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ORIGINAL PAPER

China's future investments in environmental protection and control of manufacturing industry: lessons from developed countries

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Abstract A country's manufacturing industry is an indicator of its economic competitiveness internationally. In 2009, China has its manufacturing added values surpassed the USA and now became the largest manufacturing country in the world, followed by Germany, the USA and Japan. However, manufacturing industry's development aggravates environmental resource externalities and environmental pollution. The controls for the environmental pollution are essential to achieve the manufacturing industry's sustainable development. In this comparative analysis, we examine environmental pollution control expenses, environment-related taxes and waste management capacities in the UK, Germany and Japan to seek the effective practices that China can follow to achieve sustainable development. We conclude that China's manufacturing industry needs more investments in environmental protection and control. To achieve sustainable development, recycling and environment-related taxes are effective methods for China's manufacturing industry besides government expenditures in environmental protection and control. Such measures would be a "win-win" for both economy and environment.

Keywords Manufacturing industry · Environmental protection · Sustainable development

1 Introduction

While the world has experienced rapid economic development and dramatic growth of population since the 1950s, environmental pollution and ecological destruction have become increasingly serious problems. The Chinese government began reform and opening

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in 1978. Over the last several decades, China has made remarkable achievements in economic development and has become one of the world's major manufacturing bases during the rapid globalization of the world economy. In 2009, China has its manufacturing added values surpassed the USA and now became the largest manufacturing country in the world, followed by Germany, the USA and Japan. However, the rapid growth of China's manufacturing industry was at the expense of environmental quality and has reinforced the traditional extensive development mode of high energy consumption and low production efficiency.

Theories about environmental protection and environmental economics appeared in developed countries since the 1950s, like Dales (1968), Kneese et al. (1970) and Crocker and Rogers (1971). With the environmental regulations in developed countries becoming ever stricter, their most polluting industries are gradually moving toward developing countries through foreign direct investment (FDI). Fortune 500 companies all have their subsidiaries or plants in China. They do not need to pay taxes for environmental protection because environmental taxes have not yet been introduced in China. Free environmental taxes made their production cost lower in China than in their homeland or other countries with strict environment regulations. Therefore, most subsidiaries or plants took it as a competitive advantage. This activity may partially contribute to the boom of the manufacturing industry and the degradation of environmental quality in China. For sustainable development, China must be mindful of this environmental issue to avoid China's manufacturing industry from becoming haven for polluters.

Investment in environmental protection and control can be defined as economic activities which form natural capital by allocating resources from various social funds to industrial regulation and environmental restoration (Gong and Shen 2002). The degree of investment in environmental protection and control varies among countries. In the USA, investments in environmental protection and control require the governance and administration to implement measures to prevent environmental damage and to compensate victims of environmental damage. In Japan, environmental protection and control has an even broader scope and includes, for example, environmental considerations in the development of urban infrastructure (such as roads, sewers, etc). There is no universal agreement about what the scope of investment in environmental protection and control should be, and it is still a new concept in China.

In recent years, an increasing number of studies have addressed the issues of environmental protection and control. But few have focused on environmental protection in the manufacturing industry. Magat and Viscusi (1990) argued that environmental regulation in the USA was poorly designed and insufficient to protect the environment. Other studies have focused on the economic impact of environmental regulation in the USA, such as the decrease in total factor productivity (Christainsen and Havenman 1981; Gray 1986, 1987; Gollop and Mark 1983; Barbera and Virginia 1986; Deily and Gray 1991; Gray and Shadbegian 1993; Greenstone et al. 2012), changes in production structure (Lee 2008), increased production costs in some industries (Portney 1981; Norsworthy et al. 1979; Jorgenson and Wilcoxen 1990; Conrad and Morrison 1989; Hardin 1993), especially sunk costs (Ryan 2012), the loss of manufacturing industry's comparative advantage in international markets (Jaffe et al. 1995), investment reduce (Viscusi 1983) and the blook of new product development (Hoerger et al. 1983). Although environmental regulation may have a positive impact on employment (OECD 1997), the assessment of its impact on the manufacturing industry's competitiveness is complicated by various data sources (Jaffe et al. 1995). Manufacturing activities have complex linkages with environmental regulation and pollution (Gray and Shadbegian 2002, 2003; Bartik 1988; Levinson 1996;

Henderson 1996; Kahn 1999; Helland and Whitford 2001; Cole et al. 2005). Inter-industry characteristics influence the implementation of environmental regulations through monitoring and enforcement (Decker 2006). Till now, no studies have compared investments in environmental protection and control among countries.

