THE EFFECT OF CERTIFICATION WITH THE ISO 9000 QUALITY MANAGEMENT STANDARD: A SIGNALING APPROACH

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Abstract:
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Keywords: Signaling, Certification, Management Standards, ISO 9000

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ABSTRACT

Theory suggests that certification with a management standard may reduce information asymmetries in supply chains and thereby generate a competitive advantage for certified firms. This article uses an 11-year panel of U.S. manufacturing facilities to test whether certification with the ISO 9000 Quality Management Standard generates a competitive advantage. Results suggest that certified facilities grow faster after certification, and that operational improvements do not account for this growth. Results also indicate that the growth effect is greater when buyers have greater difficulty acquiring information about suppliers.

Supply chain transactions are becoming increasingly distant and international, making it more difficult for buyers to observe the qualifications of suppliers. One solution to the resulting asymmetric information problem may be provided by multinational management standards. In this article, we propose that certification with a management standard can act as a signal of superior but unobservable attributes and thus provide a competitive benefit. Using a large longitudinal panel of U.S. manufacturing facilities, we test our hypotheses by analyzing the effect of certification with the ISO 9001 management standard.

Over the last decade, a host of management standards has emerged. Examples include the SA 8000 Labor Management Standard, the OHSAS 18001 Occupational Health and Safety Management Standard, the ISO 14001 Environmental Management Standard, and the ISO 9000 Quality Management Standard. In most cases, certification requires an organization to demonstrate that it employs a specific set of management practices. Usually, these practices must be verified by a third party auditor.

The most prominent example of a certified management standard, ISO 9000, was created by the International Organization for Standardization. It specifies requirements for a quality management system in order to demonstrate that the facility can "provide products that consistently meet customer and applicable regulatory requirements" (ISO, 2002). Certification requires an audit by an accredited third party. These audits must be renewed every three years.

Despite the prevalence and importance of management standards like ISO 9000, they remain relatively understudied. A few initial studies have proposed that management standards entail a recipe of beneficial practices and thereby improve the operational performance of certified organizations (Litsikas, 1997; Rao, Ragu & Solis, 1997). While we test for this effect in this paper, we argue that these studies have failed to fully explain the nature of certified management standards. From a theoretical perspective, they do not explain why organizations go through the added trouble and expense of obtaining official certification. Since the requirements of the standards are public and consulting firms are available to aid the adoption of practices, organizations do not need to certify to gain an operational benefit.

From an empirical perspective, previous research has failed to establish a causal relationship between certification and improvement in operational performance (Dick, 2000). A few practitioner surveys suggest an association between certification and improvement in operational performance (e.g., Rao et al, 1997; Jeng, 1998), but longitudinal studies in scholarly journals have found either no such relationship or a negative one (King & Lenox, 2001; also see Dick (2000) and Heras, Dick & Casadesus (2002) for a review).

In this paper, we argue that certification with a management standard may represent an attempt to communicate about desirable organizational attributes to parties that cannot observe them directly. This aspect of certified management standards is inherent in their design and may be critical to their function; yet, it remains little explored (Anderson, Daly, & Johnson, 1999). We use the ISO 9000 Quality Management Standard to develop our arguments, and we propose that certification provides a competitive advantage whether or not the standard actually improves the organization's operational performance. To further elaborate the discriminatory power of certification, we test whether the magnitude of this competitive advantage varies with conditions under which buyers may have greater difficulty acquiring information about suppliers. Using an 11-year panel of 19,713 U.S. manufacturing facilities and controlling for operational performance and inventory levels, we find that certification with ISO 9000 is associated with a facility growth effect. Results also indicate that this effect increases with the extent to which buyers have numerous suppliers among which they can choose. Furthermore, we find partial evidence that the effect of ISO 9000 is larger in industries where supplier attributes are more intangible. Exploratory tests of an effect of ISO 9000 on operational performance do not produce any significant results.

We organize the paper as follows: we first use the literature on Information Economics to argue that certification with a management standard may act like a market signal of superior quality. We then use the literature on consumer search behavior to identify attributes that make it more difficult for buyers to acquire information about the quality of suppliers. We describe the empirical analysis, and we discuss the study's findings and limitations.

HYPOTHESES DEVELOPMENT

The Effect of Certification with the ISO 9000 Quality Management Standard

Asked about the merits of the ISO 9000 Quality Management Standard, a manager of one company remarked that "it is similar to having a college diploma" (Naveh, Marcus, Allen, et al, 1999: 274). Whether intentionally or not, this manager draws a direct comparison with Michael Spence's theory of market signaling. College diplomas, Spence argued, can act to differentiate high productivity job applicants from low productivity ones, independent of whether or not students learn anything in the process of attending college (Spence, 1973). Because getting a diploma requires effort that is likely to be more arduous for less productive students, high productivity students are more likely to complete a college degree. In the same way, completion of the management steps needed to certify with ISO 9000 can differentiate facilities with desirable organizational attributes. For this reason, Cole (1998: 68) suggests that firms may make ISO 9000 "their primary instrument for signaling quality to their customers".

The need for information about underlying supplier attributes lends further credence to the idea that ISO 9000 certification may act as a market signal. A central difficulty in supply chain interactions is the identification of high quality suppliers. For buyers of safety sensitive products like brake components, for example, low defect rates are crucial (Michaels, 2002). However, buyers often have difficulties identifying (ex-ante) suppliers that provide consistent product quality, because the suppliers' underlying quality attributes are difficult for buyers to observe. This is because such attributes often are complex, embedded, and difficult to measure. As a result, some buyers have demanded that their upstream supply partners adopt ISO 9000 to reveal their otherwise difficult to observe attributes. Uzumeri (1997: 27), for example, finds that "large industrial purchasers in the U.S. (e.g., DuPont, General Electric, and Eastman Kodak) began to demand ISO 9000 registration from their suppliers."

Even without buyer pressure for certification, suppliers may seek certification to communicate about underlying quality attributes. If buyers are unable to tell apart high quality suppliers from low quality ones, they may shift demand to substitute products or else pay an average premium to all suppliers. Consequently, if certification with a management standard allows an organization to communicate about its unobserved quality attributes, a certified organization may be able to gain an advantage vis-à-vis its non-certified competitors.

For certification to differentiate credibly high and low quality suppliers, certification must be advantageous only for the high quality ones. In the basic market signaling models, this is accomplished by assuming that the cost of certification is inversely related to supplier quality (Riley, 2001). Thus, there are a set of market premiums for certification in which some high quality organizations can and will certify, and in which low quality ones will not. It is important to note that if the premium is too high or too low, the signal will fail to discriminate, and all organizations will choose not to certify. It also is important to note that the advantage that is provided to certifying organizations need not be a price premium. It simply must be a reward that is large enough so that certification is profitable for high quality organizations, but remains unprofitable for low quality ones. For ISO 9000, this reward could also be preferred supplier status, a more consistent supply of orders, or reduced sales costs. Observed demands by buyers for ISO 9000 certification represents evidence that buyers value certified firms.

