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An Empirical Analysis of the Incentive-Action-Performance Chain of the Principal-Agent Model

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ABSTRACT: This study empirically investigates the incentive-action-performance chain on cross-sectional plant data in the context of a just-in-time (JIT) plant manufacturing environment. Incentives in this study are of the "soft" goal-oriented variety rather than direct compensation. The empirical analysis is implemented using ordinary least squares and Heckman two-stage regressions to account for the potential endogeneity of the JIT adoption decision. We find that plant performance outcomes are associated with actions, namely, the breadth and intensities of plant JIT practices adopted by plant management, but are *not* associated with performance incentives. However, we find that the JIT adoption decision is associated with incentives. We further find that it is the essential inventory incentive aspects of JIT, such as increasing inventory turns and reducing scrap/waste, that motivate JIT adoption rather than other, arguably less central incentive aspects of JIT, such as product quality. Overall, our results are consistent with the predictions of the implicit "career" incentives Principal-Agent model but not with predictions of the standard explicit incentives Principal-Agent model.

INTRODUCTION

The most fundamental insight into management accounting offered by the Principal-Agent (P-A) literature is the importance of performance incentives in driving managements' actions. By performance incentives we mean not only direct and immediate monetary compensation, but also, more broadly, ''soft'' performance goals whose attainment is likely to lead to longer-term benefits for management in the form of advancement and job security. According to the P-A model, incentive-driven actions will in turn impact positively on expected performance outcomes.

Despite a voluminous theoretical literature, there is limited empirical evidence demonstrating the three-way linkage of incentives-actions-performance, especially as it concerns the manufacturing environment. There are many studies, both manufacturing oriented and service oriented, showing two-way linkages. Some studies demonstrate that actions are

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associated with incentives; others show that performance is directly associated with incentives; and still others provide evidence that performance is associated with actions. For example, Banker et al. (1993) show that actions are associated with incentives, without reference to performance. Banker, Potter, and Srinivasan (2000) and Said et al. (2003) are examples of studies showing that performance outcomes are associated with incentives directly, without reference to any intermediating actions. Callen et al. (2000) show that performance outcomes are associated with actions, without further reference to incentives. The findings in these studies may suffer from correlated omitted variables bias because they ignore the third linkage. In fact, with the exception of one small-sample study in the hotel service industry by Banker, Lee, Potter, and Srinivasan (2000), we are unaware of other empirical studies that rationalize the incentive-action-performance chain in its entirety. They state that, "while several research studies document that performance-based incentive plans result in performance improvement, evidence on factors leading to those improvements is lacking" (Banker, Lee, Potter, and Srinivasan 2000, 316). They proceed to extend the Banker et al. (1996) study, which found that the new hotel incentive plan had generated increased sales, by determining if sales increases were due to increased employee effort or to the selection and retention of more productive employees.

This study uses a unique data set to empirically investigate the incentive-action-performance chain on cross-sectional plant data in the context of a just-in-time (JIT) plant manufacturing environment. Incentives in this study are not in the form of monetary compensation. Rather, we measure incentives by the intensity of the performance goals facing the plant production manager as reflected, for example, in the survey question: "How important are inventory turns in evaluating the performance of your manufacturing system?" We measure actions both by JIT adoption and by plant "JITness," where by "JITness" we mean a measure of the breadth and intensities of plant JIT practices adopted by plant management. We measure performance outcomes by a number of metrics including (normalized) operating profits, profit margins, production costs, and an outcome index of plant improvements since JIT adoption.

The empirical analysis is implemented using ordinary least squares (OLS) and Heckman two-stage regressions to account for the potential endogeneity of the JIT adoption decision. We find that plant performance outcomes are associated with plant "JITness" but are *not* associated with performance incentives. In contrast, we find that the JIT adoption decision itself is associated with incentives. We further find that it is the essential inventory incentive aspects of JIT, such as increasing inventory turns and reducing scrap/waste, that motivate JIT adoption rather than other, arguably less central incentive aspects of JIT such as product quality.

Overall, these results are not consistent with the predictions of the standard explicit incentives Principal-Agent model of a three-way linkage among incentives, actions, and performance in a manufacturing environment, since we fail to find an empirical relation between incentives and actions as reflected in plant "JITness." In contrast, our results are consistent with the predictions of the implicit career concerns Principal-Agent model of Holmstrom (1982) and Dewatripont et al. (1999a, 1999b) since we find a significant relation between JIT adoption and incentives. Consistent with this model, soft incentives motivate JIT adoption because, in contrast to JIT practices, JIT adoption is highly visible, and visibility is likely to enhance the production manager's career objectives.

In what follows, the next section briefly reviews the empirical literature relating JIT to incentives and develops the hypotheses. The third section describes the sample and provides summary and univariate statistics. The fourth section shows the results of the multivariate analysis, and the final section concludes.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Literature Review: Performance Incentives and JIT

The JIT literature yields contradictory results concerning the effectiveness of JIT on *firm* level performance.[1] In contrast, extant *plant*-level studies indicate that plant performance is positively related to JIT adoption and/or to the ''JITness'' of the plant.[2] What remains unclear from this literature is whether performance incentives mediate the relation between plant ''JITness'' and plant performance, as would be predicted by the standard P-A model.[3]

There are a few empirical studies that relate JIT plant adoption and/or plant ''JITness'' to underlying incentives. Banker et al. (1993) show that the feedback of manufacturing performance outcomes to line workers is positively associated with the implementation of JIT at the plant level, which suggests that incentives motivate actions. However, this study does not investigate plant performance outcomes, so it provides no information about whether incentive-driven actions affect performance. In a field study of a JIT division of a single manufacturing firm, Young and Selto (1993) try to relate workgroup (employee) ratings to JIT implementation/performance and incentives. Unfortunately, the division manager refused to let participants respond to survey questions regarding incentives. Further, Young and Selto (1993) found that personnel ratings and compensation were unrelated to worker performance or to JIT implementation or performance.

In a longitudinal field study of a single manufacturing firm, Chenhall and Langfield-Smith (2003) report on the impact of incentive changes, such as a gain-sharing reward system, and JIT/total quality management (TQM) adoption on performance outcomes. Only minimal reference is made to the actions engendered by the incentive changes and JIT/TQM adoption. The authors find that, although gain sharing and JIT/TQM adoption led to increased productivity during the initial decade, additional organizational changes in subsequent years, such as team-based structures and value added management (VAM), were relatively unsuccessful. The authors attributed the lack of success to reduction of trust between workers and management engendered by the mechanistic control of gain sharing and the intrusiveness of VAM monitoring.

In a more comprehensive study, Sim and Killough (1998) investigate *inter alia* the relationships (1) among plant ''JITness,'' customer satisfaction performance goals, and customer contingent incentive rewards, and (2) among plant ''JITness,'' quality performance goals, and quality-contingent incentive rewards for JIT plants in the electronics industry. Counterintuitively, they find that customer satisfaction performance in JIT plants decreases significantly with customer-related performance goals and is unrelated to customer-related incentive rewards. However, they do find that customer satisfaction performance increases significantly with both the interaction between plant ''JITness'' and customer-related performance goals and with the interaction between plant ''JITness'' and customer-related incentive rewards. Surprisingly, they also find that quality performance is unrelated to quality-related performance goals, quality-related incentive rewards, or the interaction of ''JITness'' and quality performance goals. They further show that quality performance is

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[1] For firm-level studies, see Huson and Nanda (1995), Balakrishnan et al. (1996), Mia (2000), Fullerton and McWatters (2001, 2003), Kinney and Wempe (2002), Fullerton et al. (2003), Rabinovich et al. (2003), and Yasin et al. (1997, 2003).

[2] For plant-level studies, see Lawrence and Hottenstein (1999), Sim and Killough (1998), Cua et al. (2001), Shah and Ward (2003), and Callen et al. (2000, 2003, 2005).

[3] The focus on plants rather than firms is important since firms often own a mix of plants, some of which are JIT and others that are not.

significantly but *negatively* related to the interaction between ''JITness'' and quality-related incentive rewards.

