

Research on Decoupling Economic Growth from Pressure on Natural Resources and the Environment: A Case Study of Shanghai

Xiangyu Li^{1*}

¹School of Economics, Shanghai University, Shanghai, China, 200444

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Abstract: Studying the relation between economic growth and natural resources and the environment is of great significance for developing rational policies on energy conservation and emission reduction, improving the sustainability of socio-economic development as well. This paper researches the pressure on natural resources and the environment in Shanghai from 2001 to 2016, indicated by resource consumption indices and environmental pollution indices, brought about by economic growth. Using the Tapio decoupling index, Shanghai's decoupling condition of economic growth from pressure on natural resources and the environment is analysed. The study shows that Shanghai's economic development is gradually putting itself out of the pattern of high consumption and heavy pollution, with the weakening but still existing dependence of the economic growth on natural resources and the environment. Some targeted advice on policy making is given at last.

1. Introduction

Since the industrial revolution, the human societies have been demanding more and more natural resources for rapid economic development, posing a succession of problems such as resource depletion, environmental pollution and ecological imbalance, which has seriously threatened their sustainable development. Since China is undergoing a period of rapid economic development with increasing natural resource consumption, to better the regulation of natural resources in a more effective way has become one of the most important issues for China to achieve sustainable development [1].

Shanghai's strength in economy is always in the forefront in China. In 2016, the GDP of Shanghai reached 2817.865 billion China yuan, ranking first among all Chinese provinces, which indicates that Shanghai's economic development has an important role in China's economic take-off. In contrast, Shanghai's provincial green development index given in China Green Development Index Report 2016 does not rank in the top 10, showing Shanghai's green development level lags behind its economic development level, i.e., Shanghai may achieve its rapid economic growth at the cost of large investment, high consumption and heavy pollution [2]. To adapt to the new normal of the economy, Shanghai must take environmental conservation into account when developing its economy and give consideration to the affordability of the environment when exploiting natural resources. Therefore, it is an imperative task presently to work out a new development pattern featured by low cost, high efficiency and sustainability, i.e., a development pattern which can decouple economic growth from pressure on natural resources and the environment.

Some researchers have studied the relation between economic growth and pressure on natural resources and the environment. Zhang Y introduce decoupling methods into environmental pressure assessment and propose detailed decoupling assessment indicators, which are used to evaluate the decoupling condition of Chongqing's economic development [3]. Ghisellini P studies the provincial agricultural CO₂ emissions in China with index decomposition analysis, summarizing leading factors on emission growth and effects of decoupling [4]. Lu Z propose an approach combining the Kaya equation and the LMDI factor decomposition to analyze China's decoupling relationship between the carbon emissions and the economic growth, and its driving factors [5].

However, most of previous studies use a single decoupling index, which is specialized but one-sided, so it cannot reflect the overall relation between economic growth on the one hand and natural

resources and the environment on the other. In view of this, in this paper, various sorts of resource consumption and pollutant emissions are integrated into a comprehensive index to indicate pressure on natural resources and the environment with the entropy weight method. Then Shanghai's decoupling condition of economic growth from pressure on natural resources and the environment from 2001 to 2016 is evaluated by means of the index. Some advice is given at last expected to be helpful for Shanghai to develop itself into a resource-economical and environment-friendly society.

2. Theoretical Model

The pressure-state-response (PSR) framework reflecting Shanghai's coupling relation between economic development and pressure on natural resources and the environment is shown in Fig. 1. The interaction between Shanghai's rapid economic growth and the environment includes two aspects. First, the economic development brings about population concentration, expansion of urban area, rapid development of non-agricultural industries, and increases in the scale and the level of population consumption. Second, the economic development adds to pressure on natural resources and the environment, such as increases in consumption of natural resources and energy, massive waste gas emissions, massive waste water discharge and massive industrial residue, and ongoing reduction of land for ecological use. The deterioration of the environmental quality will be sure to impose negative effects on the behavioral agents, i.e., the government, companies and individuals, such as harm to residents' health, decreases in company revenue and damage to the government image. On the other hand, the behavioral agents can make response in this system through applying advanced technologies, formulating and effectively implementing proper policies, guiding the market towards a rational way, and enhancing the public awareness of environmental protection. These measures can mend the relation between the economic development and the environment, and promote the decoupling of economic growth from pressure on natural resources and the environment.