Evidence suggests that ISO 9000 may meet the requirements for a market signal. Because certification with ISO 9000 demands compliance with a wide range of quality system requirements, meeting these requirements should, *on average*, be less costly for high quality organizations (Darnall & Edwards, 2004). This is because they need to undertake fewer adjustments and are more likely to be certified with the first visit of the auditor (Hutchins, 1997). Marquardt (1992: 51) makes a similar argument when explaining that the cost of certifying depends on "where you start" and if "you've just won a Baldrige Award, registration of a plant or business may take you a few days. But if your quality system needs to be improved or created from the ground up the process can take as long as a year."

Assuming the existence of a negative relationship between firm quality and ISO 9000 certification costs, a competitive advantage should exist that encourages high quality organizations to certify, and that inhibits lower quality ones from following suit. Thus, if we observe an organization certifying, we should expect it to receive a competitive advantage vis-à-vis its non-certified competitors.

> *H1: An organization that certifies with the ISO 9000 Quality Management Standard will gain a competitive advantage vis-à-vis its non-certified competitors.*

Variations in the Effect of Certification with the ISO 9000 Quality Management Standard

If ISO 9000 acts like a signal, then the size of the competitive advantage that certification provides should depend on the extent to which buyers face greater difficulty acquiring information about underlying supplier attributes. Folta & Janney (2004) suggest that when these difficulties create higher information asymmetries, signaling results in greater returns. We explore two conditions that may increase the difficulty of acquiring information about suppliers and thus increase information asymmetries. First, we argue that buyer search costs are greater when buyers face a larger set of suppliers from which to choose. Second, we propose that buyers face greater information asymmetries when sourcing from industries in which supplier attributes are more intangible. Accordingly, we hypothesize that the competitive advantage from certification with ISO 9000 should be comparably larger for organizations that operate in industries with more numerous players, and for organizations that operate in industries with higher levels of R&D and advertising intensity.

Size of Supplying Industry. Studies in consumer search behavior have analyzed when information search costs are particularly high (e.g., Beatty & Smith, 1987; Srinivasan & Ratchford, 1991). One factor that increases buyer search costs is the size of the evoked product set, because "larger evoked set sizes imply greater cognitive costs in evaluating alternatives and greater time costs in this processing" (Schmidt & Spreng, 1991: 252). Similarly, McAfee & Oliveau (2002) argue that in the context of networks, the search costs of finding a specific resource increase as the size of the network grows.

Some of the insights on consumer search behavior may be applicable to industrial buyer behavior. While industrial buyers don't always choose among product alternatives, they choose among suppliers with differential ability to fabricate a product according to a specified design.

Thus, applying concepts from consumer search behavior to industrial buyer behavior would suggest that search costs increase with the set of potential suppliers.

To refine this argument, assume that buyers wish to be 95% confident that they have identified suppliers with above average quality. Absent any signal that differentiates supplier quality, assume that buyers learn about the distribution of supplier quality by investigating a sample of n suppliers. When the industry being investigated is smaller, the inference that can be made from a given sample is larger because each observation reduces the potential influence of unobserved suppliers on the estimated mean. For example, holding all else equal, if 10 facilities are sampled in an industry with 40 facilities, the confidence interval of the estimated mean is 40% larger (20% on each side) than it is for a similar sample in an industry with 20 facilities. This effect decreases with industry size because the effect of industry size on the confidence interval is a function of $\sqrt{(N-n/N-1)}$ where N is the industry size and n is the number of suppliers sampled. However, geographic restrictions and industry variance are likely to keep the number of supplier options within the range where this finite population effect is important.

From the above arguments it follows that if certification with ISO 9000 differentiates high quality organizations from low quality ones, certification will provide a greater advantage in industries with more numerous players. Ferguson (1996: 309) argues that the fear of choosing the wrong supplier is an important consideration driving vendor selection behavior, and that the "conservative approach to industrial buying would be to solicit proposals only from companies that have attained [ISO 9000] registration". Furthermore, "an industrial buyer is often willing to pay a higher price to avoid the possible criticism, discipline, or termination that might result from a bad [sourcing] decision" (Ferguson, 1996: 309). Because the cost of reducing the risk of a bad sourcing decision through searching is relatively greater in a large industry, the premium that buyers are willing to pay for reducing that risk in such industry should accordingly be greater. As a result, we expect:

H2: The larger the industry in which an organization operates, the greater the competitive advantage that this organization receives from certification with the ISO 9000 Quality Management Standard.

Importance of Intangibles in Supplying Industry. A supplier's quality is often a function of intangible organizational characteristics that cannot be observed through direct examination of products or services. For example, numerous intangible internal attributes caused disastrous tire quality problems at the Bridgestone-Firestone plant in Decatur, IL. Failures in internal systems for product design, production, labor management, and buyer communications all contributed to the problem (O'Rourke, 2001). Because these attributes were internal to the supplier, buyers could not detect these problems through inspection of the eventual product.

The importance of intangible attributes on supplier performance varies across industries. In some industries, internal capabilities are easier to observe and transfer, thereby reducing unobservable firm heterogeneity and turning products and services into commodities. In other industries, capabilities are hard to observe, causing sustainable intangible differences among organizations. Research suggests that investments into R&D and advertising both reflect and influence the level of such intangible differences (Aboody & Lev, 2000; Chauvin & Hirschey, 1993).

Most firms protect the value of their R&D by keeping their innovations secret (Cohen, Nelson & Walsh, 2000). Such secrecy protects innovations from expropriation, but it also makes it difficult for buyers to assess the quality of a supplier's processes and products. Aboody and Lev (2000) argue that R&D investments create information asymmetries because investments into manufacturing processes and products are unique to each firm and thus both underlying and resulting capabilities cannot be inferred through observation of other firms. Furthermore, a lack of organized markets for R&D often prevents the use of the price mechanism to derive information (Gans & Stern, 2003). Besides creating intangibles, R&D investment intensity may also reflect the extent of difficult to observe capabilities. Cohen and Levinthal (1990), for example, argue that R&D builds upon intangible capabilities that are hard to observe and transfer.

In addition to an industry's investments into R&D, an industry's advertising intensity may be indicative of the difficulty for buyers to assess the quality of suppliers (and their products). Advertising expenditures are higher when firms and product differences are more difficult to observe (Nelson, 1974). Thus, high levels of advertising intensity are reflective of intangible differences, and advertising can be one attempt to communicate about these differences by making credible claims through the creation of a reputation bond (Kirmani & Rao 2000; Nelson, 1974).

