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Adaptation assessment and analysis of economic growth since the market reform in China

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Abstract
China has experienced extraordinary institutional and socio-economic changes after 1978, and its deepening reform to market-oriented economy since 1990s was also recognized as one the most significant factors to drive China's rise in the contemporary world. Although many aspects of China's market reform have been extensively analysed in the literature, specific attention on the adaptation of economic growth to this reform has been relatively ignored. To fill this gap, this research adopts the extenics assessment method to assess this adaptation and applies the membership function coordination degree model to analyse the sustainability of such adaptation. In conclusion, China has demonstrated a significantly enhanced adaptation capacity at the expense of coordination, which requires to be further emphasised in its economic growth adaptation strategies.

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Keywords Economic adaptation; extenics assessment method; membership function coordination degree model; market economy reform

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1 Introduction

China's rapid and sustained economic growth offers several implications for the global economy (Lo D & Li G, 2011). As the economic growth rate gradually declined by 10.45%, 9.30%, 7.65%, 7.7%, 7.4% and 6.9% from 2010 to 2015 respectively, some scholars have promptly investigated into the continuity of the country's past rapid and sustainable growth and the adaptation to its recent economic slowdown (Rajah R et al., 2013; Prime P B, 2012). The government considered the current decelerating economy as a 'new norm' and a rationalised adjustment process that suited the country's basic conditions. In this process, China has been attempting to adjust and optimise its economic structure, to adopt highly reasonable economic operations, to upgrade its economic quality and achieve a highly sustainable economic growth. As the economic reform and openness policy in 1978 transformed China from a planned economy into a semi-market one, and the following economic growth at a relatively high and steady speed attributed to the institutional dimension of its market-oriented economic reform since 1992, China's economy has switched to a different path that involves improving the overall economic efficiency, advancing the extant technologies, promoting the percentage of private sectors, stimulating the investments and financial assets, and providing the safety nets and welfare programs often by the government (Rajah R et al., 2013; Prime P B, 2012). During this period, a closer link to the world economy was established after China's accession to the World Trade Organization (WTO) in 2001. Although the reform has resulted in an impressive economic progress, some daunting challenges have also been introduced (Prime P B, 2012), such as the Asian financial crisis in 1997, the global financial crisis in 2008, the SARS outbreak in 2003 and the Wenchuan earthquake in 2008. In addition, China has not yet devised any solution to escape the middle income trap (Woo W T & Zhang W, 2010).The country has also been suffering from the development inequalities in the western and eastern regions, the exacerbated rural-urban divergence, the increasing deficits in its energy sources supply, and the rising pollution issues (Li V & Lang G, 2010). Nevertheless, China maintains an overall high economic growth rate, which has been ascribed by some scholars to its favourable economic adaptation (Chakrabarti A, 2014; Watkiss P, Hunt A, Blyth W et al., 2015). Most researchers have emphasised the importance of market economy in stimulating rapid economic growth. However, only few empirical studies have assessed the adaptation of

China's economic growth. To fill this gap, this research aims to quantitatively analyse that how has the Chinese economy adapted to changes since the market economy reform.

This paper is organised as follows. Section 2 presents the theoretical lens of this study by reviewing the literature of the adaptation and economic adaptation. Section 3 then outlines the methodology. Section 4 identifies the data and discusses its application. After presenting the analysis results in Section 5, Section 6 discusses the findings and draws a conclusion.

2 Theoretical Considerations

2.1. Adaptation

Derived from evolutionary ecology, the concept of adaptation has been viewed from diverse perspectives of both natural and social sciences (Smit B & Wandel J, 2006). In the natural sciences, adaptation refers to both the current state of being adapted and to the dynamic evolutionary process, which contributes to the fitness and survival of an organisms or a system to maintain and reproduce coping with environmental changes. By contrast, social science defines adaptation as the ability to develop or survive amidst the modifications and transformations in institutions, behaviour, approaches and technologies. Adaptation is found to involve a long-term and constant process of learning, experimentation and change, which influence the vulnerability of a system (Birkmann J et al., 2013). This concept, mainly dealing with the conservation and protection of the current systems and institutional settings, may also encompass factors such as adaptive capacity, adaptation options, adaptation actions and adaptation strategies, which are available to those with uncertain vulnerability (Birkmann J, 2011). Adaptation has therefore become an important part of evaluation in resource management, climate change, economic development, risk management, planning, food security, livelihood security and sustainable development (Smit B & Wandel J, 2006). Adaptation studies often ask, 'adaptation to what?', 'who or what adapts?', 'how does adaptation occur?' and 'have the objectives been achieved?' (Fünfgeld H & McEvoy D, 2011; Preston B L & Stafford–Smith M, 2009).

2.2. Economic Adaptation

Economic adaptation is the extension of the adaptation concept in economics. From the perspective of uncertainty, MacKinnon et al. (2009) defined economic adaptation as an alternative method for economic actors to deal with the changes in their environment. Apart from reflecting complexity, diversity and variability, this concept implies an action or scheme for solving economic problems. Scholars from various fields (i.e., Steward J H, 1972; Denevan W M, 1983; O'Brien M J & Holland T D, 1992; Winterhalder B, 1980; IPCC, 1995; 2001; 2007; 2014) defined economic adaptation as the self-adaptation of the system to both internal and external environmental changes during the process of sustainable economic development. This concept is manifested as the capacity to adapt and shows a certain function correlation with economic vulnerability (Adger W N, 2006; Birkmann J et al., 2010; Smit B & Wandel J, 2006; Turner B L et al., 2003; Smit B et al., 1999). Economic adaptation also represents an effective decision-making institution that adjusts, manages and plans sustainable economic development (Adger W N et al., 2009a; Adger W N et al., 2009a; 2009b; Bertolini L, 2007). Accordingly, the implications of economic adaptation are reflected in three aspects. Firstly, the economic adaptation is a systematic concept that considered as a basic motivation to alter or adjust the structures and approaches of how the systems function in sustainable economic development whilst continuously interacting with their internal and external environments to improve their adaptation capacity (Turner B L et al., 2003; Bertolini L, 2007; Blaikie P et al., 2014). Secondly, economic adaptation is found to reduce economic vulnerability or the perception and prediction of economic exposure (Smit B & Wandel J, 2006). Thirdly, as an adaptation capacity, economic adaptation can be manifested as a strategy, institution or policy for management. Therefore, this standardised act and choice of value principles can be effectively used in economic decision making and planning.