One of the major problems with the above plant studies and, more generally, with almost all other studies that investigate just-in-time performance, whether at the plant or firm level, is that they fail to account for the endogeneity of the JIT decision. Failure to account for the endogeneity of JIT leads potentially to biased OLS coefficients and may be the cause of some of the counterintuitive results in the literature, such as found by Sim and Killough (1998). More specifically, an OLS analysis of the determinants of JIT plant performance yields consistent parameter estimators provided, *inter alia,* that the underlying sample is a random sample of the population. However, our sample of JIT plants is not random, since plants self-select to be JIT. Plant management adopts JIT as a result of a decision process, so that one can neither treat the JIT variable as exogenous nor treat the JIT sample as random. To estimate population parameters from self-selected samples, one must first specify a self-selection mechanism. In the Heckman two-stage procedure, this usually takes the form of a Probit model. The estimated values of the first-stage Probit model are then used to generate an inverse Mill's ratio for each sample observation. In the context of this study, the inverse Mill's ratio measures the covariance between the JIT choice decision and JIT performance. In the second stage, the inverse Mill's ratio selectivity term is included in the OLS regression as an additional regressor yielding consistent regression parameters. A statistically significant parameter for the inverse Mill's ratio indicates that the JIT decision and plant performance are interrelated, and that endogeneity is an issue. We are aware of only two studies that attempt either to test or to control for the endogeneity of JIT, neither of which addresses the issue of plant performance incentives (Kinney and Wempe 2002; Callen et al. 2005).

Hypothesis Development

In accordance with the conventional explicit incentives P-A model, we assume initially that senior management is unable to observe the production manager's ''true'' effort. Instead, they observe his decision to adopt JIT and his investments in various JIT practices that are informative of his ''true'' effort. As a consequence, the production manager's optimal incentive contract will be a function of the production manager's decision to adopt JIT *and* his investments in JIT practices. This model implies that management's decision to adopt JIT and invest in concomitant JIT practices is associated with plant performance incentives *and* that the production manager's actions, in turn, are associated with positive performance outcomes on average.[4]

In the standard P-A model, plant performance incentives are assumed to generate an explicit compensation contract. Absent compensation data, we assume that (1) plant managers' survey responses regarding the relative importance of specific performance incentives reflect the underlying explicit incentives, and (2) cross-sectional differences in plant managers' abilities, judgments, and expectations generate differential responses to both JIT adoption and JIT actions. There are potential alternative hypotheses. One such alternative is that plant performance incentives are irrelevant. Rather, as new technologies arise, these are adopted by industry innovators. Once the innovators adapt to the new technology, the

[4] Plant managers who adopted JIT in our sample almost uniformly tended to focus on expectations that JIT adoption would generate cost savings and generate additional sales because of increased customer satisfaction and increase their competitive edge. We assume that these goals in turn are motivated by plant managers' career and compensation concerns.

rest of the industry follows suit (a herding effect).[5] These considerations lead to our first major hypothesis (expressed in the alternative).

H1a: JIT adoption and plant ''JITness'' are associated with performance incentives, *and* performance outcomes are associated with plant ''JITness.''

Hypothesis 1a is predicated on the standard P-A model for which incentives are explicit. The incentives that we investigate empirically in this study do not involve explicit compensation but rather are of the ''soft'' implicit variety. Incentives here are defined as the perceived effect on career concerns such as employment tenure and promotion. Implicit career incentives, it can be argued, are as important in motivating managers as are explicit incentives (Holmstrom 1982). In their generalization of the Holmstrom (1982) career model, Dewatripont et al. (1999a, 1999b) show that agents are likely to be motivated by implicit career incentives to manipulate the market's and senior management's assessments of their productivity, so that the flow of information from current actions to assessment is crucial in determining the nature of these incentives. More specifically, this model supposes that performance is a function of the production manager's talent and effort. Talent is unknown to everybody, and effort is observable only to the production manager. The manager is initially paid a fixed wage, and the manager exerts effort only to further his career opportunities both inside and outside the firm in order to increase tomorrow's wage. Because adoption of JIT is highly visible, implicit career incentives may motivate production managers to adopt JIT for its ''visibility'' to the market and senior management who, in turn, may believe that JIT adoption is indicative of managerial talent. In contrast, career incentives may have little effect on the adoption of specific types of JIT actions because these are generally not observable by the market. Moreover, senior management may find that they can induce more effort from the production manager by not incentivizing through investments in JIT practices especially if too many JIT tasks weaken the link between performance and inference about the production manager's talent (Dewatripont et al. 1999a, 1999b).

These considerations lead to the following hypothesis, which differs from H1a with regard to one important link in the incentives-actions-performance chain.

H1b: JIT adoption is associated with plant performance incentives, *and* plant performance outcomes are associated with plant ''JITness.''

There is some evidence that experience with JIT, as proxied by number of years since JIT adoption, is important for JIT plant success. Yasin et al. (1997), Fullerton et al. (2003), and Callen et al. (2000, 2005) find that performance outcomes are positively and significantly associated with JIT experience. What remains unclear is whether JIT experience mediates the incentives-actions-performance chain. This leads us to our next major hypothesis.

H2: The plant incentives-actions-performance chain is positively associated with JIT experience.

[5] For a model of this sort, see Choi (1997) and, more recently, Yeung et al. (2007).

We initially test these two hypotheses using ordinary least squares, thereby abstracting from the issue of JIT endogeneity. We subsequently account for endogeneity of the JIT decision using the Heckman two-stage estimation procedure. We employ this research methodology because although, on the one hand, OLS may yield biased coefficient estimates when compared with the Heckman approach, on the other hand, OLS is a robust estimator and as such may yield more meaningful parameter estimates.

THE SAMPLE DATA AND SUMMARY STATISTICS

Sample Data

A description of the sample follows. Initially, 132 plants in the automotive parts and electronic components manufacturing industry, residing in southern Ontario, Canada, between Windsor and Oshawa, were contacted. These two industries were chosen because they contain a mix of JIT and conventional non-JIT plants operating simultaneously in the same geographical area. Plants were required to have a minimal size of at least 50 employees and to be autonomous profit centers. Of these 132 plants, 100 plants responded by providing the requisite data, 61 in auto parts and 39 in electronic parts.[6] These sample plants are controlled almost exclusively by private firms so that market data are not available for the vast majority of them.

The auto parts manufacturing plants in this study produce a variety of parts, including plastic blow-molded components, stampings and welded assemblies, filters, electroplating, heat-treated tubing, tires, glass, molded foam, shock absorbers, and noise control products. The electronic components manufacturing plants in the sample produce items such as capacitors, resistors, and printed circuit boards. Because the sample plants are situated in the same geographic location, the noise induced by cross-sectional differences in input prices and freight charges is mitigated.

Two sets of data were collected for each plant: production-related survey data and "hard" financial data. Based on a survey instrument developed by one of the authors and completed by plant production managers, the production-related survey data include plant production practices and various JIT/TQM actions adopted by each plant. These data are measured primarily on the basis of five-point Likert scales. The "hard" financial data contain information mandated by the Canadian government in its annual Census of Manufacturing. These data are obtained from each plant since they are not available from government sources on a disaggregated basis.

Plant (production) managers were asked in the survey instrument to classify their plant as JIT or non-JIT based on a narrow definition of JIT. This narrow definition emphasizes the stockless production aspect of JIT and defines JIT as "a system of manufacturing in which materials, parts, and components are produced and delivered just before they are needed ... The goal of JIT production is to come as close as possible to the concept of ideal—or zero inventory—production." Plants classified by their plant managers as non-JIT on the basis of this narrow definition were in fact deemed to be non-JIT.[7]

Self-selection for classifying the JIT plants could be problematic if plants did not define JIT with some degree of consistency. Plants classified by their plant managers as JIT on the basis of the narrow definition *and* that had adopted JIT for at least one full year are

[6] Of the 61 plants in the auto parts manufacturing plants, 56 belong to totally different firms. Of the five remaining plants, three plants belong to one firm, and two plants belong to another firm. We do sensitivity analysis on these five plants, as described further below.

[7] Unfortunately, this is not the optimal sampling approach, and in effect it creates a truncated sample. We account for truncation in the econometrics below where necessary. By truncation, we mean the issue of sample selection and not the issue of clustering of limited dependent variable observations at end points.

further tested for the extent of JIT use, utilizing the JIT/TQM data from the production survey. The one-year restriction reflects the lengthy implementation process of JIT adoption.

A plant is classified as JIT for purposes of this study if the plant manager classifies the plant as JIT based on the narrow JIT definition *and* if both of the following two criteria are satisfied as well: (1) a sum of 51 or greater is scored on the JIT practices survey, indicating that *on average* the plant uses all JIT practices half the time (an average score of 3 per technique), and (2) the plant uses two-thirds of the JIT practices at least half of the time. These criteria help to ensure that JIT is both broadly applied and intensively used by each of the sample JIT plants.

Of the 61 survey responses from the auto parts manufacturing plants, 19 plants declared themselves to be non-JIT. Of the remaining 42 plants, 3 were reclassified as non-JIT on the basis of the above criteria, resulting in a sample of 39 JIT and 22 non-JIT auto parts plants.[8] Of the 39 electronics plants that agreed to participate, 21 declared themselves JIT, with no need for reclassification, because these plants satisfied both criteria for global JIT use. The final sample of electronics components manufacturers consisted of 21 JIT plants and 18 non-JIT plants.

