The Pollution Release and Transfer Register System in the U.S. and Japan: An Analysis of Productivity

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2019

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Abstract

This study analyzes productivity in the context of environmental regulations on the provision and dissemination of environmental information. Our study measures total factor productivity (TFP) by considering the emission of toxic chemical substances in the U.S. and Japan and the two countries' corresponding policies. We apply the directional distance function to measure the Luenberger productivity indicator to estimate TFP. The data for U.S. and Japanese manufacturing firms include 386 firms over 1999 and 2007 and 466 firms over 2001 to 2008, respectively. This paper focuses on nine industries with highest pollution intensity: rubber and plastic, chemicals and allied products, paper and pulp, steel and non-ferrous metal, fabricated metal, industrial machinery, electric products, transportation equipment, and precision instruments. These nine sectors are categorized into two industry groups: the basic materials group and the processing and assembly group. The results show that productivity improved in all industrial sectors in the U.S. and Japan from 2001 to 2007. In particular, the electric product industry improved rapidly after 2002 for both countries. The enforcement of RoHS and the REACH directive in Europe might be one of the reasons for these increases. These stringent restrictions on toxic chemical substances give U.S. companies that export to the European market a strong incentive to treat their toxic chemical substances.

Keywords

Environmentally Sensitive Productivity; Toxic Chemical Substances; Pollution Release and Transfer Register; Manufacturing Sector; United States, Japan

1. Introduction

Productivity is the main driver of economic growth, and rapid growth can increase pollutant emissions due to the greater use of resources. Consequently, a conflict between economic growth and pollution arises. The literature on growth theory also shows the importance of the productivity increase by analyzing economic growth and the environment because improved productivity decreases the input demand for pollution abatement (Akao and Managi, 2007). Thus, continuous productivity progress should consider emission reductions. This study analyzes productivity by considering the environmental policies on the provision and dissemination of environmental information in the United States (U.S.) and Japan.

The improved provision and dissemination of environmental information can complement traditional policy instruments for controlling environmental performance (Tietenberg and Wheeler, 2001). The provision of information is a quasi-regulatory mechanism, as consumers, investors, the public and other stakeholders utilize the information to pressure firms to change their environmental behavior (Arora and Cason, 1996; Lyon and Maxwell, 2004). For example, the provision requiring more firm-specific environmental information may cause consumers to change their decisions on purchasing a firm's product if they care about the firm's environmental performance (Konar and Cohen, 1997; Jobe, 1999).

Previous literature on the Pollution Release and Transfer Register (PRTR) system mainly analyzes the effects of the U.S. Toxic Release Inventory (TRI), especially regarding the relationship between a firm's environmental performance and its financial performance. Two important characteristics of PRTR and TRI systems are that 1) facilities periodically send a mandatory report to the relevant authorities on their releases to air, water and soil and the disposal of other wastes, and 2) the emissions data of specific pollutants from individual facilities are accessible to the public.

The principal focus of this study is to provide a measurement of change in total factor productivity (TFP), which is decomposed into technological and efficiency change by considering environmental (i.e., nonmarket) outputs. It is important to note a priori that we are not able to judge whether the index increases over time. This is because the regulations requiring more stringent pollution abatement do not necessarily change productivity[1].

The U.S. Census Bureau published a list of pollution abatement costs and expenditures in 2005 by type of business (Table 1). We summarized the value of shipments, pollution abatement cost and abatement cost per shipment ratio by type of business. The cost-to-shipment ratio is high in the textile, paper, petroleum, chemical, nonmetallic mineral and fabric metal industries. In contrast, the cost-to-shipment ratio in the machinery, electrical equipment and transportation industries is lower

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[1] This is because the linear expansion of pollution abatement costs and pollution reduction does not necessarily change the pollution reduction per abatement cost (Pethig , 2006).

than in the other sectors. The industries with high cost-to-shipment ratios mainly incur their abatement cost upon pollution treatment, which is essentially an end-of-pipe solution. In the meantime, industries with lower cost-to-shipment ratios tend to incur abatement cost for recycling and disposal.

<Table 1. Pollution Abatement Cost and Expenditures in U.S. industry (Million U.S. $)>

In the analysis of emissions management, it is important to understand whether pollution abatement technologies are utilized more efficiently (Kolominskas, 2004). This is because the efficiency at least partially influences the cost of production and pollution abatement technologies (Jaffe et al. 2005). There are two opposing incentives that result from environmental policy on productivity growth. As an effect of such policies, two possibilities may emerge (Managi et al., 2005). First, abatement pressures might encourage a growth in productivity that reduces the actual cost of compliance below the originally estimated cost (Bunge, 1996). Second and in contrast, firms might be reluctant to increase productivity if they believe that regulators will respond by ratcheting up standards even further. In addition to changes in environmental regulations and technology, management levels also influence the productivity. Therefore, whether the productivity and technological frontier levels increase over time is an empirical question.

Previous studies that focus on productivity when considering toxic chemical substances are divided into two types; one group of studies focuses on the entire industry sector, while another group analyzes firm-level data. If we use data on entire industry sectors to estimate productivity, the characteristics of the industrial structure largely affect productivity. However, most studies that use firm-level data focus on only one industrial sector (Färe et al. 2001, Lerche, 2004; Kwon ,2006;, and Koehler, 2007). Although the PRTR system was enforced in all industrial sectors in the same year, the technical difficulty associated with reducing the emission of toxic chemical substances differs between industries. It is clear that the required capital equipment and labor for reducing toxic chemical substances differ between industries because the chemical products consumed as intermediate materials differ. We thus compare sector-level productivities by considering the emission of toxic chemical substances (called environmentally sensitive productivity, or ESP).

We select U.S. and Japanese manufacturing companies for our study for the following reasons. First, they are large emitters of chemical substances; in 2008, the U.S. and Japanese industrial sectors emitted 3.85 and 0.44 billion pounds of chemical substances, respectively. Their emission of chemical substances is larger than that of other developed countries. Lanjouw and Mody (1996) have noted that the U.S. and Japan spent a large amount of research and development expenditures on environmental technology and that their share of environmental patents in worldwide is high. Additionally, their share of pollution abatement costs and expenditures in GDP is also high. We also note that the U.S. and Japanese governments freely provide PRTR information on companies on their respective websites. Therefore, information is easily provided to the public. This study considers the differences between these industries and compares ESP by focusing on the nine manufacturing industries in the U.S. and Japan.

