ISO-14001 Standard and Firms' Environmental Performance: Evidence from the U.S. Transportation Equipment Manufacturers

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Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association and Western Agricultural Economics Association Annual Meeting, Boston, Massachusetts, July 31-August 2

Abstract

Manufacturers have been increasingly relying on environmental management systems (such as ISO 14001 based ones) to comply with government regulations and reduce waste. In this paper, we investigated the impact of ISO 14001 certification on manufacturers' toxic release by release level. We applied the censored quantile instrumental variable estimator (CQIV) to data on the U.S. transportation equipment manufacturing subsector facilities. Results show that ISO 14001 had a negative and statistically significant effect on the top 10% manufacturing sites in terms of on-site toxic release, but it did not reduce off-site toxic release. Therefore, one should not expect ISO 14001 to have a uniform impact on manufacturing sites' environmental performance. For large firms, encouraging voluntary adoption of ISO 14001 might be an effective government strategy to reduce on-site pollution. However, for small firms and for the purpose of reducing off-site pollution, other economic incentives or regulations are warranted.

Key Words: censored quantile regression, environmental performance, ISO 14001, manufacturing.

JEL Codes: *L620, Q23, Q24, Q530.*

1. INTRODUCTION

Many manufacturers have an environmental management system (EMS) to comply with government regulations and reduce waste. Most EMSs are based on International Organization for Standardization (ISO) 14001, a private standard that helps manufacturing facilities to develop organized environmental policies, goals and plans for achieving their environmental objectives, and to monitor and evaluate their success. To obtain certification to ISO 14001, a facility needs to choose a certifier (known as certification body) that will conduct an audit and determine if the facility can be certified. Adoption of ISO 14001 is fast-expanding in the world. For the United States, the number of facilities with ISO 14001 certification increased from 639 in 1999 to 6,071 in 2013 (ISO 2013). Figure 1 shows the top 10 countries with ISO 14001 certificates in 2013. China ranked the highest with over 100,000 certificates and the United States ranked the ninth.

Adoption of ISO 14001 is growing for many different reasons. First, many governments encourage self-regulation and voluntary actions among industries to reach overall environmental goals. Governments want to do this because voluntary actions in comparison with government environmental policies and economic incentives (e.g. pollution tax, pollution quotas, and emission trading) are less costly and may be administratively more acceptable to the industry (Arimura, Darnall, and Katayama 2011; Anton, Deltas, and Khanna 2004). The U.S. government has also begun to promote greater adoption of EMSs that can be implemented through the ISO 14001 certification process (Anton *et al.* 2004; Rondinelli 2001). For example, if facilities had an active EMS in place (e.g., ISO 14001 certified) at the time of a violation of environmental regulations, the Environmental Protection Agency (EPA) would reduce the penalty associated with this violation (Curkovic, Sroufe, and Melnyk 2005; Lally 1997).

Secondly, ISO 14001 adoption may result in other benefits for manufacturing facilities. These benefits include, based on the assumption that the environmental performance of facilities may improve after adopting ISO 14001, improvement in stakeholder satisfaction, fewer inspections by the EPA or other environmental regulatory agencies, better company image, lower public pressure, and lower insurance costs (Begley 1996).

Promotional efforts toward the adoption of ISO 14001 are largely based on the assumption that ISO 14001 has a positive effect on facilities’ environmental performance. However, this assumption may not hold true from either theoretical or empirical standpoints (as shown in later sections). For this reason, many researchers have begun to empirically examine the effect of ISO 14001 adoption on facilities' environmental performance. Research findings of this effect are largely inconclusive. On the one hand, some researchers found adopting ISO 14001 had strong positive impact on environmental performance (e.g. Franchetti 2011; Comoglio and Botta 2012; Nguyen and Hens 2013; Testa *et al.* 2014). On the other hand, some studies only found weakly statistically significant evidence of the effect of ISO 14001 on environmental performance (e.g. Ziegler and Rennings 2004; Dahlström *et al.* 2003; Barla 2007), and some others found no relationship between ISO 14001 adoption and environmental performance at all (e.g. King, Lenox, and Terlaak 2005; Darnall and Sides 2008; Gomez and Rodriguez 2011; Zobel 2015).

A commonality between all of the previous studies is that they did not differentiate between the levels of pollution across facilities. In reality, the effect of ISO 14001 adoption may be dependent on the actual levels of pollution a facility is currently at, which becomes the focus of this study. For example, there is a possibility that facilities with a high pollution level get certified because they want to lower public pressure and get fewer inspections from the EPA. For these types of facilities, the effect of ISO 14001 on pollution level can be weak or even positive due to selection issue. Similarly, the effect for facilities with low pollution level can also be weak because they may have reached the minimum level of pollution, and having ISO 14001 does not induce them to further reduce pollution. Therefore, we hypothesize that the effect of ISO 14001 adoption is different for facilities with various levels of pollution and this study provides the first attempt to provide empirical evidence on this issue.

2. BACKGROUND LITERATURE

ISO-14001 Standard Overview

The first version of the ISO 14000 series, ISO 14001, was released in 1996 and then revised in 2004. ISO 14001 provides a framework for facilities to follow so they can set up an effective EMS. The ISO 14001 standard can provide assurance to company management, employees, and external shareholders that environmental impact is being monitored and improved (ISO, 2002).

To be certified by ISO 14001, facilities are required to have third-party verification (the use of a third party certification body) to ensure that they follow the standard. In the first step, the facilities agree to reduce environmental impacts over time. After the facilities agree to reduce their environmental impacts, they should prove that their EMS meets the five key component of ISO 14001 requirements (Arimura, Hibiki, and Katayama 2008; Arimura *et al.* 2011). The five essential components are: (1) environmental policy—a facility needs to draft an environmental policy statement, determine objectives of the facility in terms of environment impact, and make this policy publically available, (2) planning—an agenda outlining the facility's plan to meet the goals, (3) implementation and operation—a facility will establish necessary components to implement the program such as structure and operation, training, and documentation, (4) checking and corrective action—a facility needs to perform periodic monitoring to assure that the facility's EMS meets its targets and objectives and, if not, what corrective actions should take place, and (5) management review—management staff should do periodical review, mostly once a year, to assure the EMS continues to be effective and sustainable. ISO 14001 certified facilities should follow Plan-Do-Check-Act cycle over time to maintain its registration with the ISO (BSI 1996; Welford 1998; Whitelaw 2004; Arimura *et al.* 2008).

