Workplace organization and innovation

Cindy Zoghi, U.S. Bureau of Labor Statistics*
Robert D. Mohr, University of New Hampshire
Peter B. Meyer, U.S. Bureau of Labor Statistics

July, 2005

Preliminary and incomplete, please do not quote without permission.

Abstract: When workers hold information about production inefficiencies or unmet consumer demands that can lead to innovations, particular workplace organizations may encourage or facilitate the communication and implementation of those ideas. This study uses a unique establishment-level dataset from Canada to test whether particular organizational structures are correlated with the likelihood of adopting process and product innovations. We find that establishments with decentralized decision-making or information-sharing programs are significantly more likely to innovate than other types of establishments, even after controlling for potential endogeneity. We also find that those with incentive pay plans, a high vacancy rate, and larger establishments are more likely to innovate.

* *Cindy Zoghi*, U.S. Bureau of Labor Statistics, 2 Massachusetts Ave., NE, Washington DC 20212, e-mail: Zoghi.Cindy@bls.gov; *Robert D. Mohr*, Department of Economics, Whittemore School of Business and Economics, University of New Hampshire, Durham NH 03824, e-mail: rmohr@cisunix.unh.edu; *Peter B. Meyer*, U.S. Bureau of Labor Statistics, 2 Massachusetts Ave., NE, Washington DC 20212, e-mail: Meyer.Peter@bls.gov.

The authors thank David Autor, Michael Gibbs, John W. Meyer, Leo Sveikauskas, and seminar participants at the University of New Hampshire and the 2005 SOLE meetings for helpful comments, Lucy Chung at Statistics Canada for exceptional support with the data, and the University of New Hampshire for financial support. All views expressed in this paper are those of the authors and do not necessarily reflect the views or policies of the U.S. Bureau of Labor Statistics.

I. Introduction

This study tests whether establishments with decentralized decision-making or information- sharing generate process and product innovations. There is reason to think this is the case. Workers who directly interact with customers have information about consumer preferences and constraints that managers do not have. This information may be important to spawning new product ideas. Similarly, workers who are part of the production process will know about the weaknesses and inefficiencies of the process; this information can generate innovative improvements to the process. If the worker with this private information also has the capacity to act on the information or shares the information with someone who already has such capacity, subsequent innovations are more likely. There are costly tradeoffs however -- if organizations allow workers that authority, they will be subject to more internal uncertainty and surprises, and to more principal-agent problems.

Freeman and Lazear (1995), in their theory on works councils, point to the importance of information-sharing as a solution to this dilemma. Management and workers have different information sets and can therefore increase the organization's productive efficiency by adopting institutions that increase the transmission of information. The result may be that "management and labor together discover solutions to company problems that neither would have conceived separately" (p44). While information-sharing can be the right solution for some establishments, it can impose high costs, both in terms of setting up an information infrastructure and in terms of the delay while the information is transferred. These penalties can be severe if it is necessary to react quickly to the environment.

Under rapidly changing circumstances, transferring information from the worker to another decision-maker is more costly and this may encourage decentralization, giving workers more authority to act autonomously. For example, a high tech firm may have to redefine its product frequently, change technologies in its design and production, and adapt design, marketing, and sales approaches to changing circumstances. Partly for these reasons, high tech firms are thought to have more inclusive decision-making processes.

Decentralization also comes at a cost, however. If the worker is given the authority to make decisions on the basis of her private information, the organization will likely incur agency costs. As Jensen and Meckling (1995) describe, "[b]ecause they are ultimately self-interested, the agents to whom the CEO delegates authority have objective functions that diverge from his or her own" (p.17). This means that the establishment faces a trade-off between the agency costs it faces under decentralization, and the infrastructure and time costs of information sharing. Any combination of these two approaches could support product and process innovation.

The empirical literature on innovation presents some results consistent with these hypotheses. A number of studies show that various inclusive and interactive work processes increase productivity (see Black and Lynch, 2004; Bresnahan, Brynjolfsson and Hitt, 2002, or Ichniowski, Shaw, and Prennushi, 1997 for excellent examples). There are far fewer articles linking workplace organization to innovation.[1] Typically, large nationally representative surveys lack either a direct measure of innovation or detailed information about work organization. Michie and Sheehan (1999) use two proxies for innovation to link human resources practices with innovation in a large data set of UK firms. Laursen and Foss (2003) show an association between a variety of human resource practices to innovation in data from 1,900 Danish firms, and Rogers

[1] See Rouvinen (2002) for a recent literature review and interesting results on what drives product and process innovation in general, but without a specific focus on decentralization and inclusion.

(1999) uses a panel of 698 Australian workplaces to show that better employee-management communications systematically increase reported innovations. Therrien and Léonard (2003) use the same data used here to analyze whether particular forms of enrichment practices affect the innovative nature of the establishment.

The contributions of this paper differ from this prior literature on workplace and innovation. First, our data, which includes over 19,000 observations spanning a period of four years, is more extensive than that used in prior research in this area. Second, much of the existing work follows Ichniowski, Shaw, and Prennushi (1997) in focusing on the complementarities in human resource management techniques. Firms typically use a number of different workplace practices in conjunction. One implication is that the more types of workplace practices used, the greater the rate of innovation. This result has now been verified by Michie and Sheehan (1999) and Therrien and Léonard (2003). Our approach presupposes a certain degree of complementarity, but also tries to identify tradeoffs in the sense that different groups of workplace practices imply different avenues through which firms can foster innovation. This includes consideration of some options available to a firm that is otherwise hierarchical.

The remainder of this paper is divided into 4 sections. Section II discusses theories of workplace organization and highlights how either information sharing or decentralized decision rights might increase innovation. Section III describes the data, measures of decentralization and information-sharing and an empirical strategy. Section IV presents results and section V concludes.

II. Theories of organization

We describe an informal model, inspired in part on the intuition of Jensen and Meckling (1995), to describe four types of organizational structures that could foster the use of workers'

knowledge to make useful innovations. Imagine that an establishment's "founder" chooses organizational structure to maximize profits, taking into account a link between work organization and the expected return to innovation. Many exogenous factors, such as industry, uncertainty of the market, speed of market change, and nature of inputs, affect whether such profitable innovations are possible. The founder has an *ex ante* estimate of the probabilities that workers and managers possess private information relevant to conceiving of and implementing innovations, and the founder has an *ex ante* estimate of the probability that innovations with positive expected returns will be found. In those firms that have a high probability of innovating, the organizational structure will be chosen to be consistent with stimulating innovation.