If advertising is successful in revealing information about intangible attributes, it reduces information asymmetries between suppliers and buyers. For industrial buyers, however, important information asymmetries are likely to remain. Advertising typically provides little information about differences among a firm's facilities – information that is often of great interest to industrial buyers. For example, Bridgestone/Firestone tire problems occurred predominantly at the Decatur, IL facility. As a result, identical tires from other facilities were exempted from the recall (Crigger, 2000). Indeed, many product recalls specify products fabricated at specific plants (Crabtee, 2003; Kawar, 2002). Aside from conformance to specified performance requirements, facilities also differ among other quality dimensions. In particular, responsiveness and timeliness (i.e., Just in Time delivery and agility) have become important concerns. As a result, industrial buyers frequently seek to qualify and procure from specific facilities. In both the automobile and chemical industry, for example, it is common practice for buyers to specify the plant from which they wish to procure supplies (Pyke, 2004).

For certification with ISO 9000 to provide information about differences in organizational quality, the standard needs to be indicative of intangible attributes that are linked to supplier quality. Indeed, Wenmoth & Dobbin (1994) find that certification with ISO 9000 is facilitated by leadership qualities from top management teams, a commitment of management to ongoing improvements, employee training, intra firm communication systems, as well as existing management systems and best practices. King & Lenox (2001) find that ISO 9000 certification is linked to lean production practices and that it reflects general organizational differences in the use and management of technology, material, and labor. Thus, to the extent that certification with ISO 9000 reveals information about intangible supplier differences, it should provide a greater return in industries with higher levels of R&D and advertising intensity. We expect:

> *H3: The higher the R&D and advertising intensity in the industry in which an organization operates, the greater the competitive advantage that this organization receives from certification with the ISO 9000 Quality Management Standard.*

RESEARCH METHOD

Research Context & Sample

The ISO 9000 Quality Management Standard provides an ideal context for analyzing the benefits from certification with a management standard. ISO 9000 started diffusing in 1988, thus providing a relatively large time window for a longitudinal study. Furthermore, it has diffused across many industries, thereby allowing exploration of industry effects on certification consequences.

We perform our analysis using a longitudinal sample that contains 19,713 U.S. facilities from 232 different manufacturing industries (SIC codes 2011 to 3999) and that covers a time period from 1988 until 1998. Because certification occurs on the facility level, we capture the effect of certification at the facility level rather than on the firm level. We use several data sources to construct the sample: the McGraw-Hill Directory of ISO 9000 certified companies, the Dun & Bradstreet database (D&B), the Toxic Release Inventory (TRI), data from the Bureau of Economic Analysis (BEA), and data from Compustat. Because we need information from both the TRI and the D&B datasets to construct our variables, we restrict our sample to TRI reporting facilities that we identify in the D&B database.

Measures

Dependent Variable. The dependent variable captures the competitive advantage that facilities receive from certifying with ISO 9000. To proxy this advantage, we measure facility growth (i.e., changes in production volume) before and after certification with ISO 9000. Because we are interested in capturing the effect that results from buyers being able to differentiate certified organizations from non-certified ones – rather than the effect that results from improvements in operational performance – we include in our analysis several measures of operational attributes that could confound the growth effect.

Specifying production growth (rather than production volume) as the dependent variable allows for a more careful analysis, since this 'first difference approach' takes out potentially confounding effects driven by a self-selection process into certification based on absolute production volumes.

Some assumptions underlie the argument that a growth effect approximates the competitive advantage that results from buyers' reaction to certification. First, we assume that contribution margins increase as a result of certification. Margins may increase because buyers now have a higher willingness to pay, and/or because certification has reduced the certified facility's sales costs. Second, we assume that supply functions are price elastic. This implies that facilities do not operate at their capacity constraint (or do not have a fixed constraint), and thus are able to respond to an increase in price by expanding production. (Note that this assumption introduces a conservative bias into the analysis. This is because if facilities did operate at their capacity limit, it would cause us to understate, rather than overstate, the potential advantage from certification). Whether or not a facility is a price taker or has some market power, these assumptions imply that certification would cause profit-maximizing facilities to increase production volumes, and the dependent variable will pick up this effect.[1]

The TRI dataset provides a good measure of changes in production volume ('growth') because facilities annually report their production ratios (i.e., the ratio of the production volume in *t+1* to the production volume in *t*) to the dataset. A facility that reports in year *t* a production ratio of two, for example, has doubled its production volume between *t* and *t-1* (i.e., it increased production by a 100%). A production ratio of 0.5 indicates that the facility has halved its production volume. We capture facility growth as follows:

$$Growth_{it+1} = \frac{PV_{it+1} - PV_{it}}{\left(\frac{PV_{it+1} + PV_{it}}{2}\right)} * 100 \qquad (1)$$

$$= \left(\frac{PR_{it+1} - 1}{PR_{it+1} + 1}\right) * 200 \qquad (2)$$

[1] Alternatively, facilities operating inefficiently below optimal production levels (i.e., at marginal costs below marginal benefits) would increase their production if buyers responded to certification by increasing their demand at constant prices.

with
PV_{it} = *Production Volume of facility i in year t*
PR_{it} = *Production Ratio of facility i in year t*
$PV_{it+1} = PV_{it} * PR_{it+1}$

Equation (1) expresses the growth effect as the difference in volume between year t+1 and year t, divided by the average production volume (to reduce disturbances caused by start-ups and shut-downs) and multiplied by a hundred (to arrive at a 'percentage' score). Since next year's production volume equals this year's volume multiplied by next year's production ratio, we can transform Equation (1) into Equation (2), which expresses growth in terms of a facility's annual production ratios.[2]

Independent Variables. We use the McGraw Hill directory of ISO 9000 certification to compile a list of manufacturing facilities that gained certification between 1988 and 1998. In our sample, 3317 facilities for which there is data for all independent variables certify with ISO 9000 during this period. We create a binary variable, *ISO 9000*, which takes on one in the year that the facility gains its initial certification. It remains one for the following years. In order to test the robustness of this specification to the possibility that facilities announce their intention to become certified prior to actual certification (or delay announcement of actual certification), we also specify a variable that initially is zero and takes on a value of 1/3 in the year prior to certification, 2/3 in the year of certification, and 1 in the year(s) after certification. Analysis with this alternative specification confirms the results generated by the zero-one specification.

[2] Difference scores as dependent variables may yield biased coefficients if the independent variables in year t are correlated with the state of the dependent variable in year t (i.e., PV_t) (Allison, 1990). However, in this case, the correlation between the independent variables in year t and PV_t are consistently non significant with correlation coefficients between $\alpha = 0{,}01$ and $\alpha = 0.02$, thereby indicating that this issue is less of a concern for our study.

