# Research on the logical structure and evaluation model of coupling development between strategic emerging and traditional industries

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**Abstract:** This paper analyses the necessity of coupling development between strategic emerging and traditional industries as well as its logical structure in time and space. A model, which includes the index system of coupling evaluation, the coupling degree of association model and the sustainable development model that evaluates coupling development, is constructed. The model is used to conduct an empirical study of the environmental industry and rubber manufacturing industry. Results indicate that China's environmental industry and rubber manufacturing industry are in the developmental state of moderate coupling and mild recession. Finally, some policy recommendations are summarised.

**Keywords:** strategic emerging industries; traditional industries; coupling evaluation; coupling development; high technology and innovation.

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## 1 Introduction

Emerging strategic industries refer to industries that have key technologies, broad market demands, big driving coefficient, low energy consumption and provide job opportunities with good comprehensive benefits (Jiabao, 2009). In the post-financial crisis era, many countries have concluded that technology innovation is a new engine for next economic growth and have therefore transferred their development focus from traditional industries to emerging strategic industries. After missing four technical revolutions, China chose innovation-driven and endogenous growth and decided to vigorously cultivate emerging strategic industries. In contrast to developed countries, these industries in China were developed under circumstances in which traditional industries were developed insufficiently and incompletely. Therefore the industrial development of our country is now facing a 'bimodal approaching effect': Both traditional and emerging strategic industries need to be developed during a short period. Whereas in developed countries, industrial restructuring was based on the industrialised national economy, current national conditions in China have led to the couple-development path that implies that strategic emerging industries must be closely integrated and mutually promoted with traditional industries.

Both at home and abroad, scholars have studied the relationship between traditional industries and strategic emerging industries in economic development. Isard et al. (1959) proposed the theory of industrial syntheses in 1959, which includes an industrial complex to indicate a set of economic activities occurring in a specific location. His theory illustrated that energy conservation can be achieved with the integration of technology and manufacturing. Osaka (2002) advanced the knowledge of traditional industries when he analysed the development of textile industries in Taiwan. In his theory, traditional industries and emerging industries interacted with each other and closely developed together. In an analysis of new high-tech industries and traditional industries in China, especially in the Beijing area, Dallas (1998) proposed that the Chinese government took high-tech industries as the upper with the traditional industries as the base.

Scholars in China have also attempted to apply coupling theory to industry studies. Wu and Cao (2005) discussed the factors that influence cooperative development between new high-tech industries and traditional industries from three aspects, the industrialisation of high-tech industries, the transformation of traditional industries into high-tech industries, and the construction of collaborative environment. Sheng and Zhong (2009) researched the coupling interrelationship between tourist industries and regional economies. Xi et al. (2009) qualitatively analysed the interactive relationship and coupling evolutionary process of the sports industry and city development. Sun et al. (2003) used industry coupling development theory to analyse the Chinese marine fishery based on the interaction between the economic structure and industry structure. Chen (1981) proposed a non-linear model to evaluate industry inter-relationships. Zhang and Ge (1988) proposed an embedded input-output table and optimisation scheme to analyse the influence of national economic sectors towards their optimal structure. Xue and Wang etc. (1997) proposed the theory of 'grey factors input and output', which means that the object environment, which any economic systems exist on, includes not only material basis but also non-material basis. Xue (2000) also conducted research on the input-output model consisting of recessive factors.

Through these analyses, we find that most research done by academic scholars on industries focused on the interrelationship of various industries and their corresponding characteristics. For example, Dallas studied the relationship between new high-tech industries and traditional industries and Yanchao Sheng studied the coupling relationship between tourism industry and regional economy. They tended to use the existing non-linear physical models, input-output tables and grey input-output method to analyse data and modes. China is facing a particular situation that the emerging industry's peak and the traditional industry's peak are approaching together, the 'bimodal approaching effect', which is different from other countries. It is difficult to apply existing research methods for measuring symbiotic relationships between two industries properly. To address these issues, this paper attempts to study the logical structure of applying strategic development principles to emerging industries and traditional industries using the idea of industrial coupling. In order to propose strategy, we first develop an evaluation model of industry coupling to measure the coupling relationship between strategic emerging industries and traditional industries accurately.