The notation of such a model is simple. Assuming risk-neutrality, the expected benefits of innovation, $B(I)$ depend on some exogenous benefit, b, that might be increased in the presence of private information through the adoption of organizational structures like decentralized decision making, d, or information sharing, s. So, $B(I) = b + f(d,s)$, where the function f is non-decreasing in each argument, concave, and d and s are continuous variables. There are potential agency costs, which we denote c_d, associated with adopting decentralized decision-making. These include the possible losses from decisions with mutually inconsistent objectives, and the costs of monitoring workers or adopting incentive pay in order to align objectives. There are also costs to transferring information, which include the cost of setting up and operating informational infrastructure, such as IT systems, suggestion programs, and problem-solving committees, as well as indirect costs that are a function of the delay in transferring information. These costs, which we denote c_s, depend on the nature of the organization and its products and markets, and on the complexity of the information. Finally we allow for other fixed costs of innovation that are independent of workplace organization, which we denote c_I. The founder chooses an organizational structure to maximize the expected benefits of innovation:

$$\max_{d,s}: \quad b + f(d,s) - c_d d - c_s s - c_I \qquad (1)$$

In this analysis, corner solutions, where the founder chooses not to use some aspect of work organization, are particularly relevant. For example, if the benefits of information sharing and decentralization are small (the first derivatives, f_s and f_d, are always close to zero) or the costs of these work-organization practices are high, then the founder will choose a centralized workplace, where $d = s = 0$. A centralized workplace can be consistent with innovation (if $b>c_I$), or the presence of a centralized workplace might indicate that the founder does not pursue innovation (if $b<c_I$). In addition to describing cases where the firm chooses a centralized structure, the model also highlights other possibilities where the founder chooses positive amounts of d or s, or both.

One possibility is that workers hold information that can lead to innovations, but the information *cannot* easily be communicated — in other words, the costs to communicating it hierarchically would exceed the agency costs of empowering workers. This could happen if the information were tacit (hard to communicate or hard to identify), or if the economic environment required firms to react quickly.[2] In terms of the model, this means that the marginal impact of decentralized decision rights, f_d is relatively large and the cost associated with those rights, c_d, is relatively small. In such situations, firms may optimally allocate decision making about technology and work organization to the workers. A second possibility is that workers have production-specific information that *can* quickly and easily be communicated. In this case the

[2] Some examples illustrate the scenario. The dot-com e-commerce boom had changing technologies and markets. Changing fashions can affect what the market wants. Difficulty or delay in computation or processing by managerial decision makers introduces costs similar to difficulty or delay in communication; see Van Zandt (2003) for a model of this.

marginal impact of information sharing, f_s, might be relatively large, wheras c_s is relatively small. Here labor-management committees and other formal programs that encourage information sharing, suggestions and feedback may support innovation.

The model imposes only few restrictions on $f(s, d)$, and it may be that the founder chooses to use either d or s, but not both. For example, a hierarchical structure with information sharing may best promote innovation by allowing managers to specialize in gathering information from different aspects of the production process and then integrating the information to support innovation. An illustration of such a case would be when these two innovation inputs are perfect substitutes. An internal solution, where the second order conditions hold and the founder uses positive values of both d and s, is of course also possible.

So far, we have identified four types of workplace organization that could support product and process innovation in an establishment. If the firm does not use either decentralization or information sharing, we call it *fully centralized.* If it uses only one of these two practices to a significant degree, we label it either *decentralized, without information sharing* or *centralized with information sharing.* If it uses both practices, we label it *decentralized with information sharing.*

This informal model provides a useful framework for moving forward to the empirical work. It provides a classification scheme and it highlights our working assumptions. For example, the model discounts reasons other than innovation that managers would decentralize or share information.[3] The model also assumes innovations depend on work organization.[4] In the empirical section we test the alternative hypothesis that innovations predict structure. The theory also points towards some hypotheses. Decentralization and information-sharing should both be

[3] Mohr and Zoghi (2005) show that decentralized workplaces have higher worker satisfaction, so firms may use decentralization to motivate workers rather than specifically to foster innovation. Freeman and Lazear (1995) explore the hypothesis that information sharing is used to transmit bad news and thereby induce effort.

[4] Therrien and Léonard (2003) offer a nice counterexample of a firm that adopts a new machine that may temporarily slow production and cause the firm to operate at less than full capacity. Managers might introduce special human resource practices, such as training or problem-solving teams to minimize the delay.

positively associated with innovations. While it is possible that fully centralized firms also innovate, they do so only if $b>c_I$, a more restrictive criteria than those faced by other firms. Thus, we expect that fully centralized firms should be negatively associated with innovations. A direct test of the model, linking the types of information and innovation is not possible, since we have no measure of privately held information. However, we can view relationships between these particular types of workplace organizational practices and rates of innovation as evidence which indirectly supports or undermines the hypotheses.

III. Empirical strategy and data description

The following probit model describes the relationship between the organizational structure of the workplace and its innovativeness:

$$\text{Prob}(innov_{jt} = 1) = \Phi(\alpha + \beta_1 decent\text{-}info_{jt} + \beta_2 cent\text{-}info_{jt} + \beta_3 decent\text{-}noinfo_{jt} + \gamma Z_{jt} + \varepsilon_{jt}) \qquad (2)$$

where $innov_{jt}$ is an indicator for whether establishment j has introduced an innovation in year t, $decent\text{-}info_{jt}$, $cent\text{-}info_{jt}$, and $decent\text{-}noinfo_{jt}$ are indicators for whether establishment j is decentralized with information-sharing, centralized with information-sharing, or is decentralized without information-sharing, respectively in the initial year. Z_{jt} includes other variables that are likely to affect the innovativeness of an establishment.

This project uses data on 6,322 establishments drawn from the 1999-2003 Canadian Workplace and Employee Survey (WES). Establishments were first selected from all employers in Canada with paid employees, except for those in the Yukon, Nunavut, and Northwest Territories and those in farming, fishing and trapping, religious organizations and public administration. These establishments were then re-surveyed annually for five years, the first four

of which are currently available for analysis. In 1999, 6322 workplaces were interviewed, with data collected through personal interviews[5]. In the succeeding years, responses were acquired from 6068, 6223, and 5818 of these establishments, using computer-assisted telephone interviews. In this study, we restrict the sample to those establishments with more than 10 employees, since smaller establishments were not queried about the relevant workplace practices.

