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FACTORS THAT INFLUENCE THE REJECTION OF NEW MANUFACTURING TECHNOLOGIES AND CONCEPTS

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ABSTRACT

New manufacturing technologies or concepts often are adopted to improve a firm's competitive advantage over other firms in the same industry. The benefits that a firm expects to receive as a result of that adoption are presumed to outweigh the risk factors that accompany the adoption of a new manufacturing technology. Much research has been conducted to characterize firms that adopt new technologies early in the technology's life cycle and to identify the expected benefits that most significantly affect a firm's decision to adopt a new technology or concept. However, very little research has been conducted to identify the risk factors that most significantly affect a firm's decision to reject a new technology or concept. Identification of those factors should be particularly important to developers of and proponents of new processing technologies, methods, and strategies.

We proposed nine risk factors associated with technologies and analyzed their impact on the rejection decision by applying a multinomial logit model to a sample of wood products firms in the south-central United States. The proposed risk factors were irreversibility, difficulty of modification, incompatibility, incommunicability, time to implementation, time to realization, non-trialability, discontinuity, and indivisibility. The model also included four characteristics of firms that are regularly cited in technology adoption studies. Overall, the factors seemed to explain rejection behavior well. Results suggest that risk factors associated with the technologies are more important than characteristics of the firm when considering the rejection of a technology. Difficulty of modification and incompatibility had the most significant impact on the rejection decision.

INTRODUCTION

Investigations into the reasons why firms adopt certain technologies span a variety of disciplines from agricultural economics to psychology and sociology to marketing. Technology adoption studies often consider the decision whether to adopt a new technology as dichotomous (Feder and Slade 1984; Rahm and Huffman 1984; Wozniak 1984; Harper et al. 1990; McIntosh et at 1990; Lin 1991; Baker 1992; Saha et al. 1994). In these studies, the decision process can result in one of two outcomes: either adopt or do not adopt the technology. These studies typically have one of two goals: 1) to characterize firms that are recognized as early adopters of certain technologies. or 2) to identify the benefits that firms expect to receive ,\S a result of adopting anew technology.

Studies have been conducted to characterize "innovative" firms or firms that tend to adopt new technologies early in the technologies life-cycles (e.g., Kimberly and Evanisko 1981; Feder and Slade 1984; Rahm and Huffman 1984; Wozniak

1984; Robertson and Gatignon 1986; Harper et al. 1990; McIntosh et al. 1990; Lin 1991; Baker 1992; Saba et al. 1994). These studies often focus on characteristics of adopting firms, primary decision makers within adopting firms, the industry supplying the technology, and the industry of the adopting firm. However, these identified characteristics may reflect the marketing strategies of the developers of the technologies. Robertson and Gatignon (1986) warn that "research which discovers that innovators are, for example, large firms may only be confirming the market segment selection practice of the marketer."

Knowing the characteristics of early adopters does not necessarily provide a great deal of information regarding why firms adopt certain technologies. For each technology considered, there are forces pushing toward adoption of that technology and forces pushing toward rejection of the technology. Forces pushing toward adoption of a new technology are primarily benefits expected to be gained. In many cases, the adoption and implementation of new technologies are expected to yield some competitive advantage, especially if the adopting firm is among the first in the industry to adopt (Besley and Case 1993; Stenbacka and Tombak 1994). A set of expected benefits that firms seek by adopting new technologies is given in Appendix A. This list is not exhaustive, but it reflects those benefits that are cited most often in empirical studies of technology adoption.

Many of the studies of expected benefits imply that these are the only issues considered in the technology adoption decision. This paper takes the approach that there are other factors that lead to the rejection of technol*ogy* and that these factors are not the obverse of the benefits listed in Appendix A. Our hypothesis is that reasons for rejecting a technology are more concerned with characteristics of the technology itself, rather than the characteristics of the firm, decision-maker, or competitive environment. Also, we hypothesize that forces that push a firm toward rejection of a technology are not the opposite of forces that push a firm toward adoption of that technology.

FORCE FIELD ANALYSIS

As a firm progresses through the technology adoption decision process, it encounters forces that push towards technology adoption and forces that push against technology adoption. The strengths of these forces determine a firm's position along a technology adoption continuum (Figure 1). These forces contribute varying amounts of influence during different phases of the decision process.

As mentioned earlier, forces that push toward technology adoption are, for the most part, benefits that a firm expects to receive as a result of adopting the technology. These forces are well researched and abundant in the current literature (see Appendix A). Forces that push toward technology rejection mainly consist of risk factors associated with adopting and implementing the new technology. Much of the adoption literature suggests that it is the lack of benefits that leads to non-adoption and does not consider that there may be risk factors that simply outweigh the expected benefits. At best, risk factors are typically aggregated into a single cost category or into a regulatory compliance category (e.g., Lefebvre et al. 1991; King and Ramamurthy 1992; Moore 1994; Parente and Prescott 1994). However, this gives very little insight into factors that contribute to the rejection of new technologies. Therefore, the objective of this study was *to identify factors that influence the rejection of new technologies and manufacturing concepts and to describe their effects on the technology rejection decision.*

In the following sections of this paper, the factors that were proposed as influencing the rejection of new technologies are presented and their expected effects on adoption resistance are discussed. A brief overview of data collection methods is given, followed by two models of rejection behavior. The first is a binary reject/ do not reject model, and the second is a tertiary reject/neutral/adopt model. The resulting significant factors are discussed and implications for industry are proposed.