Industry Size is the log of the number of facilities in an industry (four digit SIC code). We use information on the number of facilities in each industry from the D&B dataset to create this variable. We mean-center the variable *Industry Size* to reduce problems of multicollinearity between *ISO 9000* and the interaction variable (*Industry Size* X *ISO 9000*).

We use annual data from the Compustat database to measure an industry's investments into *R&D Intensity* and *Advertising Intensity*. Because R&D and advertising expenditures are only reported on the corporate level, we exclusively consider data from corporations that operate in a single 4-digit SIC code. For each such corporation, we calculate annual R&D and advertising intensity by dividing R&D and advertising expenditures by sales. We then average this data for each four digit SIC code and year to measure annual industry R&D Intensity and Advertising Intensity. We take the natural log and we mean-center these variables for each year.

Control Variables. It is critical to control for facility inventory and operational performance since these two factors may vary with changes in production volumes, thereby confounding the market effect that this analysis attempts to capture. Controlling for operational performance furthermore is important since ISO 9000 may directly affected it.

Operational performance is a multi-dimensional concept that refers to aspects such as defect rates, production cycle, scrap generation, productivity, and inventory turns (Samson & Terziovski; 1999, Voss, Ahlstrom & Blackmon, 1997). We focus on scrap generation to capture operational performance. Scrap generation approximates overall operational performance because process waste (scrap) is the inverse of process yield, thus providing a measure of how well the organization manages its processes (King & Lenox, 2002). Studies suggest that organizations with better processes generate less scrap (Klassen & Whybark, 1999; Rothenberg, 1999). Measuring operational performance in terms of scrap generation is furthermore suitable for our analysis because the reduction of scrap could be one of the important effects from adopting ISO 9000 (Naveh et al, 1999). As such, the measure should control well for ISO 9000-induced changes on operational performance.

We follow a method developed by King & Lenox (2000) to create *Operational Performance.* Using data on annual scrap generation from the TRI dataset, we estimate for each four digit SIC code and year the relationship between the log of the units of scrap generation and facility size and the square of facility size. For each facility and year, the residual of this estimation then indicates its performance relative to that expected for a facility of that size. We normalize the residual and inverse its sign since a positive residual indicates above average scrap generation. The value of the variable thus increases as the facility's operational performance improves.

Controlling for inventory levels is important because they may be interrelated with changes in production volumes. Facilities report to the TRI their annual inventory in weight units (pounds). The variable *Inventory* reflects annual facility inventory as the natural log of inventory pounds.

We also control for the effect of labor inputs on changes in production volumes. *Labor* represents the log of the (annual) number of employees in each facility (per D&B dataset).

To the extent that firm size (rather than facility size) is indicative of relatively more corporate resources, it may influence facility growth by providing access to financial resources, knowledge, or management. To control for this effect, we create *Firm Size,* which measures the annual log of the number of facilities in each firm.

The variable *Industry Certification* captures the percentage of certified facilities in each four digit SIC code and year. During transition periods, there is the possibility that the market reward that underlies the growth effect is influenced by the extent to which certification has spread within an industry. However, in the long run, the growth effect should be unrelated to the state of diffusion. This is because organizations will only certify to the point where the marginal benefit equals cost, and certification will stop if diffusion has reached a state in which the market no longer rewards certification.

Export measures for each four digit SIC code and year the percentage of exports of shipments. Shipment data classified by SIC code is available from the BEA, and we acquired export data from the U.S. Census Bureau. Controlling for export activities reduces the concern that potential growth effects are distorted by trends in foreign trade.

Finally, facility growth is likely to vary over time and across states as macro economic conditions change. We control for the influence of time by including *Year Fixed Effects*, and we control for the influence of states by including *State Fixed Effects*. We present the descriptive statistics of the variables in Table 1. Table 2 provides a correlation table.

Insert Tables 1 & 2 about here

Analysis

We use a general estimation equations (GEE) model to predict the change in production volume (i.e., growth) for a facility in the following year. The model takes the following form:

$$g(E[y_{i,t+1}]) = \mathbf{x}_{it}\beta$$

where $y_{i,t+1}$ represents the production growth of facility i between year t and $t+1$, $\mathbf{x}_{\mathrm{it}}$ is a vector of covariates for the ith facility at time t, and β is a vector of regression parameters. For this model, $g(.)$ is simply the identity function. GEEs are useful when one must account for correlations between observations, but they require that one specify the covariance structure of the correlated observations on a given subject (Horton & Lipsitz, 1999). In our case, this requires that one specify how the annual observations of a given facility are correlated. We chose to specify an exchangeable structure for within group correlation ($R_{u,v} = 1$ if $u = v$, and $R_{u,v} = \rho$ otherwise). To test if the results are sensitive to the specified correlation structure, we conducted robustness tests using an empirical variance estimator and by and large confirmed the reported results.[3]

Two sample selection issues require attention. The first relates to a potential selection into the sample. Specifically, our sample only includes facilities that report to the TRI dataset. Due to the reporting requirements for the TRI dataset, facility attributes like size and scrap intensity influence the probability that a facility appears in the sample. However, this sample selection would only reduce the general applicability of our results if there were reason to believe that the effect of certification systematically differs between organizations that are inside and outside the TRI dataset.

The second selection problem relates to the possibility that faster growing facilities select into certification. We devote more attention to this issue as we test the robustness of the results below.

RESULTS

Table 3 presents the results of the analysis. In assessing significance of the coefficients, we consider the conventional $p < 0.01$ cutoff-levels as well as significance levels derived from

[3] Results for robustness tests are reported in Table 4. Model 1 in Table 4 shows the analysis for the empirical variance estimator.

Leamer's formula for large sample inference (Leamer, 1978). In our analysis, coefficients with a z-value greater than 3.46 exceed the significance level as determined by Leamer's formula.[4]

Insert Table 3 about here

The first column of Table 3 provides the results of Model 1, the base model. Facilities with more employees experience relatively smaller production growth in the future, while firm size has a positive effect on facility growth. Operational performance has a negative effect on growth, which might reflect that well performing facilities operate more closely to their production border than poorer performing ones. Production growth decreases with an increase in industry size and industry advertising intensity, while it increases with R&D intensity. Furthermore, a higher degree of industry certification increases facility growth, possibly reflecting a trend towards certification in industries with growing facilities (see below for a further discussion of this issue).

Model 2 includes *ISO 9000*, the binary variable indicating certification with ISO 9000. Controlling for operational performance and inventory, we find that certified facilities experience a significantly greater production growth subsequent to certification than non-accredited facilities (H1). Specifically, certification is associated with approximately a 1.3% higher production growth per year. A Wald test indicates that Model Two fits significantly better than Model One ($p < 0.001$).

