadratic effect components proposed in the hypotheses (Neter et al. 1989). Second-order multiple regression analyses are performed for each of the six engineered wood products (i.e., PFIIs), as well as for the engineered wood products PCII model. Each regression analysis is applied to the full set of variables in order to identify which of the estimated regression coefficients are significant and in support of the hypotheses regarding expected effects. Note that nonparametric statistical tests, such as the Mann-Whitney statistic and contingency tables, which are typical analytical methods used in categorical adoption/rejection studies, cannot be used in the current study since the dependent measure is ordinal in its construction (Agresti 1990).

The generic second-order regression model takes the following form:

$$Y_i = ß_0 + ß_1(\text{Competitive Rivalry}) + ß_2(\text{Competitive Rivalry})^2 + ß_3(\text{Environmental Uncertainty}) + ß_4(\text{Risk-Loss}) + ß_5(\text{Subcontracted Framing}) + ß_6(\text{Subcontracted Carpentry}) + ß_7(\text{Years in Industry}) + ß_8(\text{Full Time Employees}) + ß_9(\text{Part Time Employees}) + ß_{10}(\text{Revenue from Single Family Construction Activities}) + ß_{11}(\text{1999 Sales Revenue}) + \varepsilon_i$$

The value Y_i represents residential construction firm innovativeness with regard to engineered wood products adoption and implementation. Examination of the generic second-order regression model reveals that two of the independent variables appear as first- and second-order powers. Regression models utilizing variables with first- and second-order (or greater) powers will nearly always be highly correlated in the X and X^2 terms (Draper and Smith 1981). In order to reduce the multicollinearity effects resulting from the use of these two variables, each of the variables are expressed as a deviation from their respective means.

Sample Frame and Data Collection

The sample frame in this study consisted of single family residential builders located in the states of California, Oregon, and Washington. A sample frame of 130 residential builders was constructed using an electronic database supplied from the information services provider Dun & Bradstreet (cf. http://www.dnb.com/). The sample frame was first stratified based on state of operation; sample units were then randomly selected from the database from each state. A total of 58, 30, and 42 were selected from California, Oregon, and Washington, respectively, based on the size of the population within each state as reported by Dun & Bradstreet (population were reported by Dun & Bradstreet as California = 715, Oregon = 379, and Washington = 523).

Data in this study was collected through the use of a telephone survey during August 2000. The telephone survey was completed by either the purchasing manager or the owner of the participating firm. The owner of the residential construction firm was also the primary purchaser of building materials for over one-half of the study participants, which reflects the fact that most residential construction firms are small one to three person operations. A significant advantage of telephone surveys relative to mail surveys is that they can be conducted in rather short spans of time, thereby reducing the effects of time-related biasing factors (e.g., changes in interest rates). A secondary reason for using a telephone survey is due to the fact that they generally result in higher response rates than mail surveys (Dillman 1978). A commercial firm specializing in telephone surveys of the wood products and residential construction industries was contracted to conduct the telephone interviews. The script used to conduct the telephone interviews was constructed using conventional survey development methodology (Rea 1997). A final survey instrument was assembled using comments and suggestions from two dozen pretest participants prior to collecting any data from the sample frame.

Results and Discussion

Survey Response

A total 127 of 130 residential builders included in the sample frame were contacted after an average of three telephone call contacts. The failure to reach an individual after nine contact attempts were made resulted in three nonresponding firms. As such, the effective response rate to the telephone survey in this study was 97.7 percent. Once contacted, the telephone survey interview took approximately one hour to complete. The very small nonresponse rate (2.3 percent) did not make it statistically practical to assess nonresponse bias in this study.

Table 2 provides a demographic characterization of survey respondents. These results show that the average tenure in the residential construction industry of responding firms to be over 20 years. The average number of full-time employees per company was reported to be 12.8, and the number of part-time employees averaged 2.2. Companies indicated that they typically employed approximately two individuals that served in managerial positions; managerial employees activities included purchasing, scheduling, product specification, auditing, accounting, marketing, and/or selling. The majority of responding firms' gross sales revenue, 87.1 percent, was generated solely from single-family residential construction in 1999. Multi-family residential and nonresidential construction accounted for 3.3 percent and 9.1 percent, respectively, of responding firms' reported gross sales revenue for 1999.