ISO 14001 and Environmental Performance

Considering the rapid, worldwide growth of ISO 14001 adoption, research about the effect of this certification on the environmental performance of facilities is also growing. As mentioned above, ISO 14001 is a non-governmental voluntary standard through which facilities can successfully implement their EMS. The certification process itself does not force facilities to improve their environmental performance as long as the facilities have satisfied the requirements for certification (Corbett and Kirsch 1999). Overall, various studies found that ISO 14001 can improve or have no impact on environmental performance, depending on the facility's location, the sector/industry, and the measure of environmental performance. When we discuss "improvement of environmental performance" or "a positive effect of certification" in this study, we mean a reduction of waste release/generation/emission as a result of certification. Table 1 provides a summary of the studies in this area, grouped by the impact of ISO 14001.

Many studies report that ISO 14001 improved environmental performance. Montabon *et al.* (2000) found evidence that ISO 14001 improved both overall environmental performance and economic efficiency of facilities. Russo and Harrison (2001) considered the electronics sector in the U.S. and have concluded that the certification can have a positive (and statistically significant) effect on toxic release reduction. Another study for the same sector by Russo (2009) indicates that ISO 14001 has a positive impact on facilities emission. Also, this study showed that the earlier they adopt it the higher the positive impacts are. These results were also supported by the Babakri *et al.* (2004) whose results indicated that recycling performance in the U.S. is significantly positively affected by ISO 14001 certification. Also, they found that smaller facilities and early adopters of the certification had greater improvement in recycling performance than bigger facilities as well as late adopters. Melnyk, Sroufe, and Calantone (2003) used North American data and found that facilities with ISO 14001 standard reduced their waste disposal. Potoski and Prakash (2005) provided evidence that ISO 14001 certified facilities in the U.S. reduced their toxic emissions faster than non-certified facilities. More recently, Franchetti (2011) used the U.S. manufacturing firm-level data and found that ISO 14001 certification reduced solid waste.

Some studies also provide evidence on the positive relationship between environmental performance and ISO 14001 standard in countries other than the United States. Ziegler and Rennings (2004) found that ISO 14001 has a weak (statistically significant at the 10% significance level) positive effect on environmental performance at German manufacturing facilities. Using Japanese facility level data, Arimura *et al.* (2008) found that ISO 14001 helped to reduce environmental impact. Nguyen and Hens (2013) used Vietnam cement industry data and found a positive relationship between ISO 14001 certification and environmental performance in this industry. Testa *et al.* (2014) examined the effect of ISO 14001 certification effect on carbonic anhydride emissions in energy-intensive facilities of Italy. Their result indicated a positive relationship between ISO 14001 certification and environmental performance.

On the other hand, several studies found that ISO 14001 certification had no statistically significant effect on the environmental performance, such as Andrews *et al.* (2003), Dahlström *et al.* (2003), and King *et al.* (2005). Barla (2007) studied the ISO-14001 certification effect on the environmental performance of the paper and pulp industry in Canada. This study indicated that facilities with ISO 14001 certification did not improve their environmental performance compared with non-certified facilities. Darnall and Sides (2008), using meta-analysis method, did not found any significant relationship between ISO-14001 certification and environmental performance improvement in the U.S. facilities. Gomez and Rodriguez (2011) tested the effect of ISO 14001 on the toxic release of industrial facilities in northern Spain and found that ISO 14001 certification did not have an impact on pollution. Similar finding was reported by Zobel (2015) using Swedish manufacturing firm-level data.

Overall, the literature largely shows an inconclusive relationship between ISO 14001 standard and environmental performance. Nawrocka and Parker (2009) used 23 different studies in a meta-analysis framework to display the relationship between environmental performance and the ISO 14001 standard. Their conclusion is that this relationship is mixed and case specific.

Our study differs from the studies above in that we examine the effect of ISO 14001 on the environmental performance of facilities at different levels of pollution. This has not been previously addressed in the literature. In the theoretical model section, we show theoretically why the relationship between ISO 14001 certification and environmental performance might depend on the levels of pollution. We subsequently provide an empirical test of the hypothesis using detailed facility-level data in the U.S. transportation equipment manufacturing subsector. In this paper, we will consider toxic release as a representative case of environmental performance.

3. THEORETICAL MODEL

From a cost-minimization perspective

In this section, we first illustrate the impact of ISO 14001 from a simple cost reduction standpoint (which is more applicable to perfect competition market structure) and then analyse the impact from a full profit-maximization perspective (which is more applicable to imperfect competition). Based on Mishan (1974) and Dasgupta, Hettige, and Wheeler (2000), optimal emission level by facilities can be determined by the following argument. For each facility, cost-minimizing emission intensity (i = pollution/output) is determined by the intersection of expected marginal penalty (EMP) and the facilities' marginal abatement cost (MAC). EMP is the price of the pollution and increases with the pollution intensity level. On the other hand, MAC is downward sloping and indicates that marginal abatement cost is higher for lower levels of emission (see Figure 2). MAC can be a function of different variables. For specific levels of pollution intensity, larger facilities will generally have lower MAC than smaller firms (Dasgupta *et al.* 2000).

Denote *tc* as the total cost of pollution to the facility that is the sum of (c) pollution abatement cost, and (*f*), the penalty for different pollution levels. We assume that pollution abatement cost is a function of pollution intensity. Also, there is a penalty associated with each level of pollution intensity. Hence, *f* is a function of pollution intensity as well. Equation 1 shows the cost function that facilities are minimizing:

(1) $tc(i) = c(i) + f(i)$.