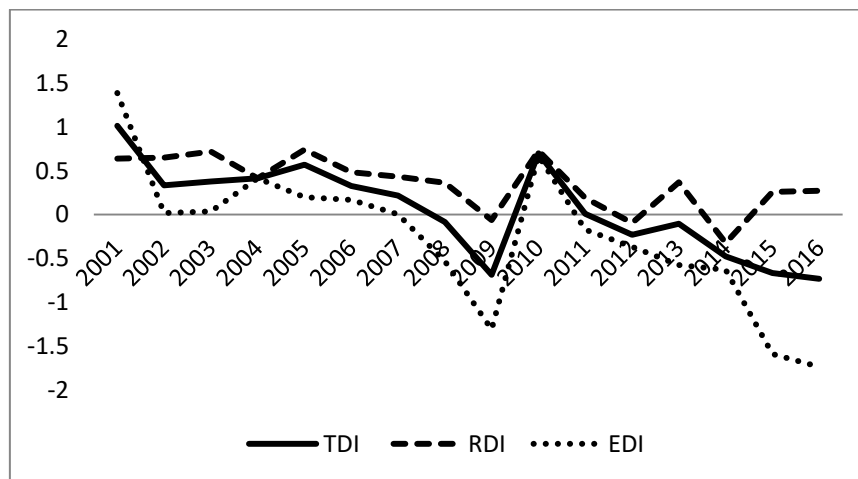


Figure 1. Shanghai's decoupling condition of economic growth from pressure on natural resources and the environment from 2001 to 2016

3. Decoupling Method and Data Processing

3.1 Decoupling method

Decoupling, a concept initially used in physics, represents the weakening or disappearance of the interrelation between two or more variables. The Organization for Economic Cooperation and Development (OECD) extended this concept to the agricultural policy field and then the World Bank introduced this concept into the field of natural resources and environment to analyze the relation between economic growth on the one hand and resource consumption and environmental pollution on the other. At present, there are three main decoupling indices: the first one is proposed by OECD in 2000 in terms of beginning values and ending values, whose actual meaning is the

annual descent rate of the load of per unit GDP on natural resources and the environment; the second one is proposed by Tapio in 2005, which is the ratio of the rate of change of the pressure on natural resources and the environment to the rate of change of the economic growth; the third one is proposed by Lu in 2001, which can reflect the relation between the economic growth rate and the descent rate of resource consumption of per unit GDP.

The Tapio decoupling index is used in this paper, which is defined as

$$\varepsilon = \frac{\Delta E / E}{\Delta G / G} \quad (1)$$

where ε denotes the Tapio decoupling index, E denotes the pressure on natural resources and the environment, and G denotes the GDP of a region in a year.

Considering that Shanghai has maintained a rapid economic growth since the reform and opening up ($\Delta G > 0$), four states are chosen to evaluate the decoupling condition of Shanghai's development, as shown in Table 1.

Table 1. Decoupling condition of economic growth from pressure on natural resources and the environment for Shanghai

Decoupling Condition	ΔE	ΔG	Decoupling Index	Implication
decoupled	< 0		$\varepsilon < 0$	Economy is growing and pressure is declining
fairly decoupled	> 0		$0 \leq \varepsilon < 0.5$	Economy is growing and pressure is slowly rising
partially decoupled	> 0	> 0	$0.5 \leq \varepsilon < 1$	Economy is growing and pressure is moderately rising
Not decoupled	> 0		$\varepsilon \geq 1$	Economy is growing and pressure is rapidly rising

3.2 Data processing

The data used in this paper to analyze Shanghai's development span 2001 to 2016, which includes the 10th Five-Year Plan period, the 11th Five-Year Plan period and the 12th Five-Year Plan period.

The economic growth is usually indicated by GDP, while there are no widely accepted indices to reflect pressure on natural resources and the environment. In this paper, pressure on natural resources and the environment is denoted by two first-level indices and several second-level indices for each. Specifically, energy consumption, electricity consumption and water consumption are the second-level indices under the first-level index resource consumption; industrial waste water discharge, industrial SO₂ emissions, industrial waste gas emissions and household garbage production are the second-level indices under the first-level index environmental pollution (see Table 2).