## 2 The background of coupling development

### *2.1 The necessity of coupling development*

The literature review indicates that domestic and overseas scholars have remained at measurement research about the fuzzy relationship among industries rather than thoroughly researching the coupling development between strategic emerging industries and traditional industries. We believe that it is necessary and feasible to accurately measure the coupling relationship between strategic emerging industries and traditional industries. By understanding their coupling relationship of simultaneous development and mutually beneficial interaction, we can release the pressure coming from 'bimodal approaching effect' which is faced by Chinese industry development. Specifically, we need to consider the following three aspects:

1 The relationship between strategic emerging industries and traditional industries should be carefully analysed in order to develop both sectors simultaneously. With strong economic growth, the relationship of strategic emerging industries and traditional industries is like that of a hull and a sail -- interaction between them benefits each other. For example, high-tech industries can create new manufacturing for the old ones and also invigorate the equipment manufacturing industry. This kind of interaction makes full use of resources and expands intermediate needs and ultimate demand. We must seize the opportunity to make this a systemic cooperation and accelerate the pace of progress.

2 Strategic emerging industries and traditional industries should be tightly integrated. New industries can be cultivated during the optimisation and upgrading of traditional industries. For example, new material technology depends on iron and steel, non-ferrous metal, and petro-chemical industries; advanced manufacturing cannot work without mechanical industry; the existing base of medical industry is indispensable for the development of biological medicine technology; and the development of next-generation internet of Things cannot break away from the existing information industry. We must realise that the development of emerging industries should be coordinated with the further development of traditional industries, rather than being separated. Coordinated development implies that emerging industries can be

developed on a solid foundation and can promote the upgrading of traditional industries. The relationship of strategic emerging industries and traditional industries is not static and overlapping, but an interactional, mutually promoting, and interpenetrating organic whole which complements each other and better serves the development of regional economies.

3 The cultivation and development of strategic emerging industries should be undertaken interactively with traditional industries and determined not only by the general regularity of the cultivation and development of emerging industries, but also by a practical choice based on the reality of regional economic development. Strategic emerging industries in our country are developed under circumstances in which traditional industries are not fully or completely developed. Right now the industry development in our country faces the situation of 'bimodal approaching effect'. The optimal solution is to make the strategic emerging industries drive with two wheels and then gradually form a benignant and interactive development.

## *2.2 The logic of the structure of coupling development*

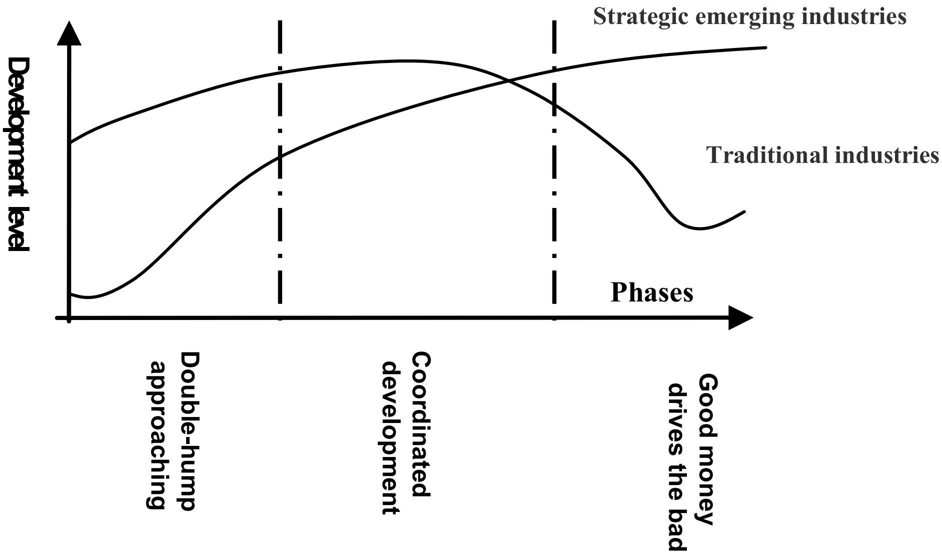
The logic of the structure of coupling development can be described through its temporal logic and its spatial logic as follows.