Models 3 to 6 test if the growth effect from certification varies across industry characteristics. Specifically, in Model 3, we test if the growth effect increases with the industry

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[4] Leamer's formula is as follows: $F_{r,n-K} > [(n-K)/r]*(n^{r/n} - 1)$. R is the number of restrictions in the test, n is the sample size, and K is the number of coefficients that are estimated in the specification (including the intercept).

size of the certified facility (H2). The coefficient for the interaction between *ISO 9000* and *Industry Size* is positive and significant, lending support to this hypothesis. The significance of the main effect of ISO 9000 is slightly reduced, but the coefficient remains clearly significant at the $p<0.01$ level (z-value = 2.92). Coefficients of the other variables remain stable, and a Wald test indicates a significantly improved model fit over Model 2 ($p < 0.0001$).

In Model 4, we include the interaction between *ISO 9000* and *R&D Intensity* (H3). The coefficient for the interaction is positive and just significant on the $p<0.01$ level, while the main effect of ISO 9000 remains strongly significant ($z = 3.08$). A Wald test suggests that Model 4 fits moderately better than Model 2 ($p < 0.01$). Model 5 includes the interaction between *ISO 9000* and *Advertising Intensity* (also testing H3). The coefficient of this interaction effect is positive and significant, and a Wald test suggests a significantly improved model fit over Model 2 ($p < 0.001$).

Finally, in Model 6, we include all three interaction effects at once. The coefficient for the main effect of *ISO 9000* falls below the Leamer cutoff (z-value = 2.74) but remains significant at the $p<0.01$ level. The reduction in significance may potentially be reflecting the simultaneous inclusion of the three interaction terms. The interaction between *ISO 9000* and *Industry Size* remains strongly significant. The interaction between *ISO 9000* and *Advertising Intensity* falls below the Leamer cutoff yet remains clearly significant at the $p<0.01$ level (z-value = 3.07). The interaction between *ISO 9000* and *R&D Intensity* is no longer statistically significant. While it is possible that correlation among the interaction terms inflates standard errors, this lack of significance (in combination with the moderate significance for the interaction between *ISO 9000* and *R&D Intensity* in Model 4) suggests that we cannot confidently show that higher levels of R&D intensity amplify the effect of ISO 9000 on facility growth. We conclude that we find stable support for Hypotheses 1 and 2, and partial support for Hypothesis 3.

The economic interpretation of the interaction terms suggests that with respect to industry size (and considering the fully specified Model 6), facilities in industries that are one standard deviation larger than the average industry can expect to grow 2.1% from ISO 9000 certification (up from 1.3% in the average sized industry (Model 2)). A one standard deviation increase in advertising intensity also increases the growth effect from ISO 9000 certification from 1.3% to 2.1%.

Robustness Checks

The Effect of Changes in Operational Performance. An important concern is that certification may cause changes in operational performance, which in turn may influence production volumes. This could result in an incorrect estimation of the growth effect caused by reduction in information asymmetries. Including *Operational Performance* as a control variable helps reduce this concern, but it may not fully capture the effect of potential changes in performance on growth. We address this issue by creating *Delta Operational Performance,* which measures changes in operational performance for each facility in each year. Including this variable to predict production growth in an otherwise identical analysis shows that its effect on growth is not significant and that its inclusion does not change the significance or sign of the other variables (with the exception of *Inventory*). We report the results of this robustness check for the fully specified model in Table 4 (Model 2).

Insert Table 4 about here

The Selection of Faster Growing Facilities into Certification. Specifying the dependent variable as a difference variable (i.e., as growth) reduces the concern that results may be spurious due a selection effect of facilities with larger production volumes. However, this difference variable cannot address the concern that faster growing facilities may select into certification. The longitudinal nature of our data complicates the otherwise suitable Heckman two-stage procedure to correct for this endogeneity.[5] Instead, we use a procedure that resembles a difference-in-difference approach (Ashenfelter & Card, 1985). We restrict our dependent variable to capture only the growth that a facility incurs beyond its average growth, which reduces the risk that we confound the increase in growth from certification with the selection of facilities with accelerating growth into certification. Thus, the dependent variable for facility i now equals production $\text{growth}_{i,t+1}$ minus average production growth_i, thereby capturing any changes in the slope of the facility's growth rate. We rerun an analysis that otherwise is identical to the one reported in Table 3, Model 6, and we report the results in Table 4, Model 3. Because this model specification is extremely conservative, it is not surprising that some results are weaker. Yet importantly, the coefficient of the main effect of *ISO 9000* remains clearly significant at the $p<0.01$ level (z-value = 2.90). The interaction effect between *ISO 9000* and *Industry Size* also remains significant at the $p<0.01$ level. However, the effect between *ISO 9000* and *Advertising Intensity* looses significance. Overall, we thus we find that even if faster growing facilities selected into certification, certification seems to be associated with a growth effect that

[5] The problem is that being certified may be both state-dependent as well as dependent upon some unobserved facility attribute (Hsiao, 1986). Without a way of telling apart these two influences, the correction of the selection (i.e., the outcome of the first stage) is biased. Current research suggests procedures for a two-period case (Honore & Kyriazidou, 2000), but the possibilities for solving the problem for a multi-period case are yet limited.

goes beyond the facility's average growth (H1), and that this effect tends to be larger in industries with more suppliers (H2).

The Effect of Shifting Production among Sites. A final concern is that multi-facility firms shift their output from their non-ISO 9000 certified facilities to certified ones. If this was the case, the production growth of certified facilities would simply reflect the firm's desire to produce as much as possible at its best plants. We investigate this concern by restricting our (otherwise identical) analysis to single-facility firms and multi-facility firms that do not have more than one facility per industry. The results for this analysis are reported in Table 4, Model 4. We find that the main effect of *ISO 9000* and the interaction effect between *ISO 9000* and *Industry Size* remain significant at the $p<0.01$ level. These results suggest that certification with ISO 9000 does affect facility growth beyond what could be explained through a potential shifting of production to certified sites, and that this growth effect is larger in industries with more numerous players. However, the interaction effects between *ISO 9000* and *Advertising Intensity* and *ISO 9000* and *R&D Intensity* are no longer significant. One explanation for this is that by restricting our sample to single facility firms, we lose 2/3 of the certified facilities, which makes it more difficult to detect potential effects of ISO 9000. As for the loss of significance of the advertising effect, another explanation exists. If ISO 9000 certification indeed is an advertising device that allows buyers to differentiate among the <u>facilities</u> of a firm (and not just among firms) - as we argued leading up to H3 – then it is not surprising to find no signaling effect for single facility firms, since buyers do not need to differentiate among the plants of these firms.