2.3. Research Objectives

Economic adaptation offers several benefits, including reduced economic vulnerability, improved sustainable economic capacity and long-term sustainable economic growth (Smit B & Wandel J, 2006; Luers A L, 2005; Hassink R, 2010). Economic adaptation has been empirically analysed in least developed countries under the guidance of National Adaptation Programmes supported by the United Nations Framework Convention on Climate Change (van Ruijven B J et al., 2014). A number of studies have investigated the effects of economic adaptation on climate change, adaptive agriculture, adaptive

infrastructure, adaptive urbanisation programs and micro insurance regimes (Mundial B, 2008). However, assessing economic adaptation and ensuring the sustainability and effectiveness of this concept remain unaddressed. Given the lack of quantitative empirical evidence, researchers have not yet reached a consensus on whether China's economy can adapt to the changes brought by the market reform to achieve a sustainable growth. In fact, only a few studies have quantitatively evaluated the macro-economy from the adaptation perspective.

This paper empirically evaluates the adaptation of China's economic growth using the extenics assessment method to explore the effectiveness of various adaptation strategies and actions in ensuring sustainable economic growth and reducing economic vulnerability.

3 Method

3.1. Extenics Assessment Method

Introduced by Cai in 1983, the extenics theory adopts formalised models to evaluate the applicability of extenics as well as the laws and methods of innovation. Extenics theory describes three elements, which are the matter, character and corresponding character value. These elements are assumed to solve contradictory and incompatible problems qualitatively and quantitatively (Cai W, 1983; 1994; 1999). The extenics assessment method generally involves six steps, namely, (1) identifying the classical domain, (2) identifying the joint domain, (3) identifying the matter-element to be evaluated, (4) identifying the weight of the evaluation index, (5) identifying the degree of correlation, and (6) identifying the category and eigenvalues of the grade variables of the evaluation object.

First step: Identifying the classical domain.

$$\text{Suppose } R_j = (U_j, C, V_j) = \begin{bmatrix} U_j & c_1 & \langle a_{j1}, b_{j1} \rangle \\ & c_2 & \langle a_{j2}, b_{j2} \rangle \\ & \cdots & \cdots \\ & c_n & \langle a_{jm}, b_{jn} \rangle \end{bmatrix} \quad (1)$$

where V_j is the classical domain of U_j, which in turn indicates the range value in evaluation index set C that is chosen according to grade U_j.

Second step: Identifying the joint domain.

$$\text{Suppose } R_U = (U, C, V_U) = \begin{bmatrix} U & c_1 & \langle a_{U1}, b_{U1} \rangle \\ & c_2 & \langle a_{U2,} b_{U2} \rangle \\ & \cdots & \cdots \\ & c_n & \langle a_{Um}, b_{Un} \rangle \end{bmatrix} \quad (2)$$

where V_U is the joint domain that serves as the range value in evaluation index set C that is chosen according to grade U.

Third step: Identifying the matter-element to be evaluated.

$$\text{Suppose } R_i = \begin{bmatrix} N & c_{ik} & v_{i1} \\ & c_{i2} & v_{i2} \\ & \cdots & \cdots \\ & c_{ik} & v_{ik} \end{bmatrix} \quad (3)$$

where N is the evaluation object, v_{ik} is the value of c_{ik} that is associated with N, $k = 1, 2, \cdots, p$ and p is the number of the secondary index.

Fourth step: Identifying the weight of the evaluation index.

$$\text{Suppose } W_i \geq 0 \ \ (i = 1, 2, \cdots, n); \ \sum_{i=1}^{n} W_i = 1 \quad (4)$$

where W_i denotes the index weight of i.

Fifth step: Identifying the degree of correlation.

The degree of correlation of the second-class index is computed as follows:

$$k_j(c_{ik}) = \begin{cases} \dfrac{\rho(v_{ik}, V_j)}{\rho(v_{ik}, V_U) - \rho(v_{ik}, V_j)} & x \notin (a_{kj}^i, b_{kj}^i) \\ 0.05 & v_{ik} = a_{kj}^i or v_{ik} = b_{kj}^i \\ \dfrac{\rho(v_{ik}, V_j)}{b_{kj}^i - a_{kj}^i} & x \in (a_{kj}^i, b_{kj}^i) \end{cases} \quad (5)$$

where $k_j(c_{ik})$ is the degree of correlation of grade j in second-class index K in order within the first-class index.

