Environmental Regulation and Innovation

A Case Study of Hazardous Substances

Draft

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1. Introduction

Since the idea of sustainability was proposed as one of the most important principles in guiding our thinking about our long-term relationship with the environment, we have been urged to take a balanced and integrated approach to the achievement of both environmental protection and economic development in the future (World Commission on Environmental and Development, 1987). While our standard of living has improved significantly in the past through the intensive industrial development, that has also produced undesirable emissions to the environment through numerous products useful in our life. As the natural environment does not possess an infinite carrying capacity, the current industrial input rates are increasingly interfering with the limited capabilities of ecosystems to cope with pollution. Responding to the serious concern on the ongoing contamination of air, water, and soil with pollutants such as non-degradable toxic metals, regulations and policies have been introduced by governments around the world for the aim of reducing emissions from industrial activities. We could observe some sign of decline in emissions rates in recent years, reflecting the efforts devoted for pollution abatement, particularly in countries located in the industrialized world.

There is a growing concern, however, about negative impacts of increasingly tightened environmental regulations on industry (Jaffe, Peterson, Portney, and Stavins, 1995). It is argued that stringent environmental regulations will force firms to invest a considerable amount of financial resources for compliance and that as a result their competitiveness will be lost against those in countries where lax regulations are implemented. In other words, environmental restrictions impose significant costs, slow productivity, and thereby hinder the ability of companies to compete in international markets (Palmer, Oates, and Portney, 1995). Theoretical analysis is often employed to show that environmental regulations should reduce productivity by requiring firms to spend additional resources for pollution abatement and control without increasing production output.

On the opposite side, an increasing number of people claim that stringent environmental regulations will enhance the competitive position of firms. For example, they argue that the ever-increasing stringency of environmental regulations will encourage firms to conduct more research and development (R&D) activities and, consequently, produce more innovation in the long run (Porter and van der Linde, 1995a). That is, the necessity to comply with environmental policy will prompt companies to re-examine their products and production processes carefully and in the end will lead to technological improvements. Spurred by stringent environmental regulations, companies will go beyond mere compliance with regulations and may succeed in creating radically new technologies. That means that regulation-induced R&D activities could lead to an innovation which has not discovered previously. Successful cases, many of which are those in the U.S., are cited to claim that stringent environmental regulations actually encourage innovation in industry (Porter and van der Linde, 1995b). Their views are conflicting, and the debate still continues. A careful analysis is required to fully evaluate the impacts of environmental regulation on innovation.

This study is aimed at examining empirically how environmental regulations affect the course and character of technological change through innovative activities of industry. As we can see in empirical studies conducted previously, it is very difficult to measure the stringency of environmental regulations and its effects on subsequent innovations at aggregate levels. To overcome the problems of previous empirical studies due to their aggregate nature and to understand well the nature of the relationship between environmental regulation and innovation, a detailed case study is conducted in this research. It is expected to shed complementary light on the question of how environmental regulations influence firms' activities with regard to the development and adoption of new technologies.

As stressed by the Organisation for Economic Co-operation and Development (1997), full development and extensive utilization of appropriate technologies in industry will be the key to achieving global sustainability. In this paper, we pick up the use of lead for solders and examine the impacts of environmental regulation on innovation by looking at the development of solders which do not contain any lead. Through our analysis of the case of innovation on lead-free solders, we discuss at the end of this paper some implications for considering how to formulate environmental policies in such a way as to encourage innovations on technologies that have the potential to reduce excessive environmental burdens while securing sound economic development.

2. Research on the Effects of Environmental Regulation on Technological Change

There are not so many empirical studies which examined the effects of environmental regulation on innovation[1]. And most of the previous studies were conducted at aggregate levels. As one of the influential studies in this area, Lanjouw and Mody (1996) used patent data to investigate the extent of innovation which occurred in the

[1] Relatively speaking, more research has been done on the diffusion of environmentally beneficial technologies, particularly those of the end-of-pipe type. For example, Kemp (1998) made a careful study of the diffusion of biological waste-water treatment technologies in the food and beverage industry in the Netherlands. Here the focus of our discussion is placed on previous studies of the development side of technological change.

1970s and 1980s. They found that the ratio of water pollution patents to total US patents was flat in the early 1970s and rose in the late 1970s to a new plateau, paralleling pollution control expenditures with a two- to three-year lag. And similarly the dramatic fall in water pollution control expenditure during the early 1980s was followed by a dip in patenting. The same pattern was also observed in industrial air pollution. Based on these findings, they suggest that certain plausible connections exist between environmental regulation and innovation.

In similar vein, Bhanagar and Cohen (1999) studied how environmental patent applications by U.S. manufacturing industries responded to environmental regulation during the period of 1983 through 1992. They found that environmental innovation, as measured by the number of successful environmental patent applications, responded to increases in pollution abatement expenditures. They also used government monitoring activities as a proxy for the stringency of environmental regulation and found that increased monitoring and enforcement activities related to existing regulations did not provide incentives to innovate. Ratnayake (1999) took a broader view of innovation, looking at R&D in addition to patents. He examined whether environmental regulations enhance or hinder R&D expenditures, using the data for eight major U.S. industries for the period from 1982 to 1992. His findings suggest no strong evidence to support the view that environmental regulations, measured by pollution abatement costs, have any significant impact on R&D expenditures on pollution abatement technologies.