Table 2. Indices of pressure on natural resources and the environment

First-Level Index	Weight	Second-Level Index	Weight
resource consumption (R)	0.5	energy consumption (R1)	RW1
		electricity consumption (R2)	RW2
		water consumption (R3)	RW3
		industrial waste water discharge (E1)	EW1
environmental pollution (E)	0.5	industrial SO ₂ emissions (E2)	EW2
		industrial waste gas emissions (E3)	EW3
		household garbage production (E4)	EW4

4. Analysis of Shanghai's Decoupling Condition

4.1 Shanghai's decoupling condition

According to the Tapio decoupling index equation and the data processing methods mentioned above, the decoupling indices can be calculated as shown in Table 3.

It can be seen that the decoupling conditions of Shanghai's economic growth from pressure on natural resources and the environment of these years span the most desirable one to the most terrible one. Specifically, the decoupled state, the fairly decoupled state, the partially decoupled state and the not decoupled state account for 43.75%, 37.5%, 12.5% and 6.25% respectively. The results show that Shanghai's economic development is mainly featured by the decoupled state and the fairly decoupled state. Therefore, it can be concluded that the dependence of Shanghai's economic growth on natural resources and the environment is weakening but still exists.

Table 3. Shanghai's decoupling condition from 2001 to 2016

Year	Resource Decoupling Index (RDI)		Environmental Decoupling Index (EDI)		Total Decoupling Index (TDI)	
2001	0.638152961	partially decoupled	1.386545081	not decoupled	1.012349021	not decoupled
2002	0.649090394	partially decoupled	0.01738803	fairly decoupled	0.333239212	fairly decoupled
2003	0.717677087	partially decoupled	0.037052322	fairly decoupled	0.377364704	fairly decoupled
2004	0.413129149	fairly decoupled	0.413480431	fairly decoupled	0.41330479	fairly decoupled
2005	0.739567728	partially decoupled	0.198719161	fairly decoupled	0.569143441	partially decoupled
2006	0.48398311	fairly decoupled	0.168104123	fairly decoupled	0.326043616	fairly decoupled
2007	0.432085006	fairly decoupled	0.00256393	fairly decoupled	0.217324468	fairly decoupled
2008	0.363150695	fairly decoupled	-0.530273822	decoupled	-0.083561564	decoupled
2009	-0.062128175	decoupled	-1.308476688	decoupled	-0.685302431	decoupled
2010	0.727494353	partially decoupled	0.670963634	partially decoupled	0.699228993	partially decoupled
2011	0.189234575	fairly decoupled	-0.171379367	decoupled	0.008927604	fairly decoupled
2012	-0.094396079	decoupled	-0.366647163	decoupled	-0.230521621	decoupled
2013	0.367461138	fairly decoupled	-0.575261843	decoupled	-0.103900352	decoupled
2014	-0.323496583	decoupled	-0.629338157	decoupled	-0.47641737	decoupled
2015	0.25834974	fairly decoupled	-1.589777302	decoupled	-0.665713781	decoupled
2016	0.271786092	fairly decoupled	-1.735252919	decoupled	-0.731733413	decoupled

The TDI of 2001 is 1.01, meaning Shanghai's rapid economic growth at that time is achieved at the cost of rapider increases of the pressure on natural resources and the environment. The

decoupled state first appears in 2008 and TDI reaches its minimum -0.685 in 2009, which may be related to the 2008 financial crisis. After 2009, the decoupling condition changes between the decoupled state and the fairly decoupled state.

As shown in Fig. 1, the DTI of 2001 to 2005 fluctuate between 0.5 to 1, indicating Shanghai was following the undesirable development pattern of high consumption and heavy pollution then.

The TDI of 2008 drops significantly, showing that Shanghai was deeply affected by the economic crisis and thus the economic growth was slow. The dramatic turn of the decoupling condition to the partially decoupled state in 2010 indicates that Shanghai was undergoing an economic recovery with higher resource consumption and heavier environmental pollution.

