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Information Technology, Production Process Outsourcing, and Manufacturing Plant Performance

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INFORMATION TECHNOLOGY, PRODUCTION PROCESS OUTSOURCING AND MANUFACTURING PLANT PERFORMANCE **

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ABSTRACT

What is the role of information technology (IT) in enabling the outsourcing of manufacturing plant production processes? Do plant strategies influence production outsourcing? Does production process outsourcing influence plant performance? This research addresses these questions by investigating the role of IT and plant strategies as antecedents of production outsourcing, and evaluating the impact of production outsourcing and IT investments on plant cost and quality. We develop a theoretical framework for the antecedents and outcomes of production outsourcing at the plant level. We validate this theoretical framework using cross-sectional survey data from U.S. manufacturing plants. Our analyses suggests that plants with greater IT investments are more likely to outsource their production processes, and that IT spending and production outsourcing are associated with lower plant cost of goods sold and higher product quality improvement. Our research provides an *integrated* model for studying the effect of IT and production outsourcing on plant performance.

Keywords: IT investment, production process outsourcing, plant strategy, plant performance, manufacturing, empirical research.

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1. INTRODUCTION

Manufacturing firms are facing increasing global competition, and simultaneous pressures on both the cost and quality of their products. Over the past two decades, manufacturing firms have responded to these pressures by investing in process and information technologies to streamline and automate operations. More recently, in an attempt to become more agile and responsive across the supply chain, manufacturers have begun to outsource core production processes and non-core support processes to focus on their core competencies [23]. For example, Cisco focuses primarily on research, development and marketing its products, and relies on suppliers and partners to manufacture and distribute its products. A recent survey of the largest U.S. manufacturers found that 80% of logistics executives reported using third-party outsourcers to handle supply chain activities, up from less than 40% in 1991 [6]. Another survey of 318 global companies active in outsourcing reported that 61% experienced cost savings, 57% found increased ability to focus on the core business, and 50% reported improvements in process speed, quality and accuracy [30].

Previous research suggests that IT infrastructure and digital platforms are critical enablers of organizational competencies and firm performance [8, 65, 66, 70, 80]. Advances in information technology have allowed firms to improve the flexibility of their supply chains by offering high-speed communication and connectivity [35, 42, 60, 62, 69]. Innovative supply chain technologies provide the infrastructure necessary for partner integration and supply chain visibility, and enable manufacturing plants to improve efficiency and effectiveness in terms of improved product quality, productivity, time to market, and other operational and strategic objectives [4]. Similarly, research has shown that the IT investments and IT-enabled capabilities are associated with improved productivity, customer satisfaction, organizational capabilities and firm performance [9, 10, 49, 51, 61].

While the above research separately shows the contributions of IT and outsourcing to business value, there is a lack of understanding of how the interrelationship between IT and outsourcing may affect firm performance. For example, there is a limited understanding of the role of IT investment in enabling the outsourcing of production processes in manufacturing plants, and the subsequent impact on plant cost and quality objectives. There is a need to understand the pathways through which IT investments enable firms to achieve their performance objectives [53, 63]. Further, while much of the previous and current research links IT usage with performance at the firm level, there is a need to study the impact of IT-enabled value creation at lower levels, such as the plant or facility level, to improve the generalizability of previous findings.

This research extends the above stream of work by studying the role of production process outsourcing and its relationship with IT investment in impacting cost reduction and quality improvement at the plant level. We pose the following three research questions: (a) What is the role of information technology (IT) in enabling the outsourcing of manufacturing plant production processes, (b) Do plant strategies influence production outsourcing, and (c) Does production process outsourcing influence plant performance? We first develop a theoretical model that synthesizes the business value of IT and operations management literatures to link IT investment, plant strategies, production outsourcing and plant performance. We then empirically validate our theoretical model by analyzing data for a cross-section of U.S. manufacturing plants, accounting for the role of important contextual variables such as plant, product and process characteristics.

2. BACKGROUND

Manufacturing plants have evolved greatly in response to changing customer and competitive dynamics. Historically, firms have focused on improving the efficiency of their production processing and assembly operations within the confines of their own manufacturing plants. However, with increased globalization and availability of a cheaper global labor pool, outsourcing has emerged as an important vehicle for plants to contract core production processes to external providers to achieve significant reductions in fixed costs, transfer demand uncertainty, and obtain access to specialized resources. A recent study suggests that the manufacturing sector makes significant use of outsourcing business processes, with durable goods manufacturers accounting for 39% of all outsourcing activity and non-durable manufacturing plants accounting for 25% [81].

Recent research suggests that the next decade will witness the next wave of offshore manufacturing in which 12 low-cost countries will account for nearly half (approximately $800 billion) of all U.S. manufacturing imports [3]. Unlike labor-intensive industries (such as textiles) and the first wave of skill-intensive industries (including consumer electronics), the next wave of manufacturing outsourcing and offshoring is expected to include more advanced, skill-intensive industries such as pharmaceuticals and telecommunications equipment. Such a significant change in the manufacturing sector will be spurred by the growth of sophisticated supplier integration capabilities (particularly in China and India) and improvements in globally competitive manufacturing capacity in these countries. Compared with IT outsourcing that has garnered significant attention in traditional IS research, manufacturing outsourcing involves a much higher level of capital expenditures. Hence, this area provides a fertile ground for further research on the role of plant-level IT investments, their impact on the degree of production outsourcing, and relationship to plant performance.

Why do firms outsource their manufacturing operations? In some cases, they do so to achieve greater production flexibility, while others outsource to expand capacity or focus on core competencies, but the vast majority of firms outsource production activities to reduce costs or improve product quality by leveraging the expertise of their suppliers [34]. Microsoft is one company that has used IT-enabled outsourcing to improve its supply chain capabilities [45]. Microsoft was able to roll out its Xbox 360 video game and entertainment system in late 2005 by relying on a network of contractors and suppliers to deliver the components and key services that are crucial to the product. Microsoft needed to retain tight control over its external processes to ensure that contract manufacturers and suppliers met its service level agreements for on-time delivery and product quality.

Microsoft needed an IT infrastructure that would provide real-time visibility into the semiconductor manufacturing process, which was critical for the outsourced production of its Xbox graphics processing unit. Microsoft deployed a business integration and intelligence solution which supported performance monitoring and enabled standardized data exchange with the shop floor systems of its contract manufacturers' and suppliers' manufacturing plants. Microsoft also deployed an ERP platform to manage its financial processes for Xbox production, and a data warehouse to gain better visibility into its supplier performance. By leveraging its IT infrastructure to provide greater visibility into the extended supply chain of its outsourced operations, Microsoft improved on-time deliveries by 20%, and reduced inventory costs by 10%. The Microsoft Xbox 360 case provides an example of IT enabling the deployment of production outsourcing operations. We draw on this example to develop our research framework to study the impact of IT on production outsourcing and plant performance.