The correlation coefficient is computed as follows:

$$\rho(v_{ik}, V_j) = \left| v_{ik} - \frac{a_{ji} + b_{ji}}{2} \right| - \frac{(b_{ji} - a_{ji})}{2} \quad (6) \text{ and}$$

$$\rho(v_{ik}, V_U) = \left| v_{ik} - \frac{a_{Ui} + b_{Ui}}{2} \right| - \frac{(b_{Ui} - a_{Ui})}{2} \quad (7)$$

After multiplying the weight vector of the second-class index by the correlation coefficient matrix of various grades of the second-class index, the correlation coefficient matrix of the first-class index is computed as follows:

$$k(c_i) = (k_j(c_i)) = \left[w_{i1}, w_{i2}, \cdots, w_{ip} \right] \bullet \begin{bmatrix} k_1(c_{i1}) & k_2(c_{i1}) & \cdots & k_m(c_{i1}) \\ k_1(c_{i2}) & k_2(c_{i2}) & \cdots & k_m(c_{i2}) \\ \cdots & \cdots & \cdots & \cdots \\ k_1(c_{ip}) & k_2(c_{ip}) & \cdots & k_1(c_{ip}) \end{bmatrix} \quad (8)$$

After multiplying the weight vector of the first-class index by the fist-class correlation coefficient, the correlation coefficient matrix of the evaluation object is expressed as follows:

$$k(N) = \left[w_1, w_2, \cdots, w_n \right] \bullet \begin{bmatrix} k_1(c_1) & k_2(c_1) & \cdots & k_m(c_1) \\ k_1(c_2) & k_2(c_2) & \cdots & k_m(c_2) \\ \cdots & \cdots & \cdots & \cdots \\ k_1(c_n) & k_2(c_n) & \cdots & k_1(c_n) \end{bmatrix} \quad (9)$$

Sixth step: Identifying the category and eigenvalues of the grade variables of the evaluation object.

Evaluation grade:

If $k_{j0}(N) = \max_{j=\{1,2,\cdots,m\}} k_j(N)$, then the evaluation object N belongs to grade j.

Evaluation coefficient:

$$\text{Suppose } j^* = \frac{\sum_{j=1}^{m} j \cdot k_j^{'}(N)}{\sum_{j=1}^{m} k_j^{'}(N)} \quad (10)$$

where $k_j^{'}(N) = \dfrac{k_j(N) - \min_j k_j(N)}{\max_j k_j(N) - \min_j k_j(N)}$ and j^* is the grading coefficient.

The extenics method has been applied in the literature as an assessment tool (i.e., Zheng G et al., 2009; Zhang Y et al., 2014; Wang M et al., 2015). As this method not only qualitatively analyses the state of being of the system during the market-oriented process but also quantitatively analyses the adaptation capacity of the system and the changes that occur at different stages, this research adopts the extenics method to assess economic growth adaptation for the first time.

3.2. Membership Function Coordination Degree Model

Coordination refers to the effective restriction and regulation of system behaviour by organizing different ingredient working together, whilst development refers to the direction of the system movement. As the integration of the coordination and development of a system, the concept of coordinative development presents an important means and direction in sustainable development. The coordination degree model is

mainly adopted in the quantitative analysis of coordinative development. In economic research and analysis, the derivative models such as the membership function coordination degree model, coefficient of dispersion minimisation coordination degree model, Gini coefficient coordination degree model and data envelopment coordination degree model are widely adopted.

This research utilizes the membership function coordination degree model to analyse the assessment results of economic adaptation. This model includes the static coordination degree model and dynamic coordination degree model. The former model estimates the grade of coordination and determines whether the systems are in coordination. The widely-adopted coordination degree classification criteria can be divided into nine levels (see Table 1). The latter model determines whether a state of development occurs amongst systems from the time series perspective (Ding L et al., 2015; Yang Q, et al., 2014; Li Y et al., 2012). A state of coordination and development amongst systems indicates the sustainable development of adaptation capacity in economic growth, whilst the lack of coordination and development implies that economic adaptation derives from sustainable development. These systems must be adjusted for them to adopt further rationalised adaptation strategies or actions in the future.

The static coordination degree model is expressed in its basic form as follows:

$$c_s(i,j) = \frac{\min\{u(i/j),(u(j/i)\}}{\max\{u(i/j),(u(j/i)\}} \qquad (11)$$

where $c_s(i,j)$ denotes the static coordination degree between systems *i* and j, that is, $0 \le c_s(i,j) \le 1$. A larger $c_s(i,j)$ implies the better coordination of the system. $u(i/j)$ denotes the degree of coordination**,** which is calculated based on the discrepancy between the actual level of development of the system and the coordination value. Such degree is calculated as follows: $u(i/j) = \exp\left\{-(x-\hat{x})^2/s^2\right\}$, where x is the actual value of the system, $\hat{x}$ is the coordination value between systems *i* and j that is generally expressed by a regression coefficient and s^2 is the mean square error of system i.

The dynamic coordination degree model is expressed as follows in its *t* basic form:

$$c_d(t) = \frac{1}{T}\sum_{K=0}^{T-1} C_s(t-k) \qquad (12)$$

where $c_d(t)$ represents the index of dynamic coordination degree within a time span of t, that is, $0 \le c_d(t) \le 1$, whilst $c_s(t-k)$ denotes the static coordination degree amongst systems in each moment. When $t_1 > t_2$ and $c_d(t_1) \ge c_d(t_2)$, the system is currently in a state of coordination of continuous development. Otherwise, the system is currently in a state of coordination of continuous decline.

Table 1: The coordination degree classification criteria.