After 2011, TDI fluctuates near zero, indicating the pressure on natural resources and the environment is reduced apparently.

The coupling of economic growth and pressure on natural resources and the environment will gradually decrease after reaching a peak, forming an inverted U curve, i.e., a Kuznets curve. After the peak is reached, the decoupling condition will get into the partially decoupled state or the fairly decoupled state first, and then turn into the decoupled state under human control. However, in some special situations, the coupling could strengthen again and thus it can be a long journey to achieve the decoupled state.

As for the decoupling condition of Shanghai's economic growth from resource consumption, it can be learned that the decoupled state, the fairly decoupled state and the partially decoupled state account for 18.75%, 31.25% and 50% respectively; as for the decoupling condition of Shanghai's economic growth from environmental pollution, it can be learned that the decoupled state, the fairly decoupled state, the partially decoupled state and the not decoupled state account for 50%, 37.5%, 6.25% and 6.25% respectively. A deep analysis of the separated indices is given as follows.

4.2 Decoupling from resource consumption

It can be learned from Fig. 2 that before 2008, the decoupling index of economic growth from energy consumption fluctuates between 0.5 and 1, reflecting Shanghai's economic growth was at the cost of high energy consumption in these years. After the 12th Five-Year Plan was published, Shanghai has invested more in energy conservation and achieved positive results. Specifically, the decoupling index of economic growth from energy consumption is declining, which means although the energy consumption continues to increase, the consumption growth is slowing down.

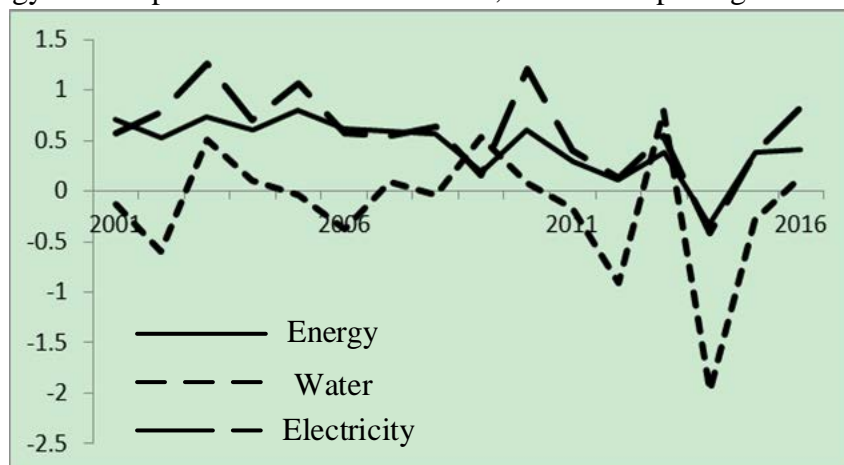


Figure 2. Shanghai's decoupling condition of economic growth from resource consumption from 2001 to 2016

The decoupling index from water consumption reaches peaks in 2003 and 2009, when the decoupling conditions are both the partially decoupled state. Except for these two years, the decoupling conditions for the other years are the decoupled state or the fairly decoupled state, which means that this index represents the best performance among the three second-level indices. This is due to the water saving measures starting to be implemented in 1990s. With so many years' efforts of the government and residents, water saving has won great popular support and thus the water

consumption is increasing only slowly.

The decoupling index from energy consumption and that from electricity consumption are both relatively low in 2008 and 2009 because of the 2008 financial crisis. But with the efforts to recover the economy, the demands for resources and energy increase in 2010 and consequently the two indices of 2010 rise up dramatically. Faced with the grim situation for energy saving since 2010, Shanghai has taken a series of measures to avoid high energy consumption. However, considering that the potential for lowering energy consumption of various industries is limited and the ongoing urbanization will inevitably bring about increases in residents' use of energy, Shanghai's energy saving task during the 13th Five-Year Plan period remains arduous.