Jaffe and Palmer (1997) looked at aggregate innovative activities rather than just environmental technologies. Using panel data on U.S. industries from the middle of the 1970s to the early 1990s, they found that lagged environmental compliance expenditures, which is used as an indicator of the regulatory stringency, have a significant positive effect on total private expenditures on R&D. However, they could not find any evidence that industries' inventive outputs, measured by successful total patent applications, were related to the compliance costs. They suggest that their finding might imply that incremental R&D activity induced by environmental regulations is not productive or produces results that accomplish only regulatory compliance but that do not come out as patentable innovations.

Overall, these studies produced mixed results on the impact of environmental regulations on innovation. These results require a careful examination, as the ways in which the stringency of environmental regulation and the extent of innovation are measured would pose some problems. Here we focus out attention to the latter. The analysis of innovation for environmental protection needs to be treated with caution. Lanjouw and Mody (1996) used patents on pollution control technology to examine the connections between environmental regulation and innovation. Their patent data cover nine environmental fields, namely, industrial and vehicular air pollution, waste pollution, hazardous and solid waste disposal, incineration and recycling of waste, oil spill clean-up, and alternative energy. Relevant patents were identified by determining the International Patent Classification (IPC) classes corresponding to various types of environmentally responsive innovation. For example, the IPC classes which are considered to include patents on technologies dealing with industrial air pollution are as follows: chemical purification of waste gases (B01D-53/34), chemical purification of waste gases by catalytic conversion (B01D-53/36), purifying/modifying gases containing carbon monoxide (C10K-1/3), adding materials to fuels or fires to reduce smoke (C10L-3), burning uncombusted material… (F23B-5), removing solid residues, i.e., soot blowers (F23J-3), and …devices for treating smoke or fumes (F23J-15). These

IPC classes were identified by using three keywords, namely, “treat,” “scrub,” and “remove.” Similarly, Bhanagar and Cohen (1999) used successful environmental patent applications as a proxy for environmental innovation. Those patents counted as environmental patents involve hazardous or toxic waste destruction or containment, recycling or reusing waste, acid rain prevention, solid waste disposal, alternative energy sources, air pollution prevention, and water pollution prevention. As we can see from these lists, most of the technologies identified as environmental technologies are equipment installed at the end of the main process to remove or reduce emissions. That is, these studies basically looked at end-of-pipe technologies when they examined the technological effects of environmental regulations. The case of clean technologies, that is, technologies for eliminating pollution from within the production process by changing the main chemical reaction and products which do not contain hazardous substances is missing from their consideration of innovations related to environmental protection.

Jaffe and Palmer (1997), on the other hand, used data on the whole R&D expenditures and patent applications in industries to examine the full extent of innovation. That is, their research covers not only technologies for environmental protection, which would include clean technologies as well as end-of-pipe technologies, but also technologies related to products and production processes in general. While this approach does not fail to capture innovations potentially influenced by environmental regulation in any way, many innovations which are not related to considerations for environmental protection are also included in the data set. Thus this method of technological measurement would not be entirely appropriate for the analysis of the effects of environmental regulation on technological change.

In sum, their results seem to suggest that increased stringency in environmental regulation encourages patent applications for environmental technologies, mainly those of the end-of-pipe type, but does not influence applications for patents on technologies in general. On the other hand, more stringent regulation seems to raise R&D expenditures in general, but not those on technologies designed for pollution abatement and control, which are basically end-of-pipe technologies. As these findings are mixed at aggregate levels, an in-depth analysis is necessary to thoroughly investigate the relationship between environmental regulation and technological change[2]. In particular, attention needs to be paid to the development of products which do not involve the use of hazardous substances such as heavy metals. While end-of-pipe process technologies are relatively easy to find, clean products are particularly difficult to identify at aggregate levels, as they do not involve pollutant emissions in the first place. Although traditionally the cause of industrial pollution has been mainly emissions from production processes, products are increasingly the source of environmental problems. Usually that means the existing products have to be replaced with different ones, as it would be difficult to achieve complete recycle of used products. New products need to be designed so that their detrimental effects on the environment will be eliminated, although their impacts on the environment may not be always predictable or even understood easily.

3. Environmental Regulation on the Use of Lead

Heavy metals including lead have been used intensively in industrial operations,

[2] Yarime examined the effects of environmental regulation on technological change in the chlor-alkali industry, with a clear distinction between end-of-pipe technologies and clean process technologies (Yarime, 2003).

discharging them into the air, water, or soil. According to one estimate, world-wide industrial emissions of cadmium (Cd), copper (Cu), zinc (Zn), and lead (Pb) into the atmosphere averaged approximately 380, 1,800, 17,000, and 22,000 tonnes per year, respectively, between 1850 and 1900 (Nriagu, 1979). From the beginning of this century to the 1980s, emissions of such heavy metals increased almost exponentially, roughly in parallel to the rate of industrial growth. In the period between 1900 and 1980 the atmospheric emission rates for copper, zinc, cadmium, and lead rose by six-, eight-, eight-, and nine-fold, respectively (Nriagu, 1994).