Serial number	Coordination degree (c_t)	Levels of coordination
1	$c_t = 0$	Complete non-coordination
2	$0 < c_t < 0.4$	Serious non-coordination
3	$0.4 \le c_t < 0.5$	Medium non-coordination
4	$0.5 \le c_t < 0.6$	Mild non-coordination
5	$0.6 \le c_t < 0.7$	Mild coordination
6	$0.7 \le c_t < 0.8$	Basic coordination
7	$0.8 \le c_t < 0.9$	Good coordination
8	$0.9 \le c_t < 1$	Excellent coordination
9	$c_t = 1$	Complete coordination

4 Data and Application

4.1. Index System

The index system of adaptation mainly focuses on adaptation capacity (Birkmann J et al., 2013; Birkmann J, 2011; Marlin A et al., 2007; Pandey V P et al., 2010). This research uses economic adaptation capacity to construct an index system. The index system of economic adaptation is selected based on scientific, systematic, dynamic, leading, adaptive and operable principles, which emphasise the economic adaptation strategies and actions that China requires to achieve sustainable economic growth. Here, the index of selected 25 adaptation capacity indicators is a combination of three sub-indices covering economic, social and nature–resource–environment systems, which are related to China's economic growth since market reform (see Table 2). For instance, the dominant sub-indices, economic adaptation, includes aspects of economic efficiency, market economy reform, economic development, social development and security, natural disaster relief, resource production and efficiency and environment investment and treatment, each is presented by one or more indicators, and altogether contributes to the adaptation capacity of the economic system.

Table 2: The Index system of economic adaptation

Capacity		Indicator	Unit	Interpretation
Economic capacity (EC)	Economic efficiency	Total factor productivity (TFP) (C1)	-	Reflects technological progress and change
		Capital productivity (C2)	-	Reflects the ratio of return on capital to economic growth
		Labour productivity (C3)	$/ per person	Reflects labour technical level and proficiency
	Market economy reform	Ratio of non-fiscal expenditure to GDP (C4)	%	Reflects the market allocation of economic resources
		Ratio of non-state-owned economy to total industrial output value (C5)	%	Reflects the market property right system reform
		Ratio of FDI to GDP (C6)	%	Reflects the degree of factor market development
		Three kinds of patent applications accepted and granted per 10,000 persons (C7)	piece	Reflects the degree of scientific and technological innovation in the market
		Ratio of R&D expenditure to GDP (D8)	%	Reflects the investments in science and technology innovation
	Economic development	Per capita GDP (C9)	$	Per capita economic welfare
		Ratio of secondary industry to GDP (C10)	%	Reflects the degree of industrialisation development
		Ratio of tertiary industry to GDP (C11)	%	Reflects the level of the development of the tertiary industry
		Ratio of consumer expenditure to GDP (C12)	%	Reflects the consumption level of residents
	Social development	Urbanisation rate (C13)	%	Reflects the degree of urbanisation development
		Ratio of education expenditure to GDP (C14)	%	Reflects the degree of educational development

Social capacity (SC)		Ratio of health expenditure to GDP (C15)	%	Reflects the degree of health service development
		Coverage rate of community service facilities (C16)	%	Reflects the degree of social service system construction
	Social security	Ratio of unemployment insurance contributors to employed persons (C17)	%	Reflects the ability to prevent unemployment risk
		Ratio of basic pension insurance to population (C18)	%	Reflects the degree of social security
Nature–resources–environment capacity (NREC)	Natural disaster relief	Expenditure on natural disaster relief per 10,000 persons (C19)	$	Reflects the economic rescue capacity for natural disasters
	Resource production and efficiency	Elasticity ratio of energy production (C20)	-	Reflects the capacity and efficiency of energy production
		Efficiency of energy conversion (C21)	%	
	Environment investment and treatment	Ratio of investments in treating industrial pollution from the secondary industry (C22)	%	Reflects the investments in industrial pollution control
		Discharge standard-meeting rate of industrial wastewaters (C23)	%	Reflects the efficiency of environmental governance
		Discharge standard-meeting rate of industrial SO2 (C24)	%	
		Percentage of industrial solid wastes produced (C25)	%	

4.2. Data Sources

The data of the indicators (in Table 2), excluding TFP, are collected from the *China Statistical Yearbooks* (1992-2015). TFP was estimated based on the C–D production of two function input factors whilst considering capital and labour. This method is one of the most objective estimation methods available in the literature by far. In order to fiure out the base year capital stock, the base year fixed investment was divided by 10% and set as

the initial capital stock (Young A, 2000). The depreciation rate was set to 6% (Hall R E & Jones C I, 1999).

4.3. Application of the Extenics Assessment Method

- Economic adaptation was classified as 'non-adaptation', 'basic adaptation' and 'adaptation in advance'. U_D denotes the level of economic adaptation, where $U_D = \{U_{1D}, U_{2D}, U_{3D}\} =$ {non-adaptation, basic adaptation, adaptation in advance}. 'Non-adaptation' occurs when the capacity to adapt obstructs or hampers economic growth. 'Basic adaptation' indicates that the capacity to adapt basically meets the demands of economic growth. 'Adaptation in advance' indicates that the capacity to adapt not only meets the demands of economic growth but also promotes sustainable economic growth in the future. A stronger adaptation capacity indicates higher chances of achieving sustainable economic development.
- C_c denotes the factor set of economic adaptation, where $C_c = \{c_{cj}, j = 1, 2, \cdots, n\}$.
- The classical and joint domains for the assessment index are determined based on the range value of an index. This paper follows the international standards, theoretical perspectives and opinions of experts in setting the standards of the three adaptation levels. Table 3 lists the adaptation indexes.
- This paper applies the entropy method in Shannon C E and Weaver W (1947) to determine the class of economic adaptation indexes (see Table 4).
- Given the complexity of the multi-factorial extension assessment method, this paper uses the Matlab 2010a software for the calculations.