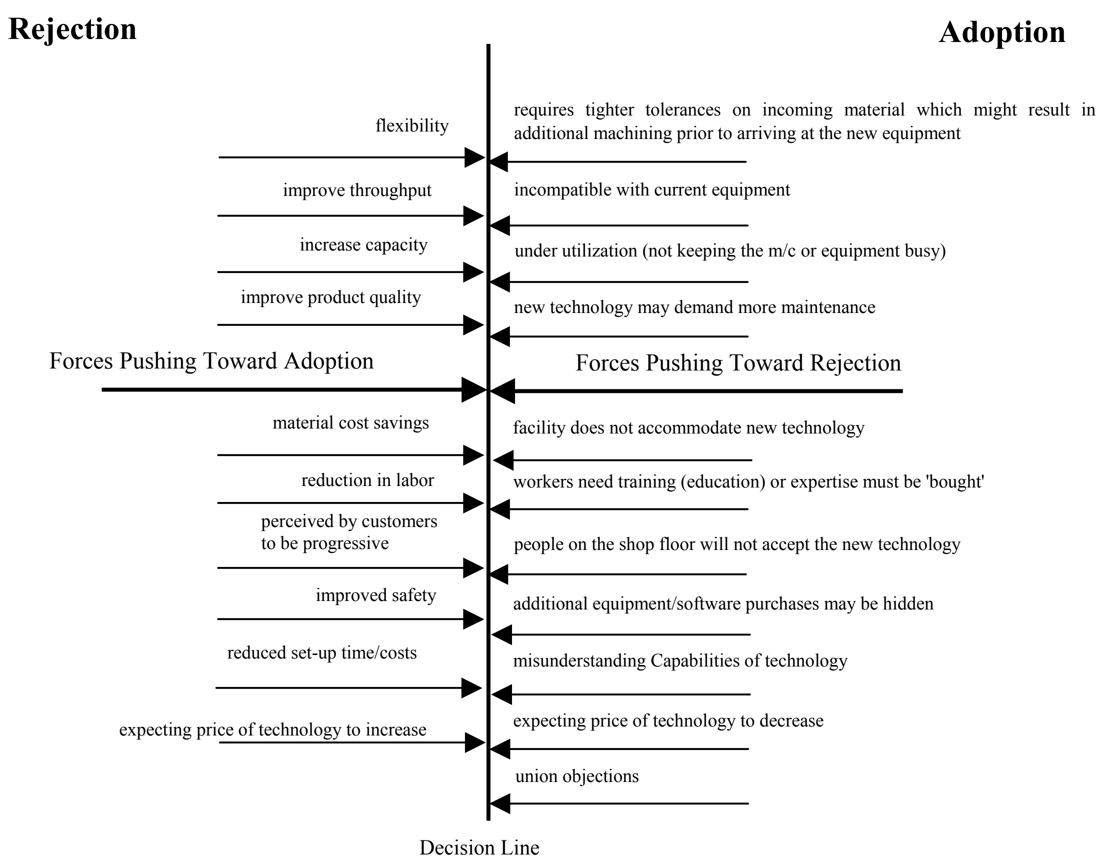

Figure I. Technology adoption continuum.

PROPOSED RISK FACTORS

At the outset, the proposed nine forces or risk factors that were expected to push toward technology rejection were incompatibility, discontinuity, non-trialability, indivisibility, incommunicability, time to implementation, time to realization; difficulty of modification, and irreversibility, Each of these factors is a characteristic of the technology being considered. An extensive review of adoption literature revealed that characteristics of the technology rarely are considered in technology adoption studies. The set of risk factors proposed here is based largely on propositions posed (but untested) by various authors in the current literature with an emphasis on Ram's (1987) work. The set was supplemented by factors identified during conversations held between the researcher and various wood products plant managers and owners (primarily in Virginia and North Carolina).

Here, each risk factor is defined and the expected effect of that factor on the rejection decision described.

Incompatibility refers to the degree of inconsistency of the considered technology with the operation of the current production and management systems. It was expected that as incompatibility increased, the probability of rejection would increase.

Discontinuity refers to the degree of disruptive influence initial implementation of a new technology will have on the current system. It was expected that increases in discontinuity would increase the probability Of rejection.

Non-trialability reflects the degree of difficulty in trying a new technology before acquisition and adoption. Because pre-acquisition test runs may reduce the risk of investing in new programs, equipment, and processing options, it was expected that increased non-trialability would increase the probability of rejection.

Indivisibility pertains to the degree of difficulty in adopting or implementing a technology in stages. Implementing a new technology in stages often allows one group of users to become familiar with the technology before other groups of users in the firm: This pilot group may uncover unexpected implementation problems and find ways to facilitate the implementation of the technology. In addition, they may be able to assist the next group of users in learning the technology and becoming familiar with it. So, if a technology may be implemented in stages, implementation and acceptance of the technology may be facilitated and the risk of overwhelming the entire firm at once may be reduced. It was expected that increased indivisibility would increase adoption resistance and the probability of rejection.

Incommunicability relates to the degree to which a technology's attributes or benefits are incapable of being communicated to potential adopters. Because the benefits of a technology are the primary driving force behind technology adoption decisions, it seems likely that the degree to which those benefits can or cannot be communicated may impact not only the adoption decision, but also the rejection decision. A firm may be unlikely to adopt a technology, even if the technology's benefits match perfectly with the firm's needs, if the firm does not know what the benefits are. Thus, it was expected that as incommunicability increased, the probability of rejection would increase.