Among these heavy metals, lead was once used for an additive to gasoline, namely, tetraethyl lead, which provided a high-octane gasoline for many years. However, this substance has now been phased out in many parts of the world, including Europe, Japan, and the US, in favor of methyl *t*-butyl ether (MTBE). Commercial production of MTBE began in 1979, shortly after the discovery of its octane-improving capability for motor fuels. Although a higher proportion of this additive was required for equivalent octane enhancement, it was less costly and eliminated the hazardous lead particulate discharges associated with the tetraethyl lead previously used for this purpose. Hence the convenient industrial method of producing tetraethyl lead, that is, the reaction of a sodium-lead alloy with chloroethane was replaced with the liquid phase reaction of methanol with isobutylene, which gives this novel, oxygenated gasoline additive (Hocking, 1998).

Regulation on the use of lead was initiated in the United States, where lead was banned in the manufacture of paint in 1978 and for solders used for joining drinking water pipework in 1986. The question of a general ban, or tax on lead was then raised in the early 1990s through a series of proposed Bills in the House of Representatives and the Senate (Soldertec, 1998). The first Reid Bill (S.2637) was the major cause for concern for the electronics industry. Through this Bill, Senator Reid wished to introduce a U.S. Congress policy stating that further releases of lead into the environment should be minimized, and means should be developed and implemented to reduce exposures to existing sources of environmentally dispersed lead. More specifically, one year after the date of enactment of the proposals no person would be permitted to manufacture, process, or distribute in commerce any solder containing more than 0.1% lead by dry weight.

Following the ban on lead in plumbing solders in the U.S., some studies had been carried out on the possibilities of using similar lead-free alloys in electronics. This work in 1990, however, was fairly limited. In particular, no process trials of lead-free alloys had yet been performed, and specific alloys tailored to the application had yet to be developed. This lack of technical data on alternatives allowed the lead and electronics industries to lobby against the inclusion of electronic solder in the general ban on lead, with the main objection that no suitable lead-free alternatives were available. Various questions were also raised with regard to impacts on product cost and competitiveness, as it was generally assumed that lead-free products were more expensive than those made using tin-lead solder. That is, should U.S. consumers be made to pay this cost? Or would U.S. manufacturers be at a cost disadvantage in other export markets where lead containing products were still allowed.

Then a revision of S.2637 was introduced. This required additional work from the Environmental Protection Agency (EPA) to inventory all products containing lead and develop a “concern list” of all products that could be anticipated to present an unreasonable risk of injury to human health or the environment. Any person could petition EPA at any time to add a product to the list, and any person who manufactured or imported a lead-containing product not on the original inventory list would have to submit a notification to EPA. Products on the list could have to be labeled as such.

The revised Reid Bill (S.729) of 1993, including the requirement of EPA, was passed through the Senate in May 1994 and sent to the House of Representatives. The proposal, however, was returned to the Senate in July 1994, with a rejection as "… in the opinion of the House of Representatives it contravenes the U.S. Constitution and infringes on the privileges of the House." While the Reid Bill was proposed at a time when the U.S. Senate had a Democratic majority, the political climate changed significantly at the end of 1994, as congressional elections returned a Republican majority to both the Senate and the House. Republicans also gained majority representation on all committees, and interventionist policies were no longer favored. Since then, no further voluntary or legislative proposals affecting lead solders in the U.S. had been seen. Currently, while several states are initiating stepped-up recycling efforts for electronics, there is no known legislation requiring the elimination of lead from electronics in the U.S.

In Europe, legislation directly affecting the solder and electronic industries has been passed by the European Commission in the Waste Electrical and Electronic Equipment (WEEE) Directive and the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) Directive, outlining targets for electronic equipment reuse and recycling (European Parliament and Council of the European Union, 2003b, 2003a). A draft of WEEE directive was published for the first time in April 1999. The second draft, which was published in July 1998, included the proposed ban on the use of lead metal in electronics assembly and the timescale in which the ban was to be implemented by January 2004. The European Commission officially adopted the WEEE proposals in June 2000 as two separate but associated draft Directives for submission to the European Parliament. The RoHS proposals required substitution of lead and other various heavy metals and brominated flame retardants from January 2008. The European Parliament voted in May 2001 to adopt proposals to amend the date for the hazardous materials ban in the draft WEEE/RoHS Directives to 2006. The Council of Ministers, representing each Member State, discussed the proposals in June 2001. They set a target date of January 2007 for a hazardous materials ban. Then the European Council Common Position documents were returned to the European Parliament in December 2001. The plenary vote of the Parliament was taken in April 2002, confirming their original position of January 2006 for a lead ban and adopting a set of Amendments. After a conciliation process, both the Council and the Parliament gave official agreement to the draft final texts of the WEEE and RoHS proposals in December 2002, with a final implementation date of July 2006. The Directives were published in the Official Journal of the European Communities in February 2003 and came into force on that date. Each EU Member State has 18 months, until August 2004, to introduce the required national legislation.