The objective of this study is to measure and understand changes in ESP. We hope to clarify how ESP changes after several environmental standards are enforced. We consider how environmental standards in the domestic market and the international market affect firm performance. We also discuss the efficiency gap between efficient firms and inefficient firms.

The TRI system in the U.S. began in 1986 and has operated for over 20 years. In contrast, the PRTR system in Japan is relatively new, having started in 2001. Some of the differences in the two countries' ESP might result from differences in the level of experiences their manufacturing companies have with the policy. We are interested in how experience affects environmental performance. A greater amount of experience with the policy in the country might lead to an increase in the marginal abatement cost if easily abatable emissions are used up. However, if voluntary action requires additional time from the firms, the opposite result might be produced. The final goal of this paper is to suggest policy implications to reduce toxic chemical substances while maintaining market competitiveness.

2. Background

In 1984, there was an accidental explosion at a pesticide plant in India; following that, there was a leak at a U.S. chemical plant. These incidents gave rise to an international movement to better understand the growing use of chemical substances. Public interest and environmental organizations around the U.S. and Japan accelerated demands for information on toxic chemicals being released outside of the facility (Khanna, 1998). Consequently, the U.S. Emergency Planning and Community Right-to-Know Act was enacted in 1986. The TRI is a publicly available U.S. Environmental Protection Agency (U.S.EPA) database that contains information on toxic chemical releases and waste management activities reported annually by certain industries as well as federal facilities[2].

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[2] Under TRI, the reports must be filed by owners and operators of facilities that meet all of the following three criteria. (1) TRI reporting requirements are limited to the manufacturing facilities within the major SIC code groups 20 through 39. In 1997, the U.S. EPA added seven additional industry sectors to the TRI requirements. These sectors started to report submissions in the reporting year 1998. (2) The number of full-time employees must be 10 (or the equivalent of 20,000 hours of work per year) or more. (3) Any facility that manufactured or processed more than 25,000 pounds or otherwise used more than 10,000 pounds of a listed toxic chemical during the course of the calendar year is required to submit a report.

Japan has enforced PRTRs since 2001; its first public release of PRTR data was on 20 March, 2003. Under this system, facilities that have more than 20 employees and produce or use chemicals on a list of 354 substances specified by law must annually report quantities used to the central government. The central government aggregates and sorts the reported data by industry type and geographic location and then provides the information to the public. Although the central government does not specify facility-level emissions in their aggregated reports, they must disclose facility-level data when requested by a citizen. The PRTR in Japan has an important role in reducing and managing the development of toxic chemicals.

Table 2 shows a historical overview of law and regulation on toxic chemical substances in the U.S. and Japan. The U.S. began to enforce pollution restriction law in the 1940s and 1950s, while Japan began to do so at the end of the 1960s. PRTR law started in 1986 as TRI in the U.S. A few years later, the U.S. government began a unique environmental pollution reduction plan known as the 33/50 Program, which was established in 1991. The 33/50 Program targeted 17 priority chemicals, such as benzene and toluene, and set as its goal a 33% reduction in the release and transfer of these chemicals by 1992 and a 50% reduction by 1995 using a 1988 baseline. The primary purpose of EPA's growing series of voluntary programs was to demonstrate the benefits of voluntary partnerships. Previous studies support the benefits of a voluntary approach to bring about targeted reductions more quickly than would regulations alone (Khanna and Damon, 1999; Gamper-Rabindran, 2006). In 2006, Japan also established a volatile organic compound (VOC) reduction plan, which has as its target a 30% reduction in the release of VOC chemical substances based on the voluntary effort of companies and business associations.

<Table 2 Historical overview of law and regulation on toxic chemical substances>

3. Methodology

This study measures environmentally sensitive productivity changes in U.S. and Japanese manufacturing firms. We apply the directional distance function (DDF) to measure the Luenberger Productivity Indicator in order to estimate TFP (Chambers et al. 1998; Fujii et al. forthcoming). The Luenberger-type TFP is considered to be more general than the widely used Malmquist Index (Chambers et al. 1998). The change in the Luenberger productivity indicator can be further decomposed into technical change and efficiency change.

3.1. Directional Distance Function (DDF)

Let $x \in \Re_{+}^{L}, b \in \Re_{+}^{R}, y \in \Re_{+}^{M}$ be vectors of inputs, environmental output (or undesirable output) and market outputs (or desirable output), respectively. Define the production technology as

$$P(x) = \{(x, y, b) : x \text{ can produce } (y, b)\}. \tag{1}$$

We assume that good and bad outputs are null-joint; a company cannot produce desirable output without producing undesirable outputs:

$$(\mathrm{y}, \mathrm{b}) \in \mathrm{P}(\mathrm{x});\ \mathrm{b}=0 \Rightarrow \mathrm{y}=0. \tag{2}$$

We also assume weak disposability. Weak disposability implies that the pollutant should not be considered freely disposable.

$$(\mathrm{y}, \mathrm{b}) \in \mathrm{P}(\mathrm{x}) \text{ and } 0 \leq \beta \leq 1 \Rightarrow (\beta \mathrm{y}, \beta \mathrm{b}) \in \mathrm{P}(\mathrm{x}). \tag{3}$$

Under the null-joint hypothesis and weak disposability, this directional distance function can be computed for firm k by solving the following optimization problem:

$$\vec{\mathrm{D}}^{\mathrm{WD}}\left(\mathrm{x}_{\mathrm{k}}^{\mathrm{l}}, \mathrm{y}_{\mathrm{k}}^{\mathrm{m}}, \mathrm{b}_{\mathrm{k}}^{\mathrm{r}}, \mathrm{g}_{\mathrm{x}^{\mathrm{l}}}, \mathrm{g}_{\mathrm{y}^{\mathrm{m}}}, \mathrm{g}_{\mathrm{b}^{\mathrm{r}}}\right) = \text{Maximize } \beta_{\mathrm{k}}, \tag{4}$$

$$\text{s.t.} \quad \textstyle\sum_{\mathrm{i}=1}^{\mathrm{N}} \lambda_{\mathrm{i}} \mathrm{x}_{\mathrm{i}}^{\mathrm{l}} \leq \mathrm{x}_{\mathrm{k}}^{\mathrm{l}} + \beta_{\mathrm{k}} \mathrm{g}_{\mathrm{x}^{\mathrm{l}}} \qquad \mathrm{l}=1, \cdots, \mathrm{L}, \tag{5}$$