Table 3: The classical domain and joint domain of economic adaptation

Index	Classical domain			Joint domain	Principle and standard
	Not adapted	Basically adapted	Adapted in advance		
Total factor productivity(TFP) (C1)	[0-1]	[1-2]	[2- higher limit]	[0- higher limit]	Opinion of experts
Capital productivity(C2)	[0-0.5]	[0.5-0.8]	[0.8-1]	[0-1]	Opinion of expert
Labor productivity (C3)	[0-10000]	[10000-30000]	[30000-higher limit]	[0- higher limit]	Opinion of expert
Ratio of expenditure on non-fiscal to GDP(C4)	[0-30]	[30-70]	[70-100]	[0-100]	International standards
Ratio of non-state-owned economy to total industrial	[0-50]	[50-80]	[80-100]	[0-100]	Theoretical perspective

output value(C5)					
Ratio of FDI to GDP(C6)	[0-5]	[5-10]	[10-100]	[0-100]	Opinion of expert
Three kinds of patents applications accepted and granted in per 10000 person (C7)	[0-1]	[1-5]	[5- higher limit]	[0- higher limit]	Opinion of expert
Ratio of expenditure on R&D to GDP (D8)	[0-10]	[10-20]	[20- higher limit]	[0- higher limit]	Opinion of expert
Per capita GDP （C9）	[0-1500]	[1500-5000]	[5000- higher limit]	[0- higher limit]	Opinion of expert
Ratio of secondary industry to GDP(C10)	[0-30]	[30-50]	[50-100]	[0-100]	Theoretical perspective
Ratio of tertiary industry to GDP(C11)	[0-50]	[50-80]	[80-100]	[0-100]	Theoretical perspective
Ratio of expenditure on consumer to GDP(C12)	[0-50]	[50-70]	[70-100]	[0-100]	Theoretical perspective
Urbanization rate (C13)	[0-30]	[30-70]	[70-100]	[0-100]	International standards
Ratio of expenditure on education to GDP(C14)	[0-4]	[4-5]	[5- higher limit]	[0- higher limit]	International standards
Ratio of total health expenditure to GDP(C15)	[0-4]	[4-5]	[5- higher limit]	[0- higher limit]	Opinion of expert
Coverage rate of community service facilities(C16)	[0-50]	[50-90]	[90-100]	[0-100]	Opinion of expert
Ratio of unemployment insurance contributors total employed persons(C17)	[0-20]	[20-70]	[70-100]	[0-100]	International standards
Ratio of statistics on basic pension insurance to total population(C18)	[0-30]	[30-70]	[70-100]	[0-100]	International standards
Expenditure on relief to natural disasters per 10000 person(C19)	[0-2]	[2-5]	[5- higher limit]	[0- higher limit]	Opinion of expert
Elasticity ratio of energy production (C20)	[lower limit -0.5]	[0.5-1]	[1- higher limit]	[lower limit - higher limit]	Theoretical perspective
Efficiency of energy conversion(C21)	[0-60]	[60-80]	[80-100]	[0-100]	Opinion of expert
Ratio of investment completed in the treatment of industrial pollution to secondary industry(C22)	[0-0.1]	[0.1-0.3]	[0.3-1]	[0-1]	Opinion of expert
Discharge standard-meeting rate of industrial wastewaters(C23)	[0-80]	[80-95]	[95-100]	[0-100]	Opinion of expert
Discharge standard-meeting rate of industrial SO2 (C24)	[0-80]	[80-95]	[95-100]	[0-100]	Opinion of expert
Percentage of industrial solid wastes produced(C25)	[0-80]	[80-95]	[95-100]	[0-100]	Opinion of expert

4.4. Application of the Membership Function Coordination Degree Model

The membership function coordination degree model was established based on the assessment results of economic adaptation. EC–SC represents the coordination between economic capacity and social capacity, EC–NREC represents that between economic capacity and resource and environment capacity, SC–NREC represents that between social capacity and resource and environment capacity and EC–SC–NREC represents that of a coupled system.

5 Results

5.1 Weight of Indexes

The weight of each adaptation capacity index was calculated using the entropy method. This weight indicates the relative importance of an adaptation capacity index with respect to the other indexes. The five indexes, namely, ratio of basic pension insurance to population (C18) (0.1347), three kinds of patent applications accepted and granted per 10,000 persons (C7) (0.1162), expenditure on natural disaster relief per 10,000 persons (C19) (0.0727), urbanisation rate (C13) (0.0539) and capital productivity (C2) (0.0506) (see Table 4), are related to the aspects of social security, market economy reform, natural disaster relief, social development and economic efficiency, respectively. Economic capacity (0.5020) has a higher weight than social capacity (0.3746) and nature–resources–environment capacity (0.1234) (see Table 5).

Table 4: Results of indexes weight and rank

Indexes	Information entropy	Utility value	Weight	Rank
Total factor productivity(TFP)(C1)	0.9629	0.0371	0.0134	23
Capital productivity(C2)	0.8626	0.1400	0.0506	5
Labor productivity(C3)	0.8614	0.1386	0.0501	6
Ratio of expenditure on non-fiscal to GDP(C4)	0.9093	0.0907	0.0328	12
Ratio of non-state-owned economy to total industrial output value(C5)	0.9478	0.0522	0.0188	21
Ratio of FDI to GDP(C6)	0.8877	0.1123	0.0406	10
Three kinds of patents applications accepted and granted in per 10000 person (C7)	0.6783	0.3217	0.1162	2
Ratio of expenditure on R&D to GDP(D8)	0.8989	0.1011	0.0365	11
Per capita GDP（C9）	0.8629	0.1371	0.0495	7
Ratio of secondary industry to	0.9559	0.0441	0.0159	22