Environmental pollution controls are essential for achieving the sustainable development of the manufacturing sector. A manufacturing sector's capacity for sustainable development depends on the government's ability to take effective action, which itself depends on the input of manpower, facilities and funds for environmental pollution control. I compared the investments in environmental protection and control in leading manufacturing countries such as China, the USA, Germany and Japan in 2009 (Wu 2009). It was a summary of my work and lack of deep analysis and detailed conclusions. I am trying to make a further study on this topic. But the data of the USA are not accessible. It has not been updated since 2009. Therefore, the UK is used to replace the USA because the UK was ranked 8th in added values of manufacturing industry of the world in 2010 and its environmental taxes are effective methods for environmental protection and control. In this comparative analysis, we examine environmental pollution control expenses, environment-related tax policies and waste management capacities in the UK, Germany and Japan to serve as a reference on environmental protection controls. To achieve sustainable development, recycling and environment-related taxes are effective methods for China's manufacturing industry besides government expenditures in environmental protection and control. Such measures would be a "win-win" for both economy and environment.

2 Analysis of environmental protection in the UK, Germany and Japan

2.1 Environmental protection in the UK

2.1.1 Environmental protection expenditure

Figure 1 shows an overall decreasing trend in total environmental protection expenditure in the UK during the last decade. There was a dramatic decrease of 31.54 % in 2002 compared with that in 2001 due to the 9/11 terrorist attacks in the USA in 2001. The economic effects arising from the 9/11 terrorist attacks were initial shock causing global

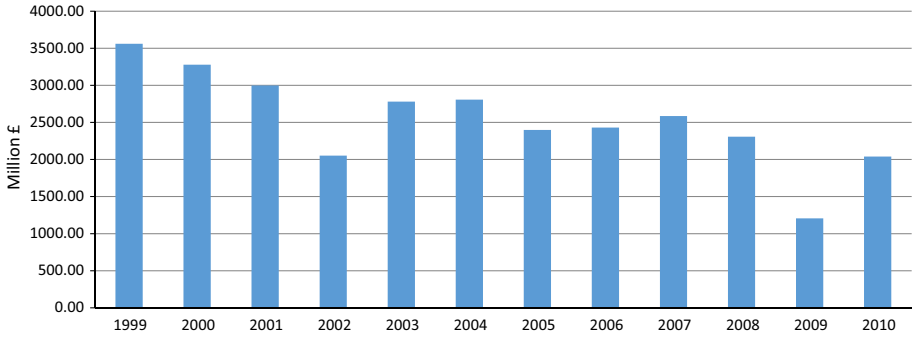

Fig. 1 Total environmental protection expenditure in the UK: 1999–2010. *Source*: Office for National Statistics, UK Environmental Accounts 2013

Table 1 Environmental protection expenditures in the UK: by industry 1999–2010 (Million £)

Industry	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Food products, beverages and tobacco products	660	497	595	495	409	580	385	525	457	481	322	472
Textiles, clothing and leather products	110	108	130	51	118	67	84	68	–	–	–	–
Wood and wood products	50	57	61	52	53	40	62	66	–	–	–	–
Paper and Pulp	510	326	177	138	235	165	233	176	49	46	48	53
Coke, petroleum and nuclear fuel	140	45	93	85	88	366	177	106	122	27.1	23	152
Chemicals and man-made fibers	540	628	710	410	618	566	495	293	655	212	105	247
Rubber and plastic products	190	231	192	108	129	151	152	146	–	–	–	–
Other nonmetallic mineral products	170	159	78	114	124	86	88	129	–	–	–	–
Basic metals and metal products	440	320	478	214	322	292	216	334	–	473	101	245
Machinery and equipment	320	399	107	114	325	202	227	187	–	–	–	–
Electrical, medical and optical equipment	120	239	95	45	57	44	30	55	–	–	–	–
Transport equipment	220	218	222	154	199	174	184	257	–	–	–	–
Other manufacturing	90	52	61	73	104	75	65	89	1303	1069	608	870
Total expenditure	3560	3279	2999	2053	2781	2808	2398	2431	2586	2308	1207	2039