$$\textstyle\sum_{\mathrm{i}=1}^{\mathrm{N}} \lambda_{\mathrm{i}} \mathrm{y}_{\mathrm{i}}^{\mathrm{m}} \geq \mathrm{y}_{\mathrm{k}}^{\mathrm{m}} + \beta_{\mathrm{k}} \mathrm{g}_{\mathrm{y}^{\mathrm{m}}} \qquad \mathrm{m}=1, \cdots, \mathrm{M}, \tag{6}$$

$$\textstyle\sum_{\mathrm{i}=1}^{\mathrm{N}} \lambda_{\mathrm{i}} \mathrm{b}_{\mathrm{i}}^{\mathrm{r}} = \mathrm{b}_{\mathrm{k}}^{\mathrm{r}} + \beta_{\mathrm{k}} \mathrm{g}_{\mathrm{b}^{\mathrm{r}}} \qquad \mathrm{r}=1, \cdots, \mathrm{R}, \tag{7}$$

$$\lambda_i \geq 0 \qquad (i=1, \cdots, N), \tag{8}$$

where l, m, r are the input, the desirable output, and the undesirable output, respectively; x is the input factor in the L ×N input factor matrix; y is the desirable output in the M × N desirable output factor matrix; and b is the undesirable output factor in the R × N undesirable output matrix. In addition, g_x is the directional vector of the input factor, g_y is the directional vector of the desirable output factors, and g_b is the directional vector of the undesirable output factors. β^k is the inefficiency score of the kth firm, and λ_i is the weight variable. To estimate the inefficiency score of all firms, the model must be independently applied N times for each firm. One objective of this study is to clarify the extent to which U.S. and Japanese manufacturing firms have improved their productivities with the respect to the toxic chemical substances under consideration. Therefore, to apply the output-oriented Luenberger indicator, we set the directional vector as $g = (0, y^m, b^r)$.

3.2. Luenberger Productivity Indicator

The TFP is computed with the results of the DDF model and derived as follows (Chambers et al. 1998).

$$\mathrm{TFP}_t^{t+1} = \mathrm{TECHCH}_t^{t+1} + \mathrm{EFFCH}_t^{t+1}, \tag{9}$$

$$\mathrm{TECHCH}_t^{t+1} = \frac{1}{2}\left\{\vec{D}^{t+1}(x_t, y_t, b_t) + \vec{D}^{t+1}(x_{t+1}, y_{t+1}, b_{t+1}) - \vec{D}^{t}(x_t, y_t, b_t) - \vec{D}^{t}(x_{t+1}, y_{t+1}, b_{t+1})\right\}, \tag{10}$$

$$\mathrm{EFFCH}_t^{t+1} = \vec{D}^{t}(x_t, y_t, b_t) - \vec{D}^{t+1}(x_{t+1}, y_{t+1}, b_{t+1}), \tag{11}$$

where x_t represents the input for year t, x_{t+1} is the input for year t+1, y_t is the desirable output for year t, and y_{t+1} is the desirable output for year t+1. $b_t$is the undesirable output for year t, and b_{t+1} is the undesirable output for year t+1. $\vec{D}^{t}(x_t, y_t, b_t)$is the inefficiency score of year t based on the frontier curve in year t. Similarly, $\vec{D}^{t+1}(x_t, y_t, b_t)$ is the inefficiency of year t+1 based on the frontier curve in year t+1.

The TFP score indicates the productivity change as compared to the benchmark year. The TFP includes all categories of productivity change, which can be broken down into Technical Change (TECHCH) and Efficiency Change (EFFCH). TECHCH shows shifts in the production frontier, while EFFCH measures changes in the position of a production unit relative to the frontier (i.e., catching up).

It is common under the DDF model to assume either constant returns to scale (CRS) or variable returns to scale (VRS). In this study, we apply the CRS to avoid infeasible calculations in time-series analysis. For example, Färe et al. (1994, 1996) pointed out that it is infeasible in the VRS model to compute productivity change. In our study, the calculation of productivity change under the VRS is infeasible. Therefore, we apply only the CRS model in this study.

4. Data

Financial data on U.S. firms come from the Mergent online financial database, while chemical substances data are from the TRI database of the EPA. Japanese manufacturing firm-level data cover the six years from 2001 to 2006, and U.S. manufacturing data cover the nine years from 1999 to 2007. Financial data on Japanese firms are provided by the Nikkei NEEDS financial database, and the chemical substances data are from the PRTR database from the Ministry of Economy, Trade and Industry (METI). The selected firms include 530 Japanese firms and 386 U.S. firms (see Table 3). This paper focuses on the nine industries discussed above.

<Table 3. Firms by industry type>

We categorize these nine sectors into two main industries: the basic material industry and the processing and assembly industry. The basic material industry includes rubber and plastic, chemical, paper, steel and fabricated metal. The processing and assembly industry includes the industrial machinery, electric product, transportation and precision instrument industrial sectors.

The total revenue of the firm is used as the market output variable, and capital stock, the number of employees and the intermediate material input are used as market input variables. These variables are deflated from year 2000 prices according to the type of industry. The deflators for the U.S. firms are taken from the source OECD database. The deflators for the Japanese firms come from the Statistics Bureau and Bank of Japan databases. The integrated toxic chemical substances risk score (i.e., the toxic risk score), which is estimated by using the toxicity weight given by the U.S. EPA, is used with undesirable output data to estimate productivity.

There are three limitations in our data. One is the different coverage of the number of chemical substances between the US and Japan. There are 426 chemical substances in the TRI database published by the U.S. EPA, and the toxicity weight covers all chemical substances in the TRI database. Meanwhile, there are 354 chemical substances in the PRTR published by the METI in Japan. The toxic weight covers only 134 chemical substances in the PRTR. Because of this mismatching, it is difficult to compare the toxic risk scores directly. Therefore, we focus more on the time series of productivity change in each country and industry. The second limitation is that the coverage of the U.S. firm data is different from that of the Japanese firm data. The Mergent online database provided consolidated financial data. Therefore, the TRI database includes parent company names. We use this information to integrate each plant's toxic chemical substance emission data into company-level data. In contrast, the Japanese PRTR database does not have parent company names; it only has company names. We thus integrate Japanese PRTR data into non-consolidated company-level data. The last limitation is the availability of capital data for U.S. firms. We use capital stock data for Japanese firm analysis, but we use the net property plant and equipment as the capital stock for U.S. firm analysis because comprehensive capital stock data are not available. In general, the net property plant and equipment is lower than the capital stock because net property plant and equipment do not include intangible assets, while capital stock includes these assets.

