Assessing innovativeness in the North American softwood sawmilling industry using three methods

Chris Knowles, Eric Hansen, and Steven R. Shook

Abstract: Using a mail questionnaire targeted at 500 softwood sawmills in the United States and Canada, firm innovativeness was assessed using three methods: (1) current technology, (2) self-evaluation, and (3) a new scale — the propensity to create and adopt scale. The results of these three methods were then compared to assess the performance of each method. Additionally, the relationship between firm innovativeness and financial performance was examined. Based on responses from 85 sawmills (19% adjusted response rate), the results show that both the self-evaluated and the propensity to create and adopt measures differentiate between mills with high and low levels of innovativeness. The composite of the propensity to create and adopt scale shows higher reliability (Chronbach's α = 0.97) than the self-evaluated scale (Chronbach's α = 0.68). Significant relationships between sawmill performance and each of the three measures of innovativeness were seen, with the propensity to create and adopt scale generally having the strongest positive relationships. Current technology was significantly related to sales growth, but not gross profit.

Résumé : À l'aide d'un questionnaire envoyé par la poste à 500 moulins à scie de conifères aux États-Unis et au Canada, l'innovativité de l'industrie a été évaluée en utilisant trois méthodes : (1) la technologie actuelle, (2) l'autoévaluation et (3) une nouveau barème — la propension à créer et adopter une échelle de mesure. Les résultats de ces trois méthodes ont par la suite été comparés pour évaluer la performance de chaque méthode. De plus, la relation entre l'innovativité de l'entreprise et sa performance financière a été examinée. Sur la base des réponses de 85 moulins à scie, (taux de réponse ajusté de 19 %), les résultats montrent que tant l'autoévaluation que la propension à créer et adopter des mesures discriminent entre les moulins à scie qui ont un taux élevé et ceux qui ont un faible taux d'innovativité. La propension à créer et adopter une échelle de mesure est plus fiable (α de Chronbach = 0,97) que l'échelle d'autoévaluation (α de Chronbach = 0,68). Des relations significatives entre la performance des moulins à scie et chacune des trois mesures d'innovativité ont été observées; la propension à créer et adopter une échelle de mesure avait généralement la plus forte relation positive. La technologie actuelle était significativement reliée à la croissance des ventes mais non au profit brut.

[Traduit par la Rédaction]

Introduction

Changes occurring over the last decade have resulted in the North American softwood sawmilling industry struggling to remain competitive, with the major drivers of change being environmental regulation and competitive factors resulting from the globalization of the forest products industry (Juslin and Hansen 2003). Previous research has identified the development and adoption of new products, processes, and business systems, or firm innovativeness, as ways firms can maintain, or even improve, competitiveness.

Innovation is an important driver of firm growth (e.g., Narver and Slater 1990; Han et al. 1998,) and being innovative through development of new or improved products, processes, or business systems can help a company better identify and satisfy consumer needs, stay ahead of the competition, explore new markets, etc. Increasingly, competitive markets have led firms to view innovation as more than just a requirement for growth, but necessary for survival (Frambach 1993; Chihiro et al. 2004). While innovativeness has been widely researched in other manufacturing fields, only recently has attention focused on the forest products industry.

While previous research has acknowledged the importance of innovativeness, many problems exist with the current methodology for measuring the innovativeness of a firm. Deshpande and Farley (2004) acknowledge the weaknesses of scales currently available and call for a universally reliable scale for measuring innovativeness. Crespell et al. (2006) also recognize the weakness of current scales for measuring innovativeness and call for the creation of a robust, reliable, and valid scale to measure the construct of innovativeness. This work compares a newly developed scale for measuring firm innovativeness with two previously developed methods for measuring firm innovativeness in an effort to begin the process of developing a universally reliable and robust scale to measure this construct. Within the overall study framework, the scale development process outlined by Churchill (1979) was followed (Knowles 2007).

This research concentrates on exploring the current situation with respect to innovativeness in the North American

Received 29 January 2007. Accepted 25 June 2007. Published on the NRC Research Press Web site at cjfr.nrc.ca on 8 February 2008.

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 doi:10.1139/X07-140

softwood sawmilling industry. The current sector situation was examined to accomplish the following objectives:

1. Assess the current level and focus of innovativeness using three methods.
2. Compare three methods for assessing firm innovativeness with regard to manufacturing processes.
3. Assess the relationship between firm innovativeness and financial performance.

Theoretical background

Innovativeness

Firm innovativeness has been defined in various ways in previous research. One common definition of an innovative firm is a firm that adopts innovations (Utterback 1974; Daft 1982; Attewell 1992). Based on this definition, the more innovations a firm adopts, the more innovative it is. Rogers (2003, p. 22) defines innovativeness as "the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than any other member of the system." Hurley and Hult (1998) presented a broader definition that included more than just the adoption of innovations, including the working environment as well defining innovativeness as "the notion of openness to new ideas as an aspect of a firm's culture." Other definitions have considered the ability of firms to adopt or create innovations. Foxall (1984) defined innovativeness as the "capacity and tendency to purchase new products and services." Gebert et al. (2003) used a definition adapted from Glynn (1996) defining innovativeness as "the capacity of an organization to improve existing products and/or processes, and the capacity to utilize the creativity resources of the organization to the full[est]."

Two components of innovativeness have been identified in the previous literature: (1) creation and (2) adoption. The definition of innovativeness used in this study is a more comprehensive definition, adapted from the previously outlined definitions. In this study, innovativeness is defined as *the propensity of firms to create and (or) adopt new products, manufacturing processes, and business systems*. These categories of innovativeness are based on previous forest industry findings (Hovgaard and Hansen 2004; Hansen et al. 2007).

Product innovation is a successful change in a firm's output and can be in the form of either goods or services (Kubeczko and Rametsteiner 2002). Process innovation (technical innovation) is the introduction of new elements in an organization's production process (Damanpour et al. 1989). Business systems innovation does not provide a new product or service, but consists of the introduction and integration of new management systems, marketing methods, administrative processes, or staff development programs (Hovgaard and Hansen 2004; Crespell et al. 2006).

Previous approaches to measuring innovativeness

Innovativeness has been studied extensively in previous literature, resulting in multiple methods for measuring this construct. Five approaches to measuring firm innovativeness were identified in previous literature: (1) current technology, (2) self-evaluation, (3) intellectual property, (4) research and development funding, and (5) number of new products. The following provides an overview of current technology and self-evaluation, the two methods used to measure innovativeness in the current work.