Taking first order conditions with respect to i yields equation (2), by which we can determine the optimal level of the pollution intensity:

(2) $\frac{\partial c}{\partial i} + \frac{\partial f}{\partial i} = 0$ or $\frac{\partial f}{\partial i} = -\frac{\partial c}{\partial i}$.

Note that in equation (2), $-\frac{\partial c}{\partial i} = MAC$ and $\frac{\partial f}{\partial i} = EMP$. MAC can be defined as the cost to reduce an extra unit of pollution intensity. EMP can be defined as the penalty for an extra unit of pollution intensity, which is the price of pollution. Figure 2 shows this basic framework. From the interaction of MAC_1 and EMP_1 the optimal level of the facility pollution intensity can be determined, which in this case is i^{*}.

Having different MAC and EMP functions, each facility has it is own unique pollution intensity level. A downward shift in MAC can occur when facilities change their production process or EMS to reduce pollution intensity (e.g. adopting ISO 14001). In fact, pollution-intensive facilities will face higher marginal cost because regulatory scrutiny intensifies at higher level of pollution intensity (e.g. marginal production cost increases as a result of more frequent inspections by the regulator) and these faciltiies also face higher pressure from consumers, shareholders, and the local community. As shown in figure 2, as a result of ISO 14001 adoption, we expect that MAC_1 shifts downward to MAC_2 and holding EMP constant at EMP_1, optimal pollution level decreases from i^* to i^1. On the other hand, certification may act as a signaling tool and reduce the pressure from consumers, shareholders, and community on the facility. As a result of this, we can expect a downward shift in EMP (from EMP_1 to EMP_2). Holding MAC constant at MAC_1, this shift leads to an increase in the pollution level by the facility from i^* to i^2. Optimal pollution intensity could, therefore, increase, decrease or remain unchanged following ISO 14001 certification. Therefore, the impact of ISO 14001 depends on the cost effect (MAC), the benefits effect (reduced EMP), and likely the original optimal pollution intensity. If the cost effect dominates, then we would expect pollution intensity to decrease due to certification. If the benefit effect dominates, pollution intensity should increase due to certification.

From a profit-maximization perspective

In this paper we propose a new framework to analyze the impact of certification on pollution intensity, in which facilities maximize profit instead of minimizing cost. The main advantage of this framework is it provides insight into why certification's effect on pollution intensity might depend on the production technology that generates pollution (we show this using a monopoly market structure) and firm size (we illustrate this point in an asymmetric Cournot model).

Consider a profit maximizing monopolist whose profit depends on price (p), quantity of production (q), and production cost (c).[1] We specify the production cost as $c[q, l(q), t)]$, where l is the total pollution level ($l = i*q$) and t denotes certification (we assume a continuous degree of

[1] We did not specify the aforementioned penalty for different pollution levels (f) to make results more generalizable. In addition, such cost is more closely tied to the pollution intensity rather than the production level, and will drop out of the first-order condition.

certification to facilitate comparative statics analysis). The inclusion of pollution level in the cost function reflects the abatement cost of pollution, which should increase with production level. The profit function for a monopolistic firm is

$$(3)\ \pi = p(q,t)q - c[q, l(q), t]\ ,$$

where we assume certification may enhance demand for the firm's products if buyers (especially institutional ones) care about this attribute. The first order condition with respect to *q* is:

$$(4)\ \frac{\partial \pi}{\partial q} = p + qp_q - c_q - c_l l_q,$$

where p_q denotes the partial derivative of p with respect to q, and so on. Totally differentiating equation (4) leads to the following:

$$(5)\ p_q dq + p_t dt + p_q dq + q\left(p_{qq} dq + p_{qt} dt\right) - \left(c_{qq} dq + c_{ql} dl + c_{qt} dt\right) - (c_{ql} dq + c_{ll} dl + c_{lt} dt)\ l_q - l_{qq} c_l dq = 0.$$

To focus on the impact of certification, we assume the following second-order derivatives are zero without losing much generalizability: p_{qt} (certification does not change the slope of the demand curve), c_{qq}, c_{ql}, and c_{ll} (constant marginal cost with respect to production and pollution). After simplifying and some rearrangement, equation (5) becomes

$$(6)\ \frac{dq}{dt} = \frac{p_t - c_{qt} - c_{lt} l_q}{-2p_q - qp_{qq} + l_{qq} c_l}$$

Note that by definition, the pollution intensity is expressed as $i = \frac{l}{q}$. To see how certification may affect pollution intensity, we can totally differentiating *i* with respect to *t* and obtain:

$$(7)\ \frac{di}{dt} = \frac{(l_q - i)}{q}\frac{dq}{dt} = \frac{(l_q - i)(p_t - c_{qt} - c_{lt} l_q)}{q(-2p_q - qp_{qq} + l_{qq} c_l)}.$$

Equation (7) warrants some additional analysis. Note that $-qp_{qq}/p_q$ is the elasticity of the slope of the inverse demand curve (a measure of the convexity of demand curve), which is generally assumed to be less than two in the literature (Dixit 1986; Zheng, Bar, and Kaiser 2010). Therefore, given the assumption of a downward sloping demand curve p_q, the $-2p_q - qp_{qq}$ term in (7) is positive (this is most clear when demand is linear and $p_{qq} = 0$). In addition, we expect that pollution increases with production ($l_q > 0$) and pollution increases cost ($c_l > 0$); certification enhances demand ($p_t \geq 0$), reduces marginal cost of production ($c_{qt} \leq 0$), and/or reduces marginal cost of pollution ($c_{lt} \leq 0$). The last three effects capture the intended impacts of certification. Therefore, the $(p_t - c_{qt} - c_{lt} l_q)$ term in (7) is positive. Assume $l(q) = \alpha_1 q + \alpha_2 q^2$, so that $\frac{(l_q - i)}{q}$

becomes α_2. Therefore, we will have three scenarios for the impact of certification on pollution intensity, depending on the production technology that determines the sign of l_{qq}.

Scenario 1: $l_{qq} = 0$, pollution increases with production linearly. Under this scenario, certification increases production but does not affect pollution intensity.