1. The environmental protection expenditure survey since 2008 was conducted using the new Standard Industrial Classification (SIC2007). Data of previous years were analyzed using SIC2003 and have not been re-categorized. 2. Data released after 2008 for each year were different from previous releases. 3. Mining and quarrying, energy production and water are not included

Source: Office for National Statistics, UK Environmental Accounts 2013

stock markets to drop sharply and then slower global economic growth. After 2002, total environmental protection expenditure had a slight increase in 2003 and 2004. It declined largely in 2009 with a decrease of approximately 44.70 % compared with that in 2008 due to the global economic downturn from 2007 to 2009. The UK government reduced expenditures in environmental protection affecting by the two economic recessions. The average of total environmental protection expenditure from 2003 to 2008 was around £2.5 billion.

The environmental protection expenditures in the UK by industry are shown in Table 1. Overall, the environmental protection expenditures by industry have shown a mixed picture between 1999 and 2010. Expenditure stood at £2.6 billion in 2007, the highest since 2002, thereafter it dropped to £1.2 billion in 2009, the lowest in record. The reduction in spending could be explained by the general downturn in the manufacturing sector and industrial production during these periods. It is hard to identify a clear trend of spending due to changes in industry size and survey classification. Among these expenditures, "Chemicals and man-made fibers" accounted for the largest share in 2000, 2001, 2003, 2004, 2005 and 2007. In 1999, 2002, 2006, 2008, 2009 and 2010, "Food products, beverages & tobacco products" held the largest share. The share of environmental protection expenditure by industry changed in 2010 with "Food products, beverages & tobacco products" ranked first, "Chemicals and man-made fibers" ranked second, and "Basic metals and metal products" ranked third. These industries are high-polluted industries, and the UK government spent more in them.

2.1.2 Environmental taxes

The thoughts of environmental taxes came from Pigou (1920), an English economist. In the early 1970s, the UK introduced environmental taxes into its tax system, adopting a "who pollutes, who pays" policy with the resulting revenues allocated for environmental protection. These taxes are applied to industries which pollute air, water and urban environment.

Environmental taxes in the UK include taxes on energy, transportation, pollution and the consumption of natural resources. Energy taxes include fossil fuel levy, climate change levy, duties on hydrocarbon oils, hydro-benefit and valued-added taxes on duty. Transportation taxes include duties of air passenger and vehicle excise. Pollution taxes include landfill tax. Taxes on resources include aggregates levy. The aggregates levy is a tax on sand, gravel and rock that are dug from the ground or dredged from the sea in the UK water. It addresses the environmental damage caused by business activities in forms of noise, dust and loss of biodiversity.

Environmental taxes are not included in government expenditures in environmental protection. They are both environmental regulations in the UK. Taxes on energy (Motor Spirit Duty in 1909) and transportation (Vehicle Excise Duty in 1937) were introduced earlier than taxes on pollution (1996) and taxes on resources (2002).

As shown in Fig. 2, environmental tax revenues rose from 1993 to 2012. The total revenues were nearly £43 billion in 2010 which was 21.5 times of government expenditures in environmental protection in the same year. Therefore, environmental tax revenues were the main environmental regulations in the UK. Among these revenues, taxes on energy accounted for the largest share. Taxes on energy, transportation and pollution exhibited upward trends from 1993 to 2012. Taxes on natural resources fluctuated without a significant trend in 2002–2012.