The survey asks respondents whether the workplace has introduced any of four specific types of innovations in the preceding year: 1) new goods or services, which "differ significantly in character or intended use from previously produced goods or services," 2) improved goods or services, which "are those whose performance has been significantly enhanced or upgraded," 3) new processes, which "include the adoption of new methods of goods production or service delivery," and 4) improved processes, which "are those whose performance has been significantly enhanced or upgraded." Table 1 shows the share of establishments that report introducing an innovation in the past year.[6] Each year, most establishments introduced some kind of innovation. About half reported new or improved products in 1999. Fewer reported process innovations than product innovations. More establishments reported improvements to existing products and processes than entirely new ones. Innovation rates of all kinds were highest in 1999 and lowest in 2002.

The survey also elicits detailed information about work organization, including the use of quality circles, teams, suggestion programs, feedback, and self directed work. It records who (workers, management or some combined team) participates in decisions over twelve different aspects of the production process, including planning of individual work, purchase of machinery,

[5] While the primary contact is typically a human resources person, in about 20% of the surveyed establishments, other respondents also answer some questions.
[6] All means reported here have been probability--weighted to adjust for the sampling framework and to protect the confidentiality of respondents.

staffing levels, and new product development. The level of detail in the information about both innovation and work organization makes the WES data set unique.

Consistent with the theory explored in the previous section, we use the allocation of decision authority to identify firms as either decentralized or centralized, and then further split these organizational styles into those that employ information-sharing techniques and those that do not. This creates four types of firms: hierarchical, centralized with information-sharing, decentralized without information-sharing and decentralized with information-sharing. We start with decision-making. In each year, we rank the establishments by the number of decisions that workers participate in making (out of the twelve possible): those that are in the 75th percentile or above are categorized as *decentralized* establishments.[7] These questions are asked twice of establishments, once in 1999 and again in 2001; thus by this definition an establishment could change organizational structure over time. In most regressions we include only an establishment's 1999 organizational structure[8].

Apart from decision-making, flows of communication between workers and management can support innovation. The WES gathers information about three workplace characteristics that indicate such inclusiveness: 1) employee suggestion programs, including employee survey feedback, 2) information sharing programs, "for example with response to firm's performance, colleagues' wages, technological or organizational change, etc.", and 3) joint labor-management committees, which include "non-legislated joint labour-management committees and task teams that generally cover a broad range of issues, yet tend to be consultative in nature." Each of these workplace characteristics is used primarily to get employee input without necessarily ceding the

[7] Clawson (1980, p. 84-85) defined an organization's level of decentralization slightly differently, by how high in the organization a decision problem must go to be resolved. Black and Lynch (1997, p. 22) report that the fraction of workers involved in decision making meetings was positively correlated to labor productivity.

[8] Using the 2001 structure or a combination yields similar results.

decision rights. We define an establishment to employ *information-sharing* if it has at least two of these three programs existing on a formal basis in the workplace.

Our criteria for dividing the firms into centralized and decentralized groups allow us to focus on differences in work organization beyond the complementarities explored in prior papers. Table 2 indicates the proportion of establishments that fall into each of these organization types. Approximately 17% (15%) of establishments with more than ten employees are decentralized (centralized) and employ information-sharing techniques by our definitions, while 25% (43%) are decentralized (centralized) and do not adopt those information-sharing programs.

We include several factors in Z_{jt} that may affect whether an establishment innovates or not. The means of these variables are included in Table 2. The size of the establishment, measured by the natural log of the number of employees, should be positively related to innovation, since there may be more product lines and services that are open to efficiency and quality improvements. Whether the establishment is part of a multi-plant firm may affect innovation, as another measure of size. The non-profit status of an organization may affect the propensity to innovate. Ten percent of establishments with more than ten employees are non-profit. Establishment age may affect innovation in that older institutions are likely to be more set in their ways and to have already invested in determining their internal structure. Furthermore, their core technologies and ways of organizing have survived a longer-term selection process. They may therefore be less likely to innovate. A strong union presence can reduce the share of rents accruing to innovation that are captured by the establishment, thus reducing the incentive to innovate. Hirsch and Link (1987) find that R&D spending is lower in unionized firms, and Acs and Audretsch (1988) find that highly unionized industries produce fewer innovations. Thirteen percent of workers in establishments with more than ten employees are covered by the union.

Two variables capture the volatility of the market. One is an indicator for whether the establishment experiences seasonal peaks in demand, which over forty percent of the sample do. The second is the vacancy rate (number of vacancies as a fraction of total employment), which is 3.7% on average in establishments with more than ten employees. Both measures of volatility should predict innovation since the establishment may adopt new processes in response to fluctuations in either the input or output markets.

Finally, Z_j includes measures of compensation schemes, and competition in the output market. The former are captured in indicators for whether a profit sharing plan or an individual incentive pay plan exists at the workplace. Such compensation schemes are believed to be an important complement to encouraging innovative activity, as they help to align the workers' interests with those of the manager. Black and Lynch (2005) argue that such pay plans are used to give workers a reason to come forward with innovations that might improve efficiency but also might put the worker's own job at risk. Fifteen percent of the sample had profit sharing plans in 1999, and 43% had incentive pay. To measure competition, we include indicators for whether the establishment is a monopoly and whether it faces significant competition (more than twenty competitors). Eight percent and 25% fall into these categories, respectively. Aghion et al. (2002) and Parente and Prescott (1999) theorize that monopolies are less likely to innovate. There are Schumpeterian-type arguments going the other way. For example, some monopolies exist because the monopolist previously innovated, and may have remained of the type to innovate further. Monopolies would also be able to benefit uniquely from competence-enhancing innovations (in the language of Tushman and Anderson (1986)), and therefore would have a particular incentive to innovate. We also include industry and year indicators.

Table 3a indicates how innovativeness varies across industry, measuring the share of establishments that had any of the four types of innovations in 1999. Establishments in finance

and insurance, and capital-intensive (often high tech) manufacturing firms, reported innovations more often than establishments in other industries did. Also especially innovative were information and cultural industries, and labor-intensive tertiary manufacturing, which includes firms with many product lines, or firms that respond quickly to changes in consumer demand.[9] Industries reporting the fewest innovations were forestry, mining, oil and gas extraction, education and health services, communications and other utilities.