Current technology

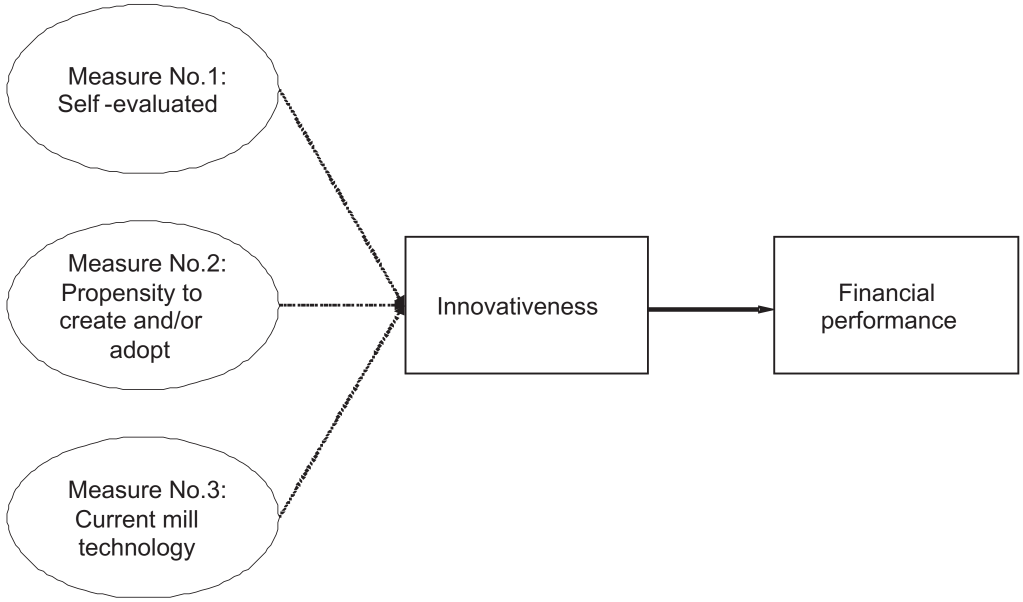
A method of measuring innovativeness commonly used in the literature is based on the technology currently being used within the firm (Robertson and Wind 1980; Robertson and Wind 1983; Kotabe 1990; Subramanian and Nilakanta 1996; West and Sinclair 1991; Lee et al. 1999). Current technology has been the most commonly used methodology to measure innovativeness in the forest products industry (Fell et al. 2003).

Fell et al. (2003) identified two methods that had been previously developed for measuring innovativeness with the current technology of the firm. With the first method, known as the Rogers method (Rogers 2003), individuals or firms are divided into adopter groups based on the time an innovation was adopted. The major advantage of this method is that it can be simply applied. However, there are several shortcomings of this method, the most significant being that respondents must be capable of recalling the time of adoption of a specific innovation (Rogers 2003). Another significant shortcoming is that the method assumes that the innovation is equally available to all potential adopters. Many innovations, for example, are only available through licensing of a patent. Depending on the type of license (e.g., exclusive versus nonexclusive) and cost, the availability of the innovation can become severely limited or widely available.

The second method of measuring innovativeness based on current firm technology, the cross-sectional method, was originally developed by Robertson (1971). In this method, innovativeness is determined by measuring the number of new products owned or used by a firm at a given point in time. Robertson (1971) assumes that the most innovative firms will be using the most new products at any time. This method improves on the Rogers method by using more than one innovation to measure innovativeness. The problem of recall is also reduced because the time of adoption is not included. However, nonadopters are excluded from further analysis because product adoption is a prerequisite in this type of analysis. The cross-sectional measure of innovativeness requires a comprehensive list of innovations in a product category.

Based on Midgley and Dowling (1978), Fell et al. (2003) determined that the Rogers method and the cross-sectional method of measuring innovativeness do not measure the same construct. Fell et al. (2003) developed a composite method to measure innovativeness designed to account for some of the limitations of both the Rogers and cross-sectional methods. The composite method is based on a product category and accounts for the time of adoption. The innovativeness score is dependent upon when innovations are adopted relative to adoption by other firms and assumes that innovations are equally available to all potential adopters. Fell et al. (2003) compared the composite method to the Rogers and cross-sectional methods. The composite method of measuring innovativeness was able to capture both elements simultaneously. The authors conclude that this method may be superior when segmenting industrial markets for new products.

Fig. 1. Study framework outlining concepts to be assessed in this study.



Rogers (2003) points out several "methodological curses" with measuring the time of adoption of innovations. One of these curses is the respondent's ability to accurately recall the time of adoption. Accurate recall is dependent upon the innovation's importance to the individual, the length of time since the innovation was adopted, and individual respondent characteristics, such as memory. Additionally, while current technology measures adoption, it does not necessarily account for implementation. Tornatzky and Klein (1982) note that a dependent measure of innovativeness should include both.

Measuring innovativeness through an assessment of technology potentially reduces bias that may be present in self-evaluated measures of innovativeness. However, a problem arises when determining if possession of the latest technology really means that a firm is innovative. For example, consider a firm that has been manufacturing a product for 80 years using the same technology. Eventually, equipment will fail beyond repair and must be replaced. In this case, replacement with state-of-the-art equipment, does not indicate an innovative firm when compared with other firms that continually adopt state-of-the-art equipment. In other words, was innovativeness the driver behind the purchase of the state-of-the-art equipment? Current technology does not provide an answer to that question. Finally, using current technology to assess innovativeness provides researchers with a measure of the level of process innovation but does little to assess product and business systems innovation.

Self-evaluation

Self-evaluation is a common method of measuring innovativeness (Carter and Williams 1959; Wallach 1983; Capon, et al. 1992; Wind and Mahajan 1997; Gebert et al. 2003; Deshpande and Farley 2004; Crespell et al. 2006). When using self-evaluation, respondents are asked to rate the innovativeness of their firm using an interval scale. Respondents are typically firm managers and thus, intimately familiar with the day-to-day operations of the firm. However, this perceptions-based approach also has the potential to introduce bias.

One weakness that is present in nearly all studies using a self-evaluation approach is the use of only one respondent per firm. Perceptions of only one respondent per firm do not allow researchers to assess response bias.

Relationship between innovativeness and performance

The relationship between innovativeness and firm performance has been widely studied in the context of many different industries (e.g., Damanpour et al. 1989; Narver and Slater 1990; Han et al. 1998; Hurley and Hult 1998). Despite the wide focus, there has been little work investigating this relationship in the context of the forest products industry.

Theoretical frame of reference and operationalization

The theoretical frame of reference used in this study can be seen in Fig. 1. This figure provides a visual representation of the concepts to be assessed in this study. Based on the figure, innovativeness is proposed to have a positive effect on the financial performance of the firm. The circles on the left side of the figure indicate three distinct methods of measuring innovativeness. The measurement of the concepts assessed in this study is discussed in the following.

Concept measurement

Innovativeness

Innovativeness was measured using the three methods as outlined in Fig. 1. Measure 1 was intended to be a direct self-evaluation of a firm's product, process, and business systems innovativeness. This measure, hereafter referred to as the self-evaluation scale, consisted of three items: product, process, and business systems innovativeness (Crespell et al. 2006). The three items were assessed using a five-point interval scale with 1 being not innovative at all and 5 being very innovative.