The survey data were used to develop three indices: an index of incentives, a ''JITness'' Action Index, and an index of performance outcomes. The indices were computed (1) by simply adding together the Likert scores of the individual index components, (2) by a principal components analysis of these scores, and (3) by ranking the scores of each component of the given index across firms and then averaging the component ranks for each firm. Since all index types yielded qualitatively similar results, we report the results for the simple additive indices only.

Summary and Univariate Statistics

Table 1, Panel A shows that JIT plants are significantly larger in terms of sales revenue ($t = -1.76$, $p = .08$) and more profitable ($t = -2.22$, $p = .03$) than non-JIT plants. These results raise potential causality concerns. Is it that JIT plants are more profitable, or are profitable plants more likely to adopt JIT?

The Incentive Index quantifies the response by plant managers to the following survey question with respect to six plant performance measures: ''How important are the following measures in evaluating the performance of your manufacturing system: inventory turns, equipment utilization, labor utilization, on-time delivery, scrap/waste reduction, and quality?'' Scores are based on a five-point Likert scale where 5 = extreme importance and 1 = no importance. Table 1, Panel B provides means and medians for the Incentive Index and each of its components stratified by JIT and non-JIT subsamples, and also by high- and low-profitability subsamples. Means and medians are similar to each other. Overall, the Incentive Index is significantly larger for JIT plants than for non-JIT plants based both on a t-test and a Mann-Whitney test, suggesting that plant managers in JIT plants are subject to greater production incentives than in non-JIT plants. Looking at the separate incentive components, as expected, JIT plants consider inventory turns and scrap/waste to be significantly more important in evaluating their manufacturing system than non-JIT plants.[9] More surprisingly, the four other incentive component differences are insignificant, but this may be due to the difficulty of measuring such variables as equipment utilization, labor utilization, and quality when compared with inventory turns and scrap/waste.

[8] We do sensitivity analysis on the three reclassified plants, as described further below.
[9] Unless stated otherwise, all test statistics and p-values in this paper are two-tailed.

TABLE 1
Summary Statistics and Univariate Tests

Panel A: Production Data in JIT and Non-JIT Plants[a]

Incentives	All Plants Mean (SD)	Non-JIT Plants Mean (Median)	JIT Plants Mean (Median)	t-statistic (p-value)	Mann-Whitney (p-value)
Sales	25.9	22.1	28.5	**−1.76**	**−2.44**
Revenue	(18.0)	(15.6)	(25.6)	**(0.08)**	**(0.02)**
Production	19.2	17.0	20.6	−1.38	**−2.41**
Costs	(12.9)	(11.8)	(18.1)	(0.17)	**(0.02)**
Operating	6.7	5.0	7.8	**−2.22**	**−2.38**
Profits	(6.3)	(3.7)	(7.0)	**(0.03)**	**(0.02)**

Panel B: Incentives in Non-JIT and JIT Plants and by High/Low Operating Income/Sales[b]

	JIT versus Non-JIT				High/Low Operating Income/Sales			
Incentives	Non-JIT Plants Mean (Median)	JIT Plants Mean (Median)	t-statistic (p-value)	Mann-Whitney (p-value)	High Oper. Income to Sales Mean (Median)	Low Oper. Income to Sales Mean (Median)	t-statistic (p-value)	Mann-Whitney (p-value)
Incentive	24.13	25.98	**−3.34**	**−3.42**	24.98	25.50	0.91	0.68
Index	(24.00)	(27.00)	**(0.00)**	**(0.00)**	(25.50)	(26.00)	(0.37)	(0.49)
Inventory	3.00	3.50	**−3.00**	**−3.06**	3.46	3.14	**−1.92**	−1.39
Turns	(3.00)	(4.00)	**(0.00)**	**(0.00)**	(3.50)	(3.00)	**(0.06)**	(0.16)
Equipment	4.45	4.48	−0.23	0.02	4.30	4.64	**2.54**	**2.14**
Utilization	(5.00)	(5.00)	(0.82)	(0.99)	(4.50)	(5.00)	**(0.01)**	**(0.03)**
Labor	4.50	4.47	0.22	−0.12	4.38	4.58	1.35	1.23
Utilization	(5.00)	(5.00)	(0.82)	(0.91)	(5.00)	(5.00)	(0.18)	(0.22)
On-Time	4.67	4.78	−0.96	−1.23	4.68	4.80	1.11	1.21
Delivery	(5.00)	(5.00)	(0.34)	(0.22)	(5.00)	(5.00)	(0.27)	(0.23)
Scrap/Waste	2.85	3.97	**−4.10**	**−3.94**	3.38	3.66	1.00	1.21
Reduction	(3.00)	(4.00)	**(0.00)**	**(0.00)**	(4.00)	(4.00)	(0.32)	(0.23)
Quality	4.65	4.78	−1.43	−1.46	4.78	4.68	−1.12	−1.12
	(5.00)	(5.00)	(0.16)	(0.14)	(5.00)	(5.00)	(0.27)	(0.26)

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TABLE 1 (continued)

Panel C: Actions: JIT Practices Used in JIT Plants by High/Low Operating Income/Sales[c]

JIT/TQM Practices	High Oper. Inc. to Sales Mean (Median)	Low Oper. Inc. to Sales Mean (Median)	t-statistic (p-value)	Mann-Whitney (p-value)
JIT Index	56.57 (56.00)	53.37 (54.00)	**−2.30** **(0.03)**	**−1.81** **(0.07)**
Kanban	2.97 (3.00)	2.97 (3.00)	0.00 (1.00)	0.28 (0.78)
Integrated Product Design	2.53 (2.00)	2.70 (3.00)	0.50 (0.62)	0.69 (0.49)
Integrated Suppliers Network	3.40 (3.00)	2.87 (3.00)	**−1.87** **(0.07)**	**−1.77** **(0.08)**
Plan to Reduce Setup Time	3.00 (3.00)	2.33 (2.00)	**−3.34** **(0.00)**	**−3.08** **(0.00)**
Quality Circles	3.00 (3.00)	2.43 (2.00)	**−2.01** **(0.05)**	−1.58 (0.11)
Focused Factory	2.40 (2.00)	2.70 (2.00)	1.01 (0.32)	0.91 (0.37)
Preventive Maintenance Programs	4.33 (4.00)	4.07 (4.00)	**−2.22** **(0.03)**	**−2.11** **(0.03)**
Line Balancing	3.43 (3.00)	3.07 (3.00)	**−1.88** **(0.07)**	**−1.83** **(0.07)**

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TABLE 1 (continued)

JIT/TQM Practices	High Oper. Inc. to Sales Mean (Median)	Low Oper. Inc. to Sales Mean (Median)	t-statistic (p-value)	Mann-Whitney (p-value)
Education about JIT	1.70 (2.00)	2.10 (2.00)	**2.00** **(0.05)**	**2.28** **(0.02)**
Level Schedules	3.23 (3.00)	3.00 (3.00)	−0.84 (0.41)	−0.58 (0.56)
Stable Cycle Rates	3.27 (3.00)	2.83 (3.00)	**−2.19** **(0.03)**	**−2.10** **(0.04)**
Market-Paced Final Assembly	3.60 (4.00)	3.03 (3.00)	**−2.52** **(0.02)**	**−2.47** **(0.01)**
Group Technology	3.00 (3.00)	2.00 (2.00)	**−5.57** **(0.00)**	**−4.83** **(0.00)**
Program to Improve Quality (product)	4.87 (5.00)	4.77 (5.00)	−0.99 (0.33)	−0.99 (0.32)
Program to Improve Quality (process)	4.87 (5.00)	4.77 (5.00)	−0.99 (0.33)	−0.99 (0.32)
Fast Inventory Transportation System	4.17 (4.00)	3.83 (4.00)	**−1.92** **(0.06)**	**−1.87** **(0.06)**
Flexibility of Worker's Skill	2.70 (3.00)	2.33 (2.00)	**−2.08** **(0.04)**	**−2.08** **(0.04)**

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TABLE 1 (continued)

Panel D: Performance Outcomes: Performance Improvements since JIT Implementation by High/Low Operating Income/Sales[d]