3. THEORY AND RESEARCH FRAMEWORK

In this section, we briefly review and synthesize the business value of IT and transaction cost economics literature that informs our theoretical model. We also draw on other research streams to develop our conceptual research model – the marketing and strategy literatures on strategy types, and the operations management literature on production outsourcing and measurement of manufacturing plant performance.

Although previous research suggests that IT investments affect several measures of firm performance [10, 49], very few studies have traced the role of IT as an enabler of intermediate capabilities that in turn impact organizational performance [51]. Recent research has shown that prudent IT investments can enable unique organizational routines that are often bundled with a firm's commitment to specific business processes [4, 44]. Customization of IT applications and technology infrastructure related to plant-specific production processes, such as fabrication and assembly of the final product, is a complex and often inimitable process.

In an outsourcing context, IT provides the basic foundation to disaggregate business processes and facilitate production process outsourcing by reducing the complexities associated with communication and coordination across organizational boundaries. IT also enables manufacturing plants to reintegrate the outcomes of outsourced processes back into their internal operations through better codification and standardization of information exchange. In other words, IT assets provide the infrastructural capabilities for manufacturing plants to outsource their production activities, and a plant's ability to leverage these capabilities leads to competitive advantage as measured by improvements in plant performance. We further note that IT-enabled capabilities are dynamic since plants must continually reconfigure their capabilities to adapt to volatile markets, especially in fast-paced technological environments where speed to market is critical [72]. Hence, a plant's ability to leverage its IT infrastructure to develop better integration and coordination capabilities with outsourcing providers creates unique competencies that allow the plant to respond effectively to dynamic changes in customer requirements.

3.1 IT Investment and Production Process Outsourcing

Transaction cost economics (TCE) provides one theoretical perspective to evaluate outsourcing considerations. Outsourcing may offer lower production costs through economies of scale or specialization, but these advantages come at the expense of higher transaction costs. The information systems (IS) literature builds on transaction cost theory by suggesting that an increase in the use of IT is associated with increased outsourcing and greater use of external markets compared to internal hierarchies [14, 41].

While previous research has addressed the effect of IT on boundaries at the firm level [28], we are not aware of any empirical work that examines the effect of IT at the plant level. Previous research notes that IT enables the representation and transfer of business process knowledge across organizational boundaries, and facilitates recording and retrieval of information about organizational processes, which makes process formalization more viable [40]. In a similar manner, IT facilitates the standardization of business processes by providing the tools to codify and modularize business process knowledge, serve as a repository to access information about standardized processes, and manage inter-organizational process dependencies [15, 52, 79]. For example, IT deployment for the outsourced production of the Xbox 360 system enabled Microsoft to improve supply chain effectiveness by facilitating the creation of private-to-public data integration processes and enabling the standardization of data exchange interfaces

[56]. IT also enabled Microsoft to better monitor supplier work in progress, provide advanced shipping notifications and synchronize inventory.

Based on the discussion above, we posit that plants with greater IT investments are more likely to outsource their production processes, because IT investments enable the coordination of inter-organizational business process workflows with contract manufacturers and suppliers through process codification, standardization and modularization.

H1: (IT-Outsourcing Hypothesis) Plants with higher levels of IT spending are more likely to outsource their plant production processes.

3.2 Plant Strategy and Production Process Outsourcing

Most firms can be classified as following a primary strategy. At one end of the spectrum, some firms focus on cost leadership by reducing their costs and achieving a lean cost structure [58]. At the other end of the spectrum, other firms pursue revenue expansion based on such as differentiation in the quality of products or services [64]. A cost leadership strategy requires achieving lower costs compared to other competitors, while a quality differentiation strategy focuses on influencing customer judgments of relative product utility and satisfaction [17]. While most firms follow either the cost leadership or quality differentiation strategies, it is also possible for firms to follow a hybrid strategy where they pursue cost leadership and quality differentiation at the same time [58, 64].[1] Our focus on these market strategies is also consistent with early strategy research that also classifies firms into these categories: firms that compete primarily based on cost (defenders), firms that pursue new market opportunities (prospectors), and intermediate firms (analyzers) [46].

[1] We thank an anonymous reviewer for suggesting that manufacturing plants could focus on "low cost" and "high quality" simultaneously. We have incorporated the consideration of such hybrid strategies into our subsequent empirical analyses.

Previous research on operations strategy supports the existence of a relationship between plant manufacturing strategies and business performance [47]. Swamidass and Newell [68] show that manufacturing performance is positively related to the specific manufacturing strategy of flexibility. Several studies show that effective manufacturing strategies begin with a focus on quality [20]. Other studies of world-class manufacturing suggest that best in class competitors compete on the basis of their manufacturing strategies, and capabilities intrinsic to such strategies [74]. Based on an empirical study of U.S. manufacturers, Ward and Duray [75] report that plant cost and quality strategies have a significant association with improvements in performance, specifically on measures of plant cost, quality, flexibility and delivery.

A firm's strategy also has a significant influence on its operating characteristics and subsequent performance in an outsourcing context. For example, the strategic orientation of a firm may affect its propensity to outsource the IT function [71]. Loh and Venkatraman [38] find that a higher business cost structure is associated with an increased propensity to outsource the IT function, suggesting that a cost reduction strategy is associated with increased IT outsourcing.

More recently, researchers have observed that the motivations for outsourcing extend beyond cost. For example, general managers' concerns about quality also drive their IT outsourcing decisions [43]. Other researchers suggest that firms engage in process outsourcing to leverage the high quality and innovation potential of business partners [59]. Using survey data from the automotive and computer industries, Ittner and Larcker [29] find that firms which more extensively use quality strategies, qualify-oriented information and quality-focused incentive systems are more likely to realize significant improvements in firm performance. For firms that follow hybrid strategies, Lacity, Feeny and Willcocks [32] developed a framework where outsourcing can be used to simultaneously achieve cost reduction and service improvement.[2]

Since outsourcing plant production processes enables firms to leverage the competencies of external partners, we posit that plants which focus on cost reduction, quality improvement or hybrid strategies are more likely to outsource their production processes.

H2a: (Low Cost Strategy-Outsourcing Hypothesis) Plants that adopt low cost strategies are more likely to outsource production processes.

H2b: (High Quality Strategy-Outsourcing Hypothesis) Plants that adopt high quality strategies are more likely to outsource production processes.

H2c: (Hybrid Strategy-Outsourcing Hypothesis) Plants that adopt hybrid strategies (low cost and high quality) are more likely to outsource production processes.

3.3 Impact of Production Process Outsourcing on Plant Performance

Manufacturing firms outsource a variety of processes in an attempt to reduce costs and improve product and service quality. Many firms have moved from a vertically integrated model to a leaner model where the firm focuses on a narrow set of activities and contracts with external outsourcing providers to perform the remaining activities.