Time to implementation is the expected length of time between the time that the decision to acquire the technology is made and the time that the technology is fully implemented. This would include time required by the technology supplier to produce and deliver the technology. If a piece of equipment cannot be delivered to a facility within a reasonable time frame, a firm may be less likely to acquire and adopt that technology. If that equipment requires an additional, extended implementation period, then likelihood of acquisition would seem even less likely. It was expected that as time to implementation increases, the likelihood of rejection increases.

Time to realization is the expected length of time from when the technology is fully implemented until the firm begins to realize benefits from that technology. Because many firms still rely on payback period as one means of justifying capital expenditures, it was expected that as time to realization increased, the probability of rejection would increase.

Difficulty of modification is the degree of difficulty associated with modifying a technology to meet a firm's specifications. Software packages are prime examples of this factor. If a software package cannot be modified to produce the information a firm desires, then the probability of adopting that package would likely drop significantly. This notion extends to other technologies. It was expected that increased difficulty of modification would increase the probability of rejection.

Irreversibility concerns the lack of the option of being able to discontinue adoption of the technology if so desired. Occasionally, investment in a particular technology may consume such a large portion of a firm's resources that if the decision is made to proceed with this investment, then there is no backing out of the decision; the technology must be made to work. Because of the risk associated with this type of technological investment, it was expected that as irreversibility increased, the probability of rejection would increase.

ADDITIONAL FACTORS CONSIDERED

Four additional factors were considered in modeling the technology rejection question: technical progressiveness, satisfaction with past experiences in adopting new technologies, firm size, and technical expertise within the firm. These four factors reflect characteristics of the firm and are based on results of past surveys of various industries.

Technical progressiveness is the degree to which a firm is committed to an innovative strategy within manufacturing. This was measured through questions regarding the importance of developing technical expertise and the firm's willingness to support experimentation with new processing equipment. In earlier studies, increased technical progressiveness characterized innovative firms (West 1990). It was proposed that low technical progressiveness would be associated with an increased likelihood of rejection of all technologies.

Satisfaction with past experiences relates to the biasing influence of past experience that a firm brings to a decision-making activity. It was proposed that lower levels of satisfaction with new technologies in the past would be associated with higher adoption resistance levels.

In this study, **firm size** indicates the number of full-time employees working for a firm. Larger firms may have better access to capital for investment in technologies (Kimberly and Evanisko 1981; Meredith 1987; Baker1992). So, firm size was treated as a surrogate measure for capital resources. It was expected that smaller firms would have higher adoption resistance levels. It was proposed that as firm size decreased, the probability of rejection would increase.

Technical expertise was measured by the number of engineers hired by a firm. Engineers often can understand the complexities of new technologies and thus, reduce the risks associated with adopting and implementing them (West and Sinclair 1992). Because this factor was found to be characteristic of innovative firms (West 1990), it was expected that lower levels of technical expertise would be associated with higher adoption resistance levels.

DATA COLLECTION

To determine if the factors described above influenced technology rejection as expected, firms were surveyed on these factors as they relate to a set of six different technologies. Development of the set of technologies. was accomplished through 1) focus group meetings with members of the Oklahoma Wood Manufacturers Association and the Agricultural Extension Service of Oklahoma, 2) reviews of studies identifying frequently used wood processing equipment in Louisiana (Vlosky 1996), and Ohio, Kentucky, and West Virginia (Bumgardner 1995), and 3) a review of "innovative" wood processing technologies identified by West (1990). The final set of six technologies was comprised of CNC machining, water-based finishes, thin saw kerf technology, self-managed/cross-functional work teams, statistical process control, and personal computer (pc)-based process control.

Data were collected through a mailed questionnaire administered to a. sample of 665 wood products firms in Arkansas, Louisiana, Mississippi, Oklahoma, and Texas. Finns surveyed were identified on a purchased mailing list as being classified under the Standard Industry Classifications 2511, 2517, 2521, and 2541.[1] All correspondence was addressed to the primary decision maker within the company (president or plant manager) using the proper name supplied on the list. If a proper name was not supplied, correspondence was addressed to the vice-president of manufacturing.

[1]SIC 2511 - Wood household furniture; SIC 2517 - Wood TV, radio, phono and sewing cabinets; SIC 2521 Wood office furniture; SIC 2541 - Wood office and store fixtures.

After adjusting for undeliverables and out-of-business firms, and considering usable surveys only, the response rate was 15% (82 o\],t of 554). Most responding firms were small as indicated by a median number of 9.25 employees. Because of the low response rate, tests for non-response bias were conducted on firm size, number of production employees, number of engineers, firm age, and number of technologies adopted. The number of technologies adopted was the only measure to indicate that non-response bias might exist. Significant differences were detected between the average number of technologies adopted by early and late respondents. Late respondents adopted fewer technologies on average ($p = 0.031$). Since later respondents did not seem to be aware of many of the six technologies, the bias was not believed to have a significant impact on the study.