### *2.2.1 Temporal logic*

According to the life circle theory of industry development, we can classify industries as infant industries, emerging industries, mature industries and declining industries (Shi and He, 2004). The law of changes among industries is a process through which the proportion of emerging industries in the national economy increases rapidly and the proportion of mature industries is large, while that of declining industry gradually decreases.

Strategic emerging industries in China were cultivated under circumstances when traditional industries have developed insufficiently and incompletely. There are equal chances of developing emerging industries in developing countries or in developed countries and China has a special advantage in developing emerging industries. In order to have a head start in the next wave of economic growth, industrial development in China must choose the development pattern that will put forward cultivating and developing strategic emerging industries and simultaneously adjusting and reconstructing traditional industries. The kind of development path we choose now is different from that of developed countries. We believe that in a relatively short period of time, China should develop strategic emerging and traditional industries simultaneously. However, the industrial development of China is now facing a 'bimodal approaching effect' in which the peak of cultivating strategic emerging industries and adjustment reconstructing traditional industries are quite close to each other. The temporal logic of our country's strategic emerging industries can be divided into three phases according to the transformation between strategic emerging and traditional industries: double-hump approaching, coordinated development and good money drives out bad money. Figure 1 illustrates each of these phases, which can be described as follows.

**Figure 1** Developing phases of strategic emerging industries and traditional industries



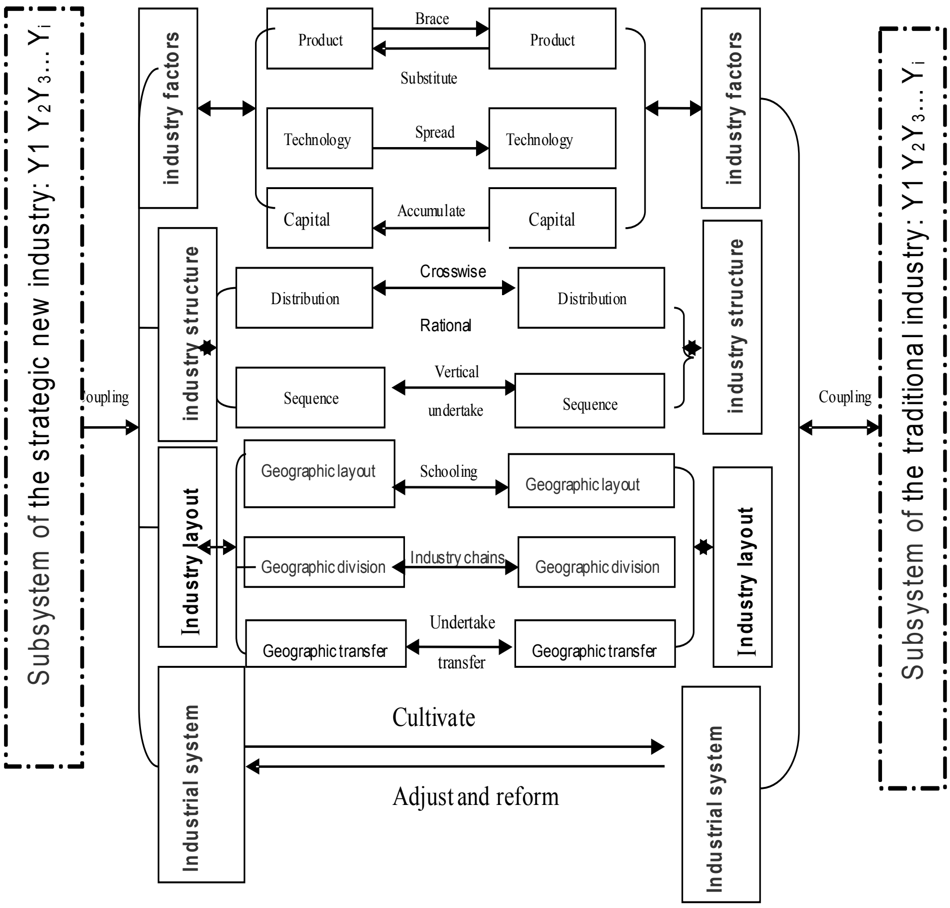

- *The phase of double-hump approaching.* This phase is the stage faced by our country's current industry. At this phase, strategic emerging industry is still in its infancy, while traditional industry is in late growth age or early maturity age. Our country needs to accelerate the development of traditional industries so as to complete industrialisation, plan in advance to develop strategic emerging industries and seize the highlands of industry development. Then the summit of traditional industries and strategic emerging industries will be achieved together as they develop over time.