Outsourcing has the potential to confer several advantages. First, by outsourcing specific activities to external providers, firms may better focus on their core value-creating processes, maximizing the effectiveness of those core processes [19]. Second, outsourcing enables plants to reduce their investments in plant facilities, equipment and manpower [7]. At the same time, outsourcing may enable plants to achieve a reduction in unit costs, because outsourcing allows

[2] While our survey data includes other plant strategies, such as customization, innovation, service and support, delivery, and product variety, we focus on the low cost, high quality and hybrid strategies because these represent foundation strategies in the strategy, marketing and operations literature [58, 64, 75]. Exploring the relationships between other types of strategies and plant performance can provide an avenue for future research.

service providers to leverage their economies of scale. Third, outsourcing may also lead to improvements in product quality because of access to the focused expertise and innovation skills of service providers [18]. Fourth, outsourcing can enhance the manufacturing flexibility of plants. Plants can buy technology from a supplier that would be costly or consume valuable time to replicate internally. A reliable network of outsourcing partners may provide firms with the ability to adjust the scale and scope of their production capacity, at lower cost, in response to fluctuations in customer demand. Therefore, we hypothesize that outsourcing production activities will be associated with lower plant costs and greater improvements in quality.

H3a: (Outsourcing-Plant Cost Hypothesis) Plants that outsource production processes are more likely to realize lower plant costs.

H3b: (Outsourcing-Product Quality Hypothesis) Plants that outsource production processes are more likely to realize greater improvements in product quality.

3.4 Information Technology and Plant Performance

We have described above the role of IT in enabling the outsourcing of plant production processes, and the role of production process outsourcing in affecting plant cost and quality performance. We note that IT may have a direct effect on plant costs and quality. A plant can leverage its IT infrastructure to integrate processes and resources within and across firms. Investment in appropriate IT solutions can also enable plants to participate in electronic (Internet) exchanges and online procurement auctions, providing a channel to identify low cost suppliers and partners for outsourced production of primary products [12, 48]. These solutions provide an avenue for plants to lower their costs of material procurement, and reduce their labor and overhead costs.

A plant's IT infrastructure also provides greater visibility into the supply chain processes of its value chain, including its partners and suppliers, which in turn enables plants to monitor real-time changes in customer requirements and product specifications, and transmit these changes electronically to its outsourcing partners. By helping to aggregate project information across the supply chain, IT should improve a plant's ability to track project progress, spot and correct deviations, and consistently execute on its business plans. Supplier portals enable plants to update information about forecasting, scheduling and pricing in one central location, which allows their suppliers to make adjustments and react more efficiently to customer-driven changes. For example, Cisco Systems' Manufacturing Connection Online (MCO) includes a supplier portal and access to the underlying source data used by Cisco and its contract manufacturers. MCO enables Cisco to increase efficiency in processes such as order fulfillment and vendor payment, and effectiveness in monitoring performance goals related to cost, quality and delivery. Hence, we hypothesize that plant-level IT investments are associated with improvements in plant performance.

H4a: (IT-Plant Cost Hypothesis) Plants with higher levels of IT spending are more likely to realize lower plant costs.

H4b: (IT-Product Quality Hypothesis) Plants with higher levels of IT spending are more likely to realize greater improvements in product quality.

3.5 Supplier Integration and Plant Performance

Supplier integration involves integration of plant processes with supplier operations, in terms of coordinating supply chain processes such as procurement and production planning. Supplier integration may involve supplier involvement in product design, or the acquisition of advanced supplier technological capabilities [54]. Close integration between a plant and its suppliers provides joint capabilities to meet customer requirements, respond to market shifts, and enables suppliers to provide input to plant production processes [21, 24].

Supplier integration allows suppliers to share their expertise regarding new ideas and technologies, enabling a more cohesive execution of day-to-day plant activities. Supplier integration reduces the internal complexity of projects and provides access to external human and technological resources that improves the coordination of communications and information exchange [31]. In his seminal study on product development projects of Japanese and U.S. automobile firms, Clark [13] found that supplier involvement in new product development enabled better integration with manufacturing plant operations by reducing engineering changes, increasing component standardization, and improving access to process data. In a recent study, Mithas, Krishnan and Fornell [50] show that firms also gain more in terms of customer knowledge when they share their customer related information with supply chain partners, and improved customer knowledge in turn helps firms to improve their customer satisfaction.

Schroeder, Bates and Junttila [67] also show that plants' ability to incorporate external and internal learning, through interactions with customers and suppliers, translates into proprietary manufacturing capabilities, an important enabler of plant performance. The ability to manage production outsourcing activities, such as assembly, staging, and fabrication of finished goods, through better supplier integration capabilities represents an important competency and competitive differentiator. Hence, we hypothesize that plants with greater supplier integration are more likely to realize greater improvements in plant performance.

H5a: (Supplier Integration-Plant Cost Hypothesis) Plants with a high degree of supplier integration are more likely to realize lower plant costs.

H5b: (Supplier Integration-Product Quality Hypothesis) Plants with a high degree of supplier integration are more likely to realize greater improvements in product quality.

We draw on the above discussion to develop our conceptual research model in Figure 1. We control for relevant plant-specific characteristics to account for differences in plant size, age, production volume, product mix, unionization, and the nature of manufacturing operations [4].

4. RESEARCH DESIGN AND METHODOLOGY

We obtained data for this research from the Industry Week-Manufacturing Performance Institute (IW-MPI) Census of Manufacturers 2004 survey of U.S. manufacturing plants. The survey was designed to collect information about manufacturing trends, outsourcing practices, plant information systems, and specific plant performance measures using a Web-based online survey. Plant managers provided data on manufacturing practices, outsourced plant processes and IT investments, while plant performance measures were based on assessments of plant records by plant controllers.[3]

The survey was electronically mailed to approximately 20,000 plant managers and controllers from IW-MPI's database of manufacturing plants. Six hundred and eighty one plants responded to the survey. Our sample for this research consists of the 326 plants that provided complete responses to the variables of interest in our model, and that outsourced at least one plant production, logistics or service process. Of these plants, 287 plants provided complete data to study the impact of IT and production outsourcing on plant costs, and 266 plants provided complete data to study the impact on plant quality.

[3] The survey questions used in this research are available from the authors on request.

In Table 1, we provide the distribution of the manufacturing plants in our study sample, based on three-digit North American Industry Classification System (NAICS) codes, and compare it to the distribution of all U.S. manufacturing plants as reported in the Statistical Abstract of the U.S. published by the U.S. Census Bureau [73]. Our study sample has a larger proportion of durable manufacturing plants compared to the U.S. Census, and a smaller proportion of non-durable manufacturing plants. Our sample of plants is drawn from three NAICS codes that represent all discrete and process manufacturing plants. NAICS code 31 represents plants that manufacture non-durable items such as food and apparel, NAICS code 32 represents plants that manufacture raw materials such as petroleum and chemicals, and NAICS code 33 represents plants that manufacture machinery and electronics.[4]

Since we obtained the data from a secondary data source, we did not have information on the profiles of non-respondent plants. To evaluate the generalizability of our findings, we compared the average dollar value of plant shipments per employee (i.e., productivity per employee) of our sample plants to the average productivity of all U.S. manufacturing plants [73]. The average employee productivity of our sample plants[5] was $249,220, while the average employee productivity in the U.S. Census data was $359,973. The difference in average plant productivity is statistically not significant, which suggests that our results can be generalized to other U.S. plants.