Consumer and IT products are the categories mainly affected by the RoHS Directive. The Directive requires the use of lead, mercury, cadmium, hexavalent chromium, and two types of brominated flame retardants, namely, PBB and PBDE, to be phased out. Some exemptions are likely to be given for the continued use of lead and other hazardous materials in essential applications. One such example is high lead alloys used for high temperature soldering. This type of tin-lead solder generally contains 90 or 95% lead and is used for internal component connections and for other similar requirements. Slightly extended target dates may also apply to high reliability products such as network infrastructure.

In Japan, the subject of legislation to regulate the use of lead in solders has not yet been taken up. Nevertheless, the control of lead has been strengthened through such measures as the review of water quality standards concerning lead, the strengthening of amendments to the Waste Disposal Law, and the enactment in April 2000 of the Home Appliances Recycling Law originally introduced in 1998. Under this legislation, electronic devices containing lead can no longer be discarded unless they are dealt with properly.

4. Analysis of Innovation on Lead-Free Soldering Technologies

To make an in-depth investigation into companies' technological responses to these environmental regulations, we examine how and when companies conducted innovative activities. It is not easy, however, to secure detailed data on R&D activities specifically linked to particular technologies. Furthermore, the use of R&D measures is not always satisfactory as a proxy for a wide range of technical activities (Griliches, 1990; Freeman, 1994). We hence examine the outputs of technological activities conducted by companies. As an indicator of innovative outputs, patenting activity is analyzed in this paper. While we assume that patent data captures the extent of R&D activities made in industry reasonably well, patents do not necessarily reflect the degree of technological progress exactly. Hence other data on the trends in the performance of various technologies are also collected from other sources, including reports published in scientific, technical, and trade journals as well as papers presented at seminars and conferences. Interviews are also conducted with experts in industry to obtain information on the timing and extent of R&D activities of companies.

We first examine the trends in patent applications made by companies located in Japan, the United States, and Europe. As there are major differences among countries in procedures and criteria for granting patents (Patel and Pavitt, 1995), international comparisons are most reliable when international patenting or patenting in one country is used. We used data on US patents in this paper because companies not only in the United States but also those in Japan and Europe would be reasonably expected to have strong incentives to obtain patent protection in the world's largest market for their technologies. Data was obtained from the web-based patent database of the US Patent and Trademark Office. This database contains patents issued since January 1, 1976.

Figure 1 shows the trends in the US patents on lead-free soldering technologies successfully applied by companies in the United States, Japan, and Western Europe. As you can see, in the 1980s there were a small number of patents on technologies related to lead-free soldering, most of which were granted to those in the United States. Then in the early 1990s, the number of patents applied for by U.S. firms jumped, following the legislative move to regulate the use of lead in the United States. Patent applications by Japanese firms started to increase a few years later. While patents applied for by U.S. firms declined before the middle of the 1990s and have never returned to the level achieved in the early period of the same decade, the number of patents granted to Japanese firms continued to grow overall through the 1990s. A similar trend can be seen in Figure 2, which shows the number of applications for Japanese patents on technologies related to lead-free soldering.

Figure 3 gives the trends in patent applications made by major companies in the Japanese electric and electronic industry. While there were a small number of patents applied for by some companies in the middle of the 1990s, a surge in patent applications can be observed in the late 1990. In particular, Matsushita Electric Industry was leading the upward trend in the Japanese industry. A more detailed examination of patent applications by Matsushita Electric Industry, shown in Figure 4, indicates that in the early 1990s many of the company's patent applications were made jointly with other companies whereas in the late 1990s patents were mostly applied for independently by the company. That suggests that at the initial state of technological development for lead-free soldering the company worked with outside companies and then started to engage in independent research and development activities later.

To see the extent of research and development activities jointly conducted between companies, we examined the inter-firm relationships by using data on joint patent applications and licensing agreements. Figure 5 gives the network of actors in industry and academia involved in innovation on lead-free soldering technologies. You could see a cluster in the figure, with its center located in the position of a manufacturer of solders, Senju Metal Industry. Indeed, this company obtained a key patent on a type of lead-free solders and subsequently licensed the patent to many solder producers. Matsushita Electric Industry worked closely with several solder manufacturers including Senju Metal Industry particularly in the early state of technological development. This could be one of the reasons that Matsushita could successfully innovate on lead-free soldering in their products earlier than the company's rivals. Table 1 gives information on the introduction of products involving lead-free solders by other firms (Suganuma, 2002).