- *The phase of coordinated development.* With the growth of strategic emerging industries and the mature development of traditional industries, the relationship between these two evolves from an interdependent and mutually promoted coupling relationship to a dual relationship of mutual promotion and repulsion. When industry development has stepped into the phase of coordinated growth, the strategic emerging industries have been established and entered their stable growth period with decelerated and balanced growth. Some of these industries may even have become leading or mainstreaming industries. Meanwhile, traditional industries enter the late-mid stage of maturity and their growth virtually stops; some may even start to atrophy in local area.
- *The phase of good money drives out the bad currency.* When the dual relationship of mutual promotion and repulsion between strategic emerging and traditional industries is transformed into mutual repulsion, the two industries enter the phase of good money drives out the bad currency. At this time, strategic emerging industries have grown into a mature stage and become new traditional industry. Meanwhile, traditional industries have completed their own mission. Some of them enter a recession age and transform into sunset industry. Some become new industries after a high tech transformation. The replacement phenomenon is apparent at this stage as

the strategic emerging industries substitute for traditional industries, which is similar to the effect of good money drives out the bad currency

### 2.2.2 Spatial logic

Coupling is a basic concept in physics. Coupling is a phenomenon in which two or more systems influence each other through interaction so as to join up. It can form dynamic incidence relation of interdependence, inter-coordination and mutual promotion when all subsystems achieve benign interaction (Su, 2000). In social science, we also use ‘coupling’ to refer to two social phenomena which combine together to function interdependently under certain conditions. Similarly, the phenomenon that two systems of different industry types interact and influence with each other through their own coupling elements can be defined as industrial coupling. The spatial logic of coupling between strategic emerging industry and traditional industry can be stated by four aspects, as in Figure 2.

**Figure 2** The coupling of spatial logic between strategic emerging industry and traditional industry



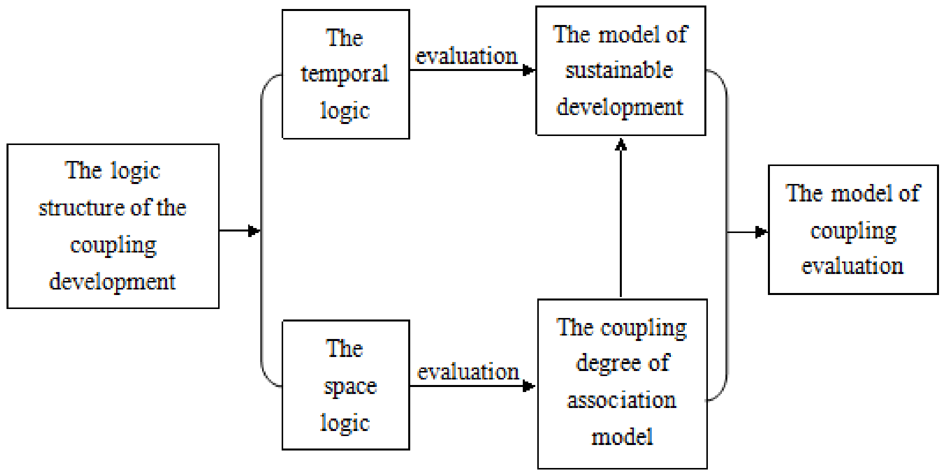
First of all, the coupling of industry factors contains the coupling of products, technology, and capital. The coupling of products means that the products of strategic emerging industries replace those of traditional industries and traditional industries support strategic emerging industries. The coupling of technology is mainly reflected through the spread of strategic emerging industries around traditional industries. The coupling of capital is mainly reflected by the capital accumulation during the process of cultivating and developing strategic emerging industries.