Table 2. Demographic characterization of survey respondents.

Sample Frame Characteristics	Mean	Standard Deviation	Number of Respondents
Company tenure in residential construction industry (years)	20.12	14.63	127
Number of full-time employees in 1999	12.79	48.28	123
Number of part-time, seasonal, and temporary employees in 1999	2.22	3.59	120
Number of employees serving managerial functions[a]	2.44	7.04	120
Percent of all the framing and carpentry work involving union members	1.52	10.08	125
Percent of 1999 gross sales revenue generated solely from single family residential construction	87.07	22.20	126
Percent of 1999 gross sales revenue generated solely from multi-family residential construction	3.32	9.76	123
Percent of 1999 gross sales revenue generated from nonresidential construction	9.07	19.09	122
[a] Employees were classified as managers if any of their employment activities included purchasing, scheduling, product specification, auditing, accounting, marketing, or selling.			

Perceptions of Market Competition and Environmental Uncertainty

Table 3 reports the residential construction managers' perceptions of competitive rivalry within the residential construction market. Six of the seven scale items yielded mean responses significantly greater than the neutral response of 3, which indicates that respondents perceive a high level of competitive rivalry within the residential construction market. Respondents were in strong agreement that the market is extremely aggressive and competitive. Price competition was perceived as being intense. Product or service introductions and modifications were reported to be relatively frequent, and product quality was viewed as high among competing firms. Substitution among competitors' products and services was perceived to be high, while sales and promotion systems of competitors were viewed as strong. Survey respondents were statistically neutral, however, as to whether companies in the market would increase their marketing budget due to heightened competition. The neutrality in the assignment of the marketing budget suggests that firms may believe that increasing the marketing budget is not an effective means of offseting the effects of heightened market competition.

Table 3. Residential construction managers' perceptions of competitive rivalry in the industry.

Competitive Rivalry Scale Item	Mean[a,b,c]	Standard Deviation
The market is extremely aggressive and competitive	4.19	1.03
The market has intense price competition	3.97	1.13
The market experiences frequent product or service introductions and modifications	3.43	1.07
Competitors' products and services are very similar	3.61	1.14
Strong competitor sales and promotion systems exist in the market	3.43	1.04
Competitors' products and services are of high quality	3.37	1.16
Companies in the market will be spending more of each of their sales dollars on	3.20*	1.28

Companies in the market will be spending more of each of their sales dollars on marketing due to increasing competition	3.26	1.28
Cronbach's Coefficient Alpha	0.58	

[a] Each survey participant was asked to indicate the extent that each competitive rivalry scale item described the nature of their company's primary market using a Likert scale bounded by 1 (Strongly Disagree) and 5 (Strongly Agree) with a midpoint of 3 (Neutral).
[b] The sample size for each scale item was 124.
[c] The * symbol indicates that the mean is not significantly different than a neutral mean response of 3 (two-tailed one-sample *t*-test; 0.05 α-level; $p \leq 0.05$).

Environmental uncertainty perceived by survey respondents is reported in **Table 4**. Survey items regarding material suppliers included predictability of price changes, product quality or design changes, and the introduction of new products, all of which were found to be statistically equivalent to the neutral value of 3. Generally, the perception of predictability of competitors' actions again resulted in responses that were not significantly different than a neutral mean response; one exception was that survey respondents felt that changes in the price of final products by competitors was unpredictable. Customer demand for both new and existing residential homes showed significant degree of predictability by respondents. Finance and capital markets also showed a significant degree of predictability, with the exception of short-term credit, which was not significantly different from a neutral mean response. The predictability of government regulations showed a significant degree of unpredictability; the exception being changes in laws and policies concerning marketing practices, which was not significantly different than a neutral value of 3. The predictability of labor unions was not significantly different than a neutral response of 3.

Table 4. Residential construction managers' perceptions of environmental uncertainty in the industry.