In this paper, we examined the effects of environmental regulation regarding the use of lead on innovative activities for the development of lead-free soldering technologies. Based on the relatively limited scope of the analysis carried out here, we could identify some reasons explaining why Japanese companies were relatively successful in developing lead-free soldering technologies ahead of their counterparts in Europe and the United States.

The move to develop lead-free soldering technologies at the industrial level in Japan was connected to the initiation of the Lead-Free Soldering Research Council in 1994 within the Japan Institute of Printed Circuits, which is currently the Japan Institute of Electronics Packaging. Since then, there have been several research consortiums, involving not only large manufacturers of consumer electronic products but also small firms producing materials and equipment for solders. Technological development and evaluation were carried out by industrial associations such as the Japanese Electronic Industries Development Association (JEIDA, currently JEITA) and the Japan Welding Engineering Society (JWES) (Yamamoto and Kobayashi, 2003). It seems that the road maps assembled by JEIDA and JEITA was particularly effective in coordinating the views and behavior of industrial actors, with clearly specified milestones towards the development of lead-free soldering technologies (Japan Electronic Industry Development Association, 2000; Japan Electronics and Information Technology Industries Association, 2002).

In the United States, immediately after the legislation on the use of lead in electronics was proposed, a four-year research initiative was started in 1994 to develop lead-free solders under the National Center for Manufacturing Sciences (NCMS) Lead-Free Soldering Project. The achievements of this project have been made available in its database, and information has been offered on various issues, such as the modification of equipment and the establishment of processes for selecting alternative materials. After the NCMS project was finished in 1997, the legislative move toward the use of lead-free solders waned, discouraging further research activities in the United States. The technological progress in Japan, coupled with the proposed regulation in Europe, however, gave creating a Task Force on lead-free soldering under the auspices of the National Electronics Manufacturing Initiative (NEMI) in May 1999. One of the main objectives of this group was set to obtain the capacity of manufacturing lead-free products by 2001, with a view to eliminating all lead by 2004. Corporate participants in this project included Celestica, Compaq, Delphi/Delco, Hp, Motorola, Intel, IBM, NIST, Nortel Networks, Solectron, and Visteon.

In Europe, the Improved Design Life and Environmentally Aware Manufacturing of Electronics Assemblies by Lead-Free Soldering (IDEALS) project was initiated in 1996 under the BRITE/EURAM programme, funded by the European Community (Marconi Materials Technology, 1999). The IDEALS project presented the first pan-European attempt to address the entire technology of the production of lead-free electronic assemblies. It featured a vertically integrated consortium of soldering consumables producers (Multicore Solders and Witmetaal/Alpha-Fry) and end-user organizations (Marconi Materials Technology, Philips, and Siemens), supported by the activities of a national center of excellence in microelectronics (NMRC). The targeted product sectors included applications in lighting, telecommunications, avionics, industrial control, and automotive control. This project was completed in 1999, concluding that a lead-free soldering technology based on Sn (Ag, Cu, Bi, Sb) alloys, possibly with minor additions to enhance aspects of soldering performance, would be technically and industrially viable.

Although large companies such as Philips and Siemens are achieving implementation of lead-free soldering, there was no pan-European industry forum, involving small- and medium-sized enterprises (SMEs), and no coherent information network or technology or research provider network has existed in Europe or the United States. One of the important issues which still remain is that there are many SMEs which are seriously lacking awareness and technology support. And implementation concerns on such issues as inventories, re-training, rework, reliability, labeling, are not yet addressed (Nimmo, 2003). As innovation on lead-free soldering technologies would require close and delicate coordination among solder materials, production process, measurement equipment, and final products, the lack of industry-wide cooperation could result in inadequate development and adoption of lead-free soldering technologies.