Outcomes	High Oper. Income Sales Mean (Median)	Low Oper. Income to Sales Mean (Median)	t-statistic (p-value)	Mann-Whitney (p-value)
Outcome Index	27.57 (27.00)	25.63 (26.00)	**−2.36 (0.02)**	**−1.83 (0.07)**
Setup Times Reduced by	1.93 (2.00)	0.70 (0.00)	**−3.79 (0.00)**	**−3.26 (0.00)**
Automation Increased by	2.17 (2.00)	2.20 (2.00)	0.15 (0.88)	0.38 (0.71)
Quality Control Increased by	3.07 (3.00)	3.07 (3.00)	0.00 (1.00)	−0.02 (0.98)
Scrap Reduced by	3.10 (2.50)	4.47 (5.00)	**4.20 (0.00)**	**3.69 (0.00)**
Defect Rate Reduced by	3.83 (4.00)	4.53 (5.00)	**2.82 (0.01)**	**2.63 (0.01)**
Lead Times Reduced by	2.77 (3.00)	1.40 (1.00)	**−4.10 (0.00)**	**−3.55 (0.00)**
Materials Inventory Reduced by	1.90 (2.00)	1.23 (1.00)	**−2.12 (0.04)**	**−2.11 (0.04)**
Worker Flexibility Increased by	1.83 (2.00)	0.43 (0.00)	**−5.03 (0.00)**	**−4.10 (0.00)**
Final Good Inventory Reduced by	1.90 (2.00)	1.73 (2.00)	−0.71 (0.48)	−0.53 (0.60)
Production Process Improved by	3.13 (3.00)	3.57 (4.00)	**1.95 (0.06)**	**1.95 (0.05)**
Product Returns Reduced by	1.93 (2.00)	2.30 (2.00)	1.42 (0.16)	0.86 (0.39)

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TABLE 1 (continued)

All statistics and p-values are two-tailed. Significant test statistics at conventional levels are bolded.

[a] This panel lists means (medians) and standard deviations (SD) of sales revenue, production costs and operating profits measured in millions of dollars for 61 JIT plants and 39 non-JIT plants in the auto parts and electronic components manufacturing industries.
The t-statistic and the Mann-Whitney statistic test for the equality of means and medians of JIT and non-JIT plants, respectively.

[b] This panel lists mean (median) scores of the plant Incentive Index and the component incentives (goals) for 61 JIT plants and 39 non-JIT plants in the auto parts and electronic components manufacturing industries. Incentives are based on the question: How important are the following measures in evaluating the performance of your manufacturing system: inventory turns, equipment utilization, labor utilization, on-time delivery, scrap/waste reduction, and quality? Scores are based on a five-point Likert scale where 5 = extreme importance and 1 = no importance. The Incentive Index is computed as the sum of the separate component scores.
The t-statistic and the Mann-Whitney statistic test for the equality of means and medians of JIT and non-JIT plants and high and low operating income per dollar of sales, respectively. High (low) is defined to be above (below) the median operating income per dollar of sales.

[c] This panel lists mean (median) scores of the JIT Index and the 17 JIT component practices (actions) for 61 JIT plants in the auto parts and electronic components manufacturing industries. Scores are based on a five-point Likert scale where 5 = always used and 1 = never used. The JIT Index is computed as the sum of the separate component scores.
The t-statistic and the Mann-Whitney statistic test for the equality of means and medians of high and low operating income per dollar of sales, respectively. High (low) is defined to be above (below) the median operating income per dollar of sales for JIT plants.

[d] This panel lists mean (median) scores of the Outcome Index and the 11 component performance outcome dimensions for 61 JIT plants in the auto parts and electronic components manufacturing industries. Scores are based on a six-point Likert scale where 5 = more than a 50 percent improvement and 0 = no improvement. The Outcome Index is computed as the sum of the separate component scores.
The t-statistic and the Mann-Whitney statistic test for the equality of means and medians of high and low operating income per dollar of sales, respectively. High (low) is defined to be above (below) the median operating income per dollar of sales for JIT plants.

Partitioning along high and low operating profits (per dollar of sales) shows that the Incentive Index is not significantly different for high- and low-profitability plants, a result that does not support H1a. However, analysis of the index components indicates that more profitable plants have significantly higher inventory turns and lesser equipment utilization. The latter result may reflect the fact that more profitable plants are better able to renew plant equipment on a more timely basis. The four other incentive component differences are insignificant. Untabulated results show that all incentive component differences are insignificant when partitioned along a high and low (above and below the median, respectively) Outcome Index, perhaps reflecting the fact that the survey-based Outcome Index is noisy when compared with more objective performance measures such as operating profits.

The production survey instrument identified 17 practices designed to capture the extent of JIT/TQM implementation and used to measure the "JITness" index. These 17 practices and the selection procedure are rooted in the findings of Flynn et al. (1995) indicating that JIT techniques interact with and are difficult to distinguish from common infrastructure and TQM practices. This simply reflects the fact that while TQM plants need not be JIT, JIT plants must necessarily place great emphasis on quality and quality improvement (Sim 2001). In the absence of quality, JIT plants would soon find themselves having to shut down or increase inventories in order to continue production. Because there is not a single accepted set of measures in the literature that defines JIT, the 17 JIT practices were culled from conversations with plant managers in the automotive parts and electronic components industries and from the extant JIT/TQM literature, including Cheng and Podolsky (1983), Im and Lee (1989), Cheng (1990), White and Ruch (1990), Billesbach (1991), Ahmed et al. (1991), and Mehra and Inman (1992). It is worth noting that of the ten JIT practices employed by Fullerton et al. (2003), nine are included in our list.[10]

The production survey asked plant production managers to indicate the extent of plant usage of each of the JIT practices using a five-point Likert scale where 5 = always used and 1 = never used. The JITness index is the sum of these scores for all 17 characteristics. A JITness index of 85 indicates that the plant utilizes all 17 techniques all of the time. An index of 17 indicates that the plant never uses any of the listed JIT/TQM techniques. Table 1, Panel C shows cross-sectional means and medians for the overall JIT Index and for each of the 17 JIT/TQM practices partitioned on high/low operating profitability. Consistent with H1a, more profitable JIT plants score significantly higher overall in terms of JIT practice breadth and intensity than less profitable JIT plants. This holds for many of the component practices as well, such as Integrated Suppliers Network, Plan to Reduce Setup Time, Quality Circles, Preventive Maintenance Programs, Line Balancing, Stable Cycle Rates, Market-Paced Final Assembly, and Group Technology. Only in the case of one JIT practice, namely, Education about JIT, are less profitable plants more active than more profitable plants, which may simply reflect the need to educate workers further because they are less effective. There are no significant differences between highly profitable and less profitable JIT plants along the other JIT practice dimensions. Untabulated results indicate that partitioning JIT practices along a high and low Outcome Index yielded results similar to partitioning along high and low Operating Profits.

The Outcome Index measures improvements in 11 performance dimensions since JIT adoption. The improvement for each dimension is measured along a six-point Likert scale where 0 indicates no improvement and 5 indicates more than 50 percent improvement. The index is the sum of the improvements along all 11 dimensions. Table 1, Panel D shows

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[10] Because the types and intensities of JIT practices (actions) adopted may be systematically related to plant properties such as size (White et al. 1999), a broader set of JIT practices is preferable to a narrower set.

the means and medians of the overall Outcome Index as well as for each of the component improvements partitioned on high/low operating profitability. As expected, more profitable JIT plants show significantly higher overall Outcome Index levels. As far as the components of the index are concerned, more profitable JIT plants show significantly higher levels than less profitable JIT plants for setup time, lead time, and material inventory reductions and worker flexibility. In contrast, less profitable JIT plants show significantly higher levels of scrap and defect rate reductions and production process improvements than more profitable JIT plants.

MULTIVARIATE ANALYSIS

Empirical Results

In view of the fact that performance as measured by operating profits, the contribution margin, and total production costs yield qualitatively similar results, we provide tables for operating profits only.[11] In addition, we show results for the Outcome Index performance measure because the latter metric yields results that are at variance somewhat with those of operating profits and the other performance measures.

Using ordinary least squares (OLS), plant operating profits normalized by sales revenue is regressed on the JIT Index, the Incentive Index, and on a number of control variables. If profitability is related to actions (conditioned on incentives), then the coefficient on the JIT Index will be positive and significant. If performance is related to incentives (conditioned on actions), then the coefficient on the Incentive Index will be positive and significant. Table 2, Panel A shows results for the case where the regression does not include an interaction term between the two indices. We further test H1 in Panel B of Table 2 by incorporating an interaction term between the Incentive Index and the JIT Index. To mitigate the issue of multicollinearity in the presence of interaction terms and to enhance interpretability of the regression, we de-mean all non-dummy regressors (Aiken and West 1991) in the regressions that follow.