Environmental Uncertainity Scale Item	Mean[a,b]	Standard Deviation	Number of Respondents
1. Predictability of Material Suppliers			
a. Material suppliers' price changes	3.07*	1.18	127
b. Material overall product quality changes	2.94*	0.99	127
c. Material suppliers' product design changes	2.97*	0.93	126
d. Material suppliers' introduction of new products	2.96*	1.04	126
Overall Subscale Mean	*2.99*	*1.04*	
2. Predictability of Competitors			
a. Competitors' price changes on final products	3.27	1.05	121
b. Competitors' overall product quality changes in construction	2.88*	0.90	120
c. Competitors' product design changes	2.96*	0.93	120
d. Competitors' introduction of new products in design and construction	2.87*	0.89	122
Overall Subscale Mean	*2.99*	*0.94*	
3. Predictability of Customers			
a. Customers' demand for existing residential homes	2.72	1.12	120
b. Customers' demand for new residential homes	2.50	1.22	126
Overall Subscale Mean	*2.61*	*1.17*	
4. Predictability of Finance and Capital Markets			

4. Predictability of Finance and Capital Markets			
a. Interest rate changes on lines of credit or other short-term debt	2.72	1.08	124
b. Interest rate changes on your long-term debt	2.50	1.03	124
c. Availability of short-term credit	2.63*	3.73	123
d. Availability of long-term credit	2.38	1.07	122
Overall Subscale Mean	*2.56*	*1.73*	
5. Predictability of Government Regulations			
a. Changes in laws and policies concerning the pricing of products and services	3.52	0.97	126
b. Changes in laws and policies concerning product standards and building codes	3.25	1.06	127
c. Changes in laws and policies concerning financial practices, including business tax issues	3.39	0.97	127
d. Changes in laws and policies concerning marketing practices	3.15*	0.88	124
e. Changes in laws and policies that affect suppliers	3.48	1.01	124
Overall Subscale Mean	*3.36*	*0.98*	
6. Predictability of Labor Unions			
a. Labor unions affecting changes in wages, hours, and working conditions in building construction trades	2.82*	0.95	96
b. Labor unions change their requirements in order to enhance their members' job security	2.86*	0.76	92
c. Labor unions affecting changes in grievance procedures in building construction trades	2.95*	0.66	91
Overall Subscale Mean	*2.88*	*0.79*	
Aggregate Mean for All Scale Items	*2.90*	*1.11*	
Cronbach's Coefficient Alpha	0.52		

[a] Each survey participant was asked to indicate they would rate each scale item based on its degree of predictability using an interval category scale bounded by 1 (Highly Predictable) and 5 (Highly Unpredictable) and containing a midpoint of 3 (Neutral).
[b] The * symbol indicates that the mean is not significantly different than a neutral mean response of 3 (two-tailed one-sample *t*-test; 0.05 α-level; $p \leq 0.05$). Overall subscale means were not tested.

Note that the Cronbach's α of 0.52 calculated for the environmental uncertainty scale was somewhat low relative to other studies where the scale has been utilized (e.g., Buchko 1994; Hitt et al. 1982). This result initially suggests that the scale may not be a reliable measure of environmental uncertainty within the context of the residential construction industry. Given that Cronbach's α assumes unidimensionality of the scale measure, however, this result may imply that environmental uncertainty is a multidimensional construct within the residential construction industry (Anderson and Gerbing 1982; Cronbach 1951).

Confirmatory factor analysis using the 22 items of the environmental uncertainty scale indicated that each of the items in each of the subscales grouped together, which indicates construct validity (Buchko 1994). Note that multidimensionality does not necessarily imply that the summated scales of subscales cannot or should not be used as a single independent variable (Buchko 1994; Miles and Snow 1978), especially when equal weighting of the subscales is desired. Also note that the highly fragmented nature of the residential construction industry may explain the low Cronbach's α value relative to past studies that have used the scale and have reported higher values. These past studies have focused on industries that are much more consolidated than the residential construction industry (Buchko 1994; Hitt et al. 1982; Miles and Snow 1978).