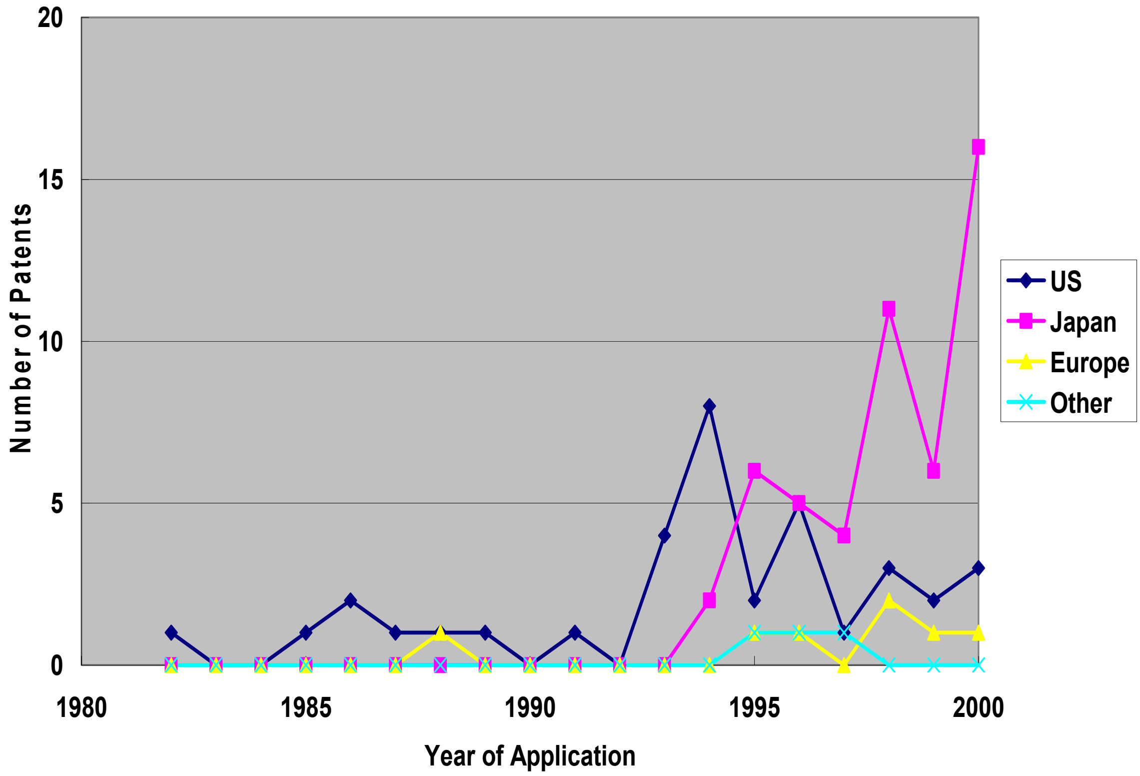

Figure 1 US Patents on Lead-Free Solders Applied by Companies in the United States, Japan, and Europe