The regression in Table 2, Panel A yields a statistically significant F-statistic ($F = 27.65$, $p < .000$) with an adjusted R^2 of 73 percent. The JIT Index is positive and significant ($t = 3.41$, $p = .001$), indicating that plant performance is positively associated with "JITness." The Incentive Index is not significant ($t = 0.58$, $p = .567$), indicating that plant performance is independent of plant managers' incentives, a result that is not supportive of H1a.[12] Consistent with H2, the JIT experience variable is positive and highly significant ($p < .000$), indicating that plants that have more experience with JIT are more profitable. We further find that plants that belong to firms that are international in scope are significantly more profitable ($t = 3.54$, $p = .001$). Also, plants for which JIT adoption require the firm to increase financing are less profitable, but the coefficient is only marginally significant at the one-tailed level ($t = -1.41$, $p = .166$). Finally, automotive parts plants are significantly less profitable than electronics components plants ($t = -4.43$, $p < .000$).

The Table 2, Panel B regression incorporates an interaction term between the JIT Index and the Incentive Index but is otherwise identical to Panel A. The interaction term controls

[11] Of course the signs of the regressor coefficients, when total production cost (normalized by sales) is the dependent variable, are in the opposite direction to the signs of the regressor coefficients when either operating profits (normalized by sales) or the contribution margin is the dependent variable. Otherwise, the results are quite similar.

[12] Untabulated results show that plant performance is not significantly related to the Incentive Index alone (absent the JIT Index regressor). However, plant performance is positively and significantly related to the JIT Index alone (absent the Incentive Index regressor). Similar results hold for the Heckman analysis.

TABLE 2[a]
OLS Regression of Operating Profits on the Incentive Index and the JIT Index

Panel A: No Interaction Term[b]

$$\mathit{OPERATING\ PROFITS} = b_0 + b_1\mathit{JIT\ INDEX} + b_2\mathit{INCENTIVE\ INDEX} + b_3\mathit{EXPERIENCE} + b_4\mathit{INTERNATIONAL} + b_5\mathit{FINANCING} + b_6\mathit{INDUSTRY}$$

Variable	Expected Sign	Coefficient	t-statistic	p-value
Intercept	?	**0.288**	**17.40**	< **0.000**
JIT INDEX	+	**0.004**	**3.41**	**0.001**
INCENTIVE INDEX	+	0.002	0.58	0.567
EXPERIENCE	+	**0.035**	**5.49**	< **0.000**
INTERNATIONAL	+	**0.052**	**3.54**	**0.001**
FINANCING	−	−0.037	−1.41	0.166
INDUSTRY	?	**−0.088**	**−4.43**	< **0.000**
F(6,53)		**27.65**		< **0.000**
Adj. R^2		0.73		
n		60		

Panel B: With Interaction Term[c]

$$\mathit{OPERATING\ PROFITS} = b_0 + b_1\mathit{JIT\ INDEX} + b_2\mathit{INCENTIVE\ INDEX} + b_3\mathit{JIT} * \mathit{INCENTIVE} + b_4\mathit{EXPERIENCE} + b_5\mathit{INTERNATIONAL} + b_6\mathit{FINANCING} + b_7\mathit{INDUSTRY}$$

Variable	Expected Sign	Coefficient	t-statistic	p-value
Intercept	?	**0.289**	**17.46**	< **0.000**
JIT INDEX	+	**0.004**	**3.24**	**0.002**
INCENTIVE INDEX	+	0.003	0.80	0.430
*JIT * INCENTIVE*	+	0.001	1.09	0.282
EXPERIENCE	+	**0.035**	**5.37**	< **0.000**
INTERNATIONAL	+	**0.051**	**3.44**	**0.001**
FINANCING	−	−0.036	−1.35	0.184
INDUSTRY	?	**−0.090**	**−4.53**	< **0.000**
F(7,52)		**23.95**		< **0.000**
Adj. R^2		0.73		
n		60		

t-statistics and p-values are two-tailed. Non-dummy regressors are mean adjusted to mitigate multicollinearity generated by interaction terms. Significant coefficients are bolded.

[a] These two panels present OLS regressions of operating profits per dollar of sales revenue on the Incentive Index and the JIT Index and other control variables.

[b] Panel A does not include an interaction term.

[c] Panel B includes an interaction term between the Incentive and JIT indices.

Variable Definitions:

OPERATING PROFITS = operating profits normalized by sales revenue;

JIT INDEX = JIT Action Index is based upon the 17 JIT/TQM practices listed in Table 1, Panel B. Scores for each metric are based on a five-point Likert scale where 5 = extreme importance and 1 = no importance. The index is measured as the sum of the scores of the 17 metrics;

(*continued on next page*)

TABLE 2 (continued)

INCENTIVE INDEX =	incentives are based on the question: How important are the following measures in evaluating the performance of your manufacturing system: inventory turns, equipment utilization, labor utilization, on-time delivery, scrap/waste, and quality? Scores for each component are based on a five-point Likert scale where 5 = extreme importance and 1 = no importance. The index is measured as the sum of the scores of the six components;
*JIT * INCENTIVE* =	an interaction term between the JIT Index and the Incentive Index;
EXPERIENCE =	number of years of experience with JIT;
INTERNATIONAL =	1 if the firm with which the plant is associated is international in scope, and 0 otherwise;
FINANCING =	1 if the firm's financing changed as a result of the plant adopting JIT and, 0 otherwise; and
INDUSTRY =	1 if industry is auto parts, and 0 otherwise.

for the possibility that adoption of JIT and the extent of plant ''JITness'' have a differential impact on performance depending upon plant incentives.[13] For example, all else equal, JIT plant managers are likely to be more concerned with inventory turn performance incentives than are non-JIT plant managers, given that a primary purpose of JIT is to reduce inventory holding costs. Thus, all else equal, operating profits of JIT plants are likely to react differentially to inventory turn performance incentives when compared with non-JIT plants, and operating profits of plants that are more heavily invested in JIT are likely to react differentially to incentives like inventory turns when compared with plants less invested in JIT.

The overall results of Panel B are qualitatively similar to those of Panel A. In particular, the interaction term is insignificant ($t = 1.09$, $p = .282$), unsupportive of the supposition that plant manager incentives and actions interact with each other to generate profits. Overall, the results of both panels of Table 2 do not appear to support H1a but are consistent with H2.

Table 3 replicates Table 2 but with the Incentive Index disaggregated into its six incentive components: inventory turns, equipment utilization, labor utilization, on-time delivery, scrap/waste reduction, and quality. The results in Table 3, Panel A are quite similar to those obtained in Table 2. Again, industry, international, the JIT Index, and experience with JIT are highly significant and of the same signs as in Table 2. Of the six incentive components, only inventory turns is both significant at conventional two-tailed levels ($t = 1.80$, $p = .078$) and with the expected positive sign. As far as the other five incentive components are concerned, only labor utilization is significant at the one-tailed level ($t = -1.43$, $p = 0.159$, two-tailed) but the sign is negative.[14]

Table 3, Panel B replicates Panel A but, in addition, interacts each of the six incentive components with the JIT Index. The Panel B results are quite similar to those of Panel A except that inventory turns are now only marginally significant at the one-tailed level and labor utilization is no longer significant. None of the interaction terms are significant.

The regressions in Table 3 show that perhaps with the exception of inventory turns, the components of the Incentives Index are not positively associated with plant performance. Furthermore, the results are not supportive of the notion that incentive components interact with JIT actions to generate performance outcomes. Thus, subject to the potential limitations of our analysis, it appears that what really matters in generating plant performance outcomes

[13] If JIT adoption is a function of herding, one would expect this interaction term to be insignificant.
[14] See below for the possible intuition of this seemingly counterintuitive result.