4.1 Variable Definition

The variables described below are defined based on responses provided by plant managers and controllers from 2004 data.

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[4] Our estimation models do control for discrete vs. process manufacturing operations (details in section 4.2), which are related to the NAICS code. We performed additional analysis to control for NAICS code in addition to nature of manufacturing operations, and our results are largely unchanged.

[5] Out of 326 plants in our sample, only 305 provided sales per employee data.

Plant Cost (COGS): Defined as the plant cost of goods sold as a percentage of revenue. The plant *COGS* consists of three components – labor, overhead, and materials costs – that provide a measure of the direct and variable costs of the manufactured product. Previous studies have used similar measures to track plant performance [80].

Quality change (QUALITY): Defined as the change in first-pass quality yield percentage of finished products over the past three years. Respondents were asked to report two metrics based on available plant records: (a) first-pass quality yield (%) in the current year, and (b) first-pass quality yield three years ago. The *QUALITY* measure is calculated as the difference between these two metrics *(a) minus (b)*. The base is 100 quality percentage points. A positive number represents an increase in quality over the past three years, and a negative number represents a decrease in quality over the past three years.[6] We computed the change in plant quality to capture the time dimension associated with improvements in plant performance.

Production Process Outsourcing (PRODOUT): A three-item index indicating the extent of outsourcing for production processes at the plant level. The three core production processes are fabrication and/or processing, assembly, and staging and/or packaging. The degree of outsourcing for each process was measured using a binary variable, where zero indicates that the process was not outsourced and one indicates that the process was outsourced.

IT Investment (ITSPEND): Level of plant spending on information technology as a percentage of annual plant sales. *ITSPEND* consists of spending at the plant level on the overall plant IT infrastructure, including software, hardware, telecommunications, and support/consulting services. It provides a measure of the intensity of IT spending to support

[6] The three-year timeframe is based on the IW-MPI survey, which was not designed by the authors. While it would have been preferable to also obtain data on change in plant COGS over a three-year duration, this data was not collected in the survey and we acknowledge this as a limitation of secondary data.

plant operations, and is similar to the IT intensity metrics conceptualized by Zhu and Kraemer [73] in their study of manufacturing firms.

Low Cost Strategy (STR_COST): Indicates whether the plant's market strategy has "low cost" as one of the top three objectives (0=no, 1=yes).

High Quality Strategy (STR_QUALITY): Indicates whether the plant's market strategy has "high quality" as one of the top three objectives (0=no, 1=yes).

Hybrid Strategy (STR_HYBRID): Indicates whether the plant's market strategy has both "low cost" and "high quality" in its top three objectives (0=no, 1=yes).

Supplier Integration (SUPPINT): Indicates whether plant operations are highly integrated with supplier operations (0=no or some integration, 1=extensive integration).

We control for the impact of plant characteristics on production outsourcing and performance. Plant age (*AGE*) represents the number of years since plant start-up to the time of the study, and plant size (*SIZE*) is measured as the number of plant employees. Large plants may have the scale required to justify adoption of production outsourcing activities. Plant age may also play a significant role, since older plants are less likely to adopt advanced manufacturing practices and often fail to realize their impact on plant performance. Union (*UNION*) indicates whether all plant production workers are represented by a union, and is measured as a binary variable (0=no or some workers represented by union, 1=all workers represented by union).

We also control for the nature of plant operations, as plant operations may also impact production outsourcing and performance. Plant volume (*VOL*) indicates whether the plant operations are characterized by a high volume of products, and plant mix (*MIX*) indicates whether the plant operations are characterized by a high mix of products. *VOL* and *MIX* are measured as binary variables (0=no, 1=yes). Discrete manufacturing (*DISCRETE*) represents operations where the primary products are measured in numeric quantities (for example, number of widgets), while process manufacturing (*PROCESS*) indicates whether the primary products are measured by weight or volume (for example, weight of raw material product). *DISCRETE* and *PROCESS* are also measured as binary variables (0=no, 1=yes).

Table 2 provides descriptive statistics for our model variables, including mean, standard deviations, and partial zero-order correlations among the model variables. Although the correlations between STR_COST and STR_HYBRID and between PROCESS and DISCRETE are high (0.75 and 0.69, respectively), our models provided reasonable values of multi-collinearity diagnostics suggesting that these correlations do not affect the stability of our parameter estimates.

4.2 Estimation Models

The research framework above describes the relationship between plant-level IT investments, plant strategies and their impact on the extent of production outsourcing within manufacturing plants. Since the dependent variable *PRODOUT* appears as an ordered choice in our dataset, for equation 1 below we use ordered probit that does not assume equal intervals between various levels in the dependent variable [25].[7]

Let the outsourcing propensities be expressed by:

$$Y_i^* = \beta_{11} ITSPEND + \beta_{12} STR\_COST + \beta_{13} STR\_QUAL + \beta_{14} STR\_HYBRID + \beta_{15} SIZE + \beta_{16} AGE + \beta_{17} VOL + \beta_{18} MIX + \beta_{19} DISCRETE + \beta_{1\text{-}10} PROCESS + \beta_{1\text{-}11} UNION + \beta_{1\text{-}12} SUPPINT + e_i \quad (1)$$

[7] For equation 1, the OLS estimation results are consistent with ordered probit estimation results.

We do not observe Y_i*, instead we observe the ordinal dependent variable *PRODOUT* that is, Y_j, $j=1,2,\ldots m$ depending on the values of thresholds or cutoff points α_{j-1} and α_j as follows:

$Y_i = j \quad if \quad \alpha_{j-1} < Y_i* < \alpha_j$ where α_j are constants with $\alpha_0 = -\propto$, $\alpha_m = +\propto$, and $\alpha_0 < \alpha_1 < \ldots < \alpha_m$.

The probability distribution of Y_i is given by:

$$\text{Probability } (Y_i = j \mid X_i) = \Phi[\alpha_j - \beta' X_i] - \Phi[\alpha_{j-1} - \beta' X_i] \quad (2)$$

where Φ denotes the cumulative normal distribution function of e_i.