The questionnaire requested information on the firm's perceptions of each of the four rum characteristics and the nine risk factors as they related to six different technologies. Firms indicated their responses through the use of Likert-type scales. Respondents were asked to provide information only for those technologies of which they were aware. Each firm also was asked to provide information that was translated into a technology adoption resistance level for each technology. Five adoption resistance levels were used: rejection, undecided but leaning to rejection, undecided, undecided but leaning to adoption, and adoption. If a firm had adopted a technology and had already disposed of that technology, the adoption resistance level was considered to be rejection.

BINARY CHOICE LOGIT MODEL

For this phase of the research, a binary model was developed to test the expected effects of each of the variables. The dependent or response variable was the categorical variable *rejecter/non-rejecter.* Firms were categorized as either a rejecter or a non-rejecter of the technology based on adoption resistance levels. Firms that had rejected a technology or were leaning to rejecting the technology were grouped in the rejecter category, and all other firms were considered non-rejecters. Binary response variables (e.g., reject, do not reject) are- often analyzed using logistic regression analysis to investigate the relationship between response probability and the explanatory variables (factors) (SAS 1989b). This model has been used in adoption studies where the two responses are 1) adoption and 2) non-adoption (e.g., Feder and Slade 1984; Wozniak 1984; Gatignon and Robertson 1989; Harper et al. 1990; Baker 1992).

The independent variables consisted of the risk factors and firm characteristics discussed earlier. The model (binary choice logit model) could be expressed as:

$$P(Y_{im}=1)=\frac{e^{\{B_o+\sum_j \beta_j x_{ij}\}}}{1+e^{\{B_o+\sum_j \beta_j x_{ij}\}}}$$

where:

Y_{im} = the rejection variable for organization i with respect to technology m (response 1 of Y_{im} corresponds to rejection and response 0 corresponds to non-rejection of technology m)

x_{i1} = technical progressiveness.1 of firm i,

x_{i2} = technical progressiveness.2 of fino i,

x_{i3} = firm i's satisfaction with past experience,

x_{i4} = firm i's size,

x_{i5} = firm i's technical expertise,

x_{i6} = firm i's perception of incommunicability of technology m,

x_{i7} = firm i's perception of non-trial ability of technology m,

x_{i8} = firm i's perception of discontinuity of technology m,

x_{i9} = firm i's perception of incompatibility of technology m,
x_{i10} = firm i's perception of irreversibility of technology m, .
x_{i11} = firm i's perception of time to implementation of technology m,
x_{i12} = firm i's perception of time to realization of technology m,
x_{i13} = firm i's perception of difficulty of modification of technology m, and
x_{i14} = firm i's perception of indivisibility of technology m.

The β coefficients were estimated by maximizing the log likelihood function using the Newton Raphson iterative method (McFadden 1974; SAS Institute Inc. 1989a).

For this model. a positive estimated coefficient would imply that a higher level of the associated factor would increase the probability of rejecting the technology and decrease the probability of not rejecting it. A negative estimated coefficient implies that a higher level of the factor decreases the probability of rejection and increases the probability of non-rejection.

Since collinearity is a concern in logistic regression analysis, Pearson's correlations were calculated for each pair of the 14 variables. The Pearson correlation coefficients ranged in magnitude from 0.00 to 0.19. Since correlation was generally low, collinearity was not believed to have a significant impact on the study.

The results of the model are given in Table 1. The benchmark level was non-rejection.

Two factors that produced significant effects at the $\alpha = 0.01$ level are incompatibility and difficulty of modification. Both factors have positive coefficients. The positive coefficient estimated for incompatibility suggests that higher incompatibility increases the probability of rejection while decreasing the probability of non-rejection. Likewise, the positive coefficient estimated for difficulty of modification implies that increased difficulty

Table 1. Results of the binomial logit model.

Effect	β Coefficient Estimate	p.,value
Intercept ,	-0.7511	0.4377
Technical progressiveness -1	**-0.6889**	**0.1422** *
Technical progressiveness-2	-0.3833	0.6981
Satisfaction with past experiences	-0.6105	0.2634
Firm size	**-6.5617**	**0.1101 ***
Technical expertise	**6.3932**	**0.1171 ***
Incommunicability	-0.6112	0.3025
N on-trial ability	-0.4131	0.4719
Discontinuity	-0.1887	0.4531
Incompatibility	**3.7340**	**0.0000** **
Irreversibility	0.3416	0.4324
Time to implementation	-0.2539	0.4168
Time to realization	0.1311	0.6605
Difficulty of modification	**1.1560**	**0.0042** **
Indivisibility	0.1300	0.7752

*Significant at the a = 0.15 level
**Significant at the a = 0.01 level

in modifying a technology to work within a particular manufacturing environment increases the chance of rejection and decreases the chance of non-rejection.

Three other factors that produced significant effects at the $\alpha = 0.15$ level are technical progressiveness, firm size, and technical expertise-all considered firm characteristics. Technical progressiveness and firm size have negative estimated coefficients. As expected, increased technical progressiveness seems to decrease the likelihood of rejection and increase the probability of non-rejection. As also expected, larger firm size seems to decrease the probability of rejection and increase the probability of non-rejection. The surprise finding in this study focuses on technical expertise. From the data gathered in this research, it seems that higher levels of technical expertise (a higher number of engineers employed by the firm) increase the probability of rejection and decrease the probability of non-rejection.