<Table 4. Data description of U.S. industrial firms >

<Table 5. Data description of Japanese industrial firms (1$=100 yen)>

5. Result

We show the results in Figure 1 to Figure 4 and Table 6 and Table 7. To discuss productivity changes in the U.S. and Japan, we set the base year at 1999 for U.S. firms and 2001 for Japanese firms. TFP, EFFCH, and TECHCH in the base year equal zero in Figure 1 to Figure 8. Figure 1, Figure 2, and Table 1 show the U.S. firms' results. Figure 3, Figure 4, and Table 2 show the Japanese firms' results.

5.1. Results for U.S. industries

From Figure 1, we find that the TFP for five U.S. basic material industries improved from 2002 and 2003 to 2007, especially for the rubber and steel industries. Next, we discuss the results for the processing and assembly industry. Figure 2 shows that the TFP improved rapidly in the machine, electric and precious instrument industries, and the TFP of these three industries showed similar trends from 1999 to 2007. One interpretation of this rapid TFP improvement in the processing and assembly industry is that technological innovation was achieved in the information technology field, which includes the semiconductor and electronic component sector, during this period. In particular, processing and assembly companies invested large amounts of capital and made great expenditures into research and development to achieve innovation and develop new products.

<Figure 1. Total Factor Productivity of the basic material industry in U.S.>

<Figure 2. Total Factor Productivity of the processing and assembly industry in U.S.>

Improvements in the TFP in the processing and assembly industry might also be related to the enforcement of environmental standards in Europe. There are three strict environmental standards for the processing and assembly industry: (1) the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS), (2) Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), and (3) End-of-Life Vehicles Directive (ELV)[3]. Under the RoHS and ELV directives, all electric and vehicle products that include an amount of toxic chemicals above a certain threshold cannot be sold in the European market. These strict environmental standards encourage U.S. firms that export to the European market begin the management of toxic chemical substances. Therefore, the improvement in TFP in the processing and assembly industry should be mainly due to the rapid technological progress and environmental standards in the European market. The transportation industry has a lower score than other industries. The results regarding the transportation industry might be because of the poor financial performance of the U.S. auto industry and other related industries.

Table 6 shows the result of the estimation of TECHCH and EFFCH. From Table 6, the improvement in TFP is mainly caused by the growth in TECHCH from 1999 to 2007 in the entire manufacturing industry in the U.S. The level of EFFCH has decreased for several industries; therefore, this structure is called the “frontier shift (FS) type”. Nevertheless, the main factor in increasing TFP is the improvement of EFFCH in the transportation industry sector. We consider this

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[3] RoHS, REACH, and ELV were promulgated in 2003, 2006, 2000 and enforced in 2006, 2007 and 2003, respectively.

the “catch up (CU) -type”. Therefore, we note an “improved as overall effect (IMP)” if TECHCH is positive and CU is around zero.

Based on Table 6, for the chemical manufacturing industry, TECHCH is positive and EFFCH is negative. This implies that the efficiency gap between efficient firms, which consist of both frontier and inefficient firms, became larger from 1999 to 2007. One interpretation of this result is that environmentally proactive firms produced better systems to manage toxic chemical substances due to new environmental standards. However, firms may maintain a reactive environmental management to minimize their environmental protection costs. This is because the TRI system itself does not regulate the emission of toxic chemicals. That is, firms that focus on the domestic market might have less incentive to reduce toxic chemical substance emissions.

Furthermore, EFFCH is negative in the industrial machine and precious instrument industries, which implies a widening efficiency gap. The processing and assembly industry tends to export to the European market. They have an incentive to manage toxic chemicals proactively in order to adjust to stringent environmental standards such as RoHS and ELV. These proactive firms reduce their consumption and emission of toxic chemical substances and do so efficiently. Therefore, firms that do not export to the global market might also be affected through their supply chain management, though this effect is limited. Therefore, the perception of environmental preferences and environmental standards differ among firms, which might be one reason why some firms manage toxic chemical substances well and others do not.

In contrast, EFFCH is positive in the electric product and transportation equipment industries, which shows that efficiency gaps in these industries became smaller from 1999 to 2007. This might be because chemical substances in these industries are mainly used for paints and bonds, and firms can reduce their toxicity by switching from highly toxic chemicals to less-toxic chemical materials. Currently, decreasing the use of toxic chemical substances is costly, but technological innovation reduces this cost and addresses several constraints such as bonding power and color quality. As a result, inefficient firms may be able to consume lower toxic chemical materials and achieve a reduction in toxicity.

<Table 6. Results of EFFCH and TECHCH indicators for U.S. manufacturing firms.>

5.2. Results for Japanese industries

Figure 3 shows that five Japanese basic material industries improved on average in terms of ESP from 2001 to 2007. In particular, TFP of these five industries rapidly increased from 2006 to 2007. Then, because of the financial crisis, TFP of the steel and fabricated metal industries decreased due to a decrease in capital productivity. The main reason for changes over 2006 and 2007 might be the VOC restrictions that were implemented in 2006. This environmental standard encouraged manufacturing companies and business associations to reduce the VOC chemical substances through partially mandatory educational seminars and workshops. These activities support small- and medium-scale firms, which tend to have difficulty reducing VOC chemical substances because of a lack of financing and knowledge to decrease VOC chemical substances.

The TFP of rubber, chemical and paper industries improved rapidly. In particular, chemical industry experienced a decrease in their toxic risk score from 2001 to 2008. The capacity of the chemical industry to successfully reduce the toxic risk score is due to the proactive activity of the Japanese Chemical Industry Association (JCIA). The JCIA consists of 180 chemical industrial firms and 75 business associations. The JCIA already started its own PRTR system in 1997 to determine how many toxic chemical substances were emitted and circulating. The JCIA also convenes many workshops and seminars to spread know-how on reducing toxic chemical substances effectively and cheaply to member firms. This progressive approach helps reactive firms as well as firms with low levels of environmental technology to reduce their toxic risk score without undermining their financial performance.