Secondly, the coupling of industry structures shows that strategic emerging and traditional industries are reasonably distributed among three big industry structures. It also shows the coupling of the newly formed and strategic emerging industries substituting for traditional industries.

Thirdly, the coupling of industry layout consists of three aspects: spatial distribution, regional division of labour, and area transfer. The coupling of spatial distribution is shown as the appearance of an industrial cluster; the coupling of regional labour division is shown as the vertical and horizontal development of industry chains; the coupling of area transfer refers to the fact that strategic emerging industries replace traditional industries that therefore transfer to inland and relatively backward regions.

Fourthly, the coupling of the industry systems is reflected by the coupling relationship between government's policies that cultivate strategic emerging industries and adjust and reform traditional industries.

**Figure 3** The structure of the coupling evaluation model




## 3 The coupling evaluation model

### *3.1 The composition and function of the model*

#### *3.1.1 The composition of the model*

Based on the analysis of temporal and space structural logic of the coupling development between strategic emerging and traditional industries, a coupling evaluation model is strongly demanded. This model should analyse and comment on the relationship of coupling development between strategic emerging and traditional industries in two dimensionalities – temporal and space structural logic – upon which, some policies and suggestions will be put forward.

The coupling evaluation model includes the coupling degree of association model and the sustainable development model, as shown in Figure 3 (see Figure 3 The structure of the coupling evaluation model).

### 3.1.2 Instructions of functions

First of all, the function of the coupling degree of association model: The coupling degree of association between strategic emerging and traditional industries refers to the positive degree of the association in the space logic of advance and development between the two industries. The function of the coupling degree of association model is to evaluate the coupling association index coefficient from the perspective of quantification, so as to confirm the degree of industry coupling.

Secondly, the function of the sustainable development model: although the coupling degree of association, to some extent, reflects the level of coupling between strategic emerging industries and traditional industries, the level of the development of the two industries is not manifested as a whole. When the coupling degree of association is fixed, the sustainable development model can be used to evaluate the temporal logic of the coupling development of the two industries.

## 3.2 The construction of model

### 3.2.1 The coupling degree of association model

*Definition 1*. Let $u$ be the order parameter of strategic emerging industries' subsystem, with $u_{ij}$ denoting the $j^{\text{th}}$ parameter of the $i^{\text{th}}$ index in the emerging industries' subsystem. The corresponding numerical value is $x_{ij}$, where $i = 1, 2, \ldots, m$, $j = 1, 2, \ldots, n$ is the number of index of strategic emerging industries' subsystem, and $m$ is the number of parameter of the $i^{\text{th}}$ index. Similarly, $w$ is the order parameter of traditional industries' subsystem, and $w_{ij}$ is the $j^{\text{th}}$ variable parameter of the $i^{\text{th}}$ index in traditional industries' subsystem. The corresponding numerical value is $y_{ij}$, where $i = 1, 2, \ldots, n'$, $j = 1, 2, \ldots, m'$, and $n'$ is the number of index of traditional industries' subsystem, and $m'$ is the number of the parameters for the $i^{\text{th}}$ index.

*Definition 2.* Let $(\alpha_{ij}, \beta_{ij})$ be the limit value of the order parameter on the stable critical point of strategic emerging industries' subsystem, $(\eta_{ij}, \xi_{ij})$ be the limit value of the order parameter on the stable critical point of traditional industries' subsystem. Then the ordered behaviour models of the subsystems of strategic emerging industries and traditional industries are:

$$u_{ij} = \left(x_{ij} - \beta_{ij}\right) / \left(\alpha_{ij} - \beta_{ij}\right),$$

where $i = 1,2,\ldots,n, j = 1,2,\ldots,m$

$$w_{ij} = \left(y_{ij} - \xi_{ij}\right) / \left(\eta_{ij} - \xi_{ij}\right),$$

where $i = 1,2,\ldots,n', j = 1,2,\ldots,m'$

In the formula, $\beta_{ij} \le xij \le \alpha_{ij}$, $\xi_{ij} \le yij \le \eta_{ij}$, so the range of $u_{ij}$ and $w_{ij}$ is from 0 to 1; that is, $u_{ij}$ and $w_{ij}$ are standardised. $u_{ij}$ and $w_{ij}$ represent $x_{ij}'$ and $y'_{ij}$ contributions to their subsystems, respectively. The closer each is to 1, the larger the contribution they make. The limit values of the order parameter ($\alpha$, $\beta$) and ($\eta$, $\xi$) should yield the benchmark year value, planned period value, and contrast standard value or ideal value over all.