Scenario 2: $l_{qq} > 0$, that is, pollution increases with production at an increasing rate. Under this scenario, the sign of (7) is positive. That is, certification will increase both production and pollution intensity.

Scenario 3: $l_{qq} < 0$, that is, pollution increases with production at a decreasing rate. Under this scenario, the sign of (7) is indeterminate. If l_{qq} is sufficiently negative, then certification will decrease production but increase pollution intensity; otherwise, certification will increase production but decrease pollution intensity.

Overall, the above analysis shows that the impact of certification on production and pollution intensity depends crucially on the production technology that generates pollution. For some facilities, especially smaller ones without much investment in new technology, certification may increase pollution intensity. Large facilities may generate pollution at a decreasing rate along with production. For them, certification should reduce pollution intensity. It is this theoretical ambiguity that necessitates an empirical investigation of the impact of certification on environmental performance.

We now show how the size of a facility might affect the impact of certification on production building on the work by Zheng *et al.* (2010). The impact of certification on facility *j*'s production in an asymmetric Cournot market assuming constant marginal cost and $l_{qq} = 0$ can be expressed as (Zheng *et al.* 2010, equation 5)

$$(8)\ \frac{dq_j}{dt} = \frac{p_t(s_j NE - E + 1)}{-p_Q(1 + N - E)}$$

where *Q* is market demand, *N* is the number of facilities supplying products in the market, s_j is the market share of the output of the *j*-th facility, and $E = -Qp_{QQ}/p_Q$ is a measure of demand curve convexity. Zheng *et al.* (2010) show that the denominator of (8) is positive. Therefore, the impact of certification on production depends on the facility's market share and demand convexity. For example, for convex demand curve that features $E > 1$, then only sufficiently large facilities' production will increase with certification. For concave demand ($E < 0$), only sufficiently small facilities' production will increase with certification, highlighting how facility size may affect the impact of certification.

4. DATA

This study uses facility-level cross-sectional data for the year of 2013 because certification data over years are not available. We focus on the facilities in the U.S. transportation equipment manufacturing subsector, which is under code 336 based on the North American Industry Classification System (NAICS). By definition, industries in this subsector produce equipment for the transportation of people and goods (U.S. Census Bureau, 2015). We chose to use this subsector because it is one of the largest industrial sectors in the United States and ISO 14001 adoption is popular in this subsector. In 2014, this subsector had 1.6 million employees (Bureau of Labor Statistics, 2015). Also, a random sample of all facilities in the U.S. industry sector shows that this subsector is the most popular in adopting ISO 14001 with 20 percent of adoption rate in 2013. In terms of pollution level, this subsector had the second highest amount of toxic release in 2013, after the metal manufacturing subsector (NAICS 331). This high degree of pollution is another reason we chose this subsector for further investigation (Toxics Release Inventory, 2013 and author calculations).

We use data from three different sources. The first part includes environmental variables such as toxic release that is obtained from The EPA Toxics Release Inventory (TRI) database. TRI contains annual facility-level data on toxic release. Based on Emergency Planning and Community-Right-To-Know Act (EPCRA) law, all manufacturing facilities in the U.S. are required to report to the EPA the amount of toxic they release into the air, land, and water for more 320 toxic chemicals. Using the TRI database, there were 1,261 facilities in the U.S. transportation equipment manufacturing subsector that reported their amount of toxic release. The second part of the data is the information about facility characteristics such as sales volume and the number of employees. We obtained this data from the ReferenceUSA Company, which provides data on U.S. businesses. Because ReferenceUSA did not have information on all facilities in our list, our usable sample size reduced to 678. Finally, information about the number and type of certification for these facilities was obtained from the Independent Association of Accredited Registrars Directory (IAAR).

5. EMPIRICAL MODEL

Measure of environmental performance

Given that total pollution/emission is assumed linearly related to pollution/emission intensity, the dependent variable in this paper is environmental performance measured by total toxic release by sample facilities in 2013. For robustness purpose, we use both on-site toxic releases and off-site transfers as dependent variables. Using disaggregated emission data, we could identify the effect of ISO 14001 adoption on a particular type of disposal method.

EPA has regulations on off-site toxic chemicals transfer under the Resource Conservation and Recovery Act (RCRA). Based on the RCRA, only facilities that meet technology-based standards for construction and operation can have off-site toxic release. There can also be extra costs, such as cost of shipping, related to off-site toxic treatment. Also, there are technical standards for waste treatment at the end-of-the-pipe (Andrews 2006; Anton *et al.* 2004). As a result, compared to off-site releases, on-site releases may be cheaper and more convenient for facilities to pursue thus can create more social pressure from the neighborhood communities and shareholders (Anton *et al.* 2004).

Control variables

We provide detailed information on all variables used in this study in Table 2. The first and most important group of variables are the types of certifications that facilities hold in 2013. In this group of variables, we have environmental certification such as ISO 14001 and other types of certification such as ISO 9001 (general quality management system). In our models, ISO 14001 is a binary variable that takes the value of one if the facility has ISO-14001 certification in 2013 and takes the value of zero otherwise. Number and type of certification for these facilities was obtained from the IAAR. Variable ISO 9001 is defined and obtained similarly.

Facility characteristics such as sales volume, production growth ratio, facility credit score, facility type, community population of the facillity location, and facility size represent the first group of independent variables. These variables are measured at 2013 and were provided by RefrenceUSA dataset except the production growth ratio. Most of these variables are self-explanatory except a few: the production growth ratio, provided by the TRI dataset, indicates the rate of production growth by each facility over the previous year. A facility credit score is a number from 0 to 100; a higher number indicates a better credit score. Four different groups of facilities are created based on facilities type. Facilities can be headquarters, branch, subsidiary, and single location. Finally, we have the industry type fixed effects. The NAICS divided the U.S. Transportation Equipment Manufacturing Subsector to seven smaller subsector groups. These subsectors are: Motor Vehicle Manufacturing (NAICS 3361), Motor Vehicle Body and Trailer Manufacturing (NAICS 3362), Motor Vehicle Parts Manufacturing (NAICS 3363), Aerospace Product and Parts Manufacturing (NAICS 3364), Railroad Rolling Stock Manufacturing (NAICS

3365), Ship and Boat Building (NAICS 3366), and other Transportation Equipment Manufacturing (NAICS 3369). To differentiate between different subsector groups, we have dummy variables for each industry.