Measure 2 was an indirect self-evaluation scale designed

Table 1. Items used in propensity to create and adopt scale and the sources each item was adapted from.

Item	Adapted from
Propensity to create new products	
Our company actively develops new products.	Avlonitis et al. (1994) and Vazquez et al. (2001)
Our company sees new products as critical to our success.	Avlonitis et al. (1994) and Gebert et al. (2003)
When it comes to creating new products, our company is far better than the competition.	Gebert et al. (2003)
Over the past three years, our company has been better than before regarding developing new products.	Gebert et al. (2003) and Wang and Ahmed (2004)
Within our company, we are able to implement new product ideas from other parts of our organization.	Hurley and Hult (1998) and Gebert et al. (2003)
Propensity to create new manufacturing processes	
Our company actively develops in-house solutions to improve our manufacturing processes.	Avlonitis et al. (1994) and Vazquez et al. (2001)
Our company sees new manufacturing processes as critical to our success.	Deshpande et al. (1993), Avlonitis et al. (1994), and Gebert et al. (2003)
When it comes to creating new processes, our company is far better than the competition.	Gebert et al. (2003) and Wang and Ahmed (2004)
Over the past three years, our company has been better than before regarding developing new manufacturing processes.	Gebert et al. (2003) and Wang and Ahmed (2004)
Within our company, we are able to implement new manufacturing process ideas from other parts of our organization.	Hurley and Hult (1998) and Gebert et al. (2003)
Propensity to create new business systems	
Our company actively develops in-house information technology solutions.	Vazquez et al. (2001)
Our company actively develops in-house managerial approaches.	Wang and Ahmed (2004)
Our company sees creating new business systems as critical to our success.	Gebert et al. (2003) and Wang and Ahmed (2004)
When it comes to creating new business systems, our company is far better than the competition.	Gebert et al. (2003) and Wang and Ahmed (2004)
Within our company, we are able to implement new business systems ideas from other parts of the organization.	Hurley and Hult (1998) and Gebert et al. (2003)
Propensity to adopt new manufacturing processes	
Our company tends to be an early adopter of new manufacturing processes.	Deshpande et al. (1993), Avlonitis et al. (1994), and Wang and Ahmed (2004)
Our company actively seeks new manufacturing processes from outside this organization.	Hurley and Hult (1998) and Jerez-Gomez et al. (2005)
Having the latest, most efficient manufacturing processes is critical for our success.	Avlonitis et al. (1994), Gebert et al. (2003), and Wang and Ahmed (2004)
Within our company, we are able to implement new manufacturing processes used by other organizations.	Jerez-Gomez et al. (2005)
Our company considers manufacturing ideas provided by external sources critical to our success.	Jerez-Gomez et al. (2005)
Propensity to adopt new business systems	
Our company tends to be an early adopter of new business systems.	Deshpande et al. (1993) and Wang and Ahmed (2004)
Having the latest, most efficient business systems is critical for our success.	Wang and Ahmed (2004)
Within our company, we are able to implement new business systems used by other organizations.	Jerez-Gomez et al. (2005)
Our company considers business systems ideas provided by external sources as critical to our success.	Jerez-Gomez et al. (2005)
Our company actively seeks new business systems from outside this organization.	Hurley and Hult (1998) and Jerez-Gomez et al. (2005)

to assess the propensity of sawmills to create and (or) adopt new product, process, and business systems. This scale, hereafter referred to as the propensity to create and adopt scale, was composed of 25 items. Each of the items was assessed using five-point Likert scales with 1 being disagree and 5 being agree. The 25 items were equally divided to measure propensity to create new products, new manufacturing process, new business systems, and the propensity to adopt new manufacturing processes and new business systems. The individual items and the sources each item was adapted from can be seen in Table 1. The propensity to adopt new products was not included in the framework because the authors argue that sawmills adopt new products by adopting the manufacturing process required to produce the product. For example, if a sawmill begins production of a finger-jointed wood product, the mill must first adopt the manufacturing process before it can begin producing the product.

Measure 3, current technology, was composed of a list of machine centers that may be used in the processing of softwood lumber. Respondents were asked to indicate whether or not their mill has each technology. For each existing machine center, respondents selected the type of scanning equipment, if any, that is currently being used and indicated the year of the last upgrade to both the machine center and the scanning equipment. Respondents indicated whether the mill used certain business systems innovations. For each of these business systems innovations the mill used, the year of adoption by the mill was collected. The processing and business systems technologies selected for use in this study were based on interviews with sawmilling experts from industry and academia.

Sawmill performance

Sawmill performance was measured using self-evaluation scales on two items: sales growth and gross profit (Crespell et al. 2006). Respondents were asked to rate their facility based on how it compares with competitors in their industry using a five-point scale with 1 being the lowest 20%, 2 being the next lower 20%, 3 being the middle 20%, 4 being the next highest 20%, and 5 being the highest 20%.

Descriptive information

To characterize the sample in this study, descriptive information was collected about each sawmill. This first piece of descriptive information collected was the relative volume of each of the following species being produced by the sawmill: (1) southern pine, (2) spruce–pine–fir west, (3) spruce–pine–fir east, (4) Douglas-fir, (5) hemlock–fir, and (6) other. Additional information included the number of employees at the sawmill, annual production volume, respondent position at the sawmill, and the number of years the respondent has been employed with the sawmill.

Questionnaire development and pretesting

A questionnaire designed to measure innovativeness in the North American softwood sawmilling industry was developed consisting of five major sections: (1) self-evaluation of innovativeness, (2) the propensity to create and adopt, (3) current sawmill technology, (4) mill performance, and (5) descriptive information about the sawmill.

The questionnaire was pretested with 13 forest industry managers, as well as reviewed by sawmilling experts in academia and industry. Minimal changes were made based on their suggestions.

Sampling

Five hundred sawmills in North America (United States and Canada) were randomly selected from *The Random Lengths big book* (Random Lengths Publications, Inc. 2004). The survey targeted the top three individuals at each sawmill including, but not limited to, the mill manager, shift supervisor, quality control supervisor, and owner. In an attempt to identify the name of the mill manager, at least two telephone calls were made to each mill. For those mill managers that were not successfully contacted, the questionnaire packet was addressed to the mill manager.

A modified Dillman approach (Dillman 1978) was used for the mailing. The first wave was mailed in May 2005, followed approximately 2 weeks later by a reminder postcard. For the first wave, each of the 500 randomly selected sawmills were sent a questionnaire packet consisting of three questionnaires, three self-addressed, stamped return envelopes, and a cover letter that briefly described the purpose of the study and identified the target audience for the questionnaire. The cover letter provided instructions for the distribution of the three questionnaires to three independent respondents.