Our OLS estimation models for the plant performance outcomes of production process outsourcing are as follows:

$$COGS = Constant + \beta_{21}PRODOUT + \beta_{22}ITSPEND + \beta_{23}STR\_COST + \beta_{24}STR\_QUAL + \beta_{25}STR\_HYBRID + \beta_{26}SIZE + \beta_{27}AGE + \beta_{28}VOL + \beta_{29}MIX + \beta_{2\text{-}10}DISCRETE + \beta_{2\text{-}11}PROCESS + \beta_{2\text{-}12}UNION + \beta_{2\text{-}13}SUPPINT + \varepsilon_2 \quad (3)$$

$$QUALITY = Constant + \beta_{31}PRODOUT + \beta_{32}ITSPEND + \beta_{33}STR\_COST + \beta_{34}STR\_QUAL + \beta_{35}STR\_HYBRID + \beta_{36}SIZE + \beta_{37}AGE + \beta_{38}VOL + \beta_{39}MIX + \beta_{3\text{-}10}DISCRETE + \beta_{3\text{-}11}PROCESS + \beta_{3\text{-}12}UNION + \beta_{3\text{-}13}SUPPINT + \varepsilon_2 \quad (4)$$

Because these models are not used for predictive purposes and we are primarily interested in parameter estimates for the coefficients of interest, the models show reasonable levels of R-squared values consistent with those observed in social sciences research [1]. We also test for multi-collinearity by computing condition indices and variance inflation factors. The highest condition index was less than 23 and highest variance inflation factor was less than 4 in all of our models, indicating that multi-collinearity is not a serious concern [5]. With the variance in size and age of the plants in our sample, we accounted for heteroskedastic error distribution and calculated heteroskedasticity consistent standard errors for all of our models [78].[8]

5. RESULTS

We now describe the results of our empirical estimation of the antecedents and performance outcomes of production process outsourcing.

5.1 Antecedents of Production Outsourcing

Ordered probit estimation results for equation 1 are shown in Table 3. Consistent with the IT-Outsourcing Hypothesis (H1), our results show a positive and statistically significant association between the level of plant IT investment and the extent of plant production process outsourcing ($\beta_{11} = 0.048$, $p<0.006$). Our results indicate that IT investments serve as an enabler of production outsourcing by providing the infrastructure that plants leverage to coordinate production planning and manufacturing decisions with their outsourcing providers.

The Low Cost Strategy-Outsourcing Hypothesis (H2a) predicts that plants with a low cost strategy are more likely to outsource production processes. This hypothesis is not supported, as the low cost strategy is not associated with the extent of production outsourcing. Consistent with the High Quality Strategy-Outsourcing Hypothesis (H2b), our results indicate that plants with a strategy of high product quality are more likely to outsource their production process ($\beta_{13} = 0.307$, $p<0.038$). The Hybrid Strategy-Outsourcing Hypothesis (H2c) predicts that plants with a hybrid strategy (low cost and high quality) are more likely to outsource production processes. This hypothesis is not supported, as the hybrid strategy is not associated with the extent of production outsourcing.

[8] We also estimated the path coefficients in equations 2 through 4 using a structural equation modeling (SEM) technique. The SEM estimates are similar to our ordered probit and OLS estimation results in Table 3.

The results related to the impact of plant characteristics on production outsourcing also provide interesting insights. First, a fully unionized plant is associated with increased production outsourcing ($\beta_{1\text{-}11}$ = 0.375, p<0.028). One potential explanation for this finding may be that union constraints in work rules or compensation may lead management to outsource certain production processes to increase workforce flexibility. We also find that high volume plants are less likely to outsource production processes (β_{17} = -0.236, p<0.060), and discrete manufacturing plants are more likely to outsource production processes ($\beta_{19} = 0.569$, p<0.004). Our results suggest that process manufacturing is likely to be associated with less production outsourcing, which can be attributed to the difficulty in separating key production activities (such as fabrication, assembly and packaging) from related processes such as asset management, logistics and R&D. These results suggest that the nature of plant manufacturing operations may play an important role in determining production outsourcing, perhaps by affecting the ease or difficulty with which key production activities can be separated from other support and logistics processes. We do not find any statistically significant effect of plant size on production outsourcing, a result consistent with prior research on IT outsourcing [38].

5.2 Plant Performance

Our estimation results for plant cost and quality are provided in columns 2 and 3, respectively, of Table 4. In the Outsourcing-Plant Cost Hypothesis (H3a), we posit that plants which outsource production processes will be more likely to realize lower costs. This hypothesis is supported, as production outsourcing has a negative and statistically significant association with plant cost of goods sold ($\beta_{21} = -3.135$, p<0.034). The Outsourcing-Product Quality Hypothesis (H3b) predicts that plants which outsource production processes are more likely to realize higher product quality. This hypothesis is also supported, as production outsourcing has a positive and moderately significant association with quality improvement ($\beta_{31} = 1.320$, $p<0.055$).

The IT-Plant Cost Hypothesis (H4a) predicts that plants with a higher level of IT investment will realize lower costs. This hypothesis is supported, as each 1% of IT spending (as a percentage of plant revenue) is associated with about 1.06% reduction in cost of goods sold ($\beta_{22} = -1.062$, $p<0.000$). The IT-Product Quality Hypothesis (H4b) predicts that plants with a higher level of IT investment will realize greater improvements in quality. This hypothesis is also supported, as IT spending is positively and moderately significantly associated with an increase in quality ($\beta_{32} = 0.383$, $p<0.090$). Our results suggest that the impact of plant IT spending on plant costs and quality consists of two components: a *direct* component that represents the direct impact of IT on cost reduction and quality improvement, and an *indirect* component that represents IT's impact on performance through the enablement of production process outsourcing. The overall impact of plant IT investments, estimated as the sum of these two components, indicates that every 1% increase in IT spending is associated with a 1.14% reduction in cost of goods sold. Similarly, the overall impact of IT on plant quality is also statistically significant at $p<0.10$, and indicates that every 1% increase in IT spending is associated with a 0.419% increase in plant quality over a three-year period.

We also tested an alternative model specification to test whether IT moderates the impact of production outsourcing on plant performance. We operationalized the moderation impact of IT using an interaction term (i.e., *PRODOUT* x *ITSPEND*) that represents the strength of the moderated relationship. We found that the interaction term was statistically not significant for both plant performance measures, thus we fail to find support for a moderating effect of IT investments on the relationship between outsourcing and plant performance. Overall, these results provide support for the argument that the overall impact of IT investments on plant performance is partially mediated through production outsourcing.

The Supplier Integration hypotheses involve the role of supplier integration in plant cost and quality performance. The Supplier Integration-Plant Cost Hypothesis (H5a) predicts that plants with extensive supplier integration will be more likely to realize lower costs. This hypothesis is not supported. The Supplier Integration-Product Quality Hypothesis (H5b) predicts that plants with extensive supplier integration will be more likely to realize greater improvements in product quality. Our results indicate that extensive supplier integration is positively and moderately statistically significantly associated with plant quality improvement ($\beta_{3\text{-}13} = 3.105$, $p<0.057$), providing support for this hypothesis. Considering the effect of plant strategies, we find a statistically significant association between plant hybrid strategy and *higher* plant costs ($\beta_{25} = 11.564$, $p<0.043$), suggesting that the dual cost-quality strategy may be difficult to execute in practice.

5.3 Additional Performance Outcomes

While cost and quality are two primary outcomes for manufacturing plants, other performance metrics are also important to assess plant operations. As part of a post hoc analysis, we analyzed additional performance measures to develop a more complete understanding of the impact of IT and production process outsourcing. The results of this analysis are presented in Table 4.