The third group of independent variables in this paper are pollution related. We use a binary variable to indicate if a facility is releasing chemicals under the Clean Air Act (CAA) regulation. The idea is that if the chemicals released are under the CAA regulation, then there may be more pressure from the public on the facility which may subsequently lead to a lower level of pollution level. In addition to chemicals, we use a dummy variable to indicate whether a facility is releasing metals that are regulated by the EPA.

Summary statistics

Table 3 shows summary statistics for the sample facilities used in this paper. The first panel shows toxic release by facility. On average facilities in 2013 release around 6,000 pounds, with two-thirds of release coming from on-site release. The second panel shows facility characteristics. Sales for these facilities in 2013 vary from 83 dollars to 22 million dollars, providing ample degree of variation for our estimation.

Table 4 shows the summary statistics for different types of certification held by facilities. About 15 percent of the facilities in our sample have at least one type of certification, and about 6 percent of the facilities have ISO 14001 certification. The most popular certification is ISO 9001 (held by 10 percent of facilities).

Statistical method and Econometric Specification

Our basic estimating equation is:

(9) $$\ln(TTR_i) = \beta_0 + \beta_1 ISO14001_i + \beta_i X_i + \mu_i + \varepsilon_i$$

where TTR_i is environmental performance in facility i which in this paper is defined as total toxic release in facility i, $ISO14001_i$ is a dummy variable previously defined, and X_i is a vector of control variables such as log of sales volume, log of population, and etc. which is explained in the Table 2, μ_i is an industry fixed effects, and ε_i captures all unobservable factors affecting the dependent variable.

We chose the econometric models to fit our objectives and nature of data. Our goal is to test the effect of ISO 14001 on environmental performance and check if this effect is different for high pollution-generating facilities compared with low pollution-generating facilities. Quantile regression is the appropriate model in this case.

A potential problem with our dataset is sample selection bias. Based on TRI dataset, facilities that manufacture or process more than 25,000 pounds of a TRI-listed chemicals or use more than 10,000 pounds of a listed chemical in a given year must report to TRI (USEPA 2013). In other words, the probability of not reporting to TRI is related to the level of toxic release, and this can cause sample selection bias. Facilities that do not report their toxic release level cannot affect our estimation (Russo 2009). To address this issue, we use the censored quantile regression (CQR) (Powell 1986).

Endogeneity is also another potential problem in our study. Specifically, in our study, this can be a potential problem because of measurement error (Frisch 1934) and sample selection (Heckman, 1979). It is possible that facilities choose to have ISO 14001 because they have high pollution level, and certification helps them lower the pressure from consumers as well as inspection regulators. The estimation will be biased if these endogeneity issues are not addressed. Anton *et al.* (2004) used an instrumental variable to deal with this issue. A quantile regression estimator that considers both our potential problems was introduced by Chernozhukov, Fernández-Val, and Kowalski (2015), known as the censored quantile instrumental variable (CQIV) estimator. Combining quantile regression with censoring and endogeneity, we use the CQIV estimator. Our preferred estimating equation becomes:

$$(10) \qquad \ln(TTR_i) = \beta_0 + \beta_1 \widetilde{ISO14001_i} + \beta_i X_i + \mu_i + \xi_i$$

where $\widetilde{ISO14001_i}$ is $ISO14001_i$ instrumented with ISO9001 in the first-stage regression equation:

$$(11) \qquad \ln(TTR_i) = \gamma_0 + \gamma_1 ISO9001_i + \gamma_i X_i + \delta_i + v_i$$

Results

Table 5 presents the empirical results. We report the coefficient for ISO 14001 here and report the estimated coefficients for the other controls in Appendix Table A1. Column (1) of Table 5 presents the OLS regression results, which shows that ISO 14001 certification does not have a statistically significant effect on total toxic release.

We then applied the quantile regression with consideration of endogeneity and censoring in our models. In the case of endogeneity, variables that are correlated with ISO 14001 adoption but not with the pollution level (i.e., the error term) are needed. To address this issue, we used ISO 9001 as instrumental variables (IV) for ISO 14001. ISO 9001 is a quality management system standard. To become certified, an organization needs to demonstrate its ability to consistently provide product that meets customer and applicable statutory and regulatory requirements, and aims to enhance customer satisfaction through the effective application of the system, including processes for continual improvement and the assurance of conformity to customer and applicable statutory and regulatory requirements (ISO, 2015).

ISO 9001 certification is a good candidate for instrument for several reasons. First, certification decisions to ISO 9001 and ISO 14001 are correlated. Christmann and Taylor (2001) investigated the relationship between ISO 14001 and ISO 9001, and their result indicates a positive relationship between these two certifications. The positive relationship is mostly because ISO 9001 certified facilities could have lower learning cost in adoption of ISO 14001. These two certifications share the management system-based approach including document and record control, internal audits, corrective actions, preventive actions, continual improvement, and management reviews (Christmann and Taylor 2001; Potoski and Prakash 2004). Second, facilities with ISO 9001 certification would be familiar with the general structure of an ISO management standard, necessary paperwork involved in certification. These facilities may already have established relationships with local ISO auditors. Therefore, it is reasonable to expect that a facility may start with ISO 9001 certification. As they become more familiar with ISO standards, they may proceed to adopt ISO 14001 environmental standard. We also tested for the weak instrument hypothesis in the first-stage regression. The t-value for the ISO 9001 coefficient (which is positive) is 3.2, implying this is not a weak instrument.