*Definition 3.* Let $\lambda_i$ be the weight of the $i^{th}$ index of the order parameter of strategic emerging industries' subsystem; $\lambda_{ij}$ be the weight of the $j^{th}$ variable parameter of the $i^{th}$ index; $u_i$ be the contribution of value in the operational indicator level for strategic emerging industries; $u$ be the comprehensive contribution value of the total operational level for strategic emerging industries, where $i = 1, 2, \ldots, n$, $j = 1, 2, \ldots, m$. Similarly, let $\delta_i$ be the weight of the $i^{th}$ index of the order parameter in the subsystem of traditional industries; $\delta_{ij}$ be the weight of the $j^{th}$ variable parameter of the $i^{th}$ index in the subsystem of traditional industries; $w_i$ be the contribution of value in the operational indicator level of traditional industries; $w$ be the comprehensive contribution value of the total operational level, where $i = 1, 2, \ldots, n'$, $j = 1, 2, \ldots, m'$. The contribution model of each operational indicator level of the subsystem is:

$$u_i = \sum_{j=1}^{m} \lambda_{ij} \cdot u_{ij}, \quad i = 1, 2, \cdots, n$$

$$w_i = \sum_{j=1}^{m'} \delta_{ij} \cdot w_{ij}, \quad i = 1, 2, \cdots, n'$$

The comprehensive contribution model of the total operational level is:

$$u = \sum_{i=1}^{n} \lambda_i \cdot u_i, \quad w = \sum_{i=1}^{n'} \delta_i \cdot w_i$$

In the formula, $u$ and $w$ refer to the contribution for the degree of order in the coupling system of strategic emerging industries' and traditional industries' subsystems, respectively, and

$$\sum_{j=1}^{j=m} \lambda_{ij} = 1, \quad \sum_{i=1}^{i=n} \lambda_i = 1,$$

$$\sum_{j=1}^{j=m'} \delta_{ij} = 1, \quad \sum_{i=1}^{i=n'} \delta_i = 1,$$

where the weight is defined by the analytic hierarchy process.

*Definition 4.* Let $C$ be the coupling degree of association between strategic emerging industries and traditional industries. We use an interactional coupling model for multi-system with the concept of capacitive coupling in physics. That is:

$$C_n = \left\{ \left(u_1 . u_2 \cdots u_m\right) \Big/ \left[ \prod \left(u_{ij} + u_j\right) \right] \right\}^{1/n}$$

Suppose there is only one strategic emerging industry and one traditional industry in the coupling system, the coupling degree of association model is defined as:

$$C = \{(u \cdot w) / [(u + w)(u + w)]\}^{1/2}$$

In this formula, $0 \leq C < 1$.

We define the following four stages of coupling development:

1 When $C = 0$, there is no coupling relationship between strategic emerging industries and traditional industries. Thus the relationship is in rudimentary stage.

2 When $0 < C \leq 0.3$, there is low coupling relationship between strategic emerging industries and traditional industries, and the relationship is in a growth stage.

3 When $0.3 < C \leq 0.7$, the coupling relationship of strategic emerging industries and traditional industries is in a middle degree of the early development stage.

4 When $0.7 < C < 1$, the relationship between strategic emerging industries and traditional industries is in a high coupling stage of middle and later period of development.

### 3.2.2 The coupling sustainable development model

Although the coupling degree of association reflects the coupling degree of strategic emerging and traditional industries to some extent, the development level of the two industries is not manifested in the model. The coupling sustainable development model is built upon the base when the coupling degree of association is added as follows. First, define

$$D = \sqrt{C \cdot T}$$

where $D$ is the coupling degree of sustainable development, $C$ is the coupling degree of association, $T = a \cdot u + b \cdot w$, $a + b = 1$, and $a$ and $b$ represent the contribution coefficients of strategic emerging industries and traditional industries, respectively. As in Table 1.