<Figure 3. Total Factor Productivity of the basic material industry in Japan>

<Figure 4. Total Factor Productivity of the processing and assembly industry in Japan>

Next, we discuss the results for the Japanese processing and assembly industry (see Figure 4). This entire sector improved its TFP from 2001 to 2008; the electric product industry particularly showed a dramatic increase. In general, toxic chemical materials are used for paints and bonds in the processing and assembly industry. Additionally, toxic chemical materials are used for melting down and solidification in the basic material industry. Paint and bond materials can are relatively easy to replace with other low-toxic chemical materials, but many toxic chemicals used in the basic material industry are very specific and difficult to replace. Therefore, the processing and assembly industry has an advantage in reduce its toxic risk score as compared to other industries.

Table 7 shows the results regarding EFFCH and TECHCH in Japanese manufacturing firms. The TFP of most industries shifted form a FS type to an IMP type from 2001 to 2008, which implies that the efficiency gap between efficient firms and inefficient firms did not shrink.

The REACH directive was enforced in 2006 in Europe, which makes firms that export to the European market more proactive in controlling toxic chemical substances. In 2018, the REACH directive plans to cover 30,000 chemical substances if a firm treats more than 1 ton per year. To address this stringent environmental standard while maintaining competitiveness in the international market, progressive firms have a key role in spreading knowledge and solving the problems together through the use of seminar and workshop in business associations. Additionally, the REACH directive allows firm to have access to comprehensive environmental management strategies through supply-chain management, and it makes firms more efficient by procuring material in an environmentally sound manner.

Comparing the U.S. results and the Japan results, we find several industries in the U.S. with TFP shifting to the CU type, but we do not find this result in Japan. One interpretation of this finding is that the PRTR was started in 2001 in Japan such that both efficient firms and inefficient firms are on a learning curve in terms of the management of toxic chemical substances (i.e., lower marginal abatement). In contrast, U.S. firms have had enough time to act to promote the management of toxic chemical substances because the TRI was started in 1986. This is because environmentally proactive firms should have already applied cost-efficient abatement technologies and management. In this case, it is difficult for firms to have a high, positive FS indicator.

Our policy implications are as follows. First, industries with a TFP that has shifted to the CU-type and IMP-type should have an incentive to innovate new technology. Second, the industries with TFP that has shifted to the FS-type should have an incentive to transfer technology and spread know-how through governmental seminars and business association workshops.

<Table 7. Results of EFFCH and TECHCH indicators in Japanese manufacturing companies>

6. Conclusion

Productivity improvements play an important role in reducing pollution while simultaneously improving standards of living. This paper contributes to the literature on productivity change in several ways. As a policy instrument, information provisions have emerged in recent years as a mainstream regulatory tool. To explore how information provisions provide firms with an incentive to improve environmental performance, we measure and compare the environmental performance in productivity terms.

We find that productivity improved in all industrial sectors in the U.S. and Japan from 2001 to 2007. In particular, the electric product industry improved rapidly after 2002. The enforcement of the RoHS and REACH directives in Europe might be one reason for these increases. These strict restrictions in toxic chemical substances give U.S. companies that export to the European market a strong incentive to treat toxic chemical substances.

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Figure 1. Total Factor Productivity of basic material industry in U.S.

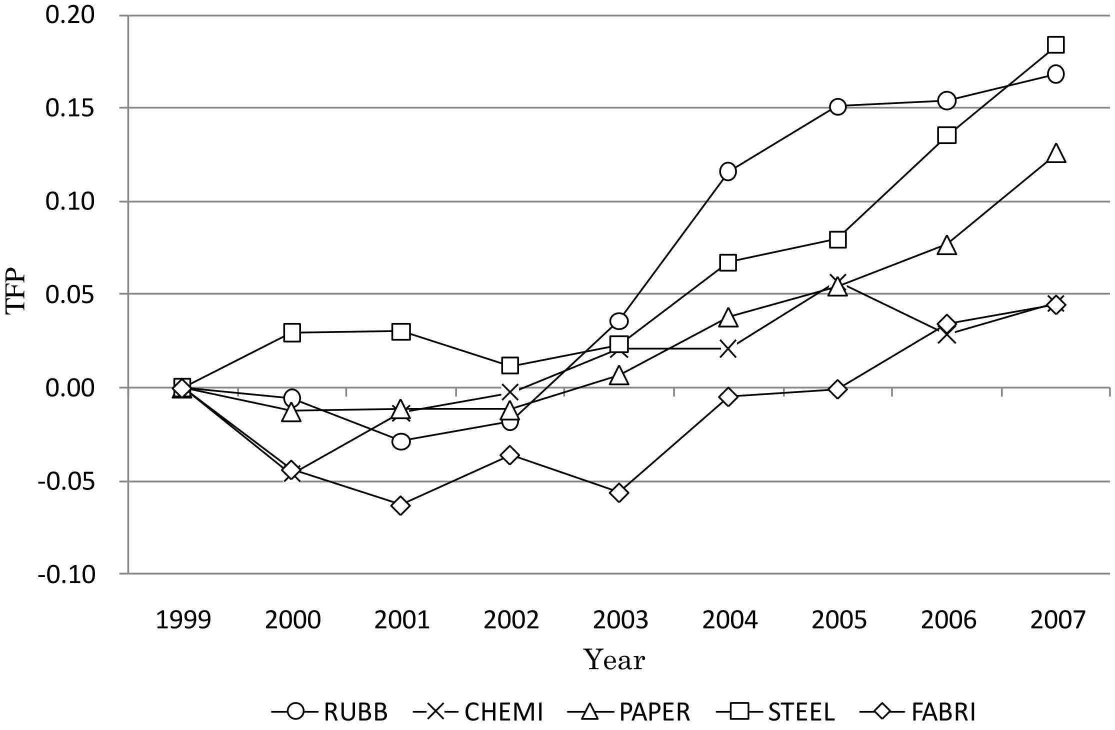

Figure 2. Total Factor Productivity of processing and assembly industry in U.S.