Despite these similarities, there is a major difference between ISO 9001 and ISO 14001. While ISO 9001 focuses on facilities' product and management quality aspects, ISO 14001 focuses on facilities' environmental aspects and impacts. With ISO 9001 certification, facilities need to fulfill requirements and ensure customer satisfaction, while continuously improving the effectiveness of its operations. ISO 9001 is to control product quality and does not require companies to account for the impact of their activities on their surroundings. However, ISO 14001 is for environmental management and facilities need to minimize its effect on the environment. One requirement of both of these standards is that facilities document their processes (assuming that facilities control the quality of their products under the ISO 9001 certification, and the environmental impact of their activities under the ISO 14001 certification) if they have those processes written down (Bénézech *et al.*, 2001; Larsen and Häversjö, 2001). Overall, ISO 9001 adoption should not affect pollution much due to the standard's scopes and emphases.

Panel A in Table 5 shows CQIV estimation results. The effect of ISO 14001 now is not statistically significant for the first, second, or third quartile of data. However, such effect is negative and statistically significant (at the 5% significance level) for the 90th percentile (that is, the top 10% of facilities in terms of total toxic release). The 95% confidence intervals of estimated parameters were obtained via non-parametric bootstrap. We used Wald test statistics to test for differences in the coefficients across quantiles. Wald test results show that the null hypothesis (that they are identical) can be rejected at the 1% significance level.

For robustness check, we differentiated pollution levels as on-site and off-site and conducted a similar analysis, respectively. These can be seen in Panel B and C in Table 5. The results indicate that the effect of ISO 14001 on on-site pollution level is similar to the effect of ISO 14001 on total toxic release level. However, we found that ISO 14001 had no statistically significant effect on off-site pollution level.

6. SUMMARY AND CONCLUSION

Manufacturers have been increasingly relying on EMSs to comply with government regulations and reduce waste. In this paper, we investigated the impact of EMSs on facilities' toxic release. More specifically, we tested the hypotheses that the effect of ISO 14001 certification is related to facilities' pollution levels. We used three different sources to collect data on facility characteristics, toxic release by facilities, and finally certification types that facilities hold.

We applied the censored quantile instrumental variable estimator (CQIV) to data on the U.S. transportation equipment manufacturing subsector facilities. CQIV estimator results indicate that ISO 14001 had a negative and statistically significant effect on the top 10% facilities in terms of on-site toxic release and total toxic release (on-site and off-site combined). We did not find any impact of ISO 14001 on off-site toxic release. In other words, ISO 14001 is effective for decreasing on-site pollution by facilities and is not effective in decreasing off-site pollution.

These findings may have important policy implications. We should not expect ISO 14001 to have a uniform impact on manufacturing sites' environmental performance, as indicated by our theoretical section and empirical evidence. We found that the impact of ISO 14001 depends on whether the toxic release is on site or off site, and on whether the toxic release is large enough. Therefore, for large facilities, encouraging voluntary adoption ISO 14001 might be an effective government strategy to reduce on-site pollution. However, for small facilities and for the purpose of reducing off-site pollution, other economic incentives or regulations are warranted.

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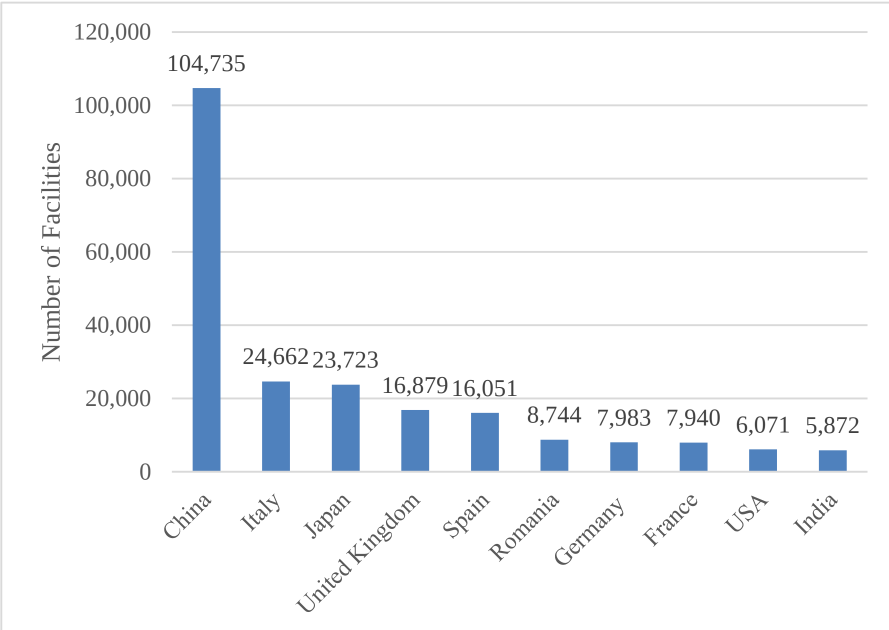
Figure 1. Top 10 Countries for ISO 14001 Certificates in 2013



Source: The ISO Survey of Certifications 2013.