In the reminder postcard, the mill manager was informed that zero of three, one of three, or two of three completed questionnaires had been received from that sawmill. The second wave, mailed approximately two weeks later, contained a questionnaire packet similar to that of the first wave. The second wave of questionnaires was followed up with telephone calls to the nonresponding mills. For mills choosing not to respond to the questionnaire after the second wave, an attempt was made to collect descriptive data to be used in testing for nonresponse bias. The information collected from the mills that did not respond included the relative volume of species processed and size, as measured by number of employees and production volume.

Analysis

Nonresponse bias was tested using the method advocated by Armstrong and Overton (1977). The first 30 respondents were compared with the last 30 respondents on the number of employees, product innovativeness, process innovativeness, and business systems innovativeness. The results of the independent samples t tests showed no significant differences between these two groups with all p values >0.05.

Nonresponse bias was also assessed using descriptive information collected through follow-up calls to nonresponding mills. Twenty-one of 47 nonresponding mills contacted provided descriptive information. The results of independent samples t tests showed no significant differences between responding and nonresponding mills on the number of employees and production volume, with all p values >0.05.

Since the questionnaires were sent to three managers at each sawmill and not all sawmills responded with three responses, the response from the mill manager was used for analysis. If the mill manager did not respond, the response of the highest ranking respondent from that mill was used. This results in only one respondent per mill used for analysis.

The first step in the analysis was to assess normality for each of the variables, with results showing all were consistent with a normal distribution.

Innovativeness

Composite values for the self-evaluation measure of innovativeness and the propensity to create and adopt scale were calculated. A one-sample t test was used to determine if the means for these scales were significantly different from the midpoint of the scale (3). The midpoint of this scale (3) indicates a neutral position regarding firm innovativeness, therefore, testing to determine if the values are significantly different from the scale midpoint gives an indication that respondents have strong opinions regarding the innovativeness of their mill. Additionally, one-way ANOVA was used to test differences among the three components of self-evaluated innovativeness and among the five components of the propensity to create and adopt innovativeness.

The current technology measure of innovativenss was assessed by creating a current technology index using the following 17 technologies: log bucking, headrig, resaw, gangsaw, edger, planer, trimmer, sorter, small log processor, curve sawing, automatic grading, automatic saw tipper, automatic saw tensioner, real-time scanning, in-line moisture meter, dry kiln, and inventory tracking system. When coding the data, responding sawmills were given a 1 for each of the technologies being used in the mill and a 0 for each that was not being used in the mill.

The current technology index was calculated by summing up the number of technologies adopted by each responding mill. The mean and standard deviation were calculated and used to identify three groups of sawmills based on level of technology adoption: high tech, medium tech, and low tech. The high-tech group included all mills with current technology index scores more than one standard deviation above the mean and the low-tech group included all mills with current technology scores more than one standard deviation below the mean. All mills within one standard deviation of the mean were included in the medium-tech group. These groups were used to determine how well the self-evaluated and propensity to create and adopt measures differentiated between high- and low-tech sawmills. One-way ANOVA was used to determine if the means of the high-, medium-, and low-tech groups were significantly different on the self-evaluated and propensity to create and adopt measures of innovativeness.

Sawmill performance

Sales growth and gross profit were used as dependent variables and each of the three measures of innovativeness were used as independent variables in simple linear regression

Table 2. Respondents' positions at the sawmills.

Position	Number of respondents	Percent
Owner	10	6
Mill manager	72	44
Shift manager	27	17
QC supervisor	24	14
Other*	32	19

*Other includes: president, vice president, controller, sales manager, regional manager, etc.

analysis to assess the relationship between performance and innovativeness. The results of the regressions using self-evaluated process innovativeness, current technology, and the propensity to create new processes and adopt new processes as dependent variables were compared to determine which measure best explains the variation in sawmill performance.

Descriptive information

The descriptive information collected was used to characterize the sample. Mean mill size (as measured by the number of employees and production volume) and total production volume were calculated. Additionally, relative production volume by species (weighted by production volume) was calculated.

Results

Response information

From an initial sample size of 500, an adjusted sample size of 447 sawmills was achieved because of 53 undeliverable survey packets. In total, 165 (adjusted response rate of 12.3%) completed questionnaires from 85 (adjusted response rate of 19.0%) different mills were returned. Of the responding mills, 32 returned one questionnaire (37.6%), 24 returned two questionnaires (28.2%), and 29 returned three questionnaires (34.1%).

Descriptive information

We were largely successful in obtaining responses from top managers at our sampled mills (Table 2), with 44% of responses coming from the mill manager. On average, respondents were employed by their current company for 17 years, with responses ranging from 1 to 60 years of tenure.

Respondents represented both large and small sawmills, as measured by the number of employees and annual production (Table 3). Responding mills were of all sizes, with a mean of 112 employees and ranging from as few as two employees up to 695 employees. The amean annual production for responding mills was 90 MMBF (1 MMBF = $\sim$2350 m^3), with a maximum of 445 MMBF and a minimum of <1 MMBF. The total annual production for responding mills was 7.5 billion board feet, representing approximately 12.2% of the total softwood lumber production in the United States and Canada in 2005 (FAS 2006).

Figure 2 shows the relative volume of species processed by the responding sawmills. It can be seen that all of the major softwood species groups are represented. The species processed in the largest volume was Douglas-fir, representing 28.3% of the total production of respondents. Southern pine represents 19.7% of total production, followed by hemlock–fir (17.8%).

Table 3. Number of employees and annual production of responding sawmills.

	n	Mean	SD	Max.	Min.
Number of employees	83	112	97	695	2
Annual production (MMBF)*	83	90	89	445	<1

*MMBF, million board feet.

Innovativeness

Table 4 contains results of the self-evaluated measure of innovativeness and the propensity to create and (or) adopt. It can be seen that the major focus of the industry, as indicated by both the self-evaluated scale and the propensity to create and adopt scale, is on process innovativeness. Process innovativeness was rated highest on both of these scales, which is consistent with the results of previous research in the sawmilling industry (Crespell et al. 2006). Additionally, self-evaluated process innovativeness was significantly higher than self-evaluated product and business systems innovativeness, and the propensity to create new processes was significantly higher than the propensity to create new products and business systems and the propensity to adopt new business systems. There was no significant difference between the propensity to adopt new processes and the other four components of the scale. No statistically significant differences existed from the midpoint of the scale for the composites of both the self-evaluated and the propensity to create and adopt scales.

The propensity to create and adopt scales have Cronbach's α values above the minimum cutoff point of 0.80 recommended by Hair et al. (1989). In contrast, the composite of the self-evaluated scale has a Cronbach's α value below this recommended cutoff point. This result indicates that propensity to create and adopt scale is more reliable than the self-evaluated scale. Construct validity of this scale is being addressed in a follow-up study in the context of the entire North American forest products industry.