TABLE 3
OLS Regression of Operating Profits on Disaggregated Incentives and the JIT Index[a]

Panel A: No Interaction Terms[b]

$$\textit{OPERATING PROFITS} = b_0 + b_1\textit{JIT INDEX} + b_2\textit{INVENTORY TURNS} + b_3\textit{EQUIPMENT UTILIZATION} + b_4\textit{LABOR UTILIZATION} + b_5\textit{ONTIME DELIVERY} + b_6\textit{SCRAP/WASTE} + b_7\textit{QUALITY} + b_8\textit{EXPERIENCE} + b_9\textit{INTERNATIONAL} + b_{10}\textit{FINANCING} + b_{11}\textit{INDUSTRY}$$

Independent Variables	Expected Sign	Coefficient	t-statistic	p-value
Intercept	?	**0.272**	**13.54**	< **0.000**
JIT INDEX	+	**0.004**	**3.23**	**0.002**
INVENTORY TURNS	+	**0.016**	**1.80**	**0.078**
EQUIPMENT UTILIZATION	+	−0.003	−0.22	0.825
LABOR UTILIZATION	+	−0.022	−1.43	0.159
ONTIME DELIVERY	+	0.017	0.99	0.327
SCRAP/WASTE REDUCTION	+	0.004	0.43	0.672
QUALITY	+	−0.002	−0.12	0.901
EXPERIENCE	+	**0.035**	**5.46**	< **0.000**
INTERNATIONAL	+	**0.053**	**3.42**	**0.001**
FINANCING	−	−0.024	−0.89	0.379
INDUSTRY	?	**−0.071**	**−2.81**	**0.007**
F(11,48)		**16.00**		< **0.000**
Adj. R^2		0.74		
n		60		

Panel B: With Interaction Terms[c]

$$\textit{OPERATING PROFITS} = b_0 + b_1\textit{JIT INDEX} + b_2\textit{INVENTORY TURNS} + b_3\textit{EQUIPMENT UTILIZATION} + b_4\textit{LABOR UTILIZATION} + b_5\textit{ONTIME DELIVERY} + b_6\textit{SCRAP/WASTE} + b_7\textit{QUALITY} + b_8\textit{JIT INDEX} * \textit{INVENTORY TURNS} + b_9\textit{JIT INDEX} * \textit{EQUIPMENT UTILIZATION} + b_{10}\textit{JIT INDEX} * \textit{LABOR UTILIZATION} + b_{11}\textit{JIT INDEX} * \textit{ONTIME DELIVERY} + b_{12}\textit{JIT INDEX} * \textit{SCRAP/WASTE} + b_{13}\textit{JIT INDEX} * \textit{QUALITY} + b_{14}\textit{EXPERIENCE} + b_{15}\textit{INTERNATIONAL} + b_{16}\textit{FINANCING} + b_{17}\textit{INDUSTRY}$$

Independent Variables	Expected Sign	Coefficient	t-statistic	p-value
Intercept	?	**0.276**	**13.25**	< **0.000**
JIT INDEX	+	**0.004**	**2.62**	**0.012**
INVENTORY TURNS	+	0.015	1.49	0.143
EQUIPMENT UTILIZATION	+	−0.006	−0.49	0.628

(*continued on next page*)

TABLE 3 (continued)

Independent Variables	Expected Sign	Coefficient	t-statistic	p-value
LABOR UTILIZATION	+	−0.014	−0.86	0.395
ONTIME DELIVERY	+	0.012	0.51	0.611
SCRAP/WASTE REDUCTION	+	0.000	0.00	1.000
QUALITY	+	0.006	0.31	0.759
*JIT * INVENTORY TURNS*	+	−0.002	−1.15	0.255
*JIT * EQUIPMENT UTILIZATION*	+	0.002	0.94	0.352
*JIT * LABOR UTILIZATION*	+	−0.002	−0.48	0.633
*JIT * ONTIME DELIVERY*	+	0.001	0.13	0.901
*JIT * SCRAP/WASTE*	+	0.002	0.75	0.459
*JIT * QUALITY*	+	−0.001	−0.25	0.804
EXPERIENCE	+	**0.033**	**4.89**	< **0.000**
INTERNATIONAL	+	**0.052**	**3.21**	**0.003**
FINANCING	−	−0.002	−0.05	0.963
INDUSTRY	?	**−0.072**	**−2.61**	**0.012**
F(17,42)		**10.27**		< **0.000**
Adj. R^2		0.73		
n		60		

t-statistics and p-values are two-tailed. Non-dummy regressors are mean adjusted to mitigate multicollinearity generated by interaction terms. Significant coefficients are bolded.
[a] These two panels show the OLS regressions of operating profits per dollar of sales revenue on the Incentive Index and the JIT Index and other control variables.
[b] Panel A does not include an interaction term.
[c] Panel B includes an interaction term between the Incentive components and JIT Indices.
Variables are defined in Tables 1 and 2.

are actions, namely the investment in specific JIT practices, not incentives. With the exception perhaps of inventory turns, incentives appear to be unrelated to outcomes, both on a stand-alone basis and/or interacting with actions.

The regressions in Table 2 and Table 3 investigate whether management "soft" incentives help to drive plant performance, based on a sample of JIT plant data. However, these regressions disregard the potential endogeneity of the managerial decision to adopt and invest in JIT. Because plants self-select to be JIT, the sample is nonrandom. Failure to account for self-selection into the JIT regime will generally yield inconsistent parameter estimates (Maddala 1983; Li and Prabhala 2005).

To account for the potential endogeneity of JIT, we re-estimate our regressions using a standard Heckman two-stage regression procedure. In the first stage, the decision to adopt JIT is modeled as a Probit regression. Specifically, we assume that the decision to adopt JIT is a function of the industry, whether the firm that owns the plant is international in scope, and, most crucially, plant incentives.[15] In the second stage, the inverse Mill's ratio from the first stage is incorporated into the performance outcome (profitability) regressions. Operating profits (normalized by sales) are assumed to be a function of the JIT Index, the Incentive Index, experience with JIT, the industry, whether the firm that owns the plant is international in scope, and whether adopting JIT requires additional financing.

[15] Since the indicator variable "if adopting JIT requires additional financing" was measured only for plants declared to be JIT by the plant production manager, it cannot be included in the Probit regression.

Table 4, Panel A provides the Probit regression results. Z-values and the associated p-values are based on Heckman standard errors. Neither industry nor whether the firm that owns the plant is international in scope are significant determinants of the decision to adopt JIT. In contrast, the Incentive Index is significantly and positively associated with the decision to adopt JIT (Z = 2.95, p = .003, two-tailed), consistent with H1b.

TABLE 4

Heckman Two-Stage Regression Analysis-Operating Profits

Panel A: Probit Analysis[a]

$$JIT = a_0 + a_1\mathit{INDUSTRY} + a_2\mathit{INTERNATIONAL} + a_3\mathit{INCENTIVE\ INDEX}$$

Independent Variables	Expected Sign	Coefficient	Z-value	p-value
Intercept	?	0.400	1.17	0.242
INDUSTRY	?	−0.326	−0.86	0.392
INTERNATIONAL	+	0.165	0.56	0.573
INCENTIVE INDEX	+	**0.183**	**2.95**	**0.003**
Log-Likelihood		**−61.181**	LR $\chi^2(3)$ = **12.24**	**0.007**
Pseudo-R^2		**0.091**		
Number of Observations		100		

Panel B: Second-Stage Heckman Analysis[b]

$$\begin{aligned}\mathit{OPERATING\ PROFITS} = {} & b_0 + b_1\mathit{JIT\ INDEX} + b_2\mathit{INCENTIVE\ INDEX} \\ & + b_3\mathit{JIT} * \mathit{INCENTIVE} + b_4\mathit{EXPERIENCE} \\ & + b_5\mathit{INTERNATIONAL} + b_6\mathit{FINANCING} \\ & + b_7\mathit{INDUSTRY} + b_8\mathit{INVERSE\ MILL'S\ RATIO}\end{aligned}$$

Independent Variables	Expected Sign	Coefficient	Z-value	p-value
Intercept	?	**0.284**	**1.89**	**0.059**
JIT INDEX	+	**0.004**	**3.35**	**0.001**
INCENTIVE INDEX	+	0.004	0.13	0.897
*JIT*INCENTIVE*	+	0.001	1.09	0.277
EXPERIENCE	+	**0.035**	**5.76**	< **0.000**
INTERNATIONAL	+	**0.052**	**2.20**	**0.028**
FINANCING	−	−0.036	−1.44	0.151
INDUSTRY	?	**−0.092**	**−1.81**	**0.071**
INVERSE MILL'S RATIO	?	0.008	0.03	0.974
Rho		0.179		
Sigma		0.047		
Wald $\chi^2(10)$		**198.65**		< **0.000**
Number of Observations		60		

p-values are based on two-stage Heckman standard errors. Z-values and p-values are two-tailed. Significant coefficients are bolded.

[a] Panel A shows the first-stage Probit regression of the JIT dummy variable (JIT = 1 for JIT plants and 0 for non-JIT plants) on variables assumed to be related to the decision to adopt JIT including the Incentive Index.

[b] Panel B shows the second-stage Heckman regression where Operating Profits per dollar of sales revenue is regressed on the JIT Index, the Incentive Index, experience with JIT, the inverse Mill's ratio from the first-stage Probit regression and other control variables.

Variables are defined in the notes to Tables 1 and 2.