GDP(C10)				
Ratio of tertiary industry to GDP(C11)	0.9173	0.0827	0.0299	14
Ratio of expenditure on consumer to GDP(C12)	0.8679	0.1321	0.0477	8
Urbanization rate(C13)	0.8509	0.1491	0.0539	4
Ratio of expenditure on education to GDP(C14)	0.9159	0.0841	0.0304	13
Ratio of total health expenditure to GDP(C15)	0.9470	0.0530	0.0191	20
Coverage rate of community service facilities(C16)	0.9364	0.0636	0.0230	18
Ratio of unemployment insurance contributors total employed persons(C17)	0.8871	0.1129	0.0408	9
Ratio of statistics on basic pension insurance to total population(C18)	0.6271	0.3729	0.1347	1
Expenditure on relief to natural disasters per 10000 person(C19)	0.7987	0.2013	0.0727	3
Elasticity ratio of energy production(C20)	0.9740	0.0260	0.0094	25
Efficiency of energy conversion(C21)	0.9716	0.0284	0.0102	24
Ratio of investment completed in the treatment of industrial pollution to secondary industry(C22)	0.9364	0.0636	0.0230	19
Discharge standard-meeting rate of industrial wastewaters(C23)	0.9182	0.0818	0.0295	15
Discharge standard-meeting rate of industrial SO2(C24)	0.9341	0.0659	0.0238	17
Percentage of industrial solid wastes produced(C25)	0.9240	0.0760	0.0275	16

Table 5: Results of weight of system capacity

Capacity	weight	Rank
Economic capacity(EC)	0.5020	1
Social capacity(SC)	0.3746	2
Nature-resources-environment capacity(NREC)	0.1234	3

5.2. Assessment of Economic Adaptation

The three system capacities and economic adaptation were assessed using the extenics method. Table 6 and Figure 1 present the calculation results.

Economic adaptation gradually moved upwards between 1993 and 2009, showed a prominent inflection point in 2010 and then gradually moved upwards again afterwards.

In other words, economic adaptation underwent 'non-adaptation' from 1993 to 2003, 'basic adaptation' from 2004 to 2010 and 'adaptation in advance' from 2011 to 2014.

Similarly, the three system capacities showed an upward trend from 1993 to 2014 (see Table 6 and Figure 1). However, unlike economic adaptation and the nature–resources–environment capacity, both economic and social capacities showed a prominent inflection point in 2012 instead of 2008. These capacities also gradually moved upwards before reaching their prominent inflection points.

Table 6: Results of economic adaption

Year	Economic capacity (EC)	Social capacity (SC)	Nature-resources-environment capacity (NREC)	Economic adaptation	Rating level
1993	1.3377	1.2158	1.0877	1.2516	Non-adaptation
1994	1.3772	1.214	1.113	1.2729	
1995	1.3773	1.2177	1.1887	1.284	
1996	1.3801	1.2279	1.1995	1.2885	
1997	1.4064	1.2347	1.1554	1.2961	
1998	1.4208	1.2558	1.1995	1.318	
1999	1.4986	1.2858	1.185	1.3596	
2000	1.5272	1.2969	1.1595	1.3773	
2001	1.5496	1.3246	1.3354	1.4257	
2002	1.6133	1.3395	1.3405	1.4611	
2003	1.6822	1.3433	1.3059	1.4848	
2004	1.7065	1.3536	1.4084	1.5101	Basical adaptation
2005	1.7326	1.3592	1.456	1.5167	
2006	1.7964	1.3661	1.5529	1.5387	
2007	1.9272	1.3699	1.652	1.5677	
2008	2.089	1.3934	2.6299	1.6503	
2009	2.4021	1.3848	2.2052	1.7495	
2010	2.6541	1.4222	2.5176	2.3822	
2011	2.7905	1.4203	2.2669	2.5641	Adaptation in advance
2012	2.8618	2.1845	2.5779	2.6181	
2013	2.8542	2.2451	2.4305	2.6017	
2014	2.8547	2.2932	2.542	2.6198	

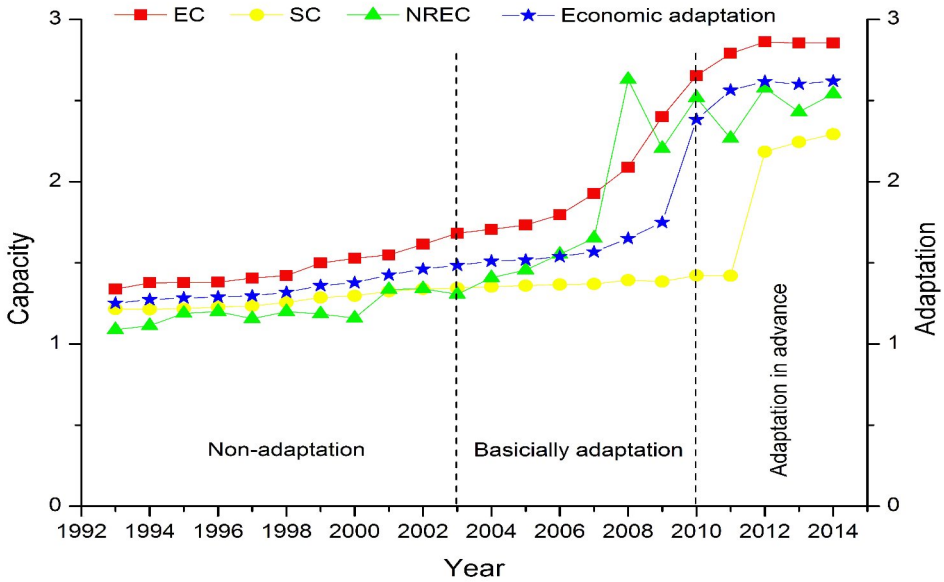

Figure 1: The trend and stage of economic adaptation

5.3. Analysis of the Coordination Degree to Economic Adaptation

Coordinating the three system capacities can promote sustainable economic growth. However, the static coordination degree model reveals the lack of coordination amongst these capacities. The static coordination degree decreased between 1993 and 2007, during which period, serious non-coordinations were illustrated in EC–SC, SC–NREC and EC–SC–NREC. At the same time, SC–NREC gradually declined from basic coordination to serious non-coordination. The coordination degrees of all capacities showed a fluctuating trend between 2008 and 2012. A very small static coordination degree was observed in serious non-coordination since 2013.