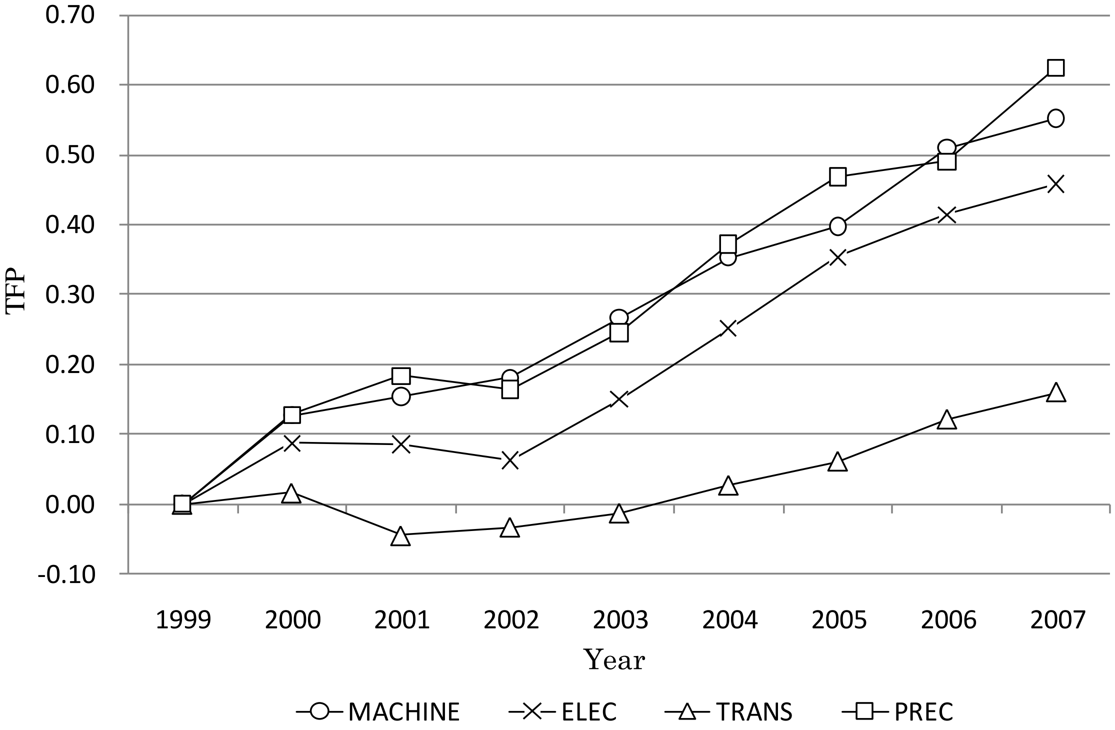

Figure 3. Total Factor Productivity of basic material industry in Japan.

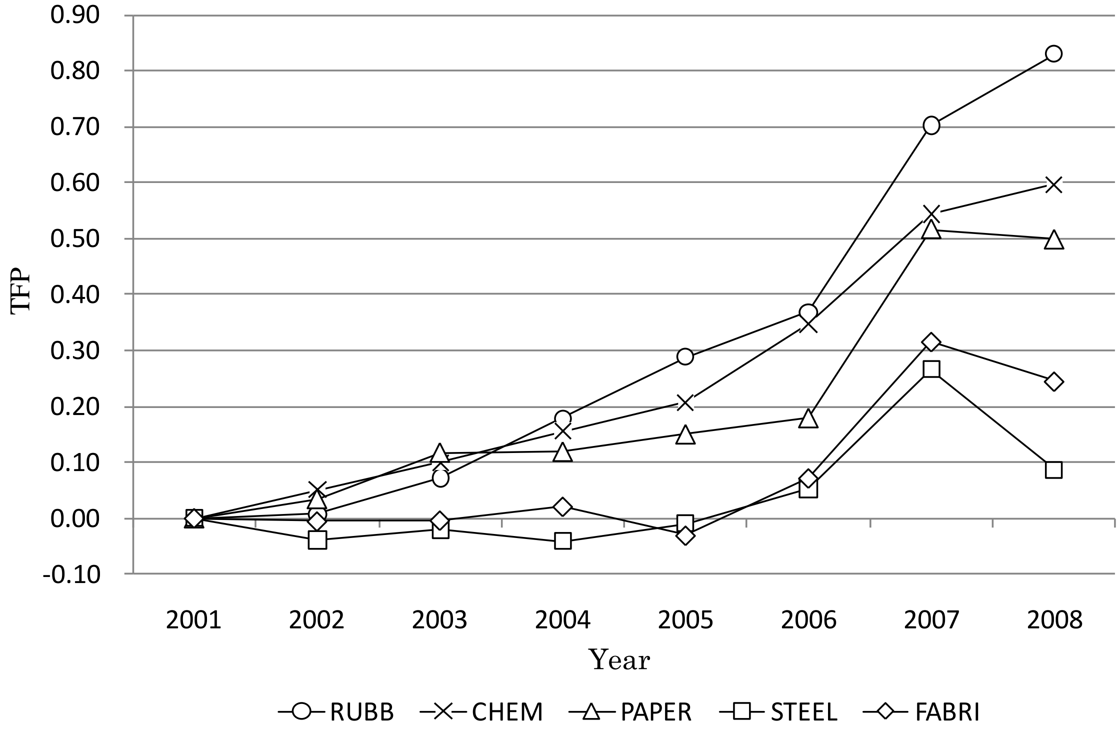

Figure 4. Total Factor Productivity of processing and assembly industry in Japan.