**Table 1** Types of coupling sustainable development

| *Coupling degree of sustainable development* | *Types of sustainable development* | *Coupling degree of sustainable development* | *Types of coupling degree of sustainable development* |
|---|---|---|---|
| 0.00–0.009 | Type of extremely decline development | 0.50–0.59 | Type of transitional development |
| 0.10–0.19 | Type of seriously decline development | 0.60–0.69 | Type of primary development |
| 0.20–0.29 | Type of middle decline development | 0.70–0.79 | Type of middle development |
| 0.30–0.39 | Type of slight decline development | 0.80–0.89 | Type of good development |
| 0.40–0.49 | On the verge of decline development | 0.90–0.10 | Type of excellent development |

### *3.3 Design of the coupling index system*

#### *3.3.1 Basic principles of index selection*

The principles for choosing the index system for coupling evaluation model of strategic emerging industries and traditional industries are:

- *Quantifiable data:* the chosen indexes should have clear meaning. The data can be drawn from statistical data directly or deduced from calculation indirectly.
- *The calculation method for index quantification should be coherent:* the quantification of the index system is the basis for later data analysis.
- *Facticity and objectivity:* the chosen of indexes should truly reflect the current situation of strategic emerging industries and traditional industries, and reveal the reality of the industries.
- *Industrial characteristics:* traditional and strategic emerging industries have their own industrial characteristics. In addition, their development trends are different. Therefore, the chosen of indexes should consider their respective industrial development characteristics.
- *Emphasis on contribution values:* in choosing indexes, those with large industrial contribution values should be selected, and the result should include the least possible number of indexes that reflect full information. This can avoid the index system becoming too large, which would decrease the operability.

**Table 2** The evaluation index system of strategic emerging industries and traditional industries

| *Industries* | *Evaluation* | *Indexes* | *Calculation method for indexes* |
|---|---|---|---|
| Strategic emerging industries | Industrial international competitiveness $u_1$ | Occupancy of the international market $u_{11}$ | $u_{11}$ = Gross export of products of the industry / gross export of the same products in the world |
| | | Ratio of income on product export $u_{12}$ | $u_{12}$ = Export purify value / income of the core business |
| | | Net export ratio $u_{13}$ | $u_{13}$ = Industrial net export / net export of the whole country |
| | Industrial beneficial contribute share $u_2$ | Industrial annual quantity of employment $u_{21}$ | $u_{21}$ = Annual quantity of employment |
| | | Industrial taxation $u_{22}$ | $u_{22}$ = Tax of the core business + income tax payable + value added tax payable |
| | | Industrial profit $u_{23}$ | $u_{23}$ = Total profit |
| | | Industrial added value $u_{24}$ | $u_{24}$ = Industrial added value |
| | | Industrial gross product $u_{25}$ | $u_{25}$ = Total industrial output value |