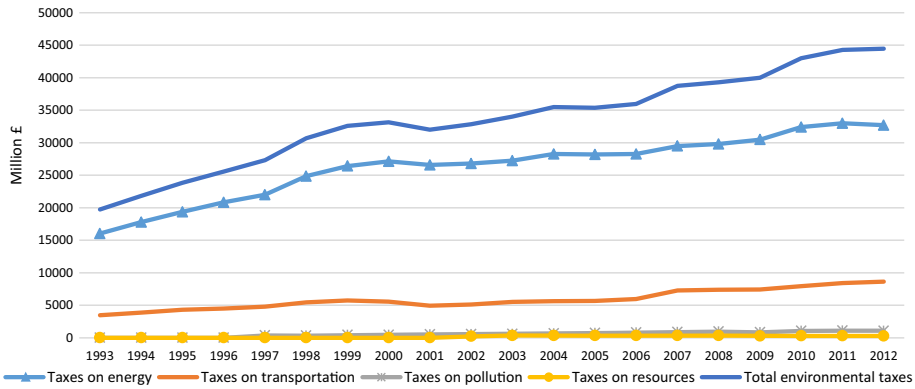

Fig. 2 Environmental tax revenues in the UK: 1993–2012. *Note* Data released after 2008 were different from previous releases. *Source*: Office for National Statistics, UK Environmental Accounts 2013

2.2 Environmental protection in Germany

2.2.1 Environmental protection expenditure

Figure 3 shows the total environmental protection expenditure and shares of different sectors in Germany. The total environmental protection expenditure in Germany has experienced two dramatic decreases in the periods of 1996–2000 and 2007–2008. Affecting the hit from euro against dollar, global economic growth slowed in the late 1990s. The exports of cars, household appliances and machine tools reduced, which contributed a big part to German economy. It caused the first decrease. The second decrease was due to global economic recession from 2007 to 2009. Differences existed in environmental protection expenditures in different sectors. The government environmental protection expenditure showed a downward trend, while the expenditure in the production industries remained stable. The expenditure in privatized public enterprises significantly improved. In 1996, the government's share was slightly less than that of privatized public enterprises. But the difference between them became large after 1996. The expenditure in privatized public enterprises had the largest share, accounting for more than 50 % of total expenditure since 2003 and climbed to 57.52 % of total expenditure in 2006.

2.2.2 Environmental taxes in Germany

Manufacturing production relies on energy consumption and brings emission and pollution. As an old manufacturing power, Germany has almost the same configuration of environmental taxes as the UK. Environment-related taxes in Germany include energy tax, electricity tax, motor vehicle tax, solid waste charges and wastewater charges. Figure 4 shows the total revenues from environment-related taxes in Germany. The revenues increased from 2001 to 2003. It reached €66,239 million in 2003 and then began to decline. Energy tax contributed most of the total revenues from environment-related taxes and fluctuated and stabilized at around €40,000 million. Electricity tax revenue had increased since 2001, but dropped by 2.05 % to €6462 million in 2005. In 2011, it rose sharply by 17.44 % to €7247 million compared with that in 2010 and fell slightly in 2012.

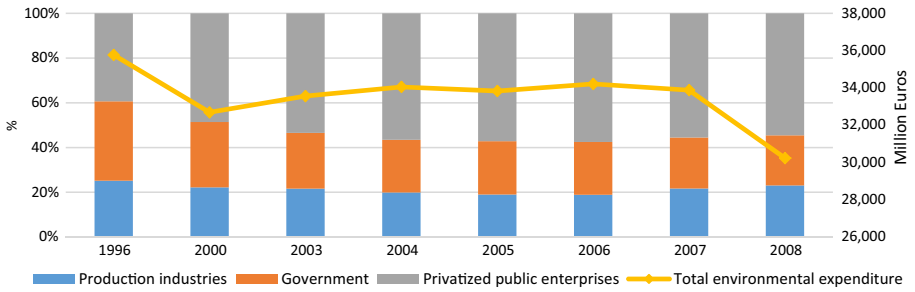

Fig. 3 Total environmental protection expenditure and shares of different sectors: 1996–2008. *Note* Construction, water supply, discharge of sewerages and discharge of waste are not included. *Source*: German Federal Statistical Office, 2013