MULTIPLE CHOICE LOGIT MODEL

The multiple choice extension of the binary model can be used to evaluate how well a set of factors predicts the response variable when the number of possible outcomes is greater than two (McFadden 1974; Gatignon and Robertson 1989; Hanneman 1997). The multiple choice logit model (multinomial logit model) has been used in an exploratory work on adoption/rejection behavior by Gatignon and Robertson (1989). It has also been used to predict extent of computer adoption and use by Baker (1992). In this research, a multiple choice logit model was designed to determine if the same factors that affect rejection influence adoption. The multiple choice logit model can be expressed as

$$P_{ij} = P(D_i = j \mid X_i) = \frac{e^{\{\beta_{oj} + X_i \beta j\}}}{\sum_k e^{\{\beta_{ok} + X_i \beta_k\}}}$$

where:

P_{ij} = probability that firm i belongs to category j,
j € {I = neutral; 2 = rejecter; 3 = adopter},
D_I = response state of firm i,
X_I = vector of variables (factors) Xii through Xi14 defined earlier for firm i,
β_j = vector of coefficients representing the marginal utilities of each of the independent variables for category j ,
β_{01} = 0,[2]and
β_I = 0.[3]

To get a full picture of the effects of each variable, the multinomial logit analysis should be conducted twice with different adoption/rejection categories as the benchmark for each analysis. For the first analysis, the neutral position is the benchmark category (or adoption resistance level) and in the second analysis, rejection is the benchmark category.

By using the neutral category as the benchmark, it is possible to get an indication of whether the factors that affect rejection also affect adoption. The results of the multinomial analysis are given in Table 2.

Incompatibility and technical expertise produced significant effects with respect to both rejection and adoption. The negative coefficient estimated for incompatibility when evaluating the probability of adoption of a technology

[2,3] Assumes that the benchmark category is neutral (j = 1).

Table 2. Multinomial logit analysis results with neutral as the benchmark.

	Adoption		Rejection	
Factor	Coefficient'	p-value	Coefficient	p-value
Technical progressiveness	-0.1134	0.8391	-0.6639	0.2010
Technical progressiveness.2	0.0495	0.9502	-0.3206	0.7711
Satisfaction with past experience	0.5683	0.3744	-0.4256	0.4642
Firm size	-6.7795	0.1460	**-9.5212**	**0.0561 ***
Technical expertise	**13.3562**	**0.0168 ** **	**14.9701**	**0.0096 *****
Incommunicability	-0.4857	0.4658	-0.9872	0.1322
Non-trialability	.,0.5509	0.4197	-0.7908	0.2235
Discontinuity	-0.4542	0.1032	-0.3890	0.1668
Incompatibility	**-2.4563**	**0.0060 *****	**3.0905**	**0.0001 *****
Irreversibility	0.7415	0.1342	0.7813	0.1119
Time to implementation	0.4476	0.2371	-0.1455	0.6628
Time to realization	-0.5377	0.1386	-0.0508	0.8741
Difficulty of modification	**-1.4857**	**0.0032 *****	0.6681	0.1340
Indivisibility	0.7004	0.1751	0.5288	0.3239

*Significant at the α= 0.10 level
**Significant at the α = 0.05 level
***Significant at the α= 0.01 level

relative to the probability of a neutral attitude toward the technology implies that the probability of adoption decreases relative to the probability of a neutral position as incompatibility increases. Incompatibility's positive coefficient found in the rejection column suggests that the probability of rejection increases as incompatibility increases.

Both coefficients estimated for technical expertise were positive when using the neutral position as the benchmark. This suggests that as technical expertise increases, the probability of adoption increases relative to the probability of a neutral position, and the probability of rejection increases relative to the probability of a neutral position. In other words, as technical expertise increases, the probability of a neutral position decreases. Keeping all other factors at their neutral levels and varying technical expertise from its lowest to its highest level confirms this interpretation of technical expertise's effect on adoption resistance levels (Figure 2).

Difficulty of modification seems to be significant in explaining adoption relative to neutrality at the α= 0.01 level, but it seems to be less significant in explaining rejection relative to neutrality. The negative coefficient estimated for adoption relative to neutrality and the positive coefficient estimated for rejection relative to neutrality suggest that as difficulty of modification increases, the likelihood of adoption decreases and the likelihood of rejection increases.

Firm size seems to be significant in explaining rejection relative to neutrality but not adoption relative to neutrality. The negative coefficient indicates that as firm size increases, the probability of rejection decreases relative to the probability of a neutral position.

The next step in this analysis was to determine the significant effects that occur with rejection as the benchmark level. The results of this modeling effort are given in Table 3.