Table 3b details innovativeness across values of the other explanatory variables in Z_{jt}. It suggests that particular workplace organization types are correlated with higher innovation. Establishments that decentralize decision making or share information innovate much more than those that do neither. Perhaps surprisingly, establishments that are centralized with information-sharing are most likely to innovate of all groups, with over 76% reporting at least one innovation in the past year[10]. Additionally, larger establishments, unionized establishments, those with seasonal demand peaks, those with high vacancy rates, and those with incentive pay have higher innovation rates than the average establishment. Monopolies have a strikingly low rate of innovation. We now turn to our regression approach to determine whether these correlations persist when all effects are measured jointly.

IV. Results

The first three columns of Table 4 report marginal effects of the probit estimation described in equation (2), using three alternative measures of the dependent variable: whether the establishment introduced a new or improved product, whether it introduced a new or improved process, and whether it introduced any innovation in the past year. The fourth column reports the

[9] A probit estimation of the probability of innovation on the industrial classification, shown in Appendix Table A2, confirms that these four industries are associated with the highest marginal increase in probability of innovation.
[10] Appendix Table A1 shows innovation rates by the individual workplace practices that comprise these organizational types. No single component appears to dominate this result.

results of a Tobit estimation of the number of these four innovation types an establishment introduced in the past year[11]. The pooled 1999-2002 sample consists of all establishments with more than ten employees. Standard errors are corrected both for sample design and for heteroskedasticity due to multiple observations per establishment.

Information-sharing is strongly correlated with innovation. Whether combined with decentralized decision-making or not, establishments that share information are 19-22% more likely to have an innovation than the excluded group, which is made up of centralized establishments without information-sharing. Establishments that are decentralized but do use information-sharing are also more likely to innovate, but the effect is about half as big. These patterns are also reflected in the number of innovation types that an establishment uses—information-sharing establishments have reported at least one more type of innovation in the past year than the excluded group, while those that are only decentralized have had on average an additional half a type.

The correlation between decentralization and innovation is consistent with our hypothesis that granting decision authority more widely would be a route to increased innovation. The result that the marginal effect of information-sharing is larger than the marginal effect of decentralization is a significant new finding. This result indicates that there are multiple workplace structures that can lead to innovation, and that a hierarchical organization may still be quite innovative, especially if it employs information-sharing techniques.

Other establishment characteristics are correlated with innovation as well. Larger establishments are more likely to innovate, presumably because they have more activities that can be improved or leveraged. Stronger union presence does not appear to be correlated with the

[11] Although respondents were not asked how many innovations they introduced in the previous year, this is a rough ranking of innovativeness. We expect that those establishments reporting all four types of innovations are more innovative in some sense than those who only report one type.

probability of any particular innovation, although it is negatively related to the number of types of innovation an establishment reports. We had expected a stronger result here, since other studies of innovative behavior had found a significant negative relationship. Nonprofit institutions appear to be less likely to generate innovations than comparable for-profit institutions.

Establishments with seasonal peaks in demand have more product innovations; perhaps some of them respond to fashions, or the lulls in business allow time for innovative activity. A high vacancy rate is strongly correlated with innovation as predicted; these may be establishments in opportunistic, turbulent circumstances. Establishments with individual incentive pay plans are more likely to report innovations, while profit sharing plans are not correlated with innovation.

Monopolies in these data were less likely to report product innovations, although the result is not statistically significant in any of the models. This relationship has also been found in other recent studies, such as Aghion et al. (2002), which found a negative relationship between concentrated industries and patent flows from firms. The data weakly support the interpretation that the conservative impulse of monopolies to protect the industrial structure overwhelms forces going the other way. Establishments with more than twenty competitors were no more likely to report innovations than the omitted reference group (those with some competitors, but fewer than twenty). Aghion et al (2002) reported, somewhat contrary to this, that high levels of competition produced low patent flows from establishments.[12]

The findings in table 4 provide evidence that decentralization and information-sharing practices predict higher innovation rates. They may not *cause* the higher innovation rates, however. First, causality might go in the opposite direction -- innovation may spur workplace reorganization. Second, both outcomes may be caused by omitted variables. For example, it may

[12] Aghion, et.al. (2002) interpret this as a structural relationship between perfect competition and lower incentives to innovate. An alternative interpretation is that perfect competition evolves from historical contexts in which most opportunities for innovation have been exhausted.

be that college-educated managers spot potential innovations and that educated managers also share information or grant decision rights. In this case, since manager education is unobserved, our results for the other variables would be biased relative to the structural relationship. In fact, our theory suggests a specific type of unobserved variable, the existence of private information in the minds of workers, which determines workplace organization, but not innovation.

In order to investigate the first of these issues, we use the longitudinal aspect of the data to test the possibility of reverse causality. Table 5 reports the results of three probit estimations on the probability of an establishment being decentralized with information-sharing, decentralized without information-sharing, and centralized with information-sharing in 2001, in each case relative to the same excluded group, those that are fully centralized in 2001. The regressors are the same as in Table 4, along with measures of the number of innovations of any kind in each year of the sample. If past innovations are correlated with the workplace organization, but later ones are not, then we have evidence of a "reverse causality" problem. Results of this estimation, shown in Table 5, do not entirely rule out an effect from innovations to workplace organization, in particular for decentralized information-sharing establishments, where the highest correlation is with the one year lagged innovations. Contemporaneous innovations are also significant for this group, as well as for the other two organization types. These results provide some evidence of reverse causality, although it does not appear to be a strong force in the data.

We take additional steps to control for the potential endogeneity of the regressors. One way to remove some of this endogeneity is to restrict the analysis to the pooled 2000-2002 sample, and use the lagged 1999 variables as regressors. This model gives up some information about the current year that might affect innovation outcomes, in order to escape the short run endogeneity of some of these regressors. For example, consider the vacancy rate of the establishment in the current year. Establishments that are producing innovative products and services are likely to

expand by hiring. Consider, as examples, Google or other fast-growing high tech companies that would report high rates of innovations and would also report high rates of open job positions. In such a case, both vacancy rates and innovation rates are informative about the firm's type, but the vacancy rate is not causal. Therefore in this regression we use a previous vacancy rate, which is more likely to tell us about the firm's type and its environment historically, and cannot be a short-run result of recent innovative outcomes. It is less endogenous than current-year vacancy rates.