Figure 2. Optimal Pollution Intensity Determination

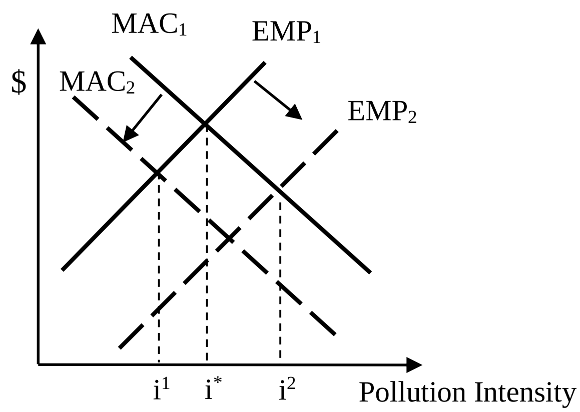


Figure 3. Log of Total Toxic Release in Different Quantiles

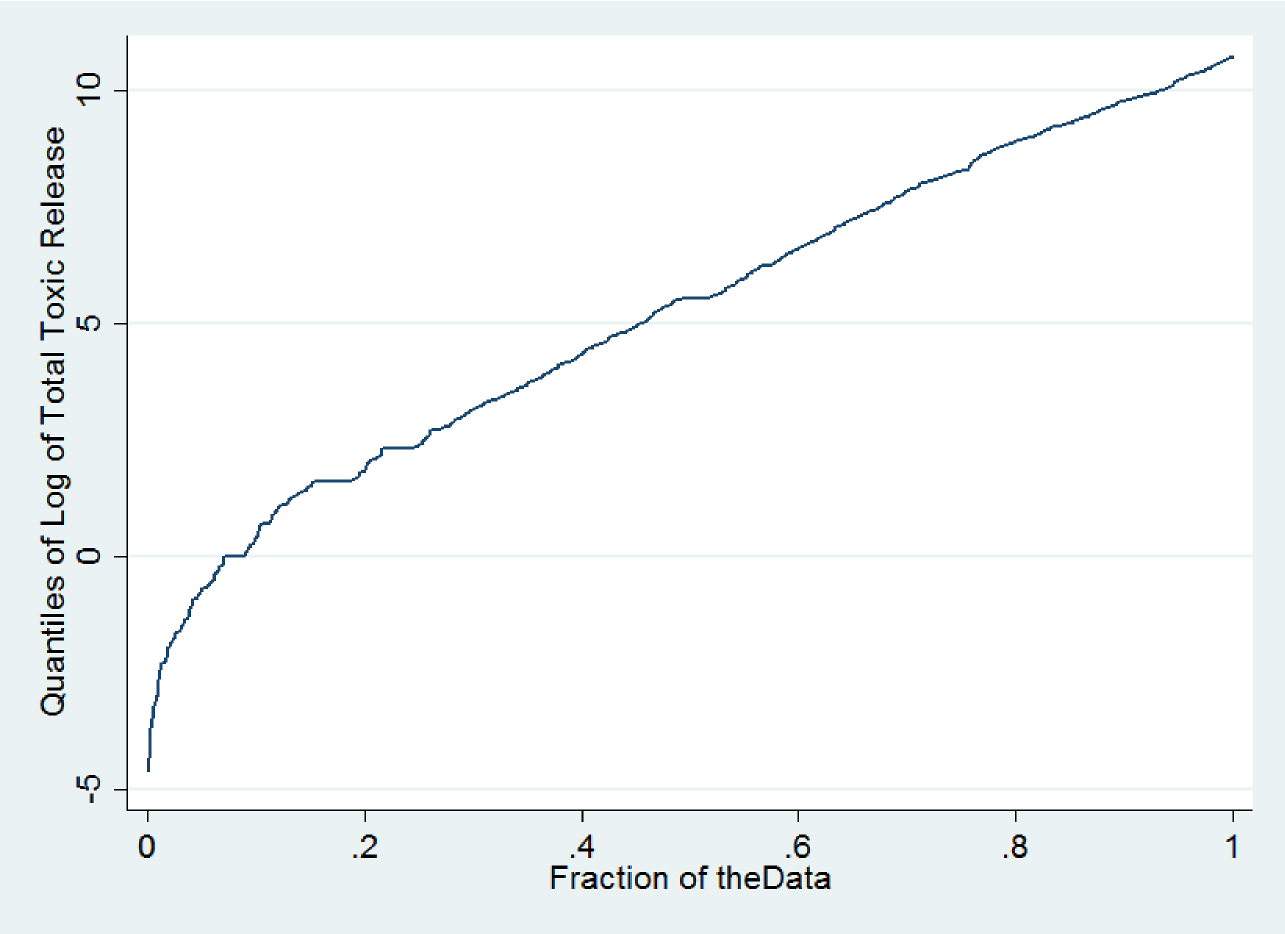


Table 1. A Summary of the Literature on How ISO 14001 Affects Environmental Performance

Authors (year)	Country	Sector/Industry	Measure of Environmental Performance	Impact of ISO 14001 on Environmental Performance
Montabon *et al.* (2000)	U.S.	Manufacturing (SIC 20-39)	not specified	Improves
Russo and Harrison (2001)	U.S.	Electronic sector	toxic release	improves
Russo (2009)	U.S.	Electronic sector	toxic release	improves
Babakri *et al.* (2004)	U.S.	Not specified	recycling	improves
Melnyk *et al.* (2003)	U.S.	manufacturing (SIC 20-39)	waste disposal	improves
Potoski and Prakash (2005)	U.S.	Manufacturing (SIC 20-39)	Toxic release	improves
Franchetti (2011)	U.S.	Manufacturing (SIC 20-39)	Solid waste generation	improves
Arimura *et al.* (2008)	Japan	manufacturing	Use of natural resources, Solid waste generation, and Wastewater effluent	improves
Comoglio and Botta (2012)	Italy	Automotive sector	Use of resources, waste management, release to water, etc	improves
Nguyen and Hens (2013)	Vietnam	cement industry	dust, SO2, and NO2	improves
Testa and *et al.* (2014)	Italy	energy intensive facilities	carbonic anhydride emissions	improves
Ziegler and Rennings (2004)	German	manufacturing (NACE-Codes 15-37)	not specified	weakly positive
Dahlström *et al.* (2003)	U.K.	Not specified	compliance with environmental regulations	did not improve
Barla (2007)	Canada	paper and pulp industry	discharges of BOD or TSS	did not improve
King *et al.* (2005)	U.S.	Manufacturing (NACE-Codes 15-37)	Deviation between observed and predicted waste generation	no relationship
Darnall and Sides (2008)	U.S.	Not specified	not specified	no relationship
Gomez and Rodriguez (2011)	Spain	manufacturing	toxic release	no relationship
Zobel (2015)	Sweden	manufacturing	waste generation	no relationship