Current technology

Figure 3 shows the percentage of responding mills currently using each of the machine centers assessed in this study. Edgers and trimmers were the most frequently used machine centers, being used in more than 90% of responding mills. Curvesaws were the least frequently used machine center, being used in just over 30% of responding sawmills.

Figure 4 shows the percentage of mills using each of eight possible processing technologies. The majority of the responding mills currently have a dry kiln, with 1986 being the mean year of adoption. Over 50% of mills currently use an inventory tracking system, with 1997 being the mean year of adoption. Just over 10% of responding mills currently use an automatic grading system.

Figure 5 outlines the type of scanning technology used by the machine center at the responding sawmills. Responding mills lacking a particular machine center were excluded from calculations. For all machine centers except the small log processor, the majority of respondents indicated their

Fig. 2. Relative volume of softwood species processed by responding mills (n = 85). Total volume produced at responding mills was 7.5 billion board feet. SPF, spruce–pine–fir. (*Includes redwood, eastern white pine, cedar, lodgepole pine, cypress, and Sitka spruce).

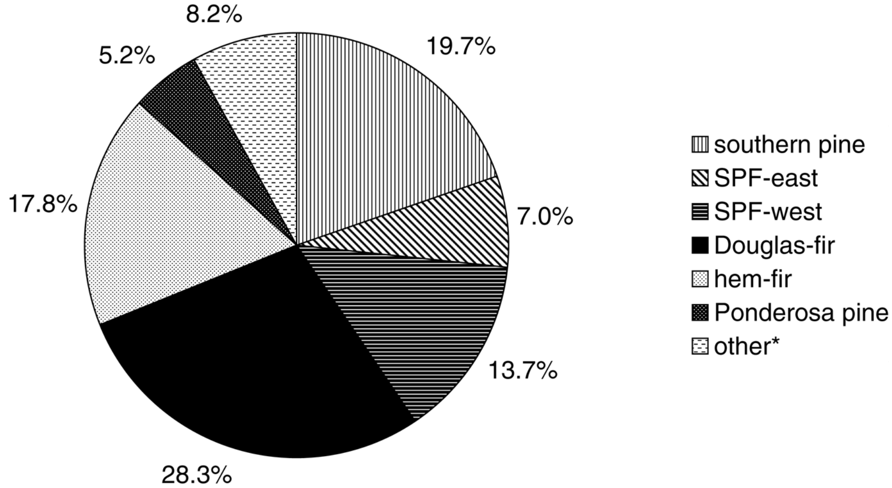


Table 4. Results of self-evaluated and propensity to create and (or) adopt measures of innovativeness in the North American softwood sawmilling industry.

Measurement	n	Mean	SD	Cronbach's α
Self-evaluated product innovativeness*	83	2.85	1.05	N/A
Propensity to create new products	82	3.10	0.92	0.92
Self-evaluated process innovativeness*	83	3.35	1.04	N/A
Propensity to create new processes*	81	3.69	0.77	0.89
Propensity to adopt new processes*	82	3.35	0.93	0.92
Self-evaluated business systems innovativeness	83	2.96	1.01	N/A
Propensity to create new business systems*	81	3.18	0.87	0.92
Propensity to adopt new business systems	80	3.01	0.85	0.94
Self-evaluated composite	83	2.97	0.79	0.68
Propensity to create and adopt composite	82	3.26	0.75	0.97

*Denotes significantly different from midpoint of scale (3) at α = 0.05.

mill does not have any scanning equipment. In fact, more than 60% of respondents do not have any scanning equipment on the log bucking, resaw, and planer machine centers. More than 50% of respondents indicated they do not have any scanning equipment on the sorter. For all machine centers except the planer and sorter, 3D was the most frequently used scanning technology.

For all machine centers, real-time scanning was more frequently used than the more advanced real-shape scanning, with <10% of responding mills using both real-time and real-shape scanning on each machine center. The planer had the lowest frequency of use of real-shape and both real-time – real-shape scanning technologies.

Relationship between innovativeness and performance

Table 5 shows the relationship between the three measures of innovativeness (current technology index, the self-evaluated measure of innovativeness, and the propensity to create and adopt measure of innovativeness) and sawmill performance. The current technology index was significantly related to sales growth, but not with gross profit.

Sales growth was significantly related to the self-evaluated process and business systems innovativeness but not to self-evaluated product innovativeness. Gross profit had a significant relationship with self-evaluated business systems innovativeness, but not with self-evaluated product or process innovativeness. Sales growth had the strongest relationship with self-evaluated process innovativeness. Gross profit had the strongest relationship with self-evaluated business systems innovativeness. The self-evaluated composite measure of innovativeness was significantly related to both sales growth and gross profit. This relationship was also stronger than any of the individual self-evaluated measures of innovativeness, showing that firms focusing on all three aspects of innovativeness are more successful than firms that only focus on one aspect of innovativeness.

Sales growth was significantly related to the each of the propensity to create and (or) adopt measures. Gross profit was related to all propensity to create and (or) adopt measures except the propensity to create new products and propensity to adopt new business systems. The strongest relationship was between the propensity to create new business systems and sales growth (r = 0.69). The propensity to create new business systems had the strongest relationship with sales growth. The create and adopt composite measure had the strongest relationship with sales growth.

Comparison of self-evaluated and propensity to create and adopt scales

Table 6 shows the results of one-way ANOVA comparing

Fig. 3. Percentage of sawmills using each machine center to process softwood lumber (n = 85).

