https://doi.org/10.1007/s10018-015-0127-0

Did the Financial Crisis Affect Environmental Efficiency? Evidence from the Japanese Manufacturing Sector

Hidemichi Fujii[1], A. George Assaf[2], Shunsuke Managi[3,4*], Roman Matousek[5]

[1] Graduate School of Fisheries and Environmental Sciences, Nagasaki University, 1-14 Bunkyo-machi, Nagasaki 852-8521, Japan, E-mail: hidemichifujii@nagasaki-u.ac.jp

[2] University of Massachusetts Amherst, 209A Flint Lab, Amherst, United States, E-mail: assaf@isenberg.umass.edu

[3] School of Engineering, Kyushu University, 744 Motooka, Nishiku, Fukuoka, 819-0395, Japan.

[4] Queensland University of Technology, Level 8, Z Block, Gardens Point, 2 George St, Brisbane QLD 4000, Australia, E-mail: manage.s@gmail.com * Corresponding Author

[5] The University of Kent, Kent Business School, Canterbury, Kent, United Kingdom, E-mail: rom.matousek@gmail.com

Abstract

This study examined the impact of the financial crisis on the environmental and technical efficiencies of the Japanese manufacturing industry. Overall, we found that while the crisis had a negative impact on technical efficiency it did not affect environmental efficiency- the only exception was the transportation equipment sector which improved its environmental efficiency following the crisis. Additionally, we found that capital intensity does not necessarily affect environmental efficiency. We discuss the implications of these findings and provide directions for future research.

Keywords: Environmental Efficiency; Technical Efficiency, Financial Crisis; Bayesian Stochastic Frontier

1. Introduction

The financial crisis has increased consumer fears and caused rapid decrease in market demand (Morita, 2014). Many sectors including the manufacturing sector have experienced a decrease in total factor productivity due to the low facility operation rate by production adjustment (Fujii, 2011; Pratap and Urrutia, 2012; Coulibaly et. al., 2013). This has however allowed manufacturing firms to decrease their energy consumption (Bekhet and Yasmin, 2014).

The country of Japan, for instance, has successfully achieved Kyoto protocol agreement due to the reduction effects of greenhouse gas (GHG) emissions triggered by the global financial and the collapse of Lehman Brothers[1] (Kuramochi (2015). Between all industries, the manufacturing industry has experienced the most significant gain in environmental efficiency due to the continuous effort by many developing countries to enforce a scrap-and-build policy for their heavy industrial sectors[2].

At the firm level, manufacturing firms have also stopped running inefficient production lines, relying instead on high energy efficient production lines to minimize production costs. The Toyota Motor Corporation (2013, p.25), for example, has recently indicated that "the Myochi plant in Japan has been consolidating its production process in order to adjust its production capacity. Both an older line and a new line had been in use for the casting process, which consumes a large amount of energy. By consolidating production into the new line, which possesses higher energy efficiency, the Myochi Plant was able to reduce usage of contracted power supply by 30%, thus reducing CO_2 emissions per unit produced by 10%". Hence, if

[1] Dumontaux and Pop (2013, p. 269) indicated that "according to the bankruptcy petition #08-13555, filed on Monday, September 15th, 2008, Lehman's total assets of $639 billion made it the largest failure in US history, about six times bigger than the largest previous failure".

[2] According to Price et al. (2011, p. 2172), in 2007, "China's State Council announced a Comprehensive Working Plan for Energy Conservation and Emission Reduction to accelerate the closing of small plants and those with outdated capacity in 14 high energy-consumption industries: electric power, iron-making, steel-making, electrolytic aluminum, ferroalloy, calcium carbide, coking, cement, coal, plate glass, pulp and paper, alcohol, monosodium glutamate, and citric acid. The policy estimates that the closures will save 118 Mtce (3.46 EJ)".

manufacturing firms have an incentive to reduce energy improvement activities and eliminate inefficient production lines, the financial crisis may have triggered even further improvements in environmental efficiency.