Table 7: Static coordination degree

	EC-SC		EC-NREC		SC- NREC		EC-SC- NREC	
Year	degree	level	degree	level	degree	level	degree	level
1993	0.1887	Serious non-coordination	0.7591	Basically coordination	0.1501	Serious non-coordination	0.3660	Serious non-coordination
1994	0.1902		0.7241		0.1494		0.3546	
1995	0.1871		0.7595		0.1429		0.3632	
1996	0.1787		0.7626		0.1356		0.3590	
1997	0.1738		0.7079		0.1327		0.3381	
1998	0.1580		0.7135		0.1180		0.3298	
1999	0.1407		0.6115	Mildly coordination	0.1013		0.2845	
2000	0.1353		0.5669	Mildly	0.0962		0.2661	

				non-coordination				
2001	0.1193		0.6413	Mildly coordination	0.0826		0.2811	
2002	0.1162		0.5594	Mildly non-coordination	0.0762		0.2506	
2003	0.1223		0.4521	Medium non-coordination	0.0739		0.2161	
2004	0.1193		0.4870		0.0724		0.2262	
2005	0.1197		0.4898		0.0722		0.2272	
2006	0.1266		0.4884		0.0756		0.2302	
2007	0.1568		0.3998		0.0834		0.2133	
2008	0.2006		0.0854		0.6764	Mildly coordination	0.3208	
2009	0.5661	Mildly non-coordination	0.3400	Serious non-coordination	0.2798	Mildly non-coordination	0.3953	
2010	0.7625	Basically coordination	0.3895		0.7437	Basically coordination	0.6319	Mildly coordination
2011	0.3888	Serious non-coordination	0.0492		0.2794	Serious non-coordination	0.2391	Serious non-coordination
2012	0.0081		0.1488		0.0016		0.0528	
2013	0.0041		0.0714		0.0004		0.0253	
2014	0.0025		0.1279		0.0004		0.0436	

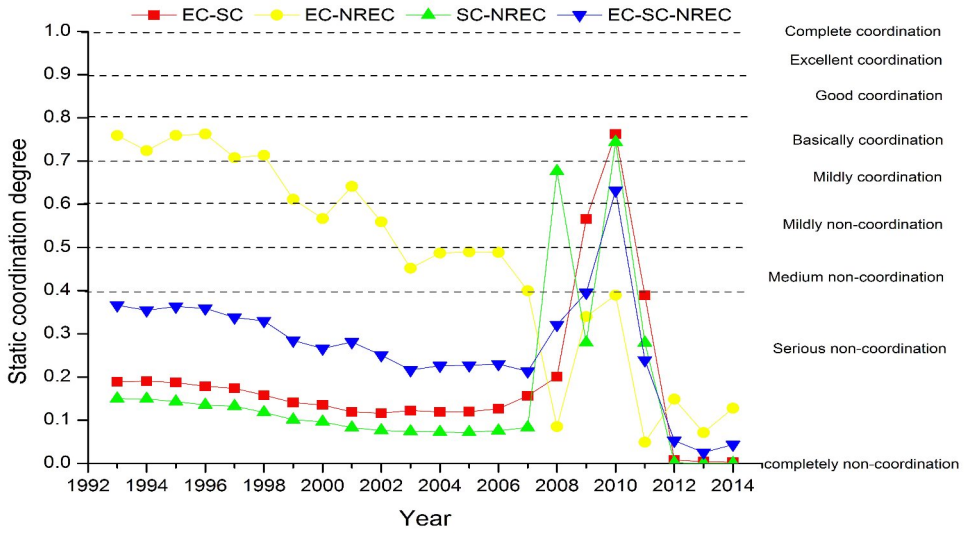

Figure 2: The trend and level of static coordination degree

Table 8. Dynamic coordination degree

Year	EC-SC		EC- NREC		SC- NREC		EC-SC- NREC	
	degree	State*	degree	State	degree	State	degree	State
1993	0.1887	-	0.7591	-	0.1501	-	0.3660	-
1994	0.1895	↑	0.7416	↓	0.1498	↓	0.3603	↓
1995	0.1887	↓	0.7476	↑	0.1475	↓	0.3613	↑
1996	0.1862	↓	0.7513	↑	0.1445	↓	0.3607	↓
1997	0.1837	↓	0.7426	↓	0.1421	↓	0.3562	↓
1998	0.1794	↓	0.7378	↓	0.1381	↓	0.3518	↓
1999	0.1739	↓	0.7197	↓	0.1329	↓	0.3422	↓
2000	0.1691	↓	0.7006	↓	0.1283	↓	0.3327	↓
2001	0.1635	↓	0.6940	↓	0.1232	↓	0.3269	↓
2002	0.1588	↓	0.6806	↓	0.1185	↓	0.3193	↓
2003	0.1555	↓	0.6598	↓	0.1144	↓	0.3099	↓
2004	0.1525	↓	0.6454	↓	0.1109	↓	0.3029	↓
2005	0.1499	↓	0.6334	↓	0.1080	↓	0.2971	↓
2006	0.1483	↓	0.6231	↓	0.1057	↓	0.2923	↓
2007	0.1488	↑	0.6082	↓	0.1042	↓	0.2871	↓
2008	0.1521	↑	0.5755	↓	0.1399	↑	0.2892	↑
2009	0.1764	↑	0.5617	↓	0.1482	↑	0.2954	↑
2010	0.2090	↑	0.5521	↓	0.1812	↑	0.3141	↑
2011	0.2185	↑	0.5256	↓	0.1864	↑	0.3102	↓
2012	0.2079	↓	0.5068	↓	0.1772	↓	0.2973	↓
2013	0.1982	↓	0.4861	↓	0.1688	↓	0.2843	↓
2014	0.1893	↓	0.4698	↓	0.1611	↓	0.2734	↓

*↑ is the state of development. ↓ is the state of decline.