Survey respondents' perceptions of the probability of loss occurring due to various risks associated with adopting engineered wood products are reported in **Table 5**. These risks included financial loss, performance loss, physical loss, loss of reputation, and loss of time. In all cases, data analysis indicates that respondents felt that the likelihood of a loss associated with adopting engineered wood products was improbable, with the mean for each scale item being significantly less than the neutral value of 3. The Cronbach's α calculated for the loss probability scale was 0.86, which provides an indication that the scale is a reliable measure.

Table 5. Residential construction managers' perceptions of the probability of loss occurring due to various risks associated with adopting engineered wood product.

Risk Perception Scale Item Question	Mean[a,b]	Standard Deviation	Number of Respondents
What is the probability that the purchase of an engineered wood product as an alternative for solid wood would lead to a *financial loss* for your company because the engineered wood product would not meet your expectations because of cost?	2.28	1.15	120
What is the probability that the purchase of an engineered wood product as an alternative for solid wood would lead to a *performance loss* for your company because the engineered wood product would function poorly or would not meet your needs, desires, or expectations?	1.88	0.95	121
What is the probability that the purchase of an engineered wood product as an alternative for solid wood would lead to a *physical loss* for your company because the engineered wood product would not be very safe, or could become dangerous or harmful?	1.65	0.82	118
What is the probability that the purchase of an engineered wood product as an alternative for solid wood would lead to a *loss of reputation* for your company because other builders and contractors would think less highly of you?	1.57	1.00	122
What is the probability that the purchase of an engineered wood product as an alternative for solid wood would lead to a *loss of time* for your company because you would have to use time and effort to research the product in order to understand its proper use and installation?	1.79	1.01	121
Aggregate Mean for All Scale Items	*1.83*	*0.99*	
Cronbach's Coefficient Alpha	0.86		

[a] Each survey participant was asked to express the probability that they perceived that their company would experience a loss with reference to each scale item question using an interval category scale bounded by 1 (Extremely Improbable) and 5 (Extremely Probable) with a midpoint of 3 (Neutral).
[b] All means were significantly different than a neutral mean response of 3 (two-tailed one-sample t-test; 0.05 α-level; $p \leq 0.05$).

Engineered Wood Products Innovation Adoption

Results reported in **Table 6** indicate the degree of adoption of six engineered lumber products among responding firms. Glue laminated beams showed the highest degree of adoption, with 93 percent of firms routinely using the product. Wood I-beams, oriented strandboard, and laminated veneer lumber were also shown to have high rates of adoption, with 79.8, 75.2, and 75.2 percent of firms routinely using these products, respectively. Finger-jointed lumber and laminated strand lumber showed lower rates of adoption; more than 25 percent of responding firms reported never having used finger-jointed lumber and laminated strand lumber.

Table 6. Distribution of firms' degree of innovation adoption along seven response categories for six engineered wood products.

Product Form	Response Category[a,b]						
	1	2	3	4	5	6	7
Finger-jointed lumber	17 (14.3)	0 (0)	13 (10.9)	2 (1.7)	6 (5.0)	11 (8.7)	70 (58.8)
Glue laminated beams (glulam)	1 (0.8)	0 (0)	3 (2.4)	0 (0)	1 (0.8)	3 (2.4)	118 (93.6)
Laminated veneer lumber (LVL)	3 (2.5)	10 (8.3)	7 (5.8)	1 (0.8)	5 (4.1)	4 (3.3)	91 (75.2)
Oriented strandboard (OSB)	2 (1.6)	8 (6.4)	4 (3.2)	1 (0.8)	5 (4.1)	4 (3.3)	91 (75.2)
Wood I-beams (e.g., TJI's)	2 (1.6)	5 (4.0)	8 (6.5)	1 (0.8)	3 (2.4)	6 (4.8)	99 (79.8)
Laminated strand lumber (e.g., TimberStrand®)	3 (2.7)	13 (11.5)	12 (10.6)	3 (2.7)	3 (2.7)	8 (7.1)	71 (62.8)

[a] Ordinal product adoption scale utilized the following response categories: 1 = "not familiar at all with product," 2 = "our firm is familiar with product but has never considered using it," 3 = "our firm is considering using product but has never used it," 4 = "our firm has made a decision not to use product," 5 = "our firm has used product but later stopped using it altogether," 6 = "our firm is currently using product but only on a trial basis," and 7 = "our firm routinely uses product."
[b] Numbers in parentheses represent the percentage of respondents in each response category.