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4.3 Decoupling from environmental pollution

Challenged by the severe economic situation, Shanghai is committed to both the economic development and the ecological development since the 11th Five-Year Plan period. Shanghai has invested a lot in controlling environmental pollution and strengthening capacities for ecological protection, pursuing the construction of a resource-economical and environment-friendly society. As a result, Shanghai has made noticeable achievements in the harmonious development between humans and nature. Before the 11th Five-Year Plan period, the decoupling conditions from industrial waste gas emissions of almost all years are the not decoupled state. Afterwards, the decoupling index fluctuates in a trend of decline, and during the 12th Five-Year Plan period, the decoupling conditions are mainly the decoupled state, meaning the pressure on the environment is getting reduced.

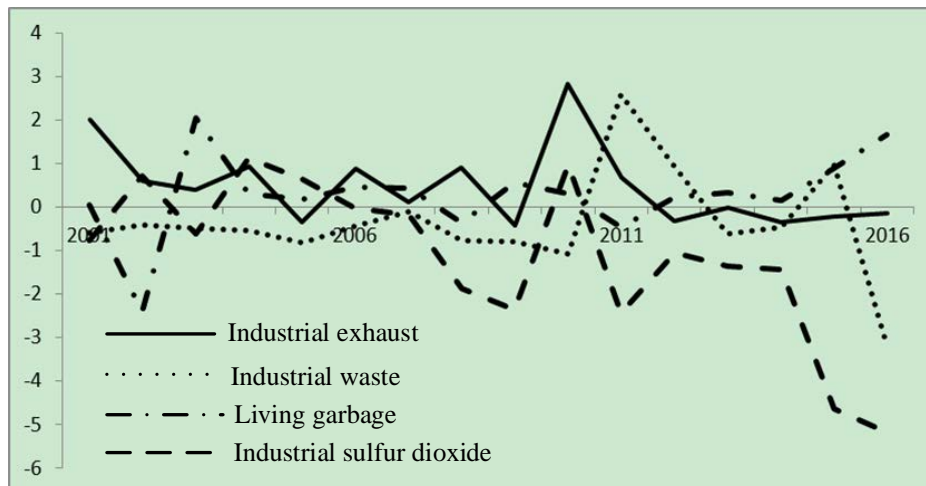


Figure 3. Shanghai's decoupling condition of economic growth from environmental pollution from 2001 to 2016

The decoupling conditions from industrial waste water discharge of most years are the decoupled state, showing that Shanghai takes strong supervision and control of waste water discharge. Since 2005, the SO₂ emissions are declining year by year with a relatively high speed, showing the SO₂ emissions are under strict control in the course of economic development. The decoupling conditions from household garbage production are mainly the fairly decoupled state. However, as the population in Shanghai is increasing rapidly these years, the decoupling index from household garbage production is on the rise. Therefore, the government needs to promote the pattern of green

living to reduce household garbage production.

5. Conclusion

Three conclusions can be drawn from the study. First, TDI is in a trend of decline and is mainly featured by the decoupled state and the fairly decoupled state, showing Shanghai's economic development is gradually putting itself out of the pattern of high consumption and heavy pollution, with the dependence of the economic growth on natural resources and the environment weakening but still existing; during the 12th Five-Year Plan period, the economic growth is basically decoupled from pressure on the environment but remains dependent on natural resources to a certain degree. Second, TDI, RDI and EDI keep fluctuating and reach their local maximums near 2001, 2006 and 2010, which are just the beginning year or the ending year of the three Five-Year Plan periods, implying that the control of resource consumption and environmental pollution is loosened in those years. Third, water consumption, waste water discharge, and SO₂ emissions are well controlled, from which the economic growth is decoupled in most of the years; in contrast, the condition is not satisfying as far as electricity consumption and household garbage production are concerned.

In summary, Shanghai is upgrading its industrial structure through a series of policies which support some industries and restrict some others. Specifically, Shanghai is boosting equipment manufacturing industries, technology-intensive industries, modern service industries and financial industries as cores of future economic development, and restricting some traditional industries which are featured by high consumption and heavy pollution. Shanghai needs to invest more in environmental protection to standardize industrial waste water treatment, improve garbage management, and strengthen supervision and law enforcement, so that excessive exploitation of natural resources and irreversible damage to the environment can be avoided, and an climate of spontaneously saving water, electricity and energy can be formed in the society. Thus, Shanghai can turn onto a sustainable development path which is efficiency-improving-oriented, resource-economical and environment-friendly.

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