Further Analysis

The Effect of ISO 9000 on Operational Performance. As part of the robustness tests above, we tested whether changes in operational performance may shape the facility growth effect that we attributed to certification with ISO 9000. While we did not find any evidence for such an influence, we decided that it would be prudent to directly analyze the potential effect that ISO 9000 may have on a facility's operational performance (independent of any facility growth). Exploring this issue is unrelated to this study's primary purpose - to investigate if certification produces results akin to a signal effect - but nonetheless is of interest when exploring the functioning of ISO 9000.

To begin testing for a potential effect of ISO 9000 on operational performance, we predict the annual percentage change in each facility's operational performance. Operational performance is captured as a facility's waste generation, which we multiply by (-1) to reflect that more waste is indicative of poorer operational performance (for more details, see pages 15 and 16).[6] We include a measure of regulatory stringency to account for the potential effect of environmental regulation on waste generation. Following Meyer (1995), and using data from the TRI dataset, this measure is based on the logged aggregate emissions per state over the sum of the Gross State Product in four polluting sectors (chemicals, pulp & paper, textiles, and petroleum products). Further details of the model specification as well as results are reported in Table 5.

The results from Models 1 and 2 in Table 5 do not provide any evidence that certification with ISO 9000 has a significant effect on percentage changes in a facility's operational performance. In Models 3 and 4, we use a cross-sectional time-series regression model with facility fixed effects to predict operational performance (as captured by (inversed) total waste volume). These models also do not yield any evidence of an effect of ISO 9000 on operational

[6] However, for calculating a percentage change in operational performance, we use a facility's absolute (rather than relative) waste generation.

performance. However, note that a facility's operational performance is a multi-dimensional concept and that our waste generation measure would fail to capture potential effects of ISO 9000 on cycle times or customer satisfaction. Furthermore, the estimated models are fairly conservative, and future research may want to specify alternative models to explore the potential effect of ISO 9000 on operational performance.

DISCUSSION

Our analysis suggests that facilities that certify with ISO 9000 experience a greater increase in production volume subsequent to certification than non-certified facilities. This effect appears to be stable across multiple model specifications and robustness checks. Furthermore, the effect increases with the size of the industry to which the certified facility belongs. This finding is robust to multiple model specifications and tests. We propose that the growth effect results from the use of certification with ISO 9000 to communicate to buyers about organizational quality attributes that otherwise would be difficult to observe. Certification allows buyers to identify suppliers with better quality attributes, which, in turn, triggers certified facilities to expand their production. We do not find any evidence that changes in operational performance or inventories confound results.

We argue that the signaling effect of ISO 9000 certification may be larger in industries where high levels of R&D and advertising expenditures create and reflect intangible supplier attributes. Accordingly, we test if the growth effect of ISO 9000 varies with an industry's advertising and R&D intensity. We find some evidence that the growth effect increases with an industry's advertising intensity, but we find no stable evidence of such an effect for industry R&D intensity. Interestingly, we also find that advertising intensity no longer affects the ISO 9000 growth effect when we restrict the analysis to single plant firms. While this lack of significance must be interpreted cautiously, it is consistent with the notion that certification systems like ISO 9000 may help remove information asymmetries with respect to performance differences among a firm's facilities - something that advertising can rarely do.

Throughout this paper, we have argued that certification with ISO 9000 may serve as a device for selecting high quality suppliers prior to actual contract formation. We have been agnostic about the duration of these supply relations. However, in long term relationships, certification with ISO 9000 may play a dual role of being a signal that differentiates potential suppliers (prior to contract formation) and a device that helps monitor supplier behavior (post contract formation). In future research, we hope to further explore differences in the exact nature of the internal attributes that certification conveys prior and post contract formation.

This study has several limitations. One limitation is that we cannot observe the quantity and value of the items that are being purchased, and how critical these items are to the buyers' products. These are important aspects, since buyers may be less concerned about supplier quality if purchasing small quantities of low value items that are not critical. However, buyers should always prefer higher quality suppliers, and certification should therefore have a differential effect even for the procurement of small volume, low value non-critical items. Nonetheless, future research should consider the role of volume, value, and criticality to explain more fully the conditions under which certification with ISO 9000 generates a competitive advantage.

Another limitation relates to our sample. Our sample only includes U.S. manufacturing facilities, which limits our ability to generalize our results beyond U.S. borders. In fact, research suggests that pay-offs for certified management standards may vary according to differences in national institutional environments (Kollman & Prakalash, 2002). ISO 9000 has diffused in over 159 countries (ISO, 2003), and future studies may explore further how cultural norms and varying business practices may shape the performance effects of certification with management standards.

We use facility growth to capture the benefits that companies may receive from communicating to buyers about their underlying quality attributes. As discussed previously, the appropriateness of measuring the competitive advantage from certification as changes in production volumes relies on the assumption that certification increases contribution margins (i.e., increases price and/or lowers sales costs) and that supply functions are price elastic. Given that these assumptions are plausible and because of the difficulties of obtaining price data for privately held facilities, we do not explore the possibility that certification may result in other rewards. However, future studies may focus on a smaller (and possibly industry specific) sample and explore such possibilities.

Yet another limitation relates to the difficulty of assessing signaling effects in real world settings. Most of these real world settings reduce the potential for finding significant results, and thus create a conservative bias for our study. A simple signaling model requires that certification must be strictly less costly for higher quality organizations and that a competitive advantage exist such that organizations above a particular quality level choose to certify and ones below that threshold level do not. Of course, in any empirical context this simple model is likely only to approximate reality. One problem may result if the cost function is such that some very high quality organizations choose not to certify. Perhaps buyers can already differentiate these organizations or these organizations already have superior practices that would have to be diluted in order to match the requirements of certification. Alternatively, certification may include a noise term because managers are not able to assess ex-ante the costs and benefits of certification. As a result of such ‘irregularities’, actual signaling equilibriums and effects may not be as clearcut as those derived from theoretical models. However, this noise creates a conservative bias for our study since it implies that buyers will be more uncertain about differences in quality between certifiers and non-certifiers. Thus, these real world effects may suggest avenues for future research, but do *not* suggest that a signaling framework is an inappropriate perspective for analyzing the ISO 9000 quality management standard.

Heras et al (2002) call attention to the problem that reverse causation may confound results. Studying the relationship between ISO 9000 and financial performance, they find that companies with higher sales growth and profitability were more likely to select into ISO 9000 certification. Ignoring the possibility for such a selection would have caused spurious interpretation of results. Our longitudinal data prohibits the use of two stage selection models. Instead, we pursue a conservative difference-in-difference approach to show that even if faster growing facilities were to select into ISO 9000, certification generates a growth effect that goes beyond a facility's average growth rate. Thus, while we cannot rule out that faster growing facilities may adopt ISO 9000, we show that such selection effect does not account for the results of this study.