As no study to date has assessed the relationship between environmental efficiency and the financial crisis, we aim in this study to test this relationship. Specifically, using a sample of firms from the Japanese manufacturing industry, we test whether the crisis has led to any significant reduction in environmental inefficiency. We also differentiate between various industries as the available energy saving activities during production adjustments are different among industries. Therefore, the characteristics of an industry must be considered when analyzing the determinants of environmental efficiency. The use of Japan as a context is by itself an important contribution as the Japanese manufacturing sector suffered a crucial decrease demand following the collapse of Lehman Brothers (Morita, 2014).

The rest of the paper is organized as follows: Next we describe the methodology. Section 3 describes the data. Section 4 presents the results. Finally, section 5 concludes.

2. Methods

We use a Bayesian stochastic frontier analysis to obtain measures of technical efficiency (TE) and environmental efficiency (EE) of firms in our sample. While our interest lies mainly in testing the impact of the financial crisis on EE, we felt that including TE would provide a more comprehensive assessment of the impact of the financial crisis on the performance of Japanese firms.

To measure EE and TE we use the methodology of Fernandez et al. (2002). Specifically, the estimation of EE involves the use of both good and bad outputs (e.g. CO_2) in a distance frontier framework. Firms are deemed to be environmentally efficient if they produce a minimum level of bad outputs given their inputs. As the methodology is well established in the literature, we refer the reader to Fernandez et al. (2002) for more technical details.

We used a Tobit analysis to test the impact of the financial crisis on TE and EE[3]. To illustrate, within the context of EE, the Tobit model can be expressed as follows.

$$EE_i^* = \beta_0 + \beta \mathrm{X}_i + \varepsilon_i \quad (1)$$

$$EE_i = EE_i^* \quad if \ \ 1 \geq EE_i^* \geq 0 \quad (2)$$

$$EE_i = 0, otherwise \quad (3)$$

An important issue was to define the financial crisis. We focus here on the financial crisis triggered by the collapse of Lehman brothers (September 15, 2008), which forced many manufacturing firms around the world to cut down their production scale in order to face the drop in market demand (Coulibaly et.al., 2013; Nguyen and Qian, 2014).[4] Hence, our financial crisis is defined in a dummy fashion as follows:

$$CRISIS = \begin{cases} 1 & if\ year = 2008\ or\ year = 2009 \\ 0 & else \end{cases} \quad (4)$$

where CRISIS reflects the effect of the financial crisis .

Based on this research framework, we aim to test whether the crisis has improved EE. As mentioned, we expect a positive relationship between the crisis and EE as most manufacturing

[3] Note that one cannot use normal regression here as the measures of TE and EE estimated in 1st stage are censored between zero to one.

[4] Because the collapse of Lehman Brothers occurred in September 2008, the financial crisis affected both 2008 and 2009 (Coulibaly et.al, 2013). To check the robustness of our estimation, we apply another financial crisis dummy (called Crisis') defined by Crisis'=1 if year =2009, Crisis' = 0 if year is not 2009. Overall, we found high consistency in the results. More details can be obtained from the authors upon request.

sectors adjusted their production lines following the crisis. Furthermore, we expect higher EE for those manufacturing sectors with stronger capital intensity as these have experienced higher level of production adjustments. We test for this issue by taking the cross product of the "CRISIS" dummy and a variable introduced to represent capital intensity.

3. Data

For the estimation of EE and TE, we rely on the Nikkei NEEDS financial database and the GHG Emission Data report. The latter is particularly used to obtain data on CO_2 emissions[5]. We use the following outputs and inputs for efficiency estimation.

- Good output: Sales
- Bad Output: CO_2
- Inputs: capital stock, number of employees, and intermediate material inputs.

Our sample covers four years of data (2006-2009) for 436 Japanese firms. We deflate the financial variables by the 2005 price for each type of industry.[6] The sample covers eight manufacturing sectors classified using the Japan Standard Industrial Classification (JSIC)[7] : (1) food, beverage, tobacco, and feed (Food: JSIC = 9 & 10); (2) production and business machinery (Machinery: JSIC = 25 & 26 & 27); (3) electrical machinery and devices (Electrical products: JSIC = 29); (4) transportation equipment (Transportation equipment: JSIC = 31); (5) chemical and applied product (Chemical: JSIC = 16); (6) rubber products (Rubber: JSIC = 19); (7) fabricated metal products (Fabricated metal: JSIC = 24) and (8) ceramic, cement, stone and

[5] This is obtained from the Mandatory Greenhouse Gas Accounting and Reporting System of the Ministry of the Environment.