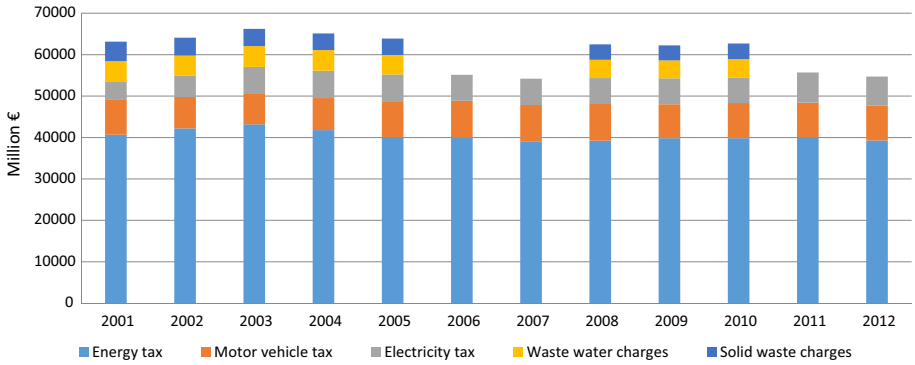

Fig. 4 Revenues from taxes and fees related to the environment: 2001–2012. *Note* Data for waste water charges, solid waste charges and total revenue from environment-related taxes and charges were not found in some years. *Source*: German Federal Statistical Office, 2013

2.3 Environmental protection in Japan

2.3.1 Environmental protection expenditure

Japan is China's neighbor country and also a competitor in manufacturing export. Unlike Germany and the UK, Japan did not levy environmental-related taxes and government environmental expenditure is its main method of environmental regulation. Figure 5 shows environmental expenditure and its share in Japan's total national budget.

There was a rapid growth in Japan's expenditure in environmental protection in 1990–2001. But it has fallen steadily since 2002. The biggest increase in environmental expenditures compared to previous year was in 1994. Then it fell till 1998. The environmental expenditure and the total national budget both began to reduce after 2001 due to the global economic recession caused by the 9/11 terrorist attacks. The share of environmental protection expenditure in total national budget rose from 1990 to 1994 and began to decrease since 1995. The largest share was 1.64 % in 1994 and then dropped dramatically to 0.8 % in 2006. There is a common phenomenon. Government expenditure in environmental protection and control will increase with the rapid growth of

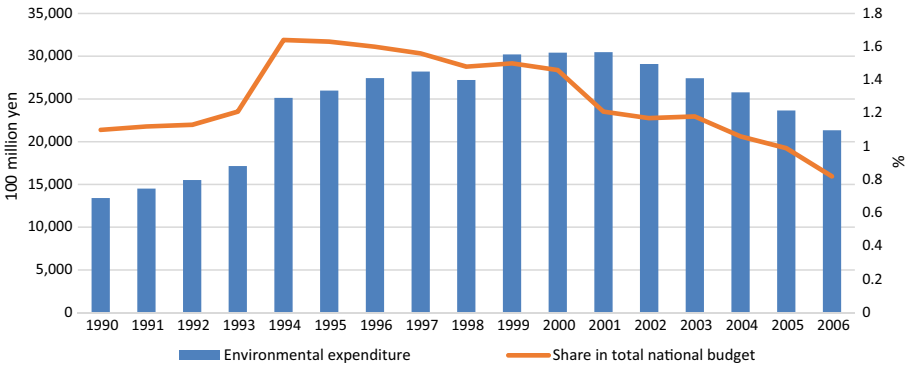

Fig. 5 Environmental expenditure and its share in Japan's total national budget: 1990–2006. *Source*: Japan Bureau of Statistics, 2013