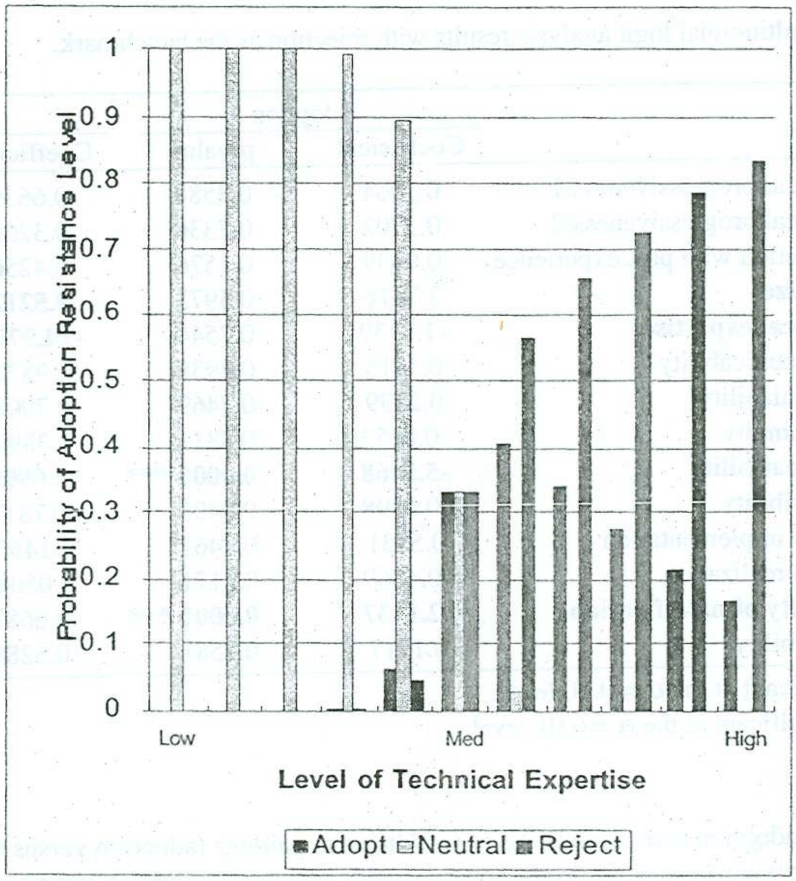

Figure 2. Effect of technical expertise on adoption resistance level.

This step provides information on factors that influence the probability of 1) adoption relative to the probability of rejection, and 2) neutrality relative to the probability of rejection. The second set of factors (i.e.. those involving the probabilities of neutrality and rejection) were identified in the previous phase of the analysis.. In fact. a comparison of the last three columns of Table 2 and the last three columns of Table 3 shows that the only differences in the results are the signs associated with the estimated coefficients. The signs are opposites because the benchmark level was swapped from neutrality (Table 2) to rejection (Table 3).

The only previously undiscovered significant effects are the effects of incompatibility and difficulty of modification on the probability of adoption relative to the probability of rejection. In both instances, the estimated coefficients are negative. So. it seems that as incompatibility increases the probability of adoption decreases relative to the probability of rejection. Thus. it seems that addressing the issue of incompatibility may be one way technology developers and technology champions may reduce the probability of rejection of a new technology. Likewise, as difficulty of modification increases the likelihood of adoption decreases relative to the likelihood of rejection. So, decreasing the difficulty of modifying a technology to work with an in-place production system seems to be a way to reduce the likelihood of rejection of that technology.

To summarize the results of these two sets of analyses.. incompatibility produced significant effects in differentiating between adoption resistance levels in three different pairings (adoption versus rejection. adoption versus neutrality. and rejection versus neutrality); difficulty of modification produced significant effects in differentiating between adoption

Table 3. Multinomial logit analysis results with rejection as the benchmark.

	Adoption		Neutrality	
Factor	Coefficient	p-value	Coefficient	p-value
Technical progressiveness. 1	0.5504	0.3588	0.6639	0.2010
Technical progressiveness.2	0.3702	0.7336	0.3206	0.7711
Satisfaction with past experience	0.9939	0.1576	0.4256	0.4642
Firm size	2.7416	0.5973	**9.5212**	**0.0561 ***
Technical expertise	-1.6139	0.7544	**14.9701**	**0.0096 *****
Incommunicability .	0.5015	0.4938	- 0.9872	0.1322
Non-trialability	0.2399	0.7469	0.7908	0.2235
Discontinuity	-0.0653	0.8319	0.3890	0.1668
Incompatibility	**-5.5468**	**0.0000 *****	**-3.0905**	**0.0001 *****
Irreversibility	-0.0398	0.9406	-0.7813	0.1119
Time to implementation.	0.5931	0.1462	0.1455	0.6628
Time to realization	-0.4869	0.2171	0.0508	0.8741
Difficulty of modification	**21537**	**0.0001 *****	-0.6681	0.1340
Indivisibility	0.1717	0.7581	-0.5288	0.3239

*Significant at the $\alpha = 0.10$ level

***Significant at the $\alpha = 0.01$ level

resistance levels in two different pairings (adoption versus rejection and adoption versus neutrality); technical expertise produced two significant effects (adoption versus neutrality and rejection versus neutrality); and firm size produced one significant effect in differentiating between neutrality and rejection.

To determine which of these factors plays the largest role in explaining differences in adoption resistance levels for the overall multinomial logit model, an analysis of variance was conducted. These results are in Table 4.

The analysis of variance' shows that the main factors in explaining variance in adoption resistance levels are incompatibility, difficulty of modification, and technical expertise. So, people who are advocating new manufacturing technologies, whether they are external or internal to the firm, should address these issues to reduce the probability of a technology being rejected. Reducing incompatibility and difficulty of modification also should increase the probability of the technology being adopted.

Incompatibility is a combination of three sub-factors: how much support upper management gave to the adoption of the technology, how much training was required to implement the technology, and how well the technology fit into the current production system. Earlier work by Oakey and O'Farrell (1992) suggested that the training issue could be one deterrent to technology adoption. Our study suggests that it could be a reason for technology rejection. Management support was cited in earlier studies as a factor in the technology diffusion process (Shrivistava and Souder 1987) and the technology adoption decision (Lefebvre et al. 1991; Meredith. 1987), Our study found additional support for those conclusions and extended this effect to the rejection side of the continuum.