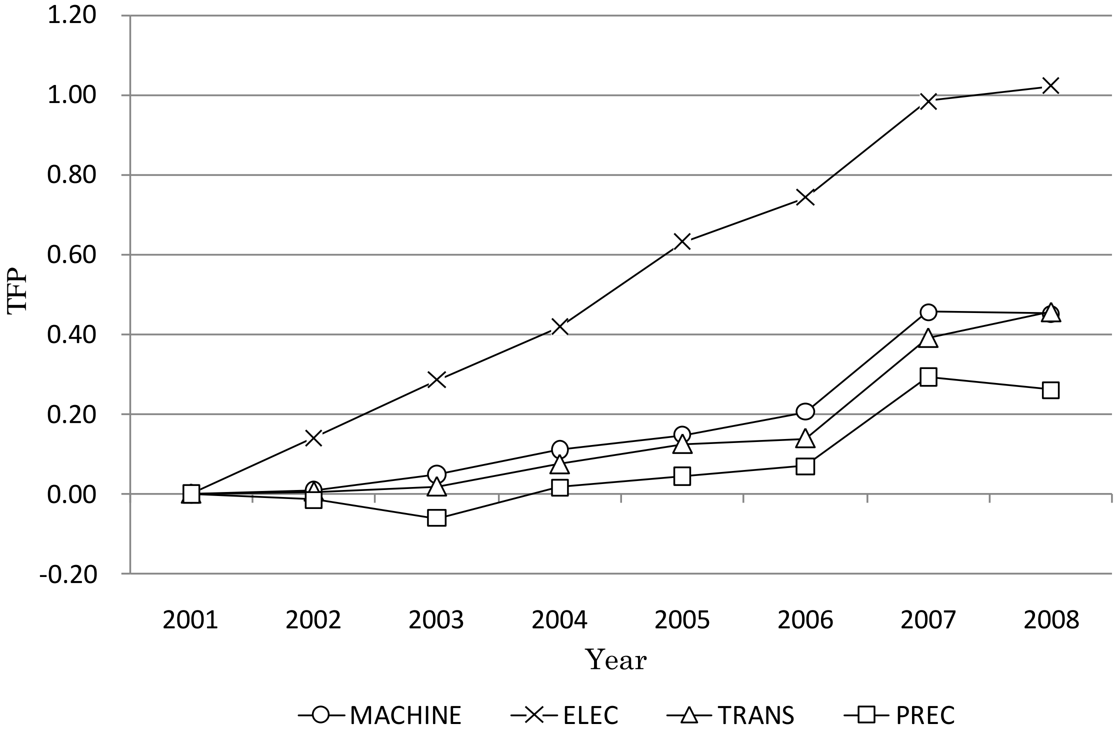

Table 1. Pollution Abatement Cost and Expenditures in U.S. industry (Million U.S. $)

	(1)Value of shipments	(2)Pollution Abatement cost	Cost per shipment ratio [(2)/(1)]	Breakdown of abatement cost			
				Treatment	Prevention	Recycling	Disposal
All industries	4,735,384	20,678	0.44%	52%	17%	8%	22%
Food	534,878	1,573	0.29%	55%	11%	7%	28%
Textile	41,149	221	0.54%	63%	7%	9%	21%
Paper	162,848	1,796	1.10%	60%	11%	7%	23%
Petroleum	476,075	3,746	0.79%	51%	35%	7%	8%
Chemical	604,501	5,217	0.86%	53%	16%	8%	24%
Plastics and rubber	200,489	503	0.25%	43%	16%	10%	32%
Nonmetallic mineral	114,321	696	0.61%	57%	18%	7%	18%
Primary metal	201,836	2,291	1.14%	54%	12%	10%	24%
Fabric metal	288,068	763	0.26%	46%	11%	12%	31%
Machinery	302,204	316	0.10%	34%	16%	11%	39%
Electrical equipment	373,932	624	0.17%	54%	9%	10%	27%
Transportation equipment	687,288	1,319	0.19%	45%	13%	12%	30%

Source: Pollution Abatement Cost and Expenditures, U.S. Bureau of the Census

Table 2. History of law and regulation about toxic chemical substances

Year	United State	Japan
-1985	-Clean Water Act (1948) (CWA was revised in 1972,1977,1987) -Clean Air Act (1955) (CAA was revised in 1970,1977,1990.) -Toxic Substances Control Act (1976)	- Basic Law for Environmental Pollution (1967-1993) - Air Pollution Control Law (1968) - Water Pollution Control Law (1970) - Chemical Substances Control Law (1973)
1985-1989	-Emergency Planning and Community Right-to-Know Act (EPCRA) was enacted (1986) -TRI started (1986)	-Amendment of chemical Substances Control Law [Start restriction of Chlorinated Organic Solvent] (1986)
1990-1994	-EPA establishes the 33/50 Program (1991) -Expansion of the chemical list raised the number of chemicals and chemical categories reported to TRI from 336 to over 600 (1994)	- Law Concerning Special Mesures for Total Emission Reduction of Nitrogen Oxides and Particulate Matte (1992) - Basic Environment Law (1993) - The Basic Environmental Plan (Define concept of environmental risk) (1994)
1995-1999	-Facility/industry expansion[4](1997) -Chemical Use Reporting[5](1997)	- Pollutant Release and Transfer Registers Law [PRTR Law] (1999)
2000-2004	-EPA held an on-line public dialogue on options for reducing the burden on the regulated industry associated with the Toxics Release Inventory (TRI) program (2003)	- Law Concerning Special Measures against Dioxins (2000) -Amendment of Chemical Substances Control Law [induced concept of environmental risk impact into ecological system] (2003)
2005-2009	- EPA revised the TRI reporting requirements to reduce burden and promote recycling and treatment as alternatives to disposal and other releases (2006)	- Amendment of Air Pollution Control Law [start restriction of VOC emission] (2006)

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[4] Seven new industry sectors are added.

[5] Expansion of the TRI to gather chemical use information and Expansion of the EPA Community Right-to-Know Program to increase the information available to the public on chemical use.

Table 3. Firms by industry type

Industry type	Type of business	Code	U.S.	Japan
Basic Material industry	Rubber and Plastic products	RUBB	14	43
	Chemicals and allied products	CHEM	54	122
	Paper and Pulp	PAPER	16	19
	Steel ,Non-ferrous metal	STEEL	23	63
	Fabricated metal	FABRI	19	28
Processing and assembly industry	Industrial Machine	MACHINE	49	68
	Electric product	ELEC	78	30
	Transportation equipment	TRANS	39	69
	Precision instrument	PREC	38	24

Table 4. U.S. industrial firms data description

	Total revenue (millions U.S.$)		Capital stock (millions U.S.$)		Cost of sales (millions U.S.$)		Number of Employees (person)		Toxic Risk Score (integrated million pound)	
	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.
1999	3,676	12,774	1,102	3,419	2,414	8,714	15,137	36,610	154	635
2000	4,083	13,759	1,187	3,578	2,622	9,797	16,048	36,877	159	627
2001	4,099	13,418	1,227	3,728	2,721	9,819	15,520	35,437	130	497
2002	4,206	14,084	1,275	3,996	2,750	9,980	15,501	34,835	145	589
2003	4,429	14,180	1,335	4,288	2,822	10,169	15,277	34,403	181	827
2004	4,905	15,103	1,359	4,662	3,003	10,536	15,661	34,547	136	647
2005	5,067	14,909	1,335	4,733	3,070	10,649	16,049	35,442	125	577
2006	5,338	15,617	1,389	4,937	3,125	10,258	16,455	34,499	144	674
2007	5,603	14,980	1,442	5,036	3,271	10,361	16,792	34,510	124	623