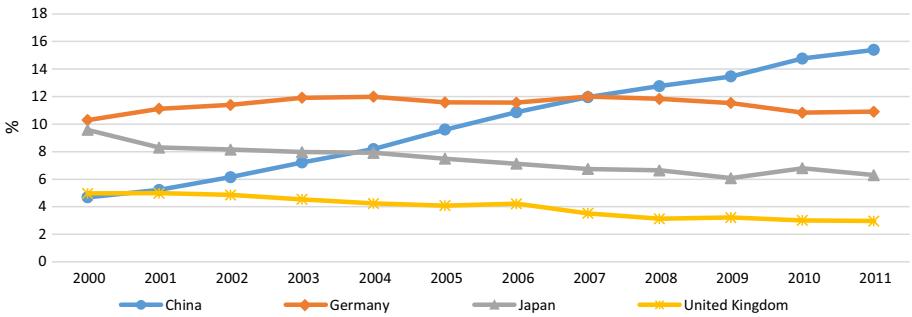

Fig. 6 Market shares of world's manufacturing export of selected countries: 2000–2011. *Source*: WTO Statistics, 2013

manufacturing industry, and it will reduce when government revenues reduce because of economic recession or export reduction. With large added value of manufacturing industry, Japan's manufacturing industry made rapid growth in the 1990s. But as shown in Fig. 6, Japan's market share of world's manufacturing export has declined since 2000 while the market share of China has dramatically increased. Accordingly, Japan reduced government expenditure in environmental protection and control after 2000.

2.3.2 *Survey of discharge and disposal of industrial waste*

Japan's disposals of industrial waste include four categories. They are direct recycle use, direct final disposal, total recycle use and total final disposal. As shown in Fig. 7, the direct recycle rate has remained relatively stable around 22 % since 1990 and it has only dropped once in 1995 to 13 %. The total recycle rate experienced an upward trend in 1990–2009, while the direct final disposal rate of midway treatment and total final disposal rate declined, dropping to 2 % and 3 % respectively in 2009. Overall, total recycling rate and direct recycle rate are higher than total final disposal rate and direct final disposal rate. Thus, Japan paid more attention to industrial waste recycle which is a good practice for sustainable development.

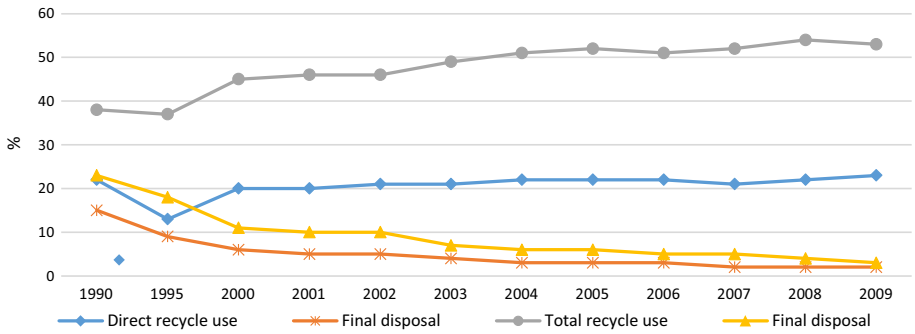

Fig. 7 Discharge and disposal rates of industrial waste in Japan: 1990–2009. *Source*: Japan Bureau of Statistics, 2013

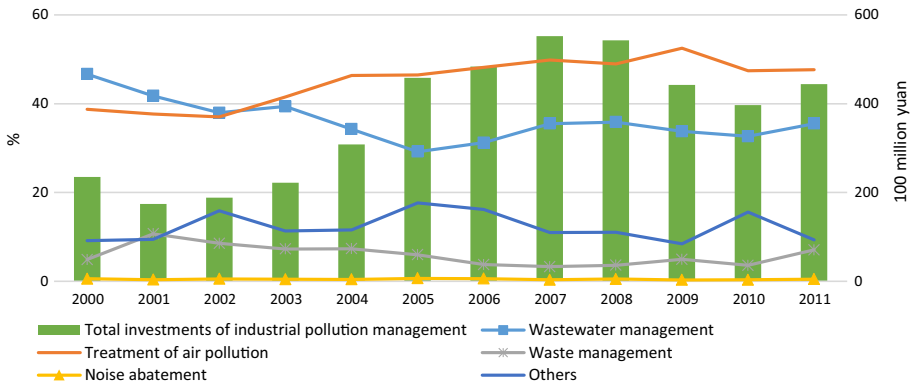

Fig. 8 Total investments in industrial pollution control and shares by categories in China: 2000–2011. *Source*: China's Statistics Yearbook 2012