Firms that perceived a technology to be difficult to modify for their production system were more likely to reject the technology than firms that perceived the technology to be less difficult to modify for their production systems: This is consistent with earlier findings of studies concerning the adopt! do not adopt decision in which.

Table 4. Analysis Of variance for multinomial logit analysis.

Source of variation	p-value
Technical progressiveness. 1	0.4209
Technical progressiveness.2	0.9421
Satisfaction with past experience	0.3683
Firm size	0.1251
Technical expertise	**0.0196***
Incommunicability	0.3178
Non-trialability	0.4445
Discontinuity	0.1924
Incompatibility	**0.0000****
Irreversibility	0.1845
Time to implementation	0.3300
Time to realization	0.3124
Difficulty of modification	**0.0003****
Indivisibility	0.3629

*Significant at the α = .051evel
**Significant at the α = .01 level

difficulty in integrating new equipment or processes with existing systems was found to be associated with nonadoption (IGng and Rarnamurthy 1992; Skinner 1984; Oakey and O'Farrell 1992). This also confirms Ram's (1987) previously untested proposition that increased amenability to modification reduces the probability of rejection.

IMPLICATIONS FOR INDUSTRY

While there may be other factors that impact technology rejection not tested in this research, three significant factors surfaced in this study: incompatibility, difficulty of modification, and technical expertise. Technology developers and champions can take several steps to reduce the probability of having a particular technology rejected as a result of the technology adoption/rejection decision process. The primary steps for decreasing technology rejection involve reducing incompatibility and difficulty of modification.

Incompatibility concerns how well the technology or manufacturing concept being considered fits into the current production and management systems. To alleviate incompatibility, technology developers might provide on-site training with the purchase/acquisition/implementation of the technology. Technology developers and champions should improve efforts to convey the technology's advantages to the upper management of a firm and gain management's support for the technology. Also, to increase adoption probability and decrease rejection probability, technology developers can increase (when possible) the options available with a technology that make it easier to fit into a particular production line (e.g., provide a translator that will work with a variety of programming languages/versions for computer controlled machinery). Because the results of this research suggest that firms that perceived a technology to be difficult to modify for their production systems were more likely to reject the technology than other firms, technology developers and champions should identify opportunities to facilitate such modification. Also, there was some evidence to suggest that decreased difficulty of modification is associated with increased probability of adoption. Therefore, finding means of making a technology more amenable to modification should result in reduced rejection rates and increased adoption rates.

The final result of this research suggests that firms with higher levels of technical expertise are less likely to be neutral about a technology than firms with lower levels of technical expertise. This may suggest that ruins with higher levels of technical expertise are more comfortable adopting or rejecting a technology because they can evaluate the technology better. Firms with lower levels of technical expertise may not feel as though they possess the expertise to flatly reject or adopt a technology, and thus they passively reject the technology by not adopting it. By targeting firms (or people) with higher levels of technical expertise, technology developers or processing strategists may increase the chance of adoption even though it may also increase the chance of rejection.

REFERENCES

Baker G. 1992. Computer adoption and use by New Mexico nonfarm agribusinesses. American Journal of Agricultural Economics (August):737-744.

Besley, T. and A. Case. 1993. Modeling technology adoption in developing countries. AEA Papers and Proceedings 83(2) May:396-402.

Bumgardner, M.S. 1995. Characteristics of innovativeness in the dimension and millwork industries of Kentucky, Ohio, Pennsylvania, and West Virginia. Master's thesis. Ohio State University. 135 pp.

Feder, G.and R. Slade. 1984. The acquisition of information and the adoption of new technology. American Journal of Agricultural Economics. (August):312-320.

Gatignon, H. and T.S. Robertson. 1989. Technology diffusion: an empirical test of competitive effects. Journal of Marketing 53(January): 35-49.

Hanneman, R. 1997. Mutinomial logit models with PROC CATMOD.Public access information. Accessed via internet at http://wizard.ucr.eduJ-rhannemalglmlmlogit.htm.accessed October 20, 1997.

Harper, J,K., M.E.Rister, J;W. Mjelde, B.M. Drees and M.O. Way. 1990. Factors influencing the adoption of insect management technology. American Journal of Agricultural Economics (November):997-1005.

Harvey, J., L.A. Lefebvre and E.Lefebvre. 1992. Exploring the relationship between productivity problems and technology adoption in small manufacturing firms. IEEE Transactions on Engineering Management 39(4):352-358.' '.

Kimberly, J.R. arid MJ. Evanisko. '1981. Organizational innovation: the influence of individual, organizational, and contextual factors <m hospital adoption of technological and administrative innovations: Academy of Management Journal 24(4):689-712.

King,W.R. and K. Ramamurthy.. 1992. Do organizations achieve their objectives from computer-based manufacturing technologies? IEEE Transactions on Engineering Management 39(2): 129-140.

Knudsen, D.C., f~R. Jacobs, D. Conway and M.K. Blake. 1994. A survey of group technology adoption in the American Midwest. Growth and Change 25(Spring):183-205.

Lefebvre, L.A., J. Harvey and E. Lefebvre, 199L Technological experience and the technology adoption decisions in small manufacturing firms. R&D Management 21(3):241-249.

Lin, J. 1991. Education and innovation adoption in agriculture: evidence from hybrid rice in China. American Journal of Agricultural Economics (August):713-723.

