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Comparative study of linkage between environmental policy instruments and technological innovation: Case study on end-of-life vehicles technologies in Japan and EU

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ABSTRACT

A growing population and urbanization is a challenge for finite natural resources. Without strict regulation to recycle, recover and reuse resources, waste is discarded with no value. Every year throughout the world, more than twenty-five million vehicles turn into end-of-life vehicles (ELV) and most of their valuable resources end up in landfill sites. This research analyses the effect of regulation on ELV innovation for additional recovery of resources in Japan and EU nations using patent data as a proxy. The analysis determines the statistical difference in patent activity before and after regulations were enacted in the case studies. The relevant data on ELV technologies was gathered for the period 1985–2013. The study suggests that in general environmental regulation in Japan drove innovation and reveals that environmental policy in Japan was more effective in enabling innovation compared to EU nations. Specifically, the results from these developed countries can be used by the rapidly growing developing countries in automobile manufacturing like China for amendment of their ELV regulation accordingly.

1. Introduction

While technology innovation has helped increase the quality of life of people all over the world, it is also certain that leaving technology innovation to market forces alone has prevented the emergence of more environmentally-friendly technologies (Morioka et al., 2006). Since Porter (1991) argued that stricter environmental regulations could trigger innovations and increase the competitiveness of the industries many studies have found similar results. Governments implement environmental regulations to either internalize environmental cost so polluters make their own decisions regarding consumption of environmental inputs or impose a limit on the level of environmental pollution for the country innovate with social optimum (Johnstone et al., 2010a; Jaffe et al., 2003). This means that Environmental regulations play a central role in promoting technological innovation and there are basically two types of polices in this regard: market-based environmental policy instruments and performance standard approaches.

There has been extensive research on finding the relationship between regulation and innovation in energy sector (Jacobsson and Johnson, 2000; Bergek and Jacobsson, 2004; Popp, 2001; Agterbosch et al., 2004; Walz, 2007), climate change and air pollution (Popp, 2003, 2005; Jaffe et al., 2003; Johnstone et al., 2010b). In the case of waste management there are rather few studies. Yabar et al. (2012) for instance analyzed the linkage between regulation and innovations related to waste recycling and incineration and found a positive correlation. Singh et al. (2016) analyzed the linkage between regulation and automobile shredder residue (ASR) in Japan. Following our previous work this paper aims not only analyze the policy innovation linkage of ELV in Japan but also compare the policy linkage between Japan and European Union (EU). Many theoretical papers highlight the advantage of market based mechanism over command-and-control (CAC) policies for inducing technological innovation (Magat, 1978; Milliman and Prince, 1989). And to measure the innovation patent is used as proxies. Patent data is most commonly used as a measure of technological innovation because they focus on outputs of the inventive process (Griliches, 1998; OECD, 2009). In the past, limited empirical studies investigated the linkage between environmental policy and innovation due to a lack of patent data availability (Popp, 2005). Now, these data are easily available from many

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countries. There have been many studies that try to find the effects of prices and environmental policies on technological innovation (Popp, 2005). Different studies indicate that patent data has many advantages compared to other alternative measures of innovation as follows (Hascic and Migotto, 2015; Popp, 2005; Yabar et al., 2012):

- They are commensurable because patents are based on an objective standard. They must satisfy the following three patentability criteria: novel, non-obvious (inventive step) and useful (with industrial application);
- They measure the intermediate outputs of the inventive process (in contrast to data on R&D expenditures that only measures the input on trade in commodities that do not necessarily embody any innovative technologies;
- Patent data is quantitative and is easy to use in statistical analysis;
- Patent data is widely available;
- The international patent system can be used to track the diffusion of technologies across countries;
- The rate of a given patent can display its potential for technological development and commercial value;
- Patent citations can help ascertain knowledge flow;
- The data can be disaggregated into specific technological fields, which is a key feature in studying "environmental" innovation.

This paper argues that CAC policies provide an advantage for inducing technological innovation. The focus of this paper is to compare the effectiveness of regulation on overall ELV technologies in Japan and the EU, In order to determine whether environmental policies were the actual drivers of specific innovations or not we analyzed the Japanese and European patent database. For the identification of the relevance of patents we analyzed the related technological processes include some information on the methodology and a summary of each chapter.