3 Comparison of environmental protection in China and other countries

3.1 China's environmental protection

China does not levy environment-related taxes like Japan currently. China's investments in environmental protection and control depend solely on government expenditures. Figure 8 shows China's total investments in industrial pollution control. It exhibited a positive trend from 2000 to 2011. While the amount in 2001 was lower than in 2000, it has drastically increased since 2002 and peaked at 55.24 billion Chinese yuan in 2007. It began to decline from 2008 to 2010 due to the global economic recession and rose again to 44.44 billion Chinese yuan in 2011, increasing 11.94 % compared with the amount in 2010. Among all the investments in China's industrial pollution control, the shares of waste water management and air pollution treatment were higher than those of waste management and others, while the share of noise abatement was the lowest. The share of waste water management decreased, and the share of air pollution treatment increased in 2000–2011. Bad air quality became an outstanding issue in China with the rapid development of

manufacturing. The reason of the increasing share of air pollution treatment was that the Chinese government put more efforts on improving air quality for the 29th Olympic Games held in Beijing in 2008. After 2009, the share of air pollution treatment began to decrease.

3.2 Comparison of total investments in environmental pollution control

The manufacturing industry has achieved rapid growth at the expense of the environmental quality. In order to improve environmental quality, the government needs to invest in environmental control of industrial pollution. The investments in environmental protection and control in China and Japan mainly depend on their government expenditures since there are no environmental-related taxes. As shown in Fig. 9, China's share of investments in industrial pollution control in its total manufacturing output was substantially lower than Japan's. The share was 2.37 % in 2005 in Japan but only 0.59 % in China, its top year. Although China has much larger total manufacturing output than Japan, the Japanese government invested more in environmental control of industrial pollution than China compared with their shares in total manufacturing output. Overall, China's investments in environmental control of industrial pollution rose dramatically from 2000 to 2010, but the total output of China's manufacturing grew much faster than its investments in environmental control of industrial pollution. The growths were not proportionately. Therefore, China's share of investments in environmental control of industrial pollution in its total manufacturing output declined. The total investments in environmental control of industrial pollution in Japan also declined during the same period (see discussion above). However, as the world leader of manufacturing production base, China needs to invest more in environmental protection and control to improve environment quality with rapid growth of manufacturing industry.

3.3 Comparison of all waste controls

Environmental control investments in manufacturing industry focused primarily on waste water, air pollution and solid waste. However, the investments in all waste controls varied between China, the UK and Germany as shown in Fig. 10. The UK investments in waste water management and solid waste management fell after rising between 2006 and 2007. German investments in waste water management and solid waste management both declined in this period. The investments in waste water management decreased in China.

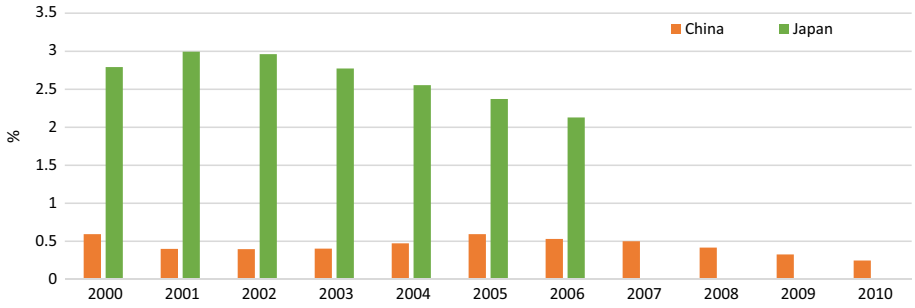

Fig. 9 Shares of investment in environmental control of industrial pollution in total manufacturing output in China and Japan: 2000–2010. *Note* China's total manufacture value comes from industrial total value in China's Statistics Yearbook. *Source*: China's Statistics Yearbook 2011 and Japanese Statistics Yearbook 2011