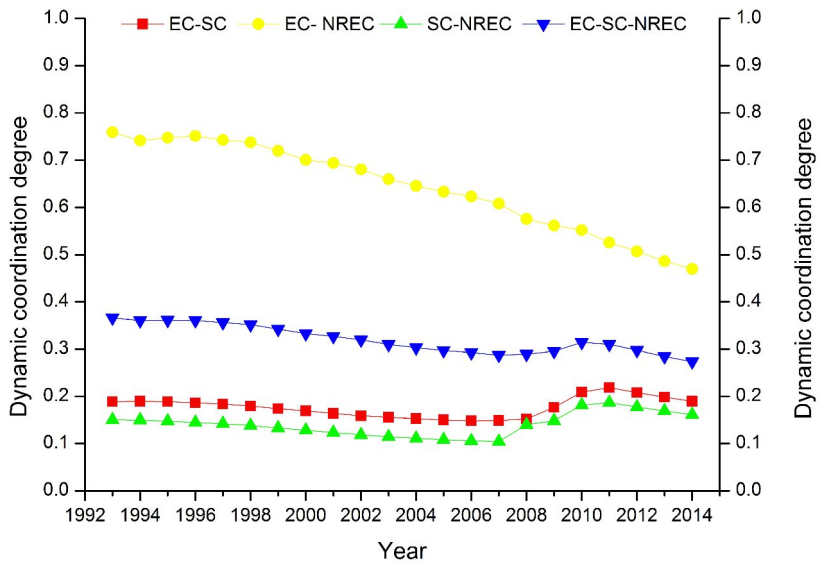

Figure 3: The trend of dynamic coordination degree

Table 8 and Figure 3 illustate the results for the dynamic coordination degree. EC–SC–NREC, EC–SC and SC–NREC showed almost the same dynamic coordination

degree, which gradually moved downwards before experiencing the state of decline between 1993 and 2008. Afterwards, the dynamic coordination degree gradually moved upwards and underwent a state of development between 2009 and 2011. Since 2012, the dynamic coordination degree gradually moved downwards and underwent a state of decline. EC–NREC obviously underwent a state of decline in 1995 and 1996.

6 Discussion and Conclusions

Using the extenics assessment method and the membership function coordination degree model, this paper assesses and analyses the coordination of China's economic adaptation since its market economic reform.

The rapid economic growth of China may be attributed to the country's favourable economic adaptation capacity. China underwent several market-oriented economic reforms since 1992, during which the country faced a weak social foundation, low resource use efficiency and serious environmental pollution despite experiencing considerable economic growth. China joined the WTO in 2001 and took advantage of the organisation's inclusive policies. China also began to construct an effective market system and implement policy measures to promote its economic adaptation. China experienced a rapid economic growth despite facing challenges in its continuous marketization process, which suggests that the constant changes in the internal and external environments of China have altered or adjusted the structure and adaptation of the system to prevent economic exposure. The challenges that face the Chinese economy may be perceived as important strategic opportunities (Summers L, 2012; Wan W P & Yiu D W, 2009). China has taken advantage of such opportunities by enhancing its adaptation capacity, and the assessment results all demonstrate significant enhancements in the adaptation capacity of China (Lo D & Li G, 2011).

The lack of coordination can result in a declining and unsustainable economic growth. The downward pressure on China's economic growth after 2010 can be ascribed to the country's declining economic adaptation capacity. However, the assessment results showed that China had a higher economic adaptation capacity during this period. Analysing the coordination degree revealed some risks in the coordination and sustainability of China's economic development, which echoed the findings of Allington N F B et al. (2012). China has been faxing serious challenges in its way to sustainable growth. The country's economic adaptation capacity is also in a state of non-coordination, indicating that the systems have been operating independently during

the economic growth process. Such lacks of coordination further compromises the overall operation of these systems, which contradicts the coordination principle of sustainable economic growth. China's economic adaptation capacity is in a state of decline when viewed from the time series and coordination perspectives, which indicates that the Chinese economy has deviated from the path towards sustainable growth.

These findings clearly demonstrate the value orientation of adaptation strategies. China must switch to a different path to achieve sustainable economic growth. The country must also adopt the necessary measures to improve the coordination of its adaptation capacity.

China has demonstrated favourable economic adaptation capacity since the market economy reform. China may achieve sustainable growth as long as the economy exercises such reform and improves coordination to avoid the inherent risks in the implementation of rationalised adaptation strategies (Norman J & Kraft, 2012). However, this study only signifies a first step towards assessing economic growth adaptation. Future work could emphasize on diagnosing and assessing the vulnerability of economic growth, which are also combined with economic sensitivity during the market reform process.

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Author Contributions

Guofang Zhai and Chongqiang Ren developed the original idea and contributed to the conceptual framework, Guofang Zhai and Chongqiang Ren wrote the paper and were responsible for data colletion, process and analysis. Shasha Li, Wei Chen and Shutian Zhou provided improving suggestions. All authors have read and approved the final manuscript.

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