2. End-of-life vehicles (ELV) regulations in Japan

2.1. Past and present scenario of ELV

In the past, lack of specific regulation on ELVs caused extensive problems of illegal dumping of waste from automobiles. One good example is illegal dumping of automobile waste in Teshima Island in Kagawa prefecture, Japan. Similar illegal dumping of automobile waste forced the government to revise the Waste Management and Public Cleansing Law in 1994 (Takatsuki, 2003). Before the law, the ASR was thrown into inert landfill sites. Since 1996 after the revision of the law, it was compulsory to dispose ASR waste into controlled landfill sites (Singh et al., 2016). The management cost of controlled landfill sites is more expensive than the inert landfill sites. The reluctance of manufacturers to reduce ASR volume and lower the treatment cost made them to invest more on research and development to find different ways to reduce waste going to landfill and help in more recovery.

Further, to solve the ELV problem, the government made specific ELV regulations for ELV recycling in 2002, partially enforced in 2003 and fully enforced in 2005. The regulations focus on recovery and recycling of (i) Fluorocarbons, (ii) Airbags and (iii) ASR. Due to proper coordination among all the stake holders related to ELV recycling, the government was successful in establishing a recycling-oriented society where more recovery of resources is undertaken.

The government set the target for ASR recycling at 30% by 2005, 50% by 2010 and 70% by 2015 (Singh et al., 2016). The ASR recycling reached 62.8% in 2005, 82.5% in 2010 and 97.5% in 2014 exceeding the target set by the government (JARC, 2015).

3. End-of-life vehicles (ELV) regulations in European Union (EU)

3.1. Regulation and objectives

The first legislation was created in the European Union (EU) related to the generation and treatment of waste in 1975 and presently there are more than 20 pieces of legislation regarding waste management (Jackson, 2012). The laws were designed to recover more valuable materials dumped into landfills as resources that can be re-used, recycled or used as a source of energy (Jackson, 2012).

In 1989, the EU Commission's Strategy of Waste Management determined ELVs to be part of the priority waste stream (Mazzanti and Zoboli, 2005). The ELV recycling process was established about 50 years ago with the start of industrialized recycling of cars (Gradin et al., 2013). After many years of work, the Commission produced an ELV Directive proposal in 1997 (European Commission, 1997). The ELV Directive came into force on the 18th of September 2000 and states that vehicle manufacturers and material and equipment manufacturers have to meet the following objectives (Gerrard and Kandlikar, 2006):

- To reduce the use of hazardous substances during vehicle design.
- To design and produce vehicles which facilitate the dismantling, re-use, recovery and recycling of end-of-life vehicles.
- To increase the use of recycled materials in vehicle manufacture.
- To ensure that components of vehicles placed on the market after 1st July 2003 do not contain mercury, hexavalent chromium, cadmium or lead (with few exceptions).

3.2. Recycling of ELV and targets

A recycling system was in place prior to the ELV regulation and overtime improvement in ELV recovery was reflected in the national policies in use after the 1990s. Before the formation of ELV Directives in the EU, ELV regulations and voluntary agreements existed in 10 European countries (i.e. Austria, Belgium, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden and the U.K (Gerrard et al., 2006)). By 1994, the recycling rate for end-of-life vehicles was around 75% by mass, not because of regulation but due to the economic value of recoverable parts and materials (Klimisch, 1994). In those days' magnet was used to separate the iron after scrapping the automobiles. But the implementation of ELV recycling law increase the recycling level as it focus more on ASR. The separation technologies separate the valuables from ASR which is mixture of polymer and metals. The recovery target in EU for 2006 was on average 85% of ELV mass, out of which 80% needed to be reused or recycled (Gradin et al., 2013). Further, the recovery target for 2015 is on average 95% of ELV mass, out of which 85% needed to be reused or recycled (Gradin et al., 2013).

4. Empirical analysis

4.1. Model specification

The World Intellectual Property Organization (WIPO) or the International Patent Classification (IPC) and the Organization and Economic Cooperation and Development (OECD) Report for Total Environmental Patents (OECD, 2011) were used to identify relevant technologies and associated patent groups that is appropriate to the focus of the study. The WIPO classify the patent data by "Section" "Class" "Subclass" "Group" and "Complete classification symbol" (Hara et al., 2016). "Section" is the highest level of

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