Bivariate correlation coefficients for the degree of adoption among various engineered wood products are reported in **Table 7**. The correlations of the degree of adoption reported for finger-jointed lumber, wood I-beams, and laminated strand lumber were found to be highly significant (p-value ≤ 0.01). Substantial statistical significance was also found between the degree of adoption for wood I-beams and glulam (p-value ≤ 0.01). The degree of adoption for finger-jointed lumber was significantly correlated with oriented strandboard, as was the degree of adoption between wood I-beams and laminated veneer lumber (p-value ≤ 0.05).

Table 7. Bivariate correlation of residential builders' use of various engineered wood products.

Engineered Wood Product Form	Kendall's tau-*b* Bivariate Correlation Coefficients (two-tailed)[a]					
	Finger-jointed lumber	Glulam	LVL	OSB	Wood I-beams	LSL
Finger-jointed lumber	1.00					
Glue laminated beams (glulam)	0.232*	1.000				
Laminated veneer lumber (LVL)	0.182	0.131	1.000			
Oriented strandboard (OSB)	0.188*	0.123	0.027	1.000		
Wood I-beams	0.254**	0.233**	0.211*	−0.018	1.000	

Wood I-beams	0.254	0.233	0.211	0.018	1.000	
Laminated strand lumber (LSL)	0.322**	0.174	0.168	−0.088	0.549**	1.000
** Kendall's tau-*b* bivariate correlation is significant at 0.01 α-level (two-tailed test). * Kendall's tau-*b* bivariate correlation is significant at 0.05 α-level (two-tailed test). [a] Sample size for individual cell bivariate correlations ranged from 111 to 124.						

Hypothesis Testing

The hypothesis that residential construction firm adoption of innovative wood-based products is greater for firms that perceive low levels of environmental uncertainty relative to those firms that perceive high levels of environmental uncertainty (H_1) was assessed using regression analysis results presented in **Table 8** (i.e., β_3). The continuous innovation adoption measure, when assessed at each of the six product form levels and at the product class level, was not found to be significantly affected by respondents' perceptions of environmental uncertainty, leading us to reject the hypothesis. Note, however, that the sign of the coefficients for five of the six product forms along the environmental uncertainty parameter was positive, as was that for the product class.

The hypothesis that the degree of innovative wood-based product adoption in the residential construction industry is greater for firms that perceive the competitive rivalry of the industry to be either high or low on a unidimensional competitive rivalry scale (H_{2a}) was also assessed using the regression analysis results reported in **Table 8** (i.e., β_1 and β_2). Competitive rivalry was not found to be significant in either a linear or nonlinear context for any of the six engineered wood product forms or for the engineered wood products class, leading us to reject the hypothesis.

In order to test Spall's (1971) hypothesis that firm perception of the competitive rivalry in the residential construction industry is greater among newer firms than older, more established firms, the survey responses for the industry tenure variable were dichotomously dummy-coded into new and old firms using a variety of split points.(4) Analysis of variance was then used to assess differences in responses to seven competitive rivalry questions (**Table 3**). Regardless of the split point used to delineate between new firms from old firms, ANOVA results consistently indicated that there were no statistically significant differences in perceptions of competitive rivalry between new and old residential construction firms. The ANOVA results lead us to reject Spall's hypothesis concerning perceptions of competitive rivalry.

(4) Split points in the ANOVA analysis were based on firm tenure in the industry. Deviations between new and old firms were based on median, mean, and first/fourth quartile splits.

Table 8. Unstandarized ß estimates of second-order regression models used to test hypotheses.