Finally, it is possible that certification with ISO 9000 merely communicates about the existence of an organization (or its products), thereby generating higher sales (and a growth in production) for this organization. We cannot fully untangle this 'advertising effect' from the signaling effect in our study, but it is not clear why organizations would use certification with ISO 9000 as a tool to advertise existence, since certification in and of itself does not trigger any publicity (besides inclusion in the directory of certified firms).

CONCLUSION

Certified management standards are rapidly diffusing across many industries. Yet uncertainty still exists about their role and function. This study explores the extent to which certification with one of the most important management standards provides a competitive advantage. We hypothesize that certification may provide a way of communicating about unobservable firm attributes, thereby generating a growth effect for certified organizations. Our results are consistent with this hypothesis. We find that certified facilities grow faster, and that this advantage does not result from changes in quality performance, inventory management, within-firm production allocation, or pre-certification growth differences. We also find that certification is particularly beneficial for organizations that operate in large and advertising intensive industries – industries where information search costs may be higher. Exploratory tests of an alternative effect of ISO 9000 on operational performance do not yield significant results.

This study has practical value for both managers and institutional agents. For managers, it suggests that they should consider certification as a means of credibly communicating to buyers. For buyers, regulators, and other institutional agents, it suggests that certified management standards might provide a viable way of reducing problems of asymmetric information. In addition to its practical relevance, the study also contributes to the literature on management standards. To understand the function of certified management standards, research must untangle how and when these standards benefit organizations. By beginning to untangle the communication and operational advantages of certification, and by exploring when such communication has greater value, this article helps to clarify how certified management standards may function.

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Table 1: Descriptive Statistics

Variable	Description	Mean	Std. Dev.	Min	Max
Competitive Advantage	Change in production volume between t and t+1.	0.90	27.46	-199.99	191.79
ISO 9000	Binary variable taking 1 if ISO 9000 adoption. Step function as alternative specification.	0.05	0.22	0.00	1.00
Industry Size	Natural log of the number of facilities per industry. Updated yearly. Mean centered.	0.01	1.04	-4.45	2.04
R&D Intensity	Natural log of annual industry average of R&D expenditures divided by sales. Mean centered.	-0.01	1.28	-1.73	5.40
Advertising Intensity	Natural log of annual industry average of advertising expenditures divided by sales. Mean centered.	-0.03	0.80	-1.30	3.21
Operational Performance	Relative facility performance compared to industry, size and year.	-0.08	0.96	-5.41	8.23
Inventory	Natural log of inventory in weight units. Updated yearly.	11.29	2.55	3.93	24.39
Labor	Natural log of the number of facility employees. Updated yearly.	4.88	1.49	0.00	11.23
Firm Size	Natural log of the number of facilities per firm. Updated yearly.	1.90	1.58	0.00	5.76
Industry Certification	Percentage of certification in each industry and year.	0.02	0.05	0.00	0.52
Export	Percentage of exports of shipments in industry. Updated yearly.	0.04	0.04	0.00	0.84

N = 165744

Year Effects and State Effects are omitted from table.

All industry-level variables are measured on the four-digit SIC code level. Note that the mean of the centered industry level variables does not perfectly equal zero because we calculated the summary statistics considering only facilities that had data for all independent variables. To mean-center, we however used the entire sample.

Facilities have zero labor if they are closed at the end of the year but have some remaining operations during some part of the year.

Operational Performance is normalized but was calculated using a larger sample than that used in the current analysis. As a result, the mean and standard deviation reported above do not match that of a normalized variable.

Table 2: Correlation among Independent Variables

VARIABLE	1	2	3	4	5	6	7	8	9	10
1 ISO 9000	1.00									
2 INDUSTRY SIZE	-0.01*	1.00								
3 R&D INTENSITY	0.08*	0.08*	1.00							
4 ADVERTISING INTENSITY	-0.01	0.09*	0.26*	1.00						
5 OPERATIONAL PERFORMANCE	-0.03*	-0.01	-0.00	-0.01*	1.00					
6 INVENTORY	0.10*	0.04*	0.05*	-0.02*	-0.20*	1.00				
7 LABOR	0.09*	-0.21*	-0.01*	-0.11*	0.02*	0.12*	1.00			
8 FIRM SIZE	0.08*	-0.11*	0.04*	-0.04*	-0.06*	0.17*	0.32*	1.00		
9 INDUSTRY CERTIFICATION	0.39*	0.07*	0.15*	-0.02*	0.00	0.13*	0.01*	0.05*	1.00	
10 EXPORT	0.12*	-0.17*	0.18*	-0.06*	0.00	0.11*	0.10*	0.07*	0.18*	1.00

N = 165744
Year Effects and State Effects are omitted from table.
* Variables correlated at $p < 0.01$.

Table 3
Basic Analysis, Growth Effect of ISO 9000

VARIABLE	MODEL 1⁺	MODEL 2#	MODEL 3'	MODEL 4^	MODEL 5°	MODEL 6"
ISO 9000		1.292**	1.016*	1.083*	1.354**	0.983*
		(0.343)	(0.348)	(0.352)	(0.343)	(0.359)
ISO X INDUSTRY SIZE			1.258**			1.127**
			(0.290)			(0.292)
ISO X R&D INTENSITY				0.562*		0.300
				(0.218)		(0.226)
ISO X ADVERTISING INTENSITY					1.327**	1.079*
					(0.339)	(0.352)
CONTROL VARIABLES						
INDUSTRY SIZE	-0.376**	-0.372**	-0.439**	-0.373**	-0.374**	-0.433**
	(0.080)	(0.080)	(0.081)	(0.080)	(0.080)	(0.081)
R&D INTENSITY	0.255**	0.249**	0.253**	0.213*	0.251**	0.234**
	(0.063)	(0.063)	(0.063)	(0.065)	(0.063)	(0.065)
ADVERTISING INTENSITY	-0.551**	-0.554**	-0.560**	-0.556**	-0.651**	-0.638**
	(0.098)	(0.098)	(0.098)	(0.098)	(0.101)	(0.101)
OPERATIONAL PERFORMANCE	-0.711**	-0.707**	-0.706**	-0.706**	-0.705**	-0.705**
	(0.077)	(0.077)	(0.077)	(0.077)	(0.077)	(0.077)
INVENTORY	0.060	0.057	0.055	0.057	0.056	0.055
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
LABOR	-3.042**	-3.054**	-3.058**	-3.056**	-3.056**	-3.060**
	(0.057)	(0.057)	(0.057)	(0.057)	(0.057)	(0.057)
FIRM SIZE	0.547**	0.540**	0.537**	0.540**	0.538**	0.535**
	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)
INDUSTRY CERTIFICATION	7.876**	6.175*	5.408*	5.942*	6.344*	5.501*
	(1.798)	(1.853)	(1.862)	(1.855)	(1.854)	(1.865)
EXPORT	4.174	3.939	4.091	3.957	3.887	4.043
	(1.895)	(1.895)	(1.896)	(1.895)	(1.895)	(1.896)
CONSTANT	14.423**	14.579**	14.621**	14.577**	14.597**	14.630**
	(0.812)	(0.813)	(0.813)	(0.813)	(0.813)	(0.813)
N	165744	165744	165744	165744	165744	165744
WALD CHI^2	3736.95	3751.30	3770.60	3758.08	3766.92	3784.92