Table 4, Panel B shows the second stage of the Heckman regression with Operating Profits as the dependent variable.[16] Importantly, both the JIT Index ($Z = 3.35$, $p = .001$, two-tailed) and experience with JIT ($Z = 5.76$, $p < .000$, two-tailed) are positively and significantly related to operating profits. In contrast, neither the Incentive Index nor the interaction term, the product of the JIT Index and the Incentive Index, are significant, although they are both positive. The variable measuring ''if the firm that owns the plant is international in scope'' is positively and significantly ($Z = 2.20$, $p = .028$, two-tailed) related to plant operating profits. The variable measuring ''whether adopting JIT requires additional financing'' is negative as expected, but significant only at the one-tailed level ($Z = -1.44$, $p = .151$, two-tailed). Electronic component plants are significantly more profitable than auto parts plants ($Z = -1.81$, $p = .071$, two-tailed). The inverse Mill's ratio is not significant, suggesting that endogeneity is not a problem. Qualitatively similar results obtain when the interaction term is dropped from the second-stage regression (untabulated).

Overall, the results of the Probit and Heckman analysis are consistent with H1b but not H1a. JIT adoption is associated with performance incentives. However, the second-stage regression is similar to the OLS analysis in that performance as measured by operating profits is not associated with incentives directly. These results are consistent with the career incentives P-A model in which production managers are incentivized to adopt JIT because it is visible to the market and signals talent, in contrast to JIT practices that are not visible to the market.[17] In addition, senior management may prefer not to incentivize production managers through their investments in JIT practices, because too many JIT tasks weaken the link between performance and inference about the production manager's talent.

Consistent with H2, experience with JIT is positively and significantly ($Z = 5.76$, $p < .000$, two-tailed) associated with operating profits, even after accounting for endogeneity of the JIT decision.

Table 5 replicates Table 4 after disaggregating the Incentive Index into its component parts. The overall results are similar to those of Table 4. Interestingly, the breakdown into incentive components in the Panel A Probit analysis shows that inventory turns ($Z = 2.00$, $p = .046$, two-tailed) and scrap/waste reduction ($Z = 3.68$, $p < .000$, two-tailed) are positively and significantly related to the decision to adopt JIT, whereas equipment utilization, on-time delivery, and quality are not significantly related to the decision to adopt JIT. These results are interesting because they suggest that the decision to adopt JIT has a lot more to do with the essential *inventory* aspect of JIT rather than other aspects such as quality. As before, labor utilization is negatively and significantly related to the adoption of JIT ($Z = -2.10$, $p = .036$, two-tailed). The negative relation may reflect the fact that our sample plants are highly unionized shops, and the unions may have objected to JIT adoption for those plants where the adoption of the new technology would likely lead to increased labor utilization.

Although the JIT adoption decision is associated with disaggregated incentives, Panel B of Table 5 shows that performance in the form of operating profits is unrelated to the disaggregated incentives. Again, the inverse Mill's ratio is not significant, so endogeneity

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[16] In theory, this regression should not involve truncated data, since dependent variable values are available for both JIT and non-JIT plants. Nevertheless, since the survey measured the components of the JIT Index only for those plants that were declared by the plant production manager to be JIT, it is not possible to differentially explain the operating profits of non-JIT plants. Hence, the data are effectively truncated, and the regression involves only the 60 data points of the JIT plants. This is not problematic from an econometrics perspective, since the Heckman two-stage procedure accounts for both data truncation and endogeneity.

[17] As researchers, we were able to access JIT practices data only because we committed to publish aggregate results. Also, these data are not in real time and may not have been available during the contracting period.

TABLE 5
Heckman Two-Stage Regression Analysis for Disaggregated Incentives

Panel A: Probit Analysis[a]

$$JIT = a_0 + a_1 INDUSTRY + a_2 INTERNATIONAL + a_3 INVENTORY\ TURNS + a_4 EQUIPMENT\ UTILIZATION + a_5 LABOR\ UTILIZATION + a_6 ONTIME\ DELIVERY + a_7 SCRAP/WASTE\ REDUCTION + a_8 QUALITY$$

Independent Variables	Expected Sign	Coefficient	Z-value	p-value
Intercept	?	0.306	0.780	0.434
INDUSTRY	?	−0.146	−0.320	0.751
INTERNATIONAL	+	0.112	0.340	0.733
INVENTORY TURNS	+	**0.356**	**2.000**	**0.046**
EQUIPMENT UTILIZATION	+	−0.130	−0.580	0.562
LABOR UTILIZATION	+	**−0.563**	**−2.100**	**0.036**
ONTIME DELIVERY	+	0.209	0.630	0.529
SCRAP/WASTE REDUCTION	+	**0.566**	**3.680**	< **0.000**
QUALITY	+	0.026	0.070	0.940
Log-Likelihood		**−52.506**	LR $\chi^2(8)$ = **29.590**	< **0.000**
Pseudo-R^2		0.220		
Number of Observations		100		

Panel B: Second-Stage Heckman Analysis[b]

$$OPERATING\ PROFITS = b_0 + b_1 JIT\ INDEX + b_2 INVENTORY\ TURNS + b_3 EQUIPMENT\ UTILIZATION + b_4 LABOUR\ UTILIZATION + b_5 ONTIME\ DELIVERY + b_6 SCRAP/WASTE\ REDUCTION + b_7 QUALITY + b_8 EXPERIENCE + b_9 ADDITIONAL\ FINANCING + b_{10} INDUSTRY + b_{11} INTERNATIONAL + b_{12} INVERSE\ MILL'S\ RATIO$$

Independent Variables	Expected Sign	Coefficient	Z-value	p-value
Intercept	?	**0.278**	**2.860**	**0.004**
JIT INDEX	+	**0.004**	**3.610**	< **0.000**
INVENTORY TURNS	+	0.014	0.48	0.633
EQUIPMENT UTILIZATION	+	−0.002	−0.12	0.902
LABOR UTILIZATION	+	−0.019	−0.44	0.656
ONTIME DELIVERY	+	0.016	0.76	0.450
SCRAP/WASTE REDUCTION	+	0.001	0.03	0.979
QUALITY	+	−0.002	−0.14	0.888
EXPERIENCE	+	**0.035**	**6.100**	< **0.000**
INDUSTRY	?	**−0.070**	**−2.670**	**0.008**
INTERNATIONAL	+	**0.052**	**3.290**	**0.001**
FINANCING	−	−0.024	−1.000	0.320
INVERSE MILL'S RATIO	?	−0.010	−0.070	0.948

(*continued on next page*)

TABLE 5 (continued)

Independent Variables	Expected Sign	Coefficient	Z-value	p-value
Rho		−0.218		
Sigma		0.045		
Wald $\chi^2(19)$		**240.57**		**< 0.000**
Number of Observations		60		

p-values are based on two-stage Heckman standard errors. Z-values and p-values are two-tailed. Significant coefficients are bolded.

[a] Panel A shows the first-stage Probit regression of the JIT dummy variable (JIT = 1 for JIT plants and 0 for non-JIT plants) on variables assumed to be related to the decision to adopt JIT including components of the Incentive Index.

[b] Panel B shows the second-stage Heckman regression where operating profit per dollar of sales revenue is regressed on the JIT Index, the Incentive Index components, experience with JIT, the inverse Mill's ratio from the first-stage Probit regression and other control variables.

Variables are defined in the notes to Tables 1 and 2.

of the JIT decision does not seem to be of consequence. Furthermore, an untabulated analysis that includes interaction variables between the JIT Index and the six disaggregated incentives in the second-stage regression yields similar results to those of Table 5. All of the interaction term coefficients are insignificant.

One reason that incentives may be related to JIT adoption but not to performance is that incentives in this study are of the ''soft'' goal performance variety rather than direct compensation. Soft incentives may be sufficient to motivate JIT adoption since JIT adoption is highly visible to the market and senior management, and visibility is likely to enhance the production manager's career objectives. In contrast, investments in specific JIT practices are not as visible, so that they have less of a motivational impact (Dewatripont et al.1999a, 1999b). Another reason may be due to the fact that the JIT plants in our study used JIT practices fairly broadly and intensively. Thus, the JIT dummy variable captures both the essential ''JITness'' of the plant, in terms of the breadth and intensity of JIT practices, as well as the decision by management to adopt JIT. Therefore, in an analysis that includes only JIT plants, such as the OLS analysis and the second-stage Heckman regression, incentives may not have sufficient cross-sectional variability to discriminate among JIT plant performance outcomes. Finally, the incentives that motivate managers to adopt or not adopt JIT as well as the incentives that motivate specific JIT practices are essentially unobservable in this study. The survey data proxies for incentives may be overly noisy, insufficiently comprehensive, or insufficiently disaggregated to really do an adequate job of describing the ''unobservable'' incentives that truly motivate JIT practice decisions.[18]

Performance measured by the Outcome Index yields results that are somewhat at variance with the results in Tables 4 and 5 for operating profits (and the other untabulated performance measures). Table 6 shows the Heckman two-stage truncated regression results where performance is measured by the Outcome Index.[19] These regressions are truncated since the survey instrument failed to inquire about the JIT practices adopted by non-JIT plants, so that the Outcome Index dependent variable is measurable only for JIT plants.