Independent Variables	Unstandardized ß Estimates of Second-order Regression Models[a,b]						
	Product Forms						Product Class
	Finger-jointed lumber	Glulam	LVL	OSB	Wood I-beams	LSL	Engineered wood

	lumber						products
Regression Constant ($ß_0$)	5.139 (5.845) [0.383]	3.858 (2.274) [0.095]	8.185 (5.185) [0.120]	3.337 (4.149) [0.425]	6.571 (4.478) [0.148]	6.964 (5.125) [0.180]	34.286 (17.707) [0.058]
Competitive Rivalry ($ß_1$)	−0.019 (0.409) [0.963]	0.086 (0.172) [0.620]	−0.119 (0.371) [0.751]	0.137 (0.311) [0.661]	−0.156 (0.337) [0.645]	−0.150 (0.358) [0.677]	−0.0607 (1.243) [0.961]
Competive Rivalry² ($ß_2$)	−0.0029 (0.057) [0.960]	−0.0074 (0.024) [0.759]	0.0174 (0.052) [0.738]	−0.0716 (0.043) [0.869]	0.0204 (0.047) [0.665]	0.0160 (0.050) [0.751]	0.0069 (0.174) [0.968]
Environmental Uncertainty ($ß_3$)	0.0073 (0.033) [0.826]	0.0192 (0.014) [0.171]	0.0015 (0.033) [0.963]	−0.0162 (0.025) [0.521]	0.0165 (0.082) [0.544]	0.0270 (0.032) [0.395]	0.0289 (0.109) [0.792]
Risk-Loss ($ß_4$)	−0.0185 (0.074) [0.803]	−0.0491 (0.031) [0.124]	0.0282 (0.067) [0.677]	0.0583 (0.056) [0.301]	−0.0122 (0.060) [0.841]	−0.0663 (0.065) [0.314]	−0.0392 (0.225) [0.863]
Subcontracted Framing ($ß_5$)	−0.286 (0.607) [0.639]	**−0.568** (0.256) [0.031]	−0.056 (0.555) [0.920]	0.527 (0.468) [0.264]	−0.753 (0.506) [0.142]	−0.490 (0.529) [0.359]	−1.667 (1.833) [0.367]
Subcontracted Carpentry ($ß_6$)	0.230 (0.602) [0.703]	**0.590** (0.257) [0.025]	0.109 (0.552) [0.844]	−0.470 (0.468) [0.320]	0.506 (0.560) [0.321]	0.122 (0.523) [0.817]	0.955 (1.807) [0.600]
Years in Industry ($ß_7$)	0.0104 (0.021) [0.623]	−0.0006 (0.009) [0.944]	**−0.0344** (0.020) [0.084]	0.0249 (0.016) [0.132]	0.0029 (0.018) [0.869]	−0.0009 (0.018) [0.959]	−0.0039 (0.063) [0.950]
Full Time Employees ($ß_8$)	0.0034 (0.022) [0.879]	0.0002 (0.009) [0.977]	−0.0109 (0.020) [0.594]	**−0.0281** (0.016) [0.089]	−0.0051 (0.018) [0.775]	−0.0073 (0.019) [0.706]	−0.0556 (0.067) [0.408]
Part Time Employees ($ß_9$)	0.0056 (0.094) [0.952]	**−0.0655** (0.034) [0.061]	0.140 (0.087) [0.112]	0.0775 (0.062) [0.218]	−0.0042 (0.067) [0.951]	0.0027 (0.081) [0.974]	0.146 (0.281) [0.606]
Single Family Revenue ($ß_{10}$)	−0.0126 (0.014) [0.929]	0.0037 (0.006) [0.517]	−1.7280 (0.012) [0.890]	−0.0084 (0.010) [0.415]	−0.0001 (0.011) [0.990]	−0.0005 (0.012) [0.969]	−0.0048 (0.043) [0.911]
1999 Sales Revenue ($ß_{11}$)	0.187 (0.218) [0.395]	0.134 (0.094) [0.161]	−0.188 (0.203) [0.357]	0.181 (0.169) [0.289]	0.306 (0.184) [0.101]	0.281 (0.192) [0.151]	1.076 (0.666) [0.112]
F-value	0.221	2.067	0.815	1.317	0.596	0.892	0.408
p-value	[0.995]	[0.038]	[0.625]	[0.239]	[0.824]	[0.554]	[0.946]
R^2	0.043	0.289	0.140	0.203	0.105	0.159	0.081

[a] An associated standard error and *p*-value for each ß estimate is provided in parentheses and brackets, respectively.
[b] Bolded ß estimates were significant at $\alpha \leq 0.10$.