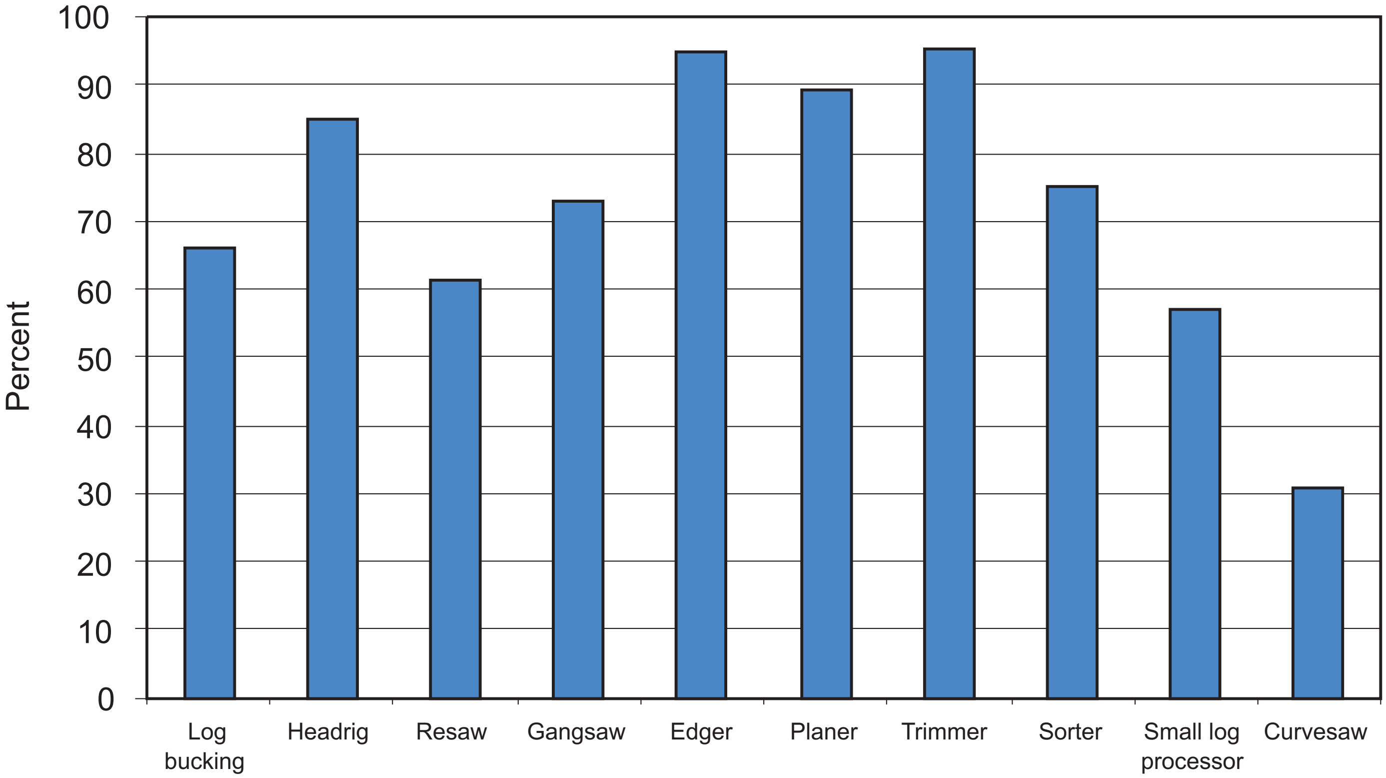
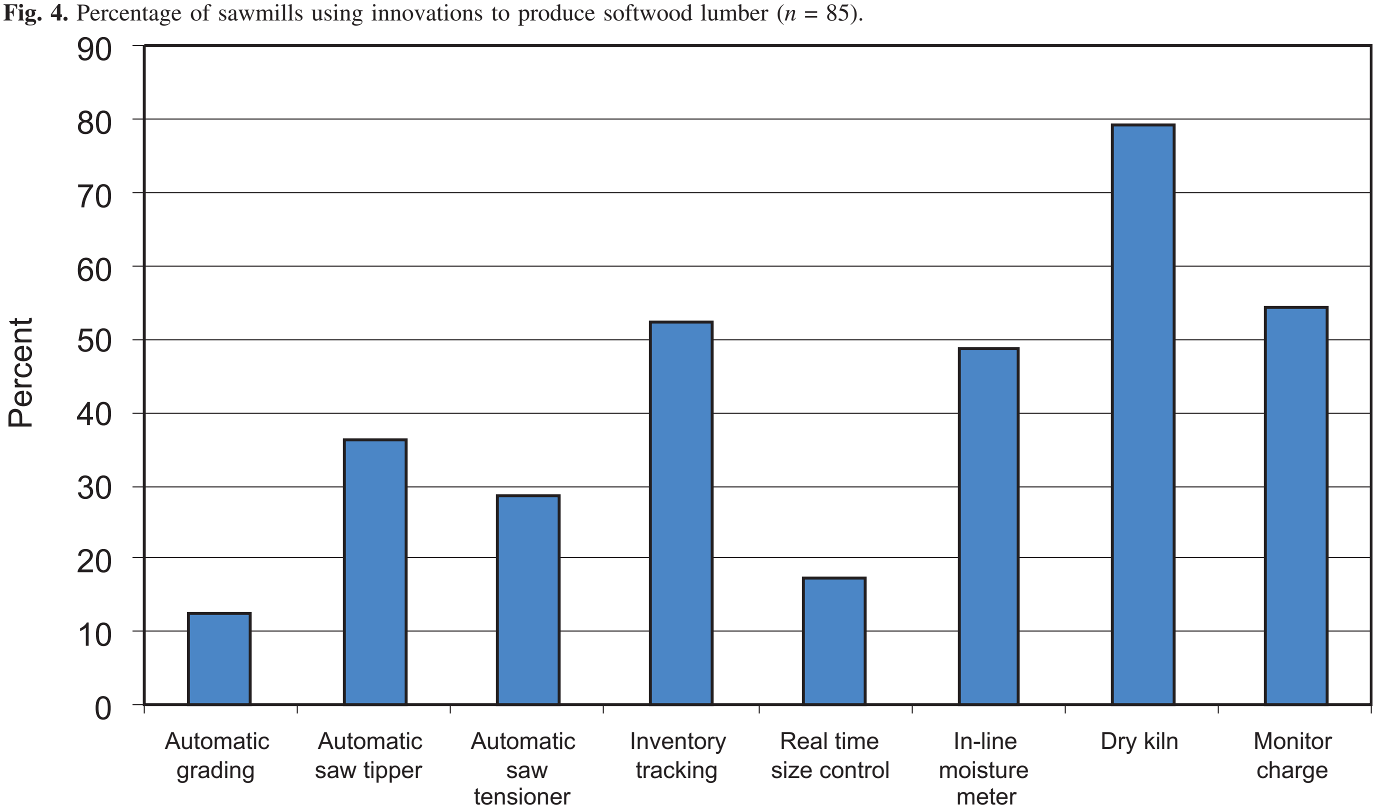


Fig. 4. Percentage of sawmills using innovations to produce softwood lumber (n = 85).



means of high-, medium-, and low-tech sawmills on the self-evaluated and propensity to create and adopt scales. Significant differences were found between high-, medium-, and low-tech mills for self-evaluated process innovatieveness, but not for self-evaluated product and business systems innovativeness. For the propensity to create and adopt, significant differences were found for all components but the propensity to create new products. These results show that