Year Effects and State Effects included in all models but omitted from table. Standard errors are in parentheses.
** significant at the Leamer cutoff (z-value > 3.46), * p< 0.01
All models use a general estimation equations model to predict the change in production volume (i.e., growth) for a facility between t and t+1. Independent and control variables are measured at t.
⁺ Model 1: Base model
Model 2: Test of H1.
' Model 3: Test of H2.
^ Model 4: Test of H3. Includes industry R&D Intensity to approximate extent of industry intangible assets.
° Model 5: Test of H3. Includes industry Advertising Intensity to approximate extent of industry intangible assets.
" Model 6: Fully specified model. Results support H1 and H2, and provide partial support to H3.

Table 4:
Robustness Checks for the Growth Effect of ISO 9000 in Fully Specified Model

VARIABLE	MODEL 1[+]	MODEL 2[#]	MODEL 3^	MODEL 4°
ISO 9000	1.028*	1.157*	0.807*	1.812*
	(0.411)	(0.378)	(0.278)	(0.635)
ISO X INDUSTRY SIZE	1.166**	1.248**	0.523*	1.264*
	(0.330)	(0.309)	(0.201)	(0.481)
ISO X R&D INTENSITY	0.254	0.243	-0.307	0.128
	(0.266)	(0.238)	(0.184)	(0.432)
ISO X ADVERTISING INTENSITY	0.920*	1.204*	0.529	0.763
	(0.420)	(0.370)	(0.322)	(0.676)
CONTROL VARIABLES				
INDUSTRY SIZE	-0.366**	-0.559**	-0.265**	-0.127**
	(0.078)	(0.091)	(0.025)	(0.104)
R&D INTENSITY	0.204*	0.237*	0.000	0.315*
	(0.069)	(0.073)	(0.024)	(0.100)
ADVERTISING INTENSITY	-0.512**	-0.691**	-0.226**	-0.804**
	(0.100)	(0.113)	(0.037)	(0.154)
OPERATIONAL PERFORMANCE	-0.671**		-0.348**	-0.674**
	(0.085)		(0.035)	(0.111)
DELTA OPERATIONAL PERFORMANCE		-0.052		
		(0.661)		
INVENTORY	0.054	0.157**	0.014	0.092
	(0.032)	(0.035)	(0.012)	(0.052)
LABOR	-3.048**	-3.329**	-0.508**	-3.364**
	(0.076)	(0.064)	(0.019)	(0.090)
FIRM SIZE	0.566**	0.635**	0.211**	1.087**
	(0.053)	(0.060)	(0.017)	(0.190)
INDUSTRY CERTIFICATION	6.694*	5.023*	2.127	7.724
	(2.562)	(1.983)	(1.917)	(3.158)
EXPORT	3.132	3.317	2.707**	-1.270
	(2.120)	(2.094)	(0.626)	(2.659)
CONSTANT	15.032**	13.726**	0.902*	13.989**
	(0.926)	(0.975)	(0.338)	(1.202)
N	165744	142390	142379	77549
WALD CHI^2	3011.43	3361.09	1548.72	1798.47

Year Effects and State Effects included in all models but omitted from table. Standard errors are in parentheses.
**significant at the Leamer cutoff (z-value > 3.46), * p< 0.01
[+] Predicting facility growth using a general estimation equations (GEE) model with an empirical variance estimator.
[#] Analysis includes *Delta Operational Performance* as independent variable. N is reduced because forming *Delta Operational Performance* ($Op.Perf._t$ – $Op.Perf_{t-1}$) causes us to lose the first observed year for each facility.
^ Difference-in-Difference approach: Dependent variable = (production $growth_{it+1}$ - average production $growth_i$). N is reduced since $growth_{it+1}$ causes us to lose the last observed year for each facility.
° Analysis for single facilities firms. Sample includes single facility firms and firms with only one facility per industry.

Table 5:
The Effect of ISO 9000 on Operational Performance

VARIABLE	MODEL 1+ Perc. Change in Operat. Perf.	MODEL 2# Perc. Change in Operat. Perf.	MODEL 3^ Absolute Operat. Perf. in t+1	MODEL 4° Absolute Operat. Perf. in t+1
ISO 9000		1.013 (0.650)		-0.049 (0.034)
ABSOLUTE OPERAT. PERF.			0.534** (0.002)	0.534** (0.002)
INVENTORY	-0.055 (0.044)	-0.058 (0.044)	-0.038** (0.005)	-0.038** (0.005)
LABOR	-0.253** (0.075)	-0.263** (0.075)	-0.105** (0.013)	-0.105** (0.013)
FIRM SIZE	-0.004 (0.070)	-0.009 (0.070)	dropped	dropped
INDUSTRY CERTIFICATION	4.855 (4.054)	3.115 (4.206)	-0.487 (0.213)	-0.408 (0.220)
EXPORT	-2.366 (2.250)	-2.492 (2.252)	-0.250 (0.635)	-0.223 (0.635)
REGULATORY STRINGENCY	29.089 (26.485)	28.991 (26.485)	0.096 (1.021)	0.100 (1.021)
CONSTANT	1.332 (4.563)	1.410 (4.563)	- -	- -
N	145336	145336	160645	160645
WALD CHI^2	6609.61	6612.33	-	-

Year Effects are included in all models but omitted from table.

State Effects are included in Models 1 and 2. Facility Effects are included in Models 3 and 4.

Standard errors are in parentheses

**significant at the Leamer cutoff (z-value > 3.46), * p< 0.01

+, # Dependent variable equals $[[(-1 * waste)_{it+1} - (-1 * waste)_{it}] / [(-1 * waste)_{it+1} + (-1 * waste)_{it}]/2] * 100$. Independent variables are captured at t. Analysis uses a GEE model with an exchangeable correlation structure for within group correlation.

^, ° Dependent variable equals $(-1 * waste)_{it+1}$. Independent variables captured at t. Analysis uses a cross-sectional time-series regression model with facility fixed effects. Firm Size is dropped due to fixed effect specification. The Constant is omitted due to fixed effect specification.