[18] In general, testing Principal-Agent theory empirically is fraught with difficulties, as emphasized by Demski and Sappington (1999).

[19] We also re-estimated this regression with the log of the Outcome Index as the dependent variable. The results are insensitive to this transformation.

TABLE 6
Heckman Two-Stage Regression Analysis-Outcome Index

Panel A: Probit Analysis[a]

$$JIT = a_0 + a_1 INDUSTRY + a_2 INTERNATIONAL + a_3 INCENTIVE$$

Independent Variables	Expected Sign	Coefficient	Z-value	p-value
Intercept	?	0.400	1.17	0.242
INDUSTRY	?	−0.326	−0.86	0.392
INTERNATIONAL	+	0.165	0.56	0.573
INCENTIVE INDEX	+	**0.183**	**2.95**	**0.003**
Log-Likelihood		**−61.181**	LR $\chi^2(3)$ = **12.24**	**0.007**
Pseudo-R^2		**0.091**		
Number of Observations		100		

Panel B: Second-Stage Heckman Analysis[b]

$$OUTCOME\ INDEX = b_0 + b_1 ADDITIONAL\ FINANCING + b_2 INDUSTRY + b_3 INTERNATIONAL + b_4 JIT\ INDEX + b_5 EXPERIENCE + b_6 INVERSE\ MILL'S\ RATIO$$

Independent Variables	Expected Sign	Coefficient	Z-value	p-value
Intercept	?	**10.109**	**0.48**	**0.630**
JIT INDEX	+	**0.260**	**3.62**	**0.000**
INCENTIVE INDEX	+	2.762	1.34	0.181
*JIT*INCENTIVE*	+	−0.001	−0.03	0.976
EXPERIENCE	+	0.276	0.69	0.489
INTERNATIONAL	+	3.345	0.69	0.493
FINANCING	−	1.824	0.92	0.357
INDUSTRY	?	−6.035	−0.96	0.335
INVERSE MILL'S RATIO	?	28.521	0.95	0.343
Rho		1.000		
Sigma		28.521		
Wald $\chi 2(7)$		**37.26**		< **0.000**
Number of Observations		60		
Treated Observations		40		

p-values are based on two-stage Heckman standard errors. Z-values and p-values are two-tailed. Significant coefficients are bolded.

[a] Panel A shows the first-stage Probit regression of the JIT dummy variable (JIT = 1 for JIT plants and 0 for non-JIT plants) on variables assumed to be related to the decision to adopt JIT including the Incentive Index.

[b] Panel B shows the second-stage Heckman regression where the Outcome Index is regressed on the JIT Index, the Incentive Index, experience with JIT, the inverse Mill's ratio from the first-stage Probit regression and other control variables.

Variables are defined in the notes to Tables 1 and 2.

The Panel A first-stage Probit regression results are, of course, identical to the Probit regression results of Table 4, Panel A. The overall second-stage results are somewhat weaker for the Outcome Index when compared with operating profits, as evidenced by the Wald Chi-square and the insignificance of all regressors except for the JIT Index. The weaker results are likely due to the fact that the Outcome Index is based on survey data and, hence, shows far less cross-sectional variability when compared with operating profits.[20] Nevertheless, as for operating profits, the JIT index coefficient is highly significant (Z = −3.62, p = .000, two-tailed).

The Heckman analysis with performance measured by the Outcome Index is also consistent with H1b but not H1a, similar to operating profits. The major difference between the two performance measures involves the JIT experience coefficient which, in contrast to operating profits, is insignificant in the case of the Outcome Index. Thus, H2 is rejected when performance is measured by the Outcome Index. Again, the latter result may be due to the relative cross-sectional homogeneity of the Outcome Index when compared with operating profits.

In an untabulated analysis, we disaggregated the JIT Incentive Index into its six components and employed a Heckman analysis with the Outcome Index as the dependent variable. The results were qualitatively similar to those with operating profits as the dependent variable (Table 5) except that, once more, the JIT experience variable proved to be positive but insignificant. We further extended the second-stage regression (untabulated) by including interaction terms of the JIT Index with each of the six incentive components. None of the interaction terms proved significant, and the results for the other coefficient estimates remained unchanged.

Robustness Checks

A number of robustness checks were undertaken to ensure the stability of the results. Instead of significance based on Heckman standard errors, we used bootstrap standard errors and jackknife standard errors but still obtained qualitatively similar results for all regressions. In a few cases, more than one plant was owned by the same firm. To account for potentially correlated plant data, the regressions were re-estimated after dropping, one at a time, all but one of the multi-plant data for each such firm. Again, the results were unaffected by this procedure. Because many plants employ Material Requirements Planning (MRP) inventory systems, it is possible that any benefits ascribed to JIT may be a consequence of the MRP system instead. However, the qualitative results remained unchanged after controlling for whether the plant utilized an MRP system. Finally, auto parts plants that were reclassified from JIT to non-JIT (see above) were dropped from the analysis, but this had no effect on the essential results.

CONCLUSION

Based on a unique data set, this study makes several contributions to the empirical Principal-Agent and JIT literature. Empirical results indicate that "soft" performance goals have the ability to incentivize managers to adopt JIT but not to invest in specific JIT practices. Furthermore, plant performance appears to be related directly to plant "JITness" but unrelated to incentives. This study also shows that it is the essential inventory aspects of JIT, such as increasing inventory turns, that appear to motivate JIT adoption rather than other, arguably less central aspects of JIT such as quality. The importance of JIT experience in driving the incentives-actions-performance chain is unclear and requires more research. When performance is measured by operating profits or the contribution margin (or total

[20] Violation of the normality assumption does not seem to be at issue. We could not reject normality of the Outcome Index using Shapiro-Wilks and Shapiro-Francia tests. In addition, we replicated our results after log transforming the Outcome Index and obtained qualitatively similar results.

production costs), experience with JIT is significantly related to performance. A significant relation does not obtain when performance is measured by an Outcome Index.

There may be a number of reasons for the finding that incentives matter for JIT adoption but not as far as investment in specific JIT practices are concerned. First, it could be that ''soft'' performance goals, unlike monetary compensation, are not sufficient to motivate specific investments in JIT, although they motivate the overall adoption of JIT at the plant level. In fact, the implicit incentive career-oriented P-A model of Holmstrom (1982) and its generalization by Dewatripont et al. (1999a, 1999b) are fully consistent with these empirical results. Second, JIT plants in this study in fact used JIT practices fairly broadly and intensively. Therefore, the JIT dummy variable in the Heckman analysis may capture not only the decision by management to adopt JIT but also plant ''JITness.'' In contrast, in an OLS regression or second-stage Heckman regression involving only JIT plants, incentives may not be able to discriminate among the JIT plants. Third, the incentives that motivate managers to adopt or not adopt JIT as well as the incentives that motivate specific JIT practices are essentially unobservable in this study, and our survey data proxies may be inadequate for describing the ''unobservable'' incentives that truly motivate JIT practice decisions.

This study has a number of weaknesses, of which three stand out. First, this study is based on a small sample of plants in two industries. Clearly, it would be beneficial to extend the analysis to a larger sample of plants and a broader group of industries. A larger sample might also allow for a more robust analysis of endogeneity using nonparametric or semiparametric techniques. Unfortunately, obtaining proprietary plant-level data is difficult, even when it involves small samples. Obtaining a sample that would allow for greater generalization remains a Herculean task. Second, unlike the JIT Index, which is computed from a comprehensive set of JIT practices and reflects extensive JIT usage by construction, the Incentive Index is potentially subject to measurement error. Given that our data are essentially cross-sectional in nature, instrumental variables to mitigate measurement error are difficult to find. Obtaining better measures of ''soft'' incentives is clearly a *desideratum*. Third, incorporating performance data for non-JIT plants as well as JIT plants might allow for a more insightful analysis of the endogeneity of the JIT decision if counterfactuals could be identified and treatment effects associated with JIT estimated (again, instruments are needed).[21] The latter approach could yield, in turn, stronger empirical results regarding the relation between incentives and outcomes in a JIT environment.

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[21] A switching regression approach might prove useful in this regard.

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