Conclusion and Limitations

Understanding the factors affecting engineered wood product adoption is critical for the development and execution of effective and efficient marketing strategies (both industry-wide and at the firm level) and forms the basis of any promotional strategy aimed at generating product awareness and increasing product acceptance within the residential construction industry. The results of this research provide evidence that factors directly related to uncertainty perceptions among residential builders are not statistically significant in influencing their adoption of engineered wood products. Furthermore, builder perceptions of competitive rivalry appear to have no correlation to innovation adoption behavior for engineered wood products. These findings run counter to a general industry mindset that perceives that uncertainty affects the adoption of innovative materials in the residential construction industry (Industry Canada 1999; Civil Engineering Research Foundation 1996; NAHB Research Center 1991; Goldberg and Shepard 1989; Tatum 1989, 1986; U.S. Congress – Office of Technology Assessment 1986).

Results of this study also coincide with an interesting proposition put forth by Ventre (1980). Ventre hypothesizes that innovative material adoption in residential construction is not related to the competitive environment of the firm. Instead, Ventre suggests that the dispersal of power and responsibility among the many actors of the residential construction industry (e.g., product manufacturers, distributors, regulators, builders, home buyers) prohibits any one actor from securing enough resources or power to redirect the system toward systematic innovative adoption processes. In other words, a pluralistic system exists in the residential construction industry to address and mitigate the resistance of innovation adoption among some industry actors among a very large pool of actors. This mitigation results in slowing the rate at which some innovations are adopted within the industry.

As with any cross-sectional, survey-based study, limitations exist in this study. First, the results reported here were formed on the basis of a sample of respondents located on the West Coast states of Washington, Oregon, and California. The industry structure and product adoption practices of the residential construction industry on the West Coast may not be representative of the U.S. as a whole. For example, it is known that residential construction firms have been quicker to adopt wood I-beams than their counterparts in the U.S. South, while the U.S. South has been faster to adopt various engineered panel technologies than the U.S. West (R.E. Taylor & Associates, Ltd. 1999). Therefore, we recommend that future research on competitive rivalry and environmental uncertainty effects on product adoption in the residential construction industry should be expanded to cover more than one geographical region of the U.S.

Second, the measurement scales used to assess builders' perceptions of uncertainty and competitive rivalry may not be capturing the true nature of these latent variables within the residential construction industry. The scales used to measure these two variables were chosen based on their past use in academic research and their reported validity and reliability. However, there is a possibility that the structure of the residential construction industry is so unique and fragmented that the measurement scales do not capture the dimensions of the residential construction industry within the U.S.

Third, study participants indicated that they routinely use several of the engineered wood products investigated in this study. This suggests that the engineered wood products examined are not necessarily "new" or applicable for study as innovative products. Note that the degree of adoption for or routine use of an engineered wood product does not necessarily correlate with volume of material used in appropriate end use applications. A routine use response, for instance, may mean that the study participant used the product only a few times during the preceding year and would not hesitate to use it again. However, the product could have been used many more times but the builder decided to use a substitute product instead. This is often the case with wood I-beams used in short span applications; when the price of solid 2x10 and 2x12 lumber decreases, many builders often switch from I-beams to solid lumber for short span applications. A builder practicing such switching behavior could indicate routine use of I-beams in the survey, but they may not be using the product in all end use applications when it would be appropriate. We suggest that future studies similar to this should include very new products as products for investigation. Additionally, alternative measures of adoption should be considered that factor in the effect of volume of material used relative to substitutes in particular end use applications so as to more closely reflect true “routine use” behavior.

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