[6] Deflators for the Japanese firms come from the Statistics Bureau and the Bank of Japan database.

[7] Detail information about JSIC is described on the HP of Ministry of Internal Affairs and Communications. (http://www.soumu.go.jp/english/dgpp_ss/seido/sangyo/index.htm)

clay products (Cement: JSIC = 21). Table 1 which shows some descriptive statistics for each of the input and output variable divided by type of sector clearly illustrates the drop in sales for most sectors following the financial crisis

<Table 1 about here>

As mentioned, for the Tobit analysis, we use a dummy variable to represent the financial crisis (CRISIS).We also use a capital intensity variable (capital stock per number of employee) to control for the impact of capital capacity in the production process. In general, a high capital-intensive firm is supposed to enjoy higher environmental efficiency (Fujii et al., 2010), and lower capital turnover due to the high dependency on capital equipment (Fujii et al., 2013). As discussed above, this paper takes the cross product of "CRISIS" and capital intensity to test the impact of capital intensity before and after financial crisis. We also use a petroleum price index provided by the International Monetary Fund[8] to control for the impact of external market conditions. For instance, the petroleum price affects a firm's production plan and its strategy to maximize corporate profit.

4. Results

We present in Table 2 the results of our Tobit analysis. The table is divided into two parts. The first part shows the results of from three different models (models 1-3) where TE acts as a dependent variable. These same models (models 4-6) are then repeated in the second part of the

[8] Price index is available from following home page. http://www.imf.org/external/np/res/commod/Table1a.pdf

table where EE acts as a dependent variable. Along, with the independent variables discussed above, we also use an industry dummy variable to control for the effect of industrial characteristics in each model.

<Table 2 about here>

First, we can see from models 1 and 2, that the crisis has a significant negative effect on TE. Additionally, the capital intensity variable is negative and significant in model 2, indicating that high capital intensive companies suffered a stronger drop in technical efficiency over the period of this study. The negative and significant coefficient of the “Crisis” variable in line with previous studies focusing on the effect of the financial crisis on the technical efficiency of Japanese manufacturing firms (Fujii et.al., 2011; Morita, 2014).

Surprisingly, the impact of the crisis on EE, though correctly signed (i.e. positive), does not seem to be significant (as indicated from models 4 -6). The interaction between the crisis and capital intensity is also not significant. Somehow, a different picture, however, is indicated from table 3 and table 4 which show the results of Tobit analysis separated by each manufacturing sector. We can see for instance, that while the impact of the crisis on environmental efficiency is positive and significant in the context of the transportation equipment sector, it remains insignificant for the remaining sectors. A possible explanation to this is that because this sector suffered a significant drop in demand, there was a stronger need to cut environmental inefficiencies around the crisis period.

<Table 3 about here>

<Table 4 about here>

5. Concluding Remarks

This study examined the impact of the financial crisis on the environmental and technical efficiencies of the Japanese manufacturing industry. We estimated both technical and environmental efficiencies using a Bayesian stochastic frontier approach, and then conducted a second-stage Tobit analysis to assess the impact of the financial crisis across several manufacturing sectors.

Overall, we found that the while the impact of the crisis is negative and significant in the context of TE, it is largely insignificant in the context of EE, with the only exception being the transportation equipment sector. Furthermore, we showed that the interaction between the capital intensity variable and the crisis is not significant in the context of the transportation equipment sector.

While our results are not very conclusive, it seems that the impact of the crisis is sector specific. We encourage future research to look more carefully at each sector separately. Policy makers may also need to consider the industrial characteristics of production when suggesting the economic recovery policy for manufacturing firms. Further research may also need to investigate the differences in environmental efforts between the service and manufacturing industries. Such analysis may provide more implications in terms of industrial characteristics.