For manufacturing plants, an important measure of plant efficiency is capacity utilization, or the plant production volume as a percent of designed plant capacity. One objective for plants is to run at a high utilization, meaning that equipment and labor capacity are being fully utilized. We find that production outsourcing is positively and moderately significantly associated with higher capacity utilization ($\beta = 2.314$, $p<0.065$). This finding is consistent with the general intent of outsourcing to reduce capital investments and utilize existing plant assets more efficiently.

Another measure of plant effectiveness is customer lead time, defined as the number of days from the time that the customer places an order to the time that the order is shipped to the customer. Customer lead time is an important determinant of customer satisfaction, which in turn has implications for the overall performance of a business unit [22]. Interestingly, we find that production outsourcing is positively associated with *higher* (i.e., unfavorable) customer lead times ($\beta = 6.019$, $p<0.056$). This finding suggests that involvement of additional outsourcing partner(s) in the production process involve additional coordination issues that may lengthen the lead time to fulfill customer orders. Our preliminary analyses suggest that there are tradeoffs in terms of the net impact of production outsourcing in manufacturing plants. Depending on a plant's competitive focus, the tradeoffs between lower cost of goods sold, higher quality improvement and longer lead times need to be balanced in order to assess the overall value of IT-enabled production outsourcing.

While manufacturing costs, such as the cost of goods sold, constitute an important internal performance measure, this metric manifests itself in the marketplace as the end price charged to the customer. To maintain and possibly expand market share, plants must be able to offer the best cost-quality tradeoff to their customers, and price is an important part of this equation. Just as production outsourcing was associated with lower costs, production outsourcing is also associated with a reduction in the price per unit charged to customers ($\beta = -0.175$, $p<0.047$). Although we cannot infer a causal relationship due to the cross sectional nature of our data, these results suggest that by facilitating lower costs, outsourcing may enable plants to compete effectively on price in a highly competitive marketplace.[9]

6. DISCUSSION

Our research objective was to study the effect of IT investment on production process outsourcing and manufacturing plant performance. We propose and empirically validate a theoretical model to explain the effect of IT investment on production outsourcing and plant performance outcomes.

6.1 Findings

Consistent with our expectations, we find that plants with higher levels of IT investment are more likely to outsource their production processes. This implies that IT enables plants to codify, standardize and modularize their business processes, and develop the integration capabilities required to outsource production to third-party providers [62, 65]. We also find that production process outsourcing is associated with lower cost and higher quality at the plant level. This finding is important and suggests that IT-enabled production outsourcing allows plants to simultaneously achieve the goals of cost reduction and quality improvement. Our findings are consistent with those of Lacity and Willcocks [33] in an IS outsourcing context. Our research also complements the work of Grover, Cheon and Teng [27] and Lee and Kim [36], who study the impact of service quality on outsourcing success.

Our paper identifies specific outcomes associated with each type of plant strategy, and tests the impact of IT investment and production outsourcing on achieving these outcomes. We find that a quality-focused plant strategy is associated with increased outsourcing, perhaps to leverage the core competencies of external providers who have greater access to technological

[9] It is equally possible that price decreases forced by the competitive market compel firms to outsource.

resources for the delivery of high quality products [37]. This finding is consistent with the findings of Grover, Teng and Cheon [26] in IT outsourcing, where prospector firms (following a revenue expansion or quality improvement strategy) are more likely to pursue outsourcing. The results suggest that quality-focused plants are more likely to outsource to access the expertise offered by contract manufacturers, who may be able to leverage their scale and skills to manufacture higher quality products. Our empirical finding on the relationship between supplier integration and quality improvement is consistent with recent research which suggests that the extent of supplier integration has a significant impact on operational excellence, revenue growth and customer satisfaction [50, 62].

We do not find support for an association between low cost plant strategy and production outsourcing. This finding suggests that plant management may believe that contracting externally may not result in lower overall costs, because of the additional costs required to support the outsourcing of manufacturing activities. This reasoning is consistent with evidence from the practitioner literature which suggests that offshore manufacturing may actually increase total manufacturing costs once indirect coordination costs for shipping and logistics, communications, and vendor management are taken into consideration [55]. Similarly, since labor costs typically account for a relatively small percentage of the cost of good sold in many industries, plants with cost reduction strategies may be inclined not to outsource due to the potential complexity of coordinating production with in-house logistics and distribution systems.

6.2 Contributions and Research Implications

This research constitutes one of the first studies to provide empirical evidence on the antecedents and outcomes of production process outsourcing in manufacturing plants, and highlights the role of IT in enabling production outsourcing. It makes three contributions that are distinct from the previous research on outsourcing. First, we develop a theoretical framework which provides an integrative understanding of how IT impacts plant performance, partly through its influence on plant outsourcing decisions. This framework can be used to study the effect of IT on outsourcing other processes, such as procurement, logistics, and asset management, and resulting performance impacts. More broadly, this study contributes to the growing literature that traces the mediating mechanisms for effect of IT on firm performance. By highlighting the role of production outsourcing to explain the effect of IT on performance, this study extends previous research that has suggested other pathways such as manufacturing capabilities, process integration capabilities, customer management capabilities and process management capabilities [4, 51, 62], and provides a foundation to identify other intervening organizational capabilities.

Second, unlike previous studies that examine outsourcing at the firm level [38, 39], our research at the plant level brings a sharper focus in terms of the unit of analysis. We avoid confounding due to omitted unobserved heterogeneity that exists to a larger extent in studying the same phenomenon at the firm level. Third, we empirically validate the role of IT investments and plant strategies on the extent of production process outsourcing. While the previous outsourcing literature [57] addresses asset specificity considerations of IT assets that may inhibit outsourcing, we extend the literature by considering how IT investments may actually facilitate outsourcing. And while prior research did not find an impact of strategy type on the extent of outsourcing [71], we find that a quality-focused plant strategy is positively associated with production outsourcing.

6.3 Managerial Implications

Our study has at least four key managerial implications. First, as plant managers evaluate whether to outsource critical production processes, they need to understand the characteristics of plants that lend themselves to outsourcing. Our study suggests that a higher level of IT investment is important for plants to effectively coordinate their operations with outsourcing providers. Second, contrary to popular perception, our findings suggest that production outsourcing decisions are not necessarily favored by plants with a low cost strategy. The finding that plants with a high quality strategy are more likely to outsource production processes, and that outsourcing has a favorable effect on cost and quality, should encourage managers of plants with a quality-focused strategy who are evaluating outsourcing alternatives.

Third, while there is a debate on whether outsourcing has a more favorable effect on cost reduction or quality improvement, our findings suggest that management can expect production outsourcing to yield simultaneous improvements in both plant costs and quality. Fourth, our findings suggest that plant managers need to ensure a high degree of integration with suppliers to fully leverage the outsourcing relationships for quality improvement.