MacPherson, AD. 1994. Industrial innovation among small and medium-sized firms in a declining region. Growth and Change 25(Spring):145-163.

McFadden, D. 1974. Conditional logit analysis of qualitative choice behavior. In: Zarembka, P. (ed.) Frontiers in econometrics, Academic Press, Inc., New York, NY, p. 105-142.

McIntosh, W.A, J.K. Thomas and D.E Albrecht. 1990. A Weberian perspective on the adoption of value rational technology. Social Science Quarterly 71(4):848-860.

Meredith, J. 1987. The strategic advantages of new manufacturing technologies for small firms. Strategic Management Journal 8(1987):249-258.

Moore, Jr., J. 1994. Barriers to technology adoption using field analytical instruments as an example. Environmental Science Technology 28(4): 193A-195A.

Oakey, R.P. and P.N. O'Farrell. 1992. The regional extent of computer numerically controlled (CNC) machine tool adoption and post adoption success in small British mechanical engineering firms. Regional Studies 26(2): 163175.

Parente, S.L. and E.C. Prescott. 1994. Barriers to technology adoption and development. Journal of Political Economy 102(2):298-321.

Rahm, M.R. and W.E. Huffman. 1984. The adoption of reduced tillage: the role of human capital and other variables. American Journal of Agricultural Economics (November):406-413.

Ram, S. 1987. A model of innovation resistance. In: Advances in Consumer Research, Vol. 14, M. Wallendorf and P. Anderson (eds.) Provo, UT: Association for Consumer Research p. 208-212.

Robertson, T.S. and H. Gatignon. 1986. Competitive effects on technology diffusion. Journal of Marketing 50(July):1-12.

Rosenberg, N., P. Ince, K. Skog and A Plantinga. 1990. Understanding the adoption of new technology in the forest products industry. Forest Products Journal 40(10):15-22.

Saba, A, H.A. Love and R. Schwart. - 1994. Adoption of emerging technologies under output uncertainty. American Journal of Agricultural Economics 76(November):836-846.

SAS Institute Inc. 1989a. *SASISTAT@* User's Guide, Version 6, Fourth Edition, Volume 1, Cary, NC: SAS Institute Inc., 943 pp.

SAS Institute Inc. 1989b. SASISTAT@User's Guide, Version 6,Fourth Edition, Volume 2, Cary, NC: SAS Institute Inc., 846 pp.

Shrivistava, P. and W.E. Souder. 1987. The strategic management of technological innovations: a review and a model Journal of Management Studies 24(1):25-41.

Skinner, W. 1984. Operations technology: blind spot m strategic management. Interfaces 14(1):116-125.

Stenbacka, R. and M. Tombak~ .1994. Strategic timing of adoption of new technologies under uncertainty. International Journal of Industrial Organization 12(1994):387 -411.

Vlosky, R.P. 1996. Opportunities for horizontal diversification in manufacturing value-added wood products. Louisiana Forest Products Laboratory Newsletter 2(2):2.

West, C.D. 1990. Competitive determinants of technology diffusion in the wood household furniture industry. Doctoral dissertation, Virginia Polytechnic Institute and State University, Blacksburg, VA, 195 pp.

West, C.D. and S.A. Sinclair. 1991. Technological assessment of the wood household furniture industry. Forest Products Journal 41(4):11-18.

West, C.D. and S.A. Sinclair. 1992. A measure of innovativeness for a sample of firms in the wood household furniture industry. Forest Science 38(3):509-524.

Wiarda, E.A. 1987. Adoption of programmable automation: a study of six midwestern states. Proceedings of the 1987 IEEE Conference on Management and Technology: Management of Evolving Systems. Atlanta, GA (October27-30.1987).

Wozniak. G.D. 1984. The adoption of interrelated innovations: a human capital approach. The Review of Economics and Statistics 66(February):70-79.

APPENDIXA: Expected Benefits of Technology Adoption

Benefit	Reference
Labor cost savings	Meredith 1987
	Wiarda 1987
	Rosenberg et al. 1990 Harveyet al. 1992
	King ana Ramamurthy 1992
Improved productivity and performance efficiency	Wiarda 1987
	West and Sinclair 1991 Harvey et aI. 1992
	King and Ramamurthy 1992
Reductions in setup/changeover times	Skinner 1984
	Meredith 1987
	Knudsen et aI. 1994 MacPherson 1994
Increased plant and production capacity	Meredith 1987
	King and Ramamurthy 1992
	West and Sinclair 1991 .
	Harvey et aI. 1992
. Higher quality products	Skinner 1984
	Robertson and Gatignon 1986
	Wiarda 1987
	West and Sinclair] 991
	King and Ramamurthy 1992
	Knudsen et at. 1994 MacPherson 1994
Increased customer service and flexibility	Skinner] 984
	Robertson and Gatignon 1986
	Wiarda 1987
	King and Ramamurthy 1992
	MacPherson 1994
New markets	Robertson and Gatignon 1986
	King and Ramamurthy 1992
	MacPherson 1994
New products	Skinner 1984
	Meredith 1987
Reputation as technology leader	Knudsen et al. 1994 Kimberly and Evanisko 1981 Meredith 1987
	Lefebvre et aI. 1991
Safety and environmental concerns	King and Ramamurthy 1992
	Meredith 1987
	Wiarda 1987