References

Bekhet, H.A., Yasmin, T. (2014). Assessment of the global financial crisis effects on energy consumption and economic growth in Malaysia: An input–output analysis. International Economics, 140, pages 49–70

Coulibaly, B., Sapriza H., Zlate, A. (2013). Financial frictions, trade credit, and the 2008–09 global financial crisis. International Review of Economics & Finance. 26, pages 25–38.

Dumontaux N., Pop. A., (2013). Understanding the market reaction to shockwaves: Evidence from the failure of Lehman Brothers. Journal of Financial Stability. 9(3), pages 269–286.

Kuramochi, T. (2015). Review of energy and climate policy developments in Japan before and after Fukushima. Renewable and Sustainable Energy Reviews, 43, pages 1320–1332.

Fernandez, C., Koop, G., & Steel, M. F. (2002). Multiple-output production with undesirable outputs. *Journal of the American Statistical Association*, *97*(458).

Fujii. H., Kaneko, S., Managi, S. (2010). Changes in environmentally sensitive productivity and technological modernization in China's iron and steel industry in the 1990s. Environment and Development Economics, vol.15(4), pp.485-504.

Fujii, H., Managi, S., Kawahara. H. (2011). The Pollution Release and Transfer Register system in the U.S. and Japan: An analysis of productivity. Journal of Cleaner Production, vol.19(12), pp.1330-1338.

Fujii, H., Iwata, K., Kaneko, S., Managi, S. (2013). Corporate environmental and economic performances of Japanese manufacturing firms: Empirical study for sustainable development. Business Strategy and the Environment vol. 22(3), pp. 187-201.

Morita, H. (2014). External shocks and Japanese business cycles: Evidence from a sign-restricted VAR model. Japan and the World Economy 30, pages 59–74.

Nguyen, H., Qian, R. (2014). Demand collapse or credit crunch to firms? Evidence from the World Bank's financial crisis survey in Eastern Europe. Journal of International Money and Finance, 47, Pages 125–144.

Pratap, S., Urrutia, S., (2012). Financial frictions and total factor productivity: Accounting for the real effects of financial crises. Review of Economic Dynamics. 15(3), pages 336–358.

Price L., Levine MD., Zhou N., Fridley D., Aden N., Lu H., McNeil M., Zheng N., Qin Y., Yowargana P. (2011). Assessment of China's energy-saving and emission-reduction accomplishments and opportunities during the 11th Five Year Plan. Energy Policy 39(4): 2165-2178.

TOYOTA MOTER COOPERATION (2013). Respect for the Planet-Toyota's Environmental Initiatives-. http://www.toyota-global.com/sustainability/report/archive/er13/

Table 1. Descriptive Statistics (Average score)

	Year	Food (65)	Machinery (69)	Electrical Products (38)	Transportation Equipment (70)	Chemical (119)	Rubber (16)	Fabricated Metal (28)	Cement (32)
Sale	2006	126,868	149,837	393,909	668,194	141,215	157,390	57,380	111,011
	2007	130,540	156,208	407,987	701,170	149,714	168,913	59,906	111,668
	2008	133,260	135,744	344,385	570,314	140,728	159,464	55,602	109,535
	2009	130,176	107,803	312,660	523,488	134,032	132,364	46,631	96,999
GHG (ton-CO_2)	2006	59,900	60,894	84,592	168,491	418,924	160,170	46,677	1,419,677
	2007	59,525	47,674	84,847	162,360	449,672	55,182	51,375	1,325,765
	2008	60,495	39,474	86,232	141,410	415,893	148,785	46,335	1,278,660
	2009	63,315	32,654	75,413	129,030	399,226	140,382	45,108	1,115,148
Employee (person)	2006	1,274	1,907	4,131	6,189	1,392	2,438	992	1,373
	2007	1,272	1,975	4,163	6,346	1,447	2,491	1,042	1,477
	2008	1,286	2,102	4,200	6,492	1,474	2,573	1,073	1,482
	2009	1,309	2,097	4,061	6,594	1,480	2,590	1,076	1,475
Capital	2006	67,672	108,984	263,192	407,043	127,507	154,790	37,939	129,583
	2007	67,580	112,876	268,638	396,330	127,403	154,042	41,138	133,136
	2008	66,621	117,907	254,714	369,736	126,301	145,626	44,002	128,725
	2009	73,043	124,370	290,437	388,931	136,981	157,374	44,614	134,881
Material	2006	85,174	96,657	298,180	520,503	87,103	113,803	40,916	76,698
	2007	86,884	99,013	308,150	540,399	91,276	119,018	42,098	75,933
	2008	87,054	87,152	261,369	452,609	84,608	114,983	40,532	75,465
	2009	86,330	75,088	242,641	434,755	78,966	97,744	36,636	67,556