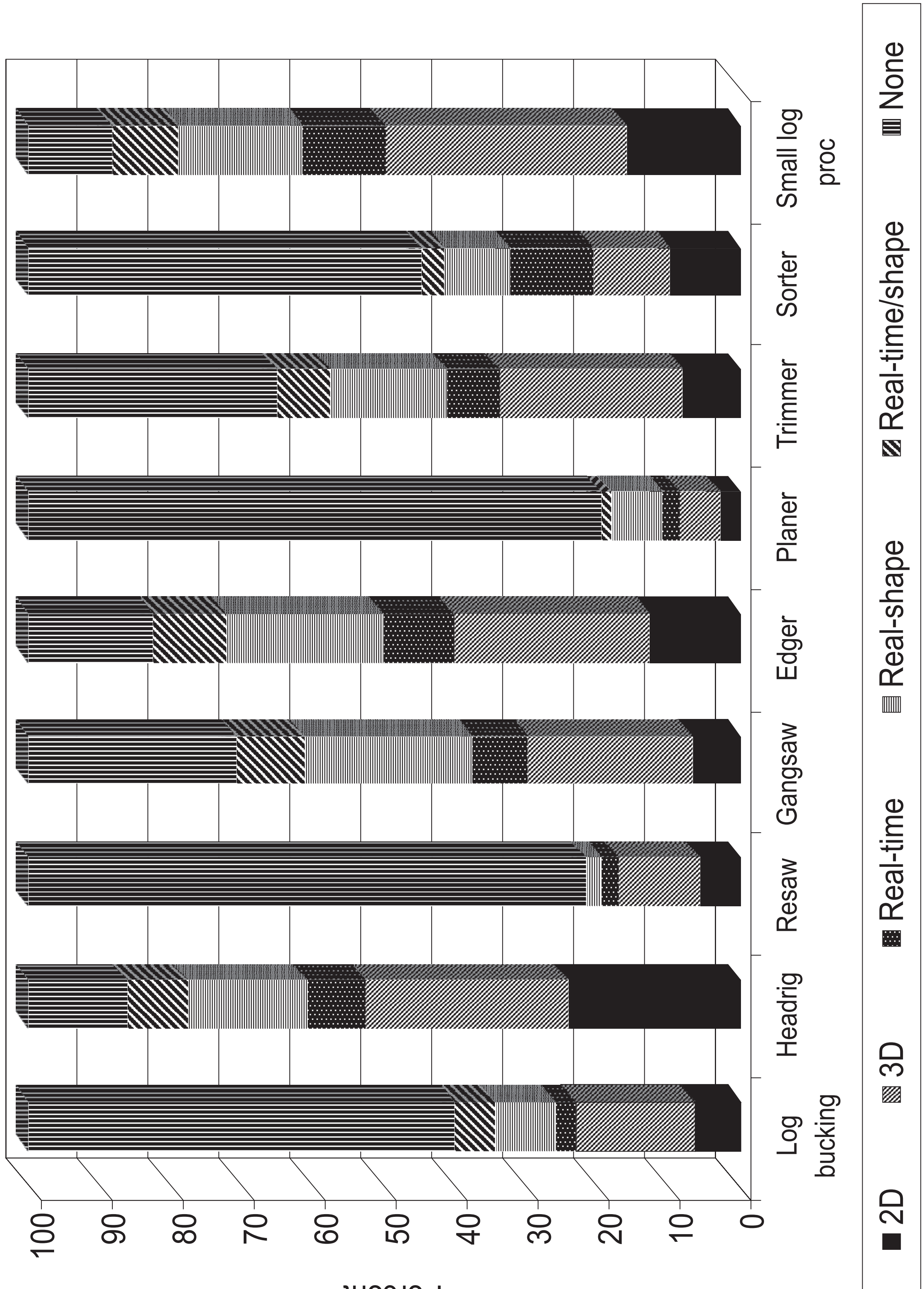


Fig. 5. Type of scanning technology used by machine centers in responding softwood sawmills (n = 85).

Table 5. Pearson's correlation coefficient (r) for the relationship between the three measures of innovativeness and performance.

	Performance	
Measures	Sales growth	Gross profit
Current technology index	0.54*	0.40
Self-evaluated		
Product innovativeness	0.46	0.46
Process innovativeness	0.62*	0.47
Business systems innovativeness	0.50*	0.48*
Composite innovativeness	0.61*	0.53*
Propensity to		
Create new products	0.55*	0.43
Create new processes	0.68*	0.54*
Create new business systems	0.69*	0.55*
Adopt new processes	0.59*	0.51*
Adopt new business systems	0.57*	0.42
Create and adopt composite	0.67*	0.54*

*Denotes significant at $\alpha = 0.05$.

the self-evaluated innovativeness scale does not differentiate between high-, medium-, and low-tech mills as well as the propensity to create and adopt scale based on the current technology within the firm.

Discussion and conclusions

Comparison of self-evaluated and propensity to create and (or) adopt scales

The results of the self-evaluated innovativeness and innovativeness assessed using the propensity to create and (or) adopt scale were similar. It is important to note that the mean values of all types of innovativeness from both scales are closer to the scale midpoint (3) than to the upper end of the scale (5), indicating that the respondents do not have strong, positive views on the innovativeness of their mills.

The major difference between these two scales is that respondents are directly attempting to assess the product, process, and business systems innovativeness of their operations using the self-evaluated scale, whereas the propensity to create and (or) adopt scale assesses these concepts indirectly, using several items. The self-evaluated methodology introduces the potential for respondents to interpret or define these constructs inconsistently. With nearly as many definitions of innovativeness as there are articles published on the subject, it follows that each manager will have a different definition of the concept. Since the propensity to create and (or) adopt scale uses multiple items to indirectly assess product, process and business systems innovativeness, the impact of differing definitions of innovativeness is reduced. Additionally, multiple item scales are generally considered to be more reliable than single-item scales (Churchill 1979).

Problems with current technology as a measure of innovativeness

Current technology is a facts-based method of measuring firm innovativeness that is easy to implement. Despite these advantages, several problems with using current technology to assess firm innovativeness were identified in this study.

The first problem is that not all respondents indicated the time of adoption for each technology. This item nonresponse resulted in artificially low technology index scores for some mills. In fact, the percentage of respondents who indicated both the presence of a given machine center and the time it was adopted were as follows: log bucking, 51.7%; headrig, 56.3%; resaw, 31.4%; gangsaw, 51.7%; edger, 51.3%; planer, 37.8%; trimmer, 51.3%; sorter, 40.3%; small log processor, 43.7%; and curvesaw, 92.3%. The amount of time involved to accurately verify time of adoption and a lack of accurate time of adoption information are some of the reasons why respondents did not indicate the time of adoption.

The second problem with using technology is that not all sawmills require the same technology. This phenomenon is what Rogers (2003) refers to as perceived compatibility. In other words, is the innovation compatible with a sawmills current needs? Capital and credit availability are also considered compatibility attributes. For instance, a firm may be interested in purchasing a new high-speed edge trimmer, but it simply does not have the funds or credit to purchase it. Does that make the sawmill less innovative?

The processing technology used in the mills depends on several factors including the composition of the raw material (species, diameter, length, etc.) and the final products produced (dimension lumber, cants, etc.), and therefore, it is difficult to determine if a mill is less or more innovative based on the technologies that are present in the mill. For example, a curve saw may not useful for a mill that only processes beams from large diameter Douglas-fir. The current technology index does not account for differences in manufacturing in the sawmilling industry and penalizes mills for not having these technologies. Creating a comprehensive, yet logical and feasible list of technologies has shown to be problematic in previous research (Rogers 2003).