Table 5. Japanese industrial firms data description (1$=100 yen)

	Total revenue (millions U.S.$)		Capital stock (millions U.S.$)		Cost of sales (millions U.S.$)		Number of Employees (person)		Toxic Risk Score (integrated million pound)	
	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.
2001	1,934	5,824	2,849	6,731	1,371	3,848	1,333	4,268	389	2,045
2002	1,990	6,032	2,689	6,394	1,370	3,890	1,389	4,486	264	1,487
2003	2,057	6,166	2,584	6,082	1,462	4,225	1,408	4,537	193	1,052
2004	2,821	6,771	2,547	5,986	1,500	4,376	1,494	4,838	151	798
2005	2,523	7,861	2,557	6,021	1,618	4,689	1,628	5,360	140	815
2006	2,842	8,928	2,588	6,112	1,680	4,929	1,782	5,939	176	1,296
2007	3,082	9,755	2,601	6,025	1,758	5,060	1,301	5,218	23	261
2008	2,970	9,235	2,652	6,183	1,677	4,620	1,113	4,382	22	261

Table 6. Result of EFFCH and TECHCH indicator in U.S. manufacturing firms

	Indicator	1999	2000	2001	2002	2003	2004	2005	2006	2007	Type
RUBB	EFFCH	0.00	0.02	0.01	-0.00	0.00	0.02	0.03	0.02	0.01	IMP
	TECHCH	0.00	-0.02	-0.04	-0.01	0.03	0.09	0.13	0.14	0.15	
CHEM	EFFCH	0.00	-0.05	-0.08	-0.20	-0.10	-0.05	-0.09	-0.10	-0.24	FS
	TECHCH	0.00	-0.00	0.06	0.20	0.12	0.07	0.15	0.12	0.28	
PAPER	EFFCH	0.00	-0.01	-0.02	-0.00	-0.01	-0.00	-0.00	-0.00	0.01	IMP
	TECHCH	0.00	0.00	0.00	-0.01	0.01	0.04	0.06	0.08	0.12	
STEEL	EFFCH	0.00	-0.02	0.00	-0.02	-0.01	-0.05	-0.03	-0.06	-0.03	IMP
	TECHCH	0.00	0.05	0.03	0.03	0.03	0.12	0.11	0.20	0.21	
FABRI	EFFCH	0.00	-0.02	-0.06	-0.05	-0.07	-0.03	-0.00	-0.05	-0.01	IMP
	TECHCH	0.00	-0.02	-0.00	0.01	0.02	0.03	0.00	0.08	0.14	
MACHINE	EFFCH	0.00	-0.00	-0.03	-0.04	-0.07	-0.08	-0.11	-0.12	-0.11	IMP or FS
	TECHCH	0.00	0.13	0.18	0.22	0.34	0.43	0.51	0.63	0.67	
ELEC	EFFCH	0.00	0.03	0.14	0.10	0.05	0.04	0.09	0.10	0.08	IMP and CU
	TECHCH	0.00	0.06	-0.06	-0.04	0.10	0.21	0.26	0.31	0.38	
TRANS	EFFCH	0.00	-0.00	-0.00	0.00	-0.00	0.02	0.03	0.06	0.07	IMP and CU
	TECHCH	0.00	0.02	-0.04	-0.04	-0.01	0.01	0.03	0.06	0.09	
PREC	EFFCH	0.00	-0.12	-0.09	-0.08	-0.15	-0.19	-0.14	-0.19	-0.11	IMP or FS
	TECHCH	0.00	0.25	0.28	0.24	0.39	0.56	0.61	0.68	0.74	

IMP: Improved as overall effect, FS: Frontier shift, CU: Catch up.

Table 7. Result of EFFCH and TECHCH indicator in Japanese manufacturing companies

	Indicator	2001	2002	2003	2004	2005	2006	2007	2008	Type
RUBB	EFFCH	0.00	0.00	0.03	0.01	0.02	0.03	-0.41	-0.37	FS and IMP
	TECHCH	0.00	0.01	0.04	0.17	0.27	0.34	1.11	1.20	
CHEM	EFFCH	0.00	-0.02	0.01	0.02	-0.00	0.04	-0.22	-0.20	FS and IMP
	TECHCH	0.00	0.07	0.09	0.14	0.21	0.31	0.76	0.80	
PAPER	EFFCH	0.00	0.02	0.01	0.01	0.02	0.01	-0.04	-0.05	FS and IMP
	TECHCH	0.00	0.02	0.11	0.11	0.13	0.17	0.55	0.55	
STEEL	EFFCH	0.00	0.02	0.03	0.01	-0.00	-0.03	-0.24	-0.39	FS and IMP
	TECHCH	0.00	-0.02	-0.04	0.01	-0.03	0.10	0.55	0.63	
FABRI	EFFCH	0.00	0.01	-0.03	-0.03	-0.03	0.01	-0.16	-0.18	FS
	TECHCH	0.00	-0.05	0.01	-0.01	0.02	0.05	0.43	0.26	
MACHINE	EFFCH	0.00	-0.00	0.03	0.06	0.05	0.06	-0.14	-0.19	FS and IMP
	TECHCH	0.00	0.01	0.02	0.05	0.10	0.15	0.59	0.64	
ELEC	EFFCH	0.00	-0.03	0.28	0.26	0.29	0.31	-0.16	0.00	FS and IMP
	TECHCH	0.00	0.17	0.01	0.16	0.34	0.44	1.15	1.02	
TRANS	EFFCH	0.00	0.05	0.08	0.06	0.06	0.08	-0.04	-0.07	FS and IMP
	TECHCH	0.00	-0.05	-0.06	0.01	0.06	0.06	0.43	0.53	
PREC	EFFCH	0.00	-0.00	-0.01	0.01	0.00	0.00	-0.18	-0.19	FS and IMP
	TECHCH	0.00	-0.01	-0.05	0.01	0.04	0.07	0.47	0.45	

IMP: Improved as overall effect, FS: Frontier shift, CU: Catch up