Table 2. Description of Variables

Variable	Definition	Variable used	Data source
Total Toxic Release	A "release" of a chemical means that it is emitted to the air or water, or placed in some type of land disposal (See the EPA website for more information).	Log of total toxic release	TRI
ISO 14001	Environmental management certification published by ISO	Dummy (1 if facility holds ISO 14001 certification, 0 otherwise)	IAAR
ISO 9001	Quality management system standard certification published by ISO	Dummy (1 if facility holds ISO 9001 certification, 0 otherwise)	IAAR
Sales Value ($)	Sales value of the facility	Log of sale for each facility	RefrenceUSA
Production Growth Ratio	An indicator of facility production volume changes with respect to the previous year. Production ratio is calculated by dividing production volume in year t to production volume in year t-1.	Continoues variable	TRI dataset
Facility Credit Score	Credit rating code of the facility (0-100). Higher number indicates better credit score.	Continoues variable	RefrenceUSA
Facility Type	Indicates facility type including headquarter, branch, subsidiary, and single location.	Dummy variable	RefrenceUSA
Community Population	Resident population of the city in which the facility is located. Some assignments can be unclear, such as when cities cross county lines. To maintain this granularity, the actual assignment is done at a zip level.	Continoues variable (log of population size)	RefrenceUSA
Size of the Facility	Indicates the square footage of the location that a facility operates at.	Continoues variable (log of facility size)	RefrenceUSA
CAA Chemical	If a facility is releasing chemical under the Clean Air Act (CAA) regulation.	Dummy variable	TRI dataset
Metal Category	If a facility is releasing metal defined by the EPA. (See the EPA website for categories and takes)	Dummy variable	TRI dataset

Table 3. Summary Statistics, 2013

Variable	Number of Observations	Mean	Min	Max	S.D
Panel A: Toxic release by facilities (unit: pound)					
Total Release	678	6,355	0	139,733	16,984
On-Site Release	678	4,679	0	139,733	15,222
Off-Site Release	678	1,674	0	93,867	7,968
Panel B: Firm characteristics					
Sales ($)	678	290,288	83	22,372,184	1,187,161
Production Ratio	678	0.98	0	7.69	0.56
Facility Credit Score	678	96	70	100	5
Community Population	678	88,225	12,500	1,000,000	198,928
Size of the Facility	678	34,980	1,250	40,000	10,058
CAA Chemical	678	0.77	0	1	0.421

Table 4. Summary of the Certification Types Held by Facilities in 2013

Certification Type	Number of Facilities	Percentage of Total Sample (Percent)
At Least One Type of Certification	102	15.05
ISO 14001- 2004	37	5.46
ISO 9001-2008	64	9.44
AS9100C-2009	19	2.80
ISO/TS 16949	30	4.42

Table 5. OLS Regression Result and Instrumental Variable Censored Quantile Regression Result at Different Quantiles

Panel A: Dependent variable: log of total toxic release (pounds)

	OLS Regression	CQIV Regression			
		25%	50%	75%	90%
		-3.31	-1.14	-1.10	-0.24**
ISO 14001	-0.92	(-9.06)	(-11.36)	(-6.63)	(-5.02)
	(0.56)	[1.52]	[2.08]	[1.16]	[-0.25]

Panel B: Dependent variable: log of total on-site toxic release (pounds)

		-1.78	-1.25	-0.56	-0.36**
ISO 14001	-1.05*	(-11.02)	(-9.50)	(-8.35)	(-4.52)
	(0.58)	[1.64]	[1.52]	[1.23]	[-0.56]

Panel C: Dependent variable: log of total off-site toxic release (pounds)

		-5.18	-1.41	-1.75	-1.47
ISO 14001	-1.25	(-11.87)	(-3.85)	(-2.11)	(-1.06)
	(0.80)	[9.74]	[10.41]	[8.06]	[11.25]

N=678

Notes: Lower bounds of bias-corrected 95% confidence intervals from bootstrap replications are in parentheses and upper bounds are in brackets. ** indicates the 95% confidence interval does not include zero. Industry dummies are not displayed but can be seen in the appendix.

t-value from first stage=6.24

Appendix A

Table A1. Instrumental Variable Censored Quantile Regression Result at Different Quantiles

	Quantiles			
	25	**50**	**75**	**90**
Log of Sales	-0.192	0116	0.111	0.084
	(-0.218)	(-0.161)	(-0.214)	(-0.220)
	[0.558]	[0.455]	[0.358]	[0.378]
Production Growth Ratio	0.674	0.433	0.224	0.129
	(-0.310)	(-0.176)	(-0.030)	(-0.321)
	[1.254]	[0.671]	[0.420]	[1.476]
Facility Credit Score	0.137	0.033	0.033	0.050
	(-0.035)	(-0.011)	(-0.007)	(-0.028)
	[0.230]	[0.187]	[0.159]	[0.118]
Facility Type (Branch)	3.090	-1.717	-0.494	-0.172
	(-3.864)	(-1.761)	(-1.668)	(-2.173)
	[4.215]	[4.908]	[6.941]	[1.330]
Facility Type (Single Location)	3.964	-1.035	-0.352	0.187
	(-3.267)	(-1.711)	(-1.151)	(-2.361)
	[5.346]	[6.475]	[7.044]	[1.791]
Log of Population	-0.232	-0.183	-0.008	-0.078
	(-0.348)	(-0.556)	(-0.454)	(-0.370)
	[0.250]	[-0.014]	[0.215]	[0.186]
Log Of Facility Size	-0.638	-0.642	-0.579	-0.480
	(-2.234)	(-2.016)	(-1.992)	(-1.650)
	[-0.453]	[-0.211]	[-0.321]	[-0.365]
CAAC Chemical	0.190	0.633	0.126	-1.518
	(-0.418)	(-0.701)	(-0.736)	(-1.011)
	[1.756]	[1.173]	[1.618]	[1.264]
Metal Category 1	-2.470	-1.890	-0.656	1.146
	(-3.992)	(-3.147)	(-2.439)	(-2.005)
	[0.116]	[2.387]	[6.317]	[3.746]
Metal Category 2	-6.486	-6.242	-4.327	-1.268
	(-8.377)	(-6.209)	(-5.692)	(-4.941)
	[-3.911]	[-1.453]	[3.010]	[1.238]
Constant	2.490	7.484	11.966	10.690
	(-3.993)	(-4.399)	0.265	2.192
	[14.475]	[15.668]	[21.854]	[28.285]

Notes: Dependent variable: log of total toxic release (pounds). Lower bounds of bias-corrected 95% confidence intervals from bootstrap replications are in parentheses and upper bounds are in brackets