Table 6 shows the results of these estimations. Information-sharing programs, both in centralized and decentralized establishments, still are strongly correlated with reported innovations. The effect of decentralization in the absence of information-sharing is much smaller and is statistically insignificant in two of the models. This suggests that either our measure of decentralization or any of the other regressors may in fact be endogenous. Other coefficients change in size and significance as well, suggesting that they were previously biased due to their relationship with the endogenous regressor. The size of the establishment is no longer significant in the three probit estimations, and even negatively affects the number of innovation types. Seasonal peaks become insignificant in this model. Profit sharing plans, previously insignificant, now are positive predictors of innovation in most specifications. The vacancy rate continues to have a strong positive effect on innovation[13].

As a further step to eliminate potential endogeneity, we add a set of controls for whether the establishment reported any of the four innovation types in 1999. Unobservable establishment characteristics that affect innovative behavior are approximately held fixed in the 1999 measures of innovation. Table 7 shows that year 1999 innovations strongly predict current innovations, especially those that are of the same type, i.e. product or process. Again, information-sharing is

[13] Further concerns about the endogeneity of the vacancy rate led us to attempt a specification in which we replaced the establishment's own vacancy rate with an industry-averaged vacancy rate. This did not change the results significantly.

independently a strong, positive predictor of innovations, although the size of the effect is somewhat smaller. Decentralization alone, while positive in all specifications, is only statistically significant in the estimation of the number of types of innovations. For the most part, the effects of the other predictors remain the same, with the exception of the monopoly indicator, which is now positive and significant in one specification.

Finally, the longitudinal nature of the data also enables us to test for endogeneity by including establishment fixed effects to the model in equation (2). In such estimation, effects are identified for those establishments that change workplace organization, measured here as a binary variable, between 1999 and 2001. This is a noisy source of variation, much of which probably comes from small differences in workplace practices, interpretation of the survey question, or reporting mistakes. Furthermore, changes in organizational practices would not usually immediately yield changes in innovative activity. We will report the results nonetheless as one control for endogeneity.

Table 8 reports the results of this estimation. In the fixed effects logit models, establishments that *adopt* information-sharing techniques are much more likely to report innovations. Although this might be true by definition if the respondent interprets the innovation question to refer to changes such as the adoption of information-sharing programs, the result also holds up, and is even larger, in the product innovation specification, suggesting that this is not the only reason for the correlation. Although size and union presence were statistically insignificant in the pooled estimations, the effects are large and significant in this model. Growing establishments are also more likely to report innovations, while those with growing union presence are less likely to do so. Those establishments whose demand becomes more volatile by becoming seasonal or by having an increased vacancy rate are more likely to innovate. Although the overall explanatory power of these estimations is quite low, our aim here is not to fully explain

innovative behavior, but rather to confirm the relationship between organizational structure and innovation, which this model shows.

V. Conclusion

We use the Canadian WES data to identify whether an establishment is decentralized or centralized, based on a series of questions on the extent of worker participation in decision making in the establishment. We further divide these organizational types by whether or not the establishment employs information-sharing techniques to transfer information to and from employees. We theorize that information-sharing and decentralization are two alternate methods of bridging the gap between information vital to innovative activity and the authority to act on such information. The WES contains four explicit measures of innovation, covering new products, improved products, new processes and improved processes.

We test whether there is a correlation between decentralization or information-sharing and innovation, controlling for a number of establishment characteristics, including industry, establishment size, degree of competition, use of incentive pay plans, non-profit status, and demand volatility. We find that information-sharing is strongly related to innovation, regardless of whether the establishment is decentralized or hierarchical. Decentralization in the absence of information-sharing is only weakly related to innovation. While we cannot be certain that this relationship is causal, we have used several different techniques to control for potential endogeneity, and have looked for evidence of reverse causality. Using a variety of tests and controls, we continue to find a strong predictive effect of workplace organizational structure on innovation.

References:

Acs, Zoltan J. and David B. Audretsch. 1988. "Innovation in Large and Small Firms: An Empirical Analysis" *The American Economic Review 78: 4*, 678-690.

Aghion, Philippe, Nicholas Bloom, Richard Blundell, Rachel Griffith, and Peter Howitt. 2002. "Competition and Innovation: An Inverted U Relationship." http://post.economics.harvard.edu/faculty/aghion/papers/comp_and_innov.pdf

Angrist, Joshua D. and Alan B. Krueger. 2001. "Instrumental Variables and the Search for Identification: From Supply and Demand to Natural Experiments." *Journal of Economic Perspectives 15:4* (Fall), 69-85.

Black, Sandra E. and Lisa Lynch. 2004. "What's Driving the New Economy: The Benefits of Workplace Innovation." *The Economic Journal* 114(Feb.), F97-F116.

Black, Sandra E., and Lisa M. Lynch. 2005 "Measuring Organizational Capital in the New Economy." In *Measuring Capital in the New Economy*, eds. Carol Corrado, John Haltiwanger, and Dan Sichel. Chicago: University of Chicago Press

Black, Sandra E., and Lisa M. Lynch. 1997. "How to Compete: The Impact of Workplace Practices and Information Technology on Productivity." NBER working paper #6120. Available online at http://www.nber.org/papers/w6120.

Bresnahan, Timothy F.; Erik Brynjolfsson and Lorin M. Hitt. 2002. "Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-Level Evidence" *Quarterly Journal of Economics* (Feb.) 339-376.

Clawson, Dan. 1980. *Bureaucracy and the Labor Process: The Transformation of U.S. Industry, 1860-1920.* New York: Monthly Review Press.

Freeman, Christopher and Edward Lazear. 1995. "An Economic Analysis of Works Councils," in (J. Rogers and W. Streeck, eds.), *Works Councils*, pp. 27-52, Chicago, IL: University of Chicago Press.

Hirsch, Barry T. and Albert N. Link. 1987. "Labor Union Effects on Innovative Activity" *Journal of Labor Research 8: 4*, 323-332.

Ichniowski, Casey, Kathryn Shaw, and Giovanna Prennushi, 1997, "The Effects of Human Resources Management Practices on Productivity: A Study of Steel Finishing Lines," *American Economic Review* 87: 3, 291-313.