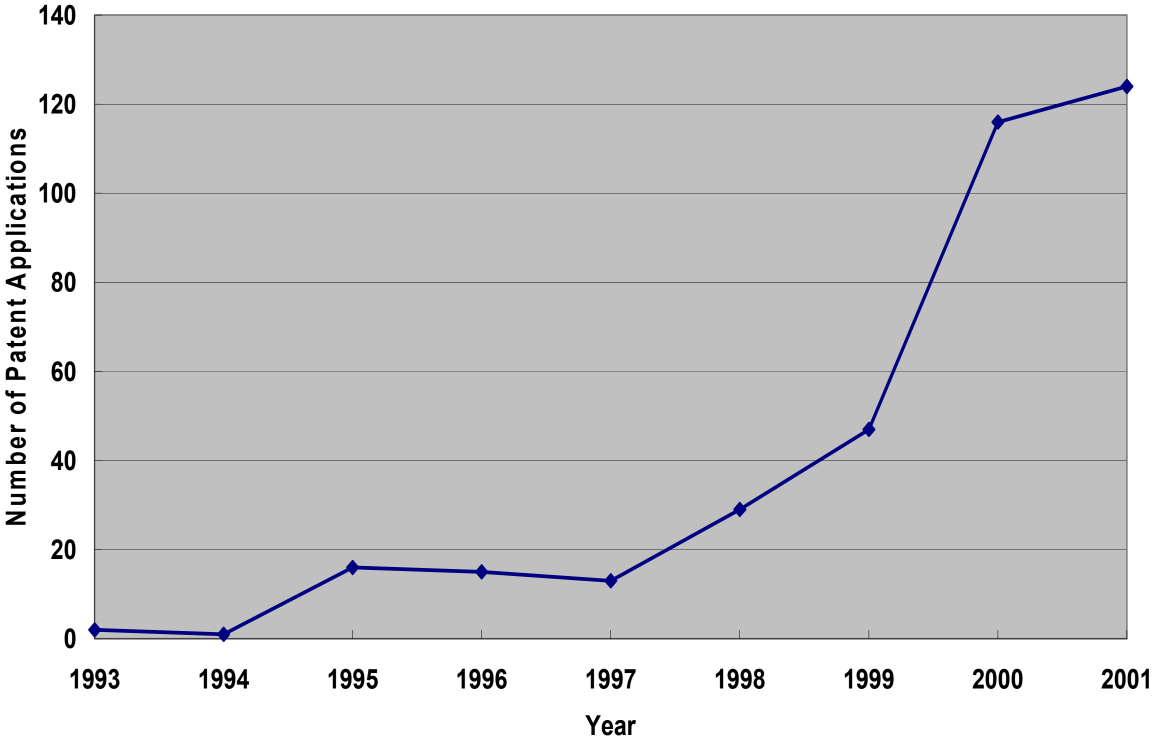

Figure 2 Application for Japanese Patents on Lead-Free Soldering Technologies

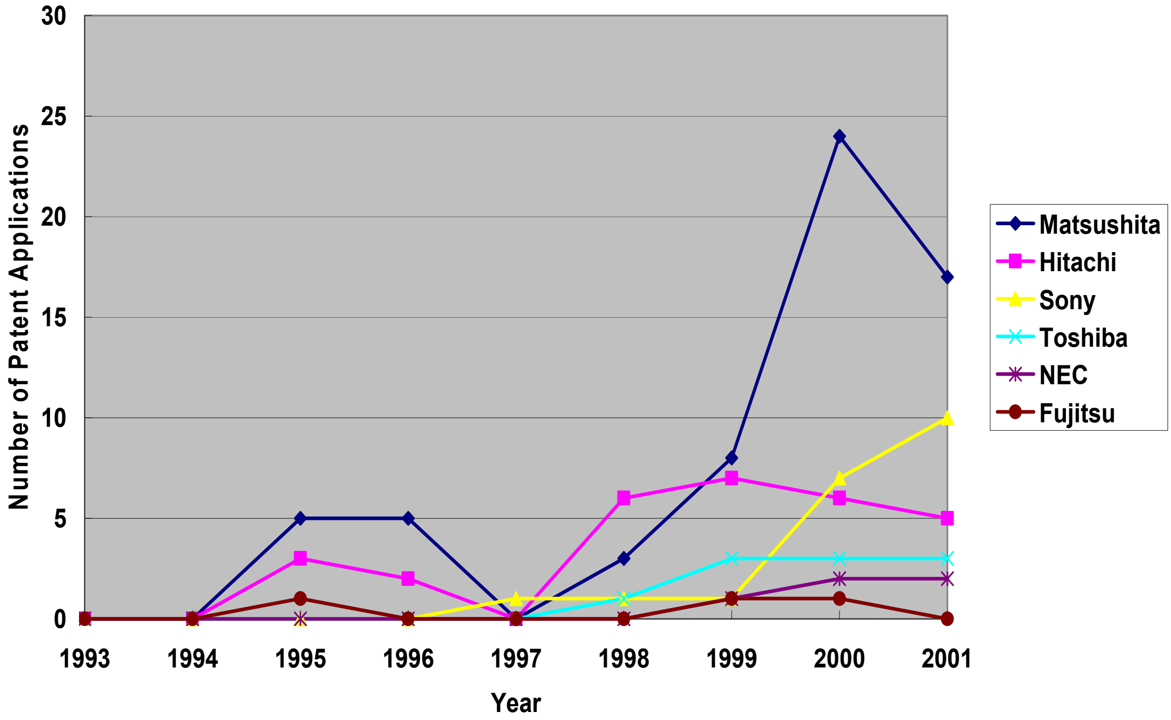

Figure 3 Application for Japanese Patents on Lead-Free Solders by Japanese Electronic Firms

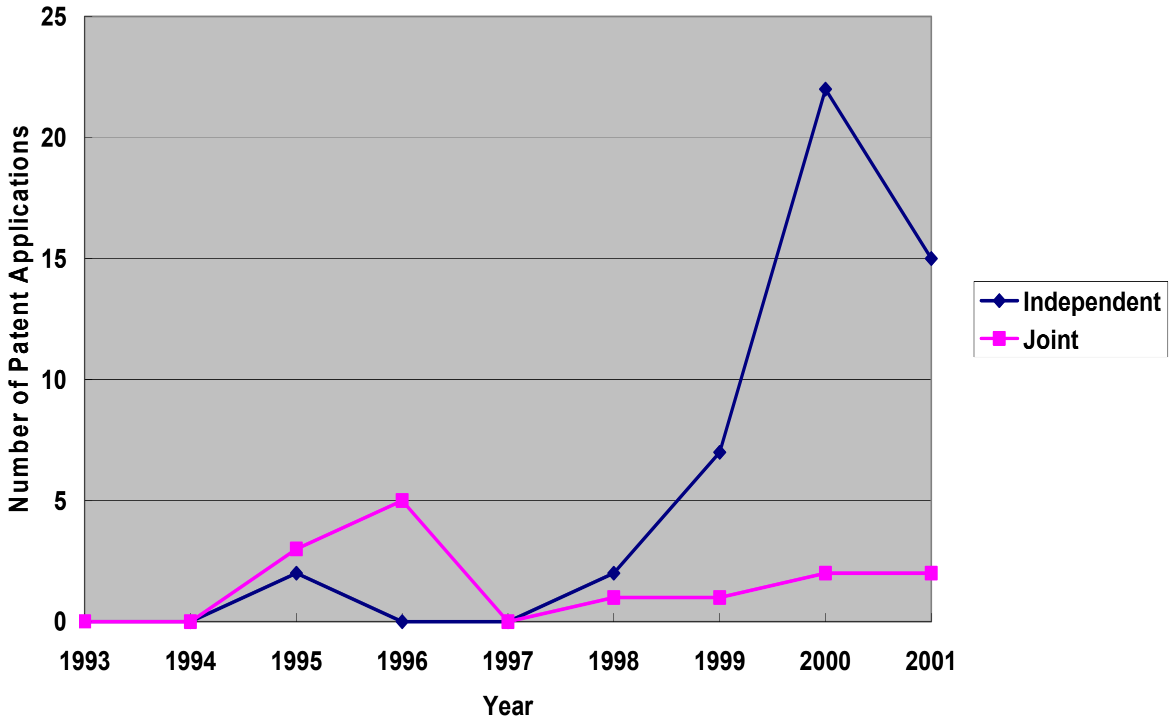

Figure 4 Application for Japanese Patents on Lead-Free Soldering Technologies by Matsushita Electric Industry