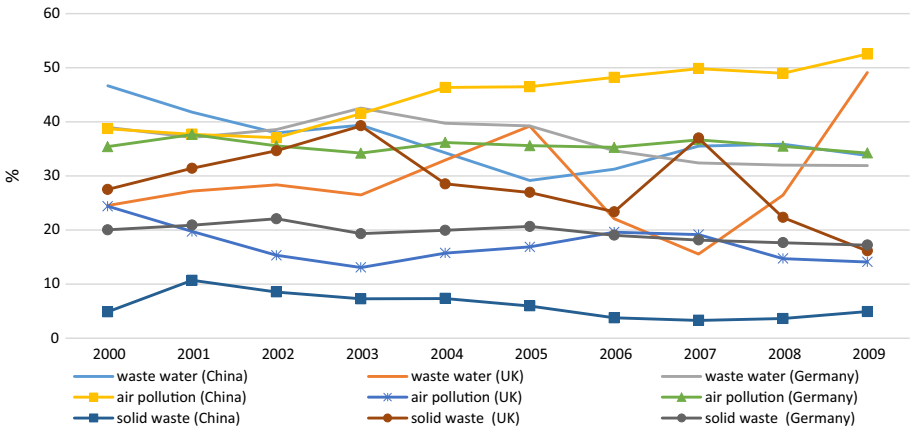

Fig. 10 Shares of input of waste water management, air pollution treatment and solid waste management: 2000–2009. *Source*: International Statistics Yearbook, China Statistics Yearbook, UK National Statistics and Deutsche Statistiches Bundesant

But China's share of investments in air pollution treatment was around 50 %, the highest share among these countries since 2003. It is because the Chinese government made many efforts in improving air quality for the 29th Olympic Games. The share of solid waste management was quite small in China from 2000 to 2009. China has the same environmental control configuration as Germany. Clearly, China's investments in solid waste management were dwarfed by those of the UK and Germany. China has to input more to solid waste management as its share in environmental control investments is much lower than shares of waste water management and air pollution treatment.

4 Conclusions

Foreign direct investment has played a significant role in promoting the Chinese manufacturing industry's development since China's reform and opening, but has also led to a large increase in environmental pollution. Since the 17th National Congress of the Chinese Communist Party, the Chinese government has issued a series of regulations to strengthen environmental control. While certain improvements have been made, environmental quality issues remain challenging because of the constraints of China's economic development mode. There is large room for energy saving and emission reduction. Although China's investments in environmental protection and control have experienced a significant growth in recent years, they are far from adequate and environmental protection in the manufacturing industry is still very weak.

Compared with the share of environmental pollution control investments in total manufacturing output in Japan, we found that environmental pollution control investments in China's manufacturing industry were far lower. In 2005, the share of environmental pollution control investments in total manufacturing output was 2.37 % in Japan while it was only 0.59 % in China. China's share of environmental pollution control investments in its total manufacturing output did not increase with the same growth of its total manufacturing output though there was a substantial increase in its environmental pollution control investments.

Like China, Japan does not have environmental-related taxes and government environmental expenditure is its main method of environmental regulation. But Japan's total recycling rate and direct recycle rate were higher than total final disposal rate and direct final disposal rate. Japan paid more attention to industrial waste recycle. China should adopt this for sustainable development.

Manufacturing production relies on energy consumption and brings emission and pollution. Besides government environmental protection expenditure, environmental taxes have proved an effective means of environmental regulation in the UK, Germany and other countries and the revenues are used for pollution control. But in China, government environmental expenditure is currently the only means of environmental protection, and there are no environmental taxes or other effective control measures.

In summary, China's manufacturing industry has made remarkable achievements during its recent development, but at the expense of environmental quality. China's manufacturing industry lacks of sustainable competitiveness with its characteristics of high pollution and high energy consumption. China has to invest more in environmental protection and control in order to compete internationally. Recycling is a good practice for China's sustainable development. Besides government expenditure in environmental protection and control, environment-related taxes on energy, transportation, pollution and resource are effective methods for China's manufacturing industry to achieve sustainable development. Such measures would be a "win-win" for both economy and environment.

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