Jensen, Michael C. and William H. Meckling, 1995, "Specific and General Knowledge, and Organizational Structure," *Journal of Applied Corporate Finance*, vol. 8, no. 2.

Laursen, K. and N. J. Foss. 2003. "New Human Resource Management Practices, Complementarities, and the Impact on Innovation Performance." *Cambridge Journal of Economics* 27, 2: 243-63.

Michie, J. and M. Sheehan. 1999. "HRM Practices, R&D Expenditure and Innovative Investment: Evidence from the UK's 1990 Workplace Industrial Relations Survey." *Industrial and Corporate Change* 8: 211-34.

Mohr, Robert and Cindy Zoghi. 2005. "Is Job Enrichment Really Enriching?" Mimeo, University of New Hampshire.

Parente, Stephen L. and Edward C. Prescott. 1999. "Monopoly Rights: A Barrier to Riches." *American Economic Review*, 89(5): 1216-1233.

Rogers, Mark. 1999. "Innovation in Australian Workplaces: an Empirical Analysis," *Australian Bulletin of Labour,* 24(4): 334-351.

Rouvinen, Petri. 2002. "Characteristics of product and process innovators: some evidence from the Finnish innovation survey," *Applied Economics Letters*, 9, 575-580.

Therrien, Pierre and André Léonard 2003. *Empowering Employees: A Route to Innovation*, Statistics Canada: Ottawa. Catalogue no. 71-584-MIE.

Tushman, Michael L., and Philip Anderson. 1986. Technological Discontinuities and Organizational Environments. *Administrative Science Quarterly* 31: 439-465.

Van Zandt, Timothy. 2003. "Real-Time Hierarchical Resource Allocation." INSEAD working paper. http://faculty.insead.edu/vanzandt/papers/Resource1.pdf

Table 1. Percent of establishments innovating in the 1999-2002 WES, by type of innovation

	1999	2000	2001	2002
New product or service	44.17	31.56	40.07	29.10
Improved product or service	53.29	43.61	46.00	33.52
New process	37.26	31.12	32.83	20.60
Improved process	45.55	37.76	37.39	28.14
Any innovation	63.0	54.1	57.3	45.3
Number of observations	4123	4021	4089	3940

Notes: All estimates are calculated using probability weights. Sample restricted to those establishments with more than 10 employees.

Table 2. Workplace characteristics in 1999 WES

	Mean
Organizational type:	
Decentralized & info-sharing	.171
Decentralized without info-sharing	.249
Centralized & info-sharing	.149
Centralized without info-sharing	.431
Industry:	
Forestry, mining, oil and gas extraction	.015
Labor-intensive tertiary manufacturing	.049
Primary product manufacturing	.025
Secondary product manufacturing	.031
Capital-intensive tertiary manufacturing	.053
Construction	.051
Transportation, warehousing, wholesale trade	.133
Communication and other utilities	.021
Retail trade and consumer services	.288
Finance and insurance	.072
Real estate, rental and leasing operations	.015
Business services	.110
Education and health services	.105
Information and cultural industries	.031
Other vars:	
Ln (establishment size)	3.28
Union coverage rate	.131
Nonprofit institution (yes = 1)	.098
Part of multi-plant establishment	.328
Ln (establishment age)	2.19
Seasonal demand peaks (yes = 1)	.405
Vacancy rate	.037
Profit-sharing plan (yes = 1)	.151
Individual incentive pay plan (yes = 1)	.427
Monopoly (yes = 1)	.081
More than twenty competitors (yes = 1)	.246

Notes: All estimates are calculated using probability weights. Sample restricted to those establishments with more than 10 employees.

Table 3a. Share of establishments innovating, by industry

	Percent innovating
Full sample	63.0
Industry:	
Forestry, mining, oil and gas extraction	45.0
Labor-intensive tertiary manufacturing	66.5
Primary product manufacturing	62.2
Secondary product manufacturing	71.4
Capital-intensive tertiary manufacturing	82.8
Construction	54.0
Transportation, warehousing, wholesale trade	70.1
Communication and other utilities	52.6
Retail trade and consumer services	59.6
Finance and insurance	73.3
Real estate, rental and leasing operations	64.9
Business services	62.3
Education and health services	50.1
Information and cultural industries	68.4

Notes: All estimates are calculated using probability weights. Sample restricted to those establishments with more than 10 employees. Table A2 splits these effects by innovation type.

Table 3b. Share of establishments innovating, by workplace characteristics

	Percent innovating
Decentralized & info-sharing	74.1
Decentralized without info-sharing	66.1
Centralized & info-sharing	76.6
Centralized without info-sharing	52.0
Less than 50 employees	62.0
50 – 99 employees	67.5
100 – 249 employees	64.7
At least 250 employees	74.8
Unionized	64.7
Non-unionized	62.6
Nonprofit institution	47.9
For-profit institution	64.6
Establishment part of multi-plant firm	66.4
Stand-alone establishment	61.3
Establishment age less than five years	62.2
Establishment age 5 – 14 years	64.6
Establishment age at least 15 years	62.2
Seasonal demand peaks	63.6
No seasonal demand peaks	62.6
Vacancy rate = 0	60.2
Vacancy rate less than .03	73.8
Vacancy rate at least .03	68.6
Profit-sharing plan	71.3
No profit-sharing plan	61.5
Individual incentive pay plan	67.5
No individual incentive pay plan	59.6
Monopoly	57.0
Not monopoly	63.5
More than twenty competitors	64.4
Under twenty competitors	62.5

Notes: All estimates are calculated using probability weights. Sample restricted to those establishments with more than 10 employees.