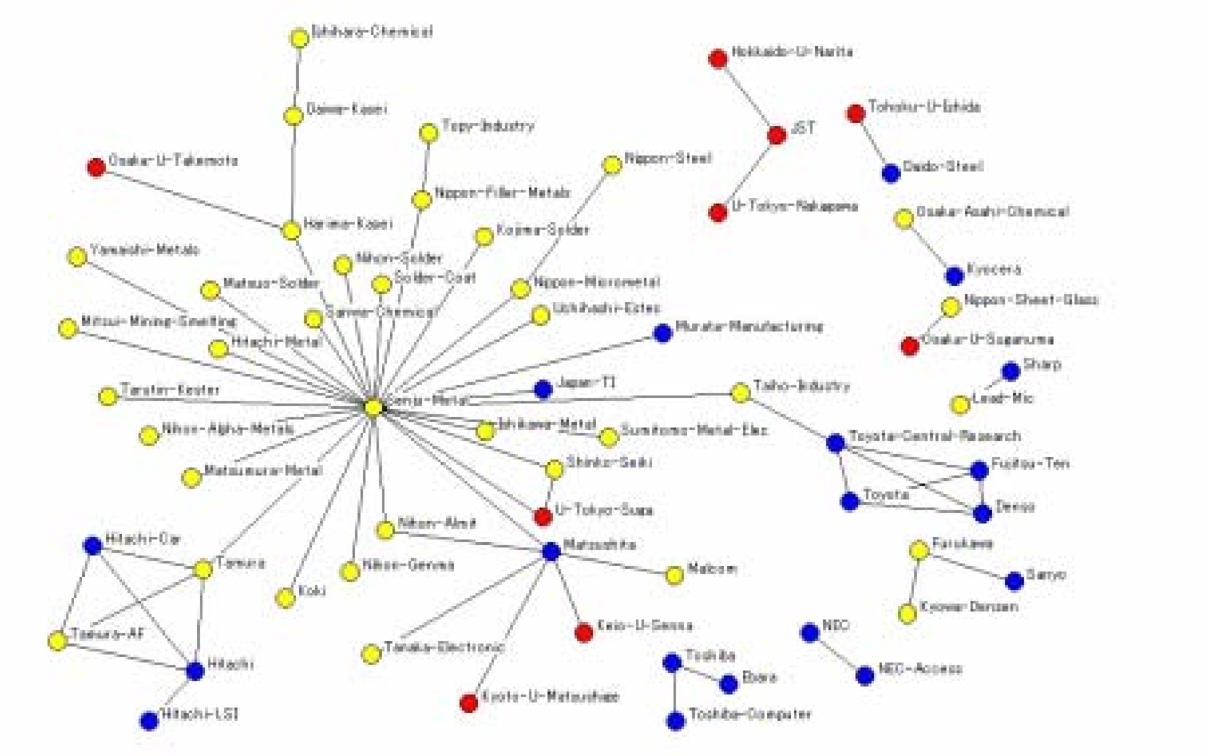

Figure 5 Network of Actors in the Development of Lead-Free Soldering Technologies in Japan

Table 1 Development of Lead-Free Soldering Technologies by Firms in the Electric and Electronic Industry

Manufacturer	Date	Development
Matsushita Electric Industry	Oct 1998	Applied to compact MD players
	End 1999	Applied to VCRs
	Jan 2000	Applied to cassette players
	End 2002	Eliminate all lead
NEC	Dec 1998	Applied to pagers (beepers)
	Oct 1999	Applied to notebook PCs
	Mar 2001	Reduce 1997 volume by half
	Dec 2002	Eliminate all lead
Hitachi	Feb, Oct 1999	Applied to camcorders, refrigerators
	From 2000	Applied to vacuum cleaners, washing machines, and air conditioners
	From 2000	Applied to notebook PCs
	Mar 2002	Reduce 1997 volume by half
	Mar 2002	Eliminate all lead in in-house manufacturing
	Mar 2004	Eliminate all lead in Hitachi Group
Sony	Mar 2000	Applied to camcorders
	Oct 2000	Applied to TVs, notebook PCs
	2005	Eliminate all lead
Toshiba	Dec 2000	Applied to TVs, refrigerators, washing machines, home laundry, cleaners, etc.
	2000	Applied to main products
	2003	Used in all products
Fujitsu	Oct 2000	Adopt lead-free for all LSI
	Dec 2001	Adopt lead-free for half of PWB
	Dec 2002	Eliminate all lead
Philips Electronics	Dec 1999	Applied to electric lighting PCBs
Ericsson	2001	Applied to cell phones
	2002	Adopt lead-free for 80% of new products and halogen-free PCBs
Motorola	Dec 2002	Applied to cell phones

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