Note1: Unit of Sale, Capital, and Material data are million Japanese Yen (2005 year price).

Note2: Figure in parentheses represent number of firms in each industry.

Table 2. Tobit Analysis

	Dependent variable is TE						Dependent variable is EE					
	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Crisis	-0.002	*	-0.002	*	-0.001		0.004		0.004		0.024	
oil price	0.000		0.000		0.000		-0.014		-0.007		-0.008	
Intensity	-		-0.027	***	-0.017		-		1.176	***	1.377	***
Crisis*Intensity	-		-		-0.018		-		-		-0.375	
Constant	0.796	***	0.798	***	0.798	***	0.883	***	0.781	***	0.771	***
Industry dummy	YES		YES		YES		YES		YES		YES	
# of obs	1,744		1,744		1,744		1,744		1,744		1,744	
F-value	80.09		69.72		63.56		416.52		335.60		311.18	
Prob > F	0.000		0.000		0.000		0.000		0.000		0.000	

Note: *, **, and *** indicate statistical significance at the 10, 5%, and 1% levels, respectively.

Table 3. Result of Tobit analysis (dependent variable is TE) by type of industrial sectors

	Food		Machinery		Electrical Products		Transportation Equipment		Chemical		Rubber		Metal		Cement	
Crisis	-0.002		-0.004	**	-0.007		-0.001		0.003		0.004		0.006		-0.001	
Oil price	0.001		-0.002		0.001		-0.000		0.002		-0.004		-0.005		0.001	
Intensity	-0.021		-0.031	***	-0.508	***	0.067	***	0.124	***	0.352	***	0.234		-0.074	***
Crisis*Intensity	0.017		0.009		-0.074		0.021		-0.036		-0.015		-0.077		-0.035	
Constant	0.793	***	0.792	***	0.805	***	0.795	***	0.7648	***	0.776	***	0.791	***	0.802	***
# of obs	256		276		152		280		476		64		112		128	
F-value	0.68		10.23		13.88		3.02		10.56		8.64		1.78		3.73	
Prob > F	0.607		0.000		0.000		0.018		0.000		0.000		0.137		0.007	

Note: *, **, and *** indicate statistical significance at the 10, 5%, and 1% levels, respectively.

Table 4. Result of Tobit analysis (dependent variable is EE) by type of industrial sectors

	Food		Machinery		Electrical Products		Transportation Equipment		Chemical		Rubber		Metal		Cement	
Crisis	0.005		0.035		0.034		0.116	***	-0.024		0.053		0.037		0.005	
Oil price	-0.015	**	-0.029		-0.028		0.019		0.008		-0.033		0.001		-0.008	
Intensity	0.132	**	0.886	***	1.661	***	1.868	***	3.083	***	5.369	***	5.597	***	0.292	***
Crisis*Intensity	0.022		-0.147		0.391		-2.984	***	-0.009		-1.083		0.044		-0.036	
Constant	0.859	***	0.581	***	0.579	***	0.430	***	0.352	***	0.467	***	0.409	***	0.853	***
# of obs	256		276		152		280		476		64		112		128	
F-value	21.12		6.30		13.45		12.20		220.25		15.91		26.59		8.55	
Prob > F	0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.000	

Note: *, **, and *** indicate statistical significance at the 10, 5%, and 1% levels, respectively.