Table 4. Effect of 1999 organizational structure and establishment characteristics on the probability of innovation in 1999-2002 WES

	Product Innovation	Process Innovation	Either Innovation	Number of Innovation Types
1999: Decentralized &	.2178***	.2113***	.2030***	1.321***
info-sharing (yes = 1)	(.044)	(.050)	(.043)	(.086)
1999: Decentralized w/o	.1142***	.0773**	.1028***	.4569***
info-sharing (yes = 1)	(.030)	(.033)	(.030)	(.069)
1999: Centralized &	.1916***	.1987***	.1882***	1.119***
info-sharing (yes = 1)	(.035)	(.036)	(.033)	(.084)
Ln (establishment size)	.0290**	.0343***	.0387***	.0148
	(.013)	(.013)	(.013)	(.036)
Union coverage rate	-.0085	.0120	.0041	-.3721***
	(.045)	(.045)	(.044)	(.100)
Nonprofit institution	-.1470***	-.0939*	-.1427***	-.7871***
(yes = 1)	(.054)	(.053)	(.056)	(.133)
Part of multi-plant firm	.0331	.0537*	.0383	.2532***
(yes = 1)	(.031)	(.032)	(.031)	(.065)
(Ln (establishment age))	-.0062	-.0097	-.0062	-.0836***
	(.013)	(.014)	(.013)	(.024)
Seasonal peaks (yes = 1)	.0596**	.0173	.0394	.2355***
	(.028)	(.029)	(.028)	(.060)
Vacancy rate	.2989***	.1797***	.2761***	1.139***
	(.082)	(.071)	(.084)	(.239)
Profit-sharing plan	-.0009	.0377	.0224	.0565
(yes = 1)	(.034)	(.037)	(.035)	(.079)
Individual incentive pay	.0662**	.0459*	.0739***	.3717***
plan (yes = 1)	(.028)	(.027)	(.028)	(.059)
Monopoly (yes = 1)	-.0137	.0372	-.0241	-.0110
	(.039)	(.045)	(.039)	(.105)
20+ competitors	-.0303	.0128	-.0130	-.0785
(yes = 1)	(.036)	(.035)	(.036)	(.066)
Pseudo-R^2	.0709	.0797	.0740	.0254

Notes: Cols. 1-3 are marginal effects of probit regressions. Col. 4 are Tobit effects. All are adjusted with probability weights and to control for clustering due to multiple observations in the same establishment, one for each year. * = p-value<.1, ** = p<.05, *** = p<.01. Each regression also includes a full set of 13 industry and year indicators. N = 14,594

Table 5. Predictive effect of past, present and future innovations on 2001 workplace organization: test of reverse causality

	Dependent variable: 2001 workplace organization type:		
	Decentralized & info-sharing	**Decentralized w/o info-sharing**	**Centralized & info-sharing**
1999: any innovation	.0296	.0129	-.0052
	(.030)	(.053)	(.050)
2000: any innovation	.1024***	-.0776	.0711
	(.033)	(.054)	(.045)
2001: any innovation	.0257	.0927*	-.0192
	(.031)	(.057)	(.057)
2002: any innovation	.0657**	.0425	.1557***
	(.037)	(.054)	(.058)
Number of observations	2065	2161	1916

Marginal effects of probit estimation. Model includes all variables included in Table 4. Sample is restricted to the organization type indicated relative to fully centralized.

Table 6. Effect of 1999 organizational structure and 1999 establishment characteristics on the probability of future innovation in 2000-2002 WES

1999 value of :	**Product Innovation**	**Process Innovation**	**Either Innovation**	**Number of Innovation Types**
Decentralized &	.1926***	.1636***	.1819***	1.035***
info-sharing (yes = 1)	(.040)	(.047)	(.039)	(.106)
Decentralized w/o	.0812**	.0484	.0466	.3157***
info-sharing (yes = 1)	(.036)	(.041)	(.038)	(.080)
Centralized &	.1847***	.1950***	.1613***	1.055***
info-sharing (yes = 1)	(.055)	(.051)	(.053)	(.109)
Ln (establishment size)	.0226	.0173	.0228	-.1231***
	(.015)	(.016)	(.015)	(.040)
Union coverage rate	.0434	.0531	.0386	-.0270
	(.060)	(.058)	(.060)	(.134)
Nonprofit institution	-.1232**	-.0600	-.0994	-.6310***
(yes = 1)	(.060)	(.060)	(.066)	(.158)
Part of multi-plant firm	.0206	.0384	.0368	.1551**
(yes = 1)	(.036)	(.038)	(.036)	(.079)
(Ln (establishment age))	-.0207*	-.0330***	-.0198	-.1644***
	(.013)	(.013)	(.013)	(.028)
Seasonal peaks (yes = 1)	.0060	-.0208	-.0191	-.0640
	(.032)	(.033)	(.033)	(.070)
Vacancy rate	.1990	.5549***	.4660**	1.863***
	(.138)	(.221)	(.209)	(.303)
Profit-sharing plan	.0263	.0937**	.0784**	.2463***
(yes = 1)	(.037)	(.040)	(.036)	(.097)
Individual incentive pay	.0490	.0378	.0562*	.3911***
plan (yes = 1)	(.033)	(.035)	(.034)	(.072)
Monopoly (yes = 1)	.0375	.0540	.0223	.0695
	(.063)	(.071)	(.062)	(.120)
20+ competitors	-.0151	.0083	.0017	-.0193
(yes = 1)	(.040)	(.039)	(.041)	(.078)
Pseudo-R^2	.0486	.0734	.0563	.0194

Notes: Cols. 1-3 are marginal effects of probit regressions. Col. 4 are Tobit effects. All are adjusted with probability weights and to control for clustering due to multiple observations in the same establishment, one for each year. * = p-value<.1, ** = p<.05, *** = p<.01. Each regression also includes a full set of 13 industry and year indicators. N = 10,409

Table 7. Effect of 1999 organizational structure and 1999 establishment characteristics on the probability of future innovation in 2000-2002 WES, with controls for 1999 innovations