There are several factors (constraints) that can result in a firm not using specific machines, yet the firm would be found to be very innovative if the constraints did not exist. In other words, the constraints act as moderators of innovativeness. Availability of capital and availability of credit, in particular, are two finance-related factors that can significantly impede the purchase and use of equipment. Pre-existing equipment and the ability to integrate innovative technologies with the pre-existing equipment is another factor that can impede the adoption of equipment innovations. Other competitive advantages, such as an extremely efficient and effective distribution channels, can allow the firm to focus its resources on maintaining this competitive advantage such that innovative equipment purchases are considered relatively unimportant and (or) unnecessary. These factors are not accounted for when using current technology to assess firm innovativeness.

A third problem with the technology index is related to inconsistency between multiple respondents from the same mill. Current technology was assessed in this study by respondents indicating if the mill had each of a list of technologies. Since each of the three respondents from one mill worked in the same mill, the assessment of technology should be consistent among the respondents. However, this was often not the case with the respondents in this research. Out of the mills with two or three respondents, the current technology responses were inconsistent in 44 out of 53 cases. As a result of these inconsistencies, only one response from each mill was used.

Table 6. Comparison of high-, medium-, and low-tech sawmills.

	Mean			
	High	Medium	Low	
Scale	n = 17	n = 48	n = 19	P value
Self-evaluated product	3.0	2.8	2.4	0.177
Self-evaluated process	3.7a	3.5a	2.5b	0.001*
Self-evaluated business systems	3.0	3.1	2.4	0.065
Self-evaluated composite	3.2a	3.1a	2.4b	0.004*
Propensity to create new products	3.3	3.1	2.8	0.276
Propensity to create new processes	4.0a	3.6a	2.8b	<0.001*
Propensity to create new business systems	3.4a	3.1b	2.6b	0.024*
Propensity to adopt new processes	3.7a	3.3a	2.6b	<0.001*
Propensity to adopt new business systems	3.2a	2.9b	2.4b	0.034*
Propensity to create/adopt composite	3.5a	3.2a	2.6b	0.002*

Note: Values with different letters denote significant differences from Tukey's test at α = 0.05.
*Denotes significant at α = 0.05.

Finally, the use of current technology does not account for all three aspects of innovativeness — product, process, and business systems. Of the eight technologies assessed in this study, seven were manufacturing technologies and one was a business system. This method relies on one business system to account for that aspect of innovativeness and fails to account for product innovativeness.

Despite the problems associated with using current technology to assess firm innovativeness, the current technology measure used in this study did effectively discriminate between high-, medium-, and low-innovative companies in all but three cases (Table 6), showing significant differences on one of the three components of the self-evaluated scale and four of the five components of the propensity to create and adopt scale. However, the current technology measure did have a weaker relationship with sawmill performance than both the self-evaluated and propensity to create and adopt measures (Table 5).

Performance and innovativeness

Consistent with previous research in the North American softwood sawmilling industry, respondents felt their operations were most innovative in the area of manufacturing processes. Performance also generally had the strongest positive relationship with process innovativeness. Sales growth had the strongest positive relationship with self-evaluated process innovativeness and the propensity to create and (or) adopt new processes. Gross profit, on the other hand, had the strongest relationships with the self-evaluated business systems innovativeness and the propensity to create new business systems. The composite of the propensity to create and (or) adopt scale had strong, positive relationships with both of the performance measures. This result is consistent with previous work showing that firms benefit from a balanced, innovative focus (Damanpour et al. 1989).

One potential reason for the relatively weak relationships between current technology and sawmill performance is that mills with more innovative equipment will likely have higher capacity. As a result, the mill must sell more product. The increased volume of product will not necessarily be sold at an increased margin, but may actually be sold at a lower margin to keep the mill from holding excess inventory.

Use of multiple respondents

The data collection in this study aimed to collect responses from multiple individuals within each sampled mill. The goal of this approach was to allow for testing of response bias. Rogers (2003) noted that respondent recall is an issue when using current technology as a measure of firm innovativeness. This problem was evident with the current technology measure used in this study. As previously indicated in this article, 44 out of 53 mills with multiple responses had inconsistencies in their current technology data.

However, when examining the data from the self-evaluated and propensity to create measures of firm innovativeness for mills with three respondents, analysis with ANOVA indicated there was no significant difference among respondents within a mill. These results indicate that multiple respondents may have inconsistencies with fact-based memory recall such as current technology. However, there does not appear to be a problem with subjective, perception-based measurements when using multiple respondents.

Limitations

One limitation of this research is a small sample size. While the response rate for this study is consistent with other industrial-based studies targeting top managers, a larger sample size might lead to more explanatory power in the relationship between firm performance and the propensity to create and (or) adopt. Additionally, an attempt was made to obtain more than one response from each mill. This methodology was not completely successful with only 29 out of 85 responding mills providing responses from three people. This inconsistency in responses among mills resulted in analysis performed using only the response from the mill manager or the highest ranking respondent for mills without a response from the mill manager.

An additional limitation is the use of a self-evaluated measure of performance. Respondents indicated the financial performance of their sawmills relative to their competition. This methodology, while commonly used in previous literature, has the potential to introduce response bias.

The comparison of the three-item self-evaluated scale to the 25-item propensity to create and adopt scale presents a potential limitation. This comparison needs to be justified in other industries to verify that higher coefficient α values for the propensity to create and adopt scale are not merely the result of using eight times as many items.

There are also limitations regarding the propensity to create and adopt scale. This scale uses indirect self-evaluation of innovativeness with 25 items, and therefore, it has the potential to introduce response bias. However, analysis of response bias in mills with three responses indicates that there was no response bias with this scale. This scale is newly developed and requires further refinement, a potential focus of future work.

Future work

The initial analysis of the propensity to create and (or) adopt scale shows that it performs well compared to previously developed measures of firm innovativeness. However, this iteration of the scale is only the initial attempt to develop a new, robust measure of innovativeness. Additional work is being done to refine this scale.

Managerial implications

The softwood sawmilling industry has traditionally had a commodity product orientation. As a result, firms have focused on producing at the lowest cost and improving processing efficiency by creating and (or) adopting new processing technology. Focusing exclusively on new processing technology may not be the best strategy because it inhibits innovation in other areas of the firm. Firms that were innovative in all three areas, product, process, and business systems, performed better than firms with a primary focus on manufacturing processes. The results show that there is room for improvement in all aspects of innovativeness. This is particularly true for product innovativeness, which respondents ranked lowest with both the self-evaluated and the propensity to create and adopt scales. Managers should keep in mind that the innovative focus of the organization must be coherent with the firm's strategic orientation. Consequently, changes in firm strategy may be required to successfully implement a new innovative orientation.

Acknowledgements

The authors would like to thank Pablo Crespell, Jochen Czabke, Erlend Nybakk, Rajat Panwar, and John Tokarczyk for their thoughtful critique of this article.

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