6.4 Limitations and Further Research

We acknowledge three limitations of this research. First, since the scope of the survey was limited to U.S. manufacturing plants, our findings may not be generalizable to firms in other industries and outside the U.S. Second, because of the cross-sectional nature of our data, our findings only show associational patterns. Because previous research suggests a lagged effect between IT investments and performance outcomes [11], there is a need to collect longitudinal data to study lagged relationship between IT investments, production outsourcing, and plant performance outcomes. Studies using longitudinal data will also enable researchers to deal with some of the endogeneity issues that are difficult to address in a cross-sectional dataset.[10] While we do not have longitudinal data, the associational patterns in this study provide a foundation and starting point for future longitudinal studies. Such longitudinal studies could be complemented by in-depth case studies within organizations to gain a contextual understanding of the impact of IT on production outsourcing. Third, due to the nature of the secondary data, we do not have any information on the degree of production outsourcing for each process, which would have provided a better understanding of the antecedents and consequences of outsourcing.

Several areas appear promising for further research. First, further research is needed to evaluate the impact of IT on the outsourcing of plant support processes, and to study the impact of other plant strategies on outsourcing and plant performance. Second, firms have a choice of outsourcing within the U.S. or outside the U.S. [2]. There is a need for further research to explore when firms are more likely to outsource to an offshore location [76]. In particular, are firms with higher levels of IT investment more capable of offshore outsourcing? Third, the outsourcing and offshoring of production and service processes has implications for employment and wages in the U.S. economy. There is a need for research to study the phenomenon of outsourcing and offshoring at the occupation and activity levels to understand the types of occupations and activities that lend themselves to outsourcing and offshoring [52]. Fourth and finally, because emerging technologies such as Radio Frequency Identification (RFID) are likely to further integrate plants with their supply chain partners, it will be useful to study how adoption of these newer technologies may impact production outsourcing and plant performance [16, 77].

[10] While the IW-MPI survey is conducted each year, it does not facilitate a longitudinal analysis because plant ID's

7. CONCLUSION

In this study, we developed and empirically tested a model for the effect of IT investment on production outsourcing and plant performance. Using data covering a broad cross-section of U.S. manufacturing plants, we found that IT investments are positively associated with plant production outsourcing. In turn, production outsourcing is associated with lower plant costs and higher plant quality. The key contribution of this research is to highlight the role of IT investment in enabling production outsourcing, and its positive impact on plant performance.

Our study also examines the role of plant strategies and their influence on production outsourcing in manufacturing plants. Contrary to popular opinion, our results indicate that quality-focused plant strategies are associated with greater production outsourcing. We also observe that the level of supplier integration is an important driver of plant performance, as greater integration of plant processes with supplier processes is associated with improvements in plant quality. Our research provides an integrated perspective on the role of IT in a manufacturing outsourcing context, which has traditionally been ignored in the prior IS literature that has primarily focused on IT outsourcing, and the operations literature that has typically focused on production outsourcing without considering the enabling role of IT. This research and findings are important as manufacturing plants prepare themselves to meet the challenges and opportunities in the emerging global economy.

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are not tracked from one year to the next.

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Figure 1: Conceptual Research Model

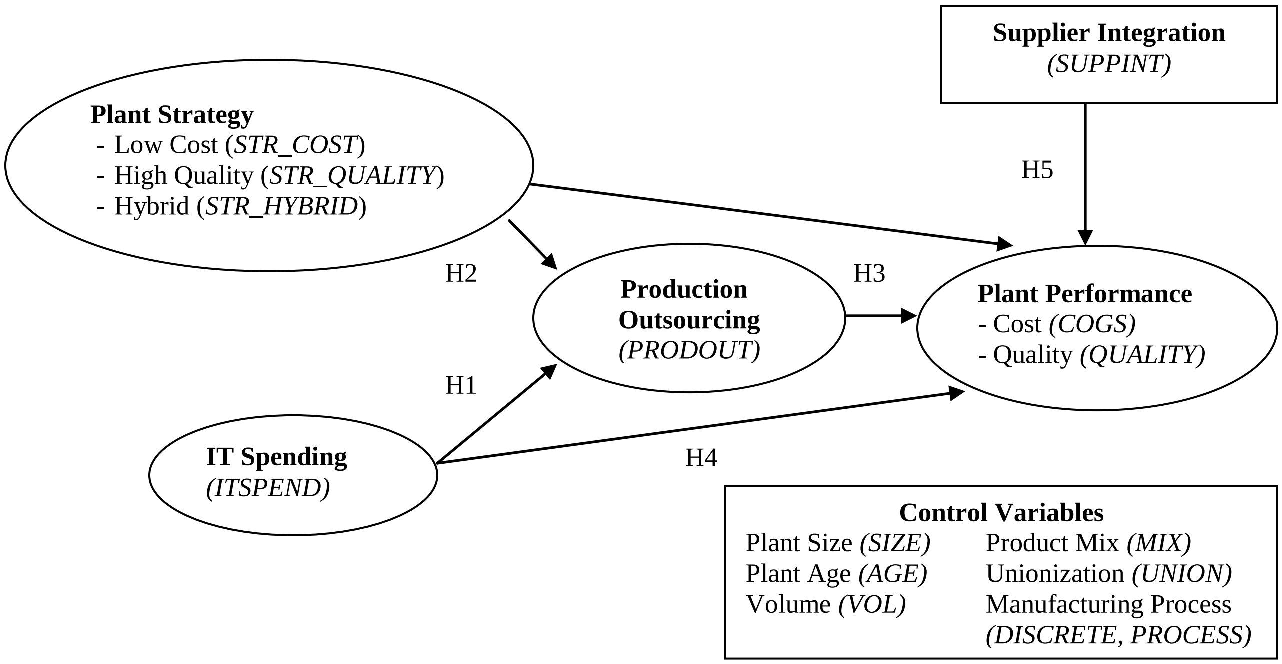

Table 1: Distribution of Manufacturing Plants in our Study

NAICS Code	Industry Sector	Percent of Sample[1]	Percent of U.S. Manufacturers[2]
311	Food	4.36	7.66
312	Beverage and tobacco products	0.93	0.87
313	Textile mills	1.87	1.14
314	Textile products	0.00	2.13
315	Apparel	0.00	3.64
316	Leather and allied products	0.00	0.44
321	Wood products	1.56	4.91
322	Paper	2.18	1.59
323	Printing and related support activities	1.87	10.80
324	Petroleum and coal products	0.31	0.66
325	Chemicals	8.10	3.81
326	Plastics and rubber products	4.36	4.45
327	Nonmetallic mineral products	1.25	4.82
331	Primary metals	5.30	1.73
332	Fabricated metal products	16.82	17.60
333	Machinery	17.44	8.17
334	Computers and electronic products	9.97	4.56
335	Electrical equipment, appliances, and components	5.30	1.86
336	Transportation equipment	9.03	3.56
337	Furniture and related products	3.74	6.34
339	Miscellaneous products	5.61	9.26
	Total	**100%**	**100%**

NOTES

1. Based on 321 out of the 326 manufacturing plants in equation 2. The remaining five manufacturing plants did not provide an NAICS code.
2. Source: U.S. Census Bureau, *Statistical Abstract of the United States: 2002*