1999 value of :	Product Innovation	Process Innovation	Either Innovation	Number of Innovation Types
Decentralized &	.1366***	.0992**	.1276***	.6113***
info-sharing (yes = 1)	(.039)	(.046)	(.041)	(.104)
Decentralized w/o	.0579	.0281	.0246	.1682**
info-sharing (yes = 1)	(.036)	(.044)	(.039)	(.078)
Centralized &	.1319**	.1394***	.1109*	.6638***
info-sharing (yes = 1)	(.059)	(.054)	(.058)	(.108)
Ln (establishment size)	.0221	.0161	.0224	-.1142***
	(.014)	(.016)	(.015)	(.039)
Union coverage rate	.0610	.0693	.0570	.0798
	(.056)	(.054)	(.057)	(.131)
Nonprofit institution	-.1001*	-.0602	-.0852	-.5255***
(yes = 1)	(.058)	(.060)	(.064)	(.156)
Part of multi-plant firm	.0162	.0261	.0248	.0888
(yes = 1)	(.037)	(.039)	(.037)	(.078)
(Ln (establishment age))	-.0134	-.0321**	-.0141	-.1303***
	(.013)	(.013)	(.013)	(.028)
Seasonal peaks (yes = 1)	-.0268	-.0464	-.0530	-.2625***
	(.033)	(.034)	(.034)	(.069)
Vacancy rate	.1370*	.5393***	.4226**	1.527***
	(.077)	(.219)	(.199)	(.294)
Profit-sharing plan	.0314	.0985**	.0836**	.2693***
(yes = 1)	(.040)	(.044)	(.040)	(.094)
Individual incentive pay	.0339	.0278	.0447	.3056***
plan (yes = 1)	(.033)	(.036)	(.035)	(.070)
Monopoly (yes = 1)	.0553	.0800	.0423	.1994*
	(.064)	(.078)	(.064)	(.116)
20+ competitors	-.0401	-.0214	-.0253	-.2119***
(yes = 1)	(.038)	(.037)	(.040)	(.077)
New product	.1418***	.0439	.1155***	.6387***
	(.038)	(.041)	(.039)	(.082)
New process	.0421	.1041**	.0878**	.4751***
	(.043)	(.043)	(.043)	(.097)
Improved product	.1009**	.0340	.0613	.4955***
	(.045)	(.043)	(.047)	(.093)
Improved process	.0052	.0815*	.0195	.2368**
	(.048)	(.044)	(.048)	(.102)
Pseudo-R^2	.0859	.1054	.0885	.0330

Notes: Cols. 1-3 are marginal effects of probit regressions. Col. 4 are Tobit effects. All are adjusted with probability weights and to control for clustering due to multiple observations in the same establishment, one for each year. * = p-value<.1, ** = p<.05, *** = p<.01. Each regression also includes a full set of 13 industry and year indicators. N = 10,409

Table 8. Effect of organizational structure and establishment characteristics on the innovations in 1999-2002 WES, with establishment fixed effects included

	Product Innovation	Process Innovation	Either Innovation	Number of Innovation Types
Decentralized &	.5885***	.4836***	.5575***	.3212***
info-sharing (yes = 1)	(.096)	(.094)	(.097)	(.051)
Decentralized w/o	.1632*	.0941	.0803	.0756*
info-sharing (yes = 1)	(.086)	(.087)	(.085)	(.046)
Centralized &	.4186***	.2432***	.3252***	.2089***
info-sharing (yes = 1)	(.094)	(.094)	(.094)	(.051)
Ln (establishment size)	.1518*	.2560***	.2991***	.1322***
	(.087)	(.083)	(.083)	(.044)
Union coverage rate	-.1863	-.2328*	-.2653**	-.1884***
	(.127)	(.125)	(.126)	(.067)
Seasonal peaks (yes = 1)	.2073***	.2401***	.2482***	.1680***
	(.077)	(.077)	(.077)	(.041)
Vacancy rate	.5312*	.9832**	1.181***	.1123
	(.324)	(.422)	(.476)	(.084)
Profit-sharing plan	-.0523	.0808	.0346	.0105
(yes = 1)	(.096)	(.095)	(.097)	(.052)
Individual incentive pay	.1089	.0572	.0302	.0668
plan (yes = 1)	(.076)	(.077)	(.077)	(.041)
Pseudo-R^2	.0084	.0082	.0100	.0226
Number of observations	8623	8642	8617	14594

Notes: Cols. 1-3 are effects of fixed effects logit regressions. Col. 4 are linear fixed effects. * = p-value<.1, ** = p<.05, *** = p<.01. Each regression also includes a full set of 13 industry and indicators. N = 10,409

Table A1. Workplace organization and components in 1999 WES, by whether or not innovating

	Fraction innovating
Decentralized decision-making	
Decide on daily planning of individual work	.625
Decide on weekly planning of individual work	.629
Decide on follow-up of results	.697
Decide on customer relations	.680
Decide on quality control	.688
Decide on purchase of necessary supplies	.680
Decide on machine/equipment maintenance	.662
Decide on setting staffing levels	.512
Decide on filling vacancies	.851
Decide on training	.667
Decide on choice of production technology	.727
Decide on product/service development	.708
Information –sharing	
Suggest	.774
Info-sharing	.763
Committee	.755

Notes: All estimates are calculated using probability weights. Sample restricted to those establishments with more than 10 employees.

Table A2. Effect of industry on the probability of innovations

	New Product	New Process	Improved Product	Improved Process
Finance and insurance	**0.44**	**0.31**	**0.38**	**0.26**
Capital-intensive tertiary manufacturing (printing, machinery manufacturing, computer and electronics, lighting, transportation equipment)	**0.37**	**0.20**	**0.33**	**0.22**
Labor-intensive tertiary manufacturing (food, beverage, tobacco, textile, apparel, leather, furniture, and miscellaneous manufacturing)	**0.37**	**0.15**	**0.28**	**0.15**
Information and culture	**0.32**	**0.14**	**0.29**	**0.15**
Secondary product manufacturing (chemicals; plastic, rubber, and fabricated metal products)	**0.34**	**0.14**	**0.23**	**0.15**
Primary product manufacturing (wood, paper, petroleum, coal, metal, and nonmetallic mineral products)	**0.21**	**0.09**	**0.22**	**0.15**
Retail trade and consumer services	**0.33**	**0.07**	**0.25**	0.02
Transportation, storage and wholesale trade	**0.28**	**0.08**	**0.21**	**0.04**
Business services	**0.23**	**0.07**	**0.19**	**0.07**
Communication and other utilities	**0.23**	**0.09**	**0.16**	**0.07**
Education and health services	**0.20**	**0.06**	**0.14**	0.01
Real estate, rental, and leasing operations	**0.14**	-0.01	**0.12**	-0.03
Construction	0.02	**-0.07**	0.01	**-0.09**
year 2000	**-0.05**	**-0.04**	**-0.06**	**-0.05**
year 2001	**-0.02**	**-0.04**	**-0.02**	**-0.05**
year 2002	**-0.10**	**-0.11**	**-0.13**	**-0.11**

Notes: estimates shown are marginal effects of probit regressions, which are adjusted with probability weights and to control for clustering due to multiple observations in the same establishment, one for each year. The omitted reference industry is extraction industries (forestry, mining, oil) and the omitted reference year is 1999.
Figures in bold are statistically significant at $p<.05$.