Table 2: Descriptive Statistics and Correlation Matrix

		Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	*PRODOUT*	0.57	0.73	1.00														
2	*COGS*	65.19	20.59	-0.13*	1.00													
3	*QUALITY*	6.53	8.06	0.14*	-0.00	1.00												
4	*ITSPEND*	2.48	3.40	0.13*	-0.18*	0.20*	1.00											
5	*STR_COST*	0.25	0.43	-0.09	0.06	0.02	0.01	1.00										
6	*STR_QUALITY*	0.69	0.46	0.07	0.06	-0.03	0.04	-0.08	1.00									
7	*STR_HYBRID*	0.15	0.36	-0.08	0.15*	0.01	-0.03	0.75*	0.28*	1.00								
8	*SIZE*	2.04	1.01	0.05	0.09	-0.11	-0.10	0.09	0.08	0.09	1.00							
9	*AGE*	3.64	0.74	-0.01	-0.02	-0.03	-0.08	-0.04	-0.04	-0.09	0.12*	1.00						
10	*VOLUME*	0.37	0.48	-0.12*	0.08	-0.13*	-0.01	0.19*	-0.01	0.09	0.22*	-0.01	1.00					
11	*MIX*	0.71	0.45	0.08	-0.04	-0.05	-0.19*	-0.14*	-0.01	-0.16*	0.17*	0.13*	-0.19*	1.00				
12	*DISCRETE*	0.71	0.45	0.26*	0.02	0.03	0.01	-0.00	-0.07	-0.03	0.03	-0.02	-0.14*	0.11	1.00			
13	*PROCESS*	0.16	0.37	-0.22*	-0.07	-0.08	-0.06	-0.01	0.07	0.00	-0.07	-0.00	0.11*	-0.11*	-0.69*	1.00		
14	*UNION*	0.14	0.35	0.07	0.04	-0.08	-0.10	0.04	-0.04	0.00	0.14*	0.16*	0.17*	-0.00	-0.04	-0.00	1.00	
15	*SUPPINT*	0.11	0.31	0.06	0.01	0.11	0.03	-0.04	-0.01	-0.01	0.07	0.01	0.02	-0.02	-0.02	-0.02	0.03	1.00

* correlation significant at $p<0.05$

LEGEND
1. *SIZE*: Number of employees at this plant location. 1=less than 100, 2=100-249, 3=250-499, 4=500-1000, and 5=>1000 employees
2. *AGE*: Years since plant start-up. 1=less than 5 years, 2=5-10 years, 3=11-20 years, and 4=>20 years
3. *VOLUME*: 0=low volume, 1=high volume
4. *MIX*: 0=low mix, 1=high mix
5. *DISCRETE*: 0=no, 1=discrete manufacturing
6. *PROCESS*: 0=no, 1=process manufacturing
7. *UNION*: Extent of union representation. 0=none or some workers, 1=all workers
8. *SUPPINT*: 0=none or some supplier integration, 1=extensive supplier integration

Table 3: Parameter Estimates of Production Process Outsourcing and Plant Performance Models

	Ordered Probit	OLS	
	(1) *PRODOUT*	(2) *COGS*	(3) *QUALITY*
PRODOUT	-	-3.135** (0.034)	1.320* (0.055)
ITSPEND	0.048*** (0.006)	-1.062*** (0.000)	0.383* (0.090)
STR_COST	0.031 (0.455)	-6.172 (0.146)	0.664 (0.376)
STR_QUALITY	0.307** (0.038)	0.564 (0.421)	-0.643 (0.310)
STR_HYBRID	-0.358 (0.144)	11.564** (0.043)	0.269 (0.459)
SIZE	0.055 (0.220)	1.077 (0.210)	-0.570* (0.072)
AGE	-0.047 (0.304)	-0.505 (0.378)	-0.137 (0.428)
VOLUME	-0.236* (0.060)	2.233 (0.203)	-1.924** (0.022)
MIX	0.116 (0.238)	-2.824 (0.160)	-0.456 (0.335)
DISCRETE	0.569*** (0.004)	-1.539 (0.338)	-1.065 (0.210)
PROCESS	-0.430* (0.068)	-8.327* (0.051)	-1.761* (0.087)
UNION	0.375** (0.028)	1.565 (0.344)	-1.631* (0.086)
SUPPINT	0.141 (0.255)	-0.100 (0.489)	3.105* (0.057)
Intercept	-	71.875*** (0.000)	8.725** (0.012)
N	326	287	266
R-squared	0.08	0.09	0.10
Chi-square	48.27	-	-
Prob > Chi-square	0.000	-	-
F	-	3.37	2.09
Prob > F	-	0.000	0.015

One-tailed p-values are shown in parentheses (robust for OLS)
*p<0.1; ** p<0.05; *** p<0.01

Table 4: Impact of IT and Production Outsourcing on Plant Performance: Post-hoc Analyses

	(A) *CAPACITY UTILIZATION*	(B) *LEAD TIME*	(C) *CUSTOMER PRICE*
PRODOUT	2.314* (0.065)	6.019* (0.056)	-0.175** (0.047)
ITSPEND	-0.811** (0.040)	0.372 (0.264)	-0.006 (0.401)
STR_COST	0.418 (0.464)	2.475 (0.423)	-0.376* (0.092)
STR_QUAL	-1.111 (0.333)	-2.832 (0.301)	0.030 (0.433)
STR_HYBRID	1.035 (0.424)	-4.374 (0.375)	-0.100 (0.393)
SIZE	5.160*** (0.000)	5.083* (0.036)	-0.006 (0.471)
AGE	1.470 (0.194)	-4.730 (0.160)	0.085 (0.211)
VOLUME	4.413** (0.039)	-20.315*** (0.000)	0.239* (0.071)
MIX	-1.456 (0.288)	-3.416 (0.232)	-0.196 (0.113)
DISCRETE	-2.506 (0.203)	1.661 (0.376)	-0.783*** (0.000)
PROCESS	2.405 (0.282)	1.026 (0.441)	-0.449** (0.047)
UNION	-0.772 (0.404)	6.923 (0.202)	0.110 (0.297)
SUPPINT	-0.294 (0.465)	-2.462 (0.335)	0.176 (0.232)
Intercept	54.276*** (0.000)	39.675** (0.028)	4.951*** (0.000)
N	308	307	325
R-squared	0.13	0.08	0.10
F-test	3.45	2.43	3.47
Prob > F	0.000	0.004	0.000

Robust one-tailed p-values are shown in parentheses
*p<0.1; ** p<0.05; *** p<0.01

LEGEND

A. In the IW-MPI survey, customer lead time is defined as the number of days from order entry through production to shipment.
B. Capacity utilization is defined as production volume as a percent of designed plant capacity.
C. The survey asks how much the per-unit price charged to customers has changed in the past year. Response options were (1) decreased more than 10%, (2) decreased 6-10%, (3) decreased 1-5%, (4) stayed the same, (5) increased 1-5%, (6) increased 6-10%, and (7) increased more than 10%.

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