**Table 2** The evaluation index system of strategic emerging industries and traditional industries (continued)

| *Industries* | *Evaluation* | *Indexes* | *Calculation method for indexes* |
|---|---|---|---|
| Strategic emerging industries | Industrial capability of independent innovation $u_3$ | Ratio cost on introduction of industrial technological assimilation $u_{31}$ | $u_{31}$ = Industrial cost on digest of technological assimilation / cost on introduction of technology |
| | | Industrial ratio of R&D input $u_{32}$ | $u_{32}$ = Cost of R&D activities/industrial income of core business |
| | | Ratio of the income of the new products $u_{33}$ | $u_{33}$ = Income of the new products / income of the core business |
| | | Owning rate of the own brand $u_{34}$ | $u_{34}$ = Quantity of famous brands of the interior capital enterprises / quantity of all the famous brands |
| | | Owning rate of the own patent $u_{35}$ | $u_{35}$ = Quantity of the applied patents of the interior capital enterprises / quantity of the applied patents of all enterprises |
| Traditional industries | Industrial economic efficiency $w_1$ | Asset profit-tax rate $w_{11}$ | $w_{11}$ = Profit-tax amount / asset amount |
| | | Coefficient of scale effect $w_{12}$ | $w_{11}$ = The sales income of the large and medium sized enterprises /the sales income of the whole industry |
| | | Labour productivity $w_{13}$ | $w_{11}$ = Industrial added value / industrial annual quantity of employment |
| | Industrial development potential $w_2$ | Industrial contribution rate $w_{21}$ | $w_{11}$ = Industrial added value / all added value in the regional industries |
| | | Industrial growth rate $w_{22}$ | $w_{11}$ = (Industrial added value-industrial added value in last year) / industrial added value in last year |
| | Industrial market performance $w_3$ | Income elasticity of demand $w_{31}$ | $w_{31}$ = (Industrial sales income-industrial sales income in last year) / (industrial sales income in last year * growth rate of national income per capita) |
| | | Market share $w_{32}$ | $w_{32}$ = Industrial sales income / industrial sales income in the whole country |
| | Dominant advantage index $w_4$ | Location-based commerce $w_{41}$ | $W_{41}$ = (Industrial sales income/industrial sales income in the region) / (industrial sales income / industrial sales income in the whole country) |
| | | Comparative profit-tax rate $w_{42}$ | $w_{42}$ = (Industrial profit tax amount/industrial gross product) / (Industrial profit and tax amount in the whole country / gross product of the industry in the whole country) |
| | Regional terms in use $w_5$ | Labour absorption rate $w_{51}$ | $w_{51}$ = Industrial annual quantity of employment / industrial gross product |

### *3.3.2 Index selection*

The coupling degree of association between strategic emerging and traditional industries are chosen according to related literature and the previously given principles. The indexes of strategic emerging industries include industrial international competitiveness, industrial beneficial contributing share and industrial capability of independent innovation. The indexes of traditional industries include industrial economic efficiency, industrial development potential, industrial market performance, dominant advantage index, and regional terms in use. Table 2 lists these chosen indexes, as in Table 2.

## 4 Data and evaluation

### *4.1 Choice of the sample data*

Due to data availability, we can only empirically study the degree of association between one strategic emerging industry and one traditional industry. We chose the representative environmental protection industry and the rubber product industry as the objects of our research.

**Table 3** Selection of the sample data

| | *Index level of evolution* | *Actual value $x_{ij}$* | *Lower limit of the order parameter $\beta_{ij}$* | *Upper limit of the order parameter $\alpha_{ij}$* |
|---|---|---|---|---|
| Strategic emerging industries | Industrial international market share | 0.44% | 0.0009 | 0.13 |
| | Industrial export income | CNY 9.34million | CNY 5.0 million | CNY 45.8million |
| | Industrial net export ratio | 0.134% | 0.0004 | 0.087 |
| | Industrial gross products | CNY 5.4 billion | CNY 3.43 billion | CNY 10.45 billion |
| | Industrial added value | CNY 73.131 million | CNY 54.20 million | CNY 202.30 million |
| | Industrial contribution margin | CNY 221.109million | CNY 160.2 million | CNY 963.1 million |
| | Industrial tax amount | CNY 17.51 million | CNY 14.64 million | CNY 82.47 million |
| | Industrial annual quantity of employment | 0.92 million people | 0.56 million people | 6.2 million people |
| | Owning rate of the own patent | 0.098% | 0.0005 | 0.0052 |
| | Owning rate of the own brands | 11.3% | 0.05 | 0.45 |
| | Sales ratio of the new products | 0.97% | 0.0062 | 0.042 |
| | R&D availability | 34.9% | 0.18 | 0.55 |
| | Cost ratio of introduction of technology assimilation | 57.8% | 0.34 | 0.95 |

**Table 3** Selection of the sample data (continued)

| | *Index level of evolution* | *Actual value $y_{ij}$* | *Lower limit of the order parameter $\xi_{ij}$* | *Upper limit of the order parameter $\eta_{ij}$* |
|---|---|---|---|---|
| Traditional industries | Asset profit tax rate | 1.36% | 0.011 | 0.02 |
| | Coefficient of scale effect | 0.3318 | 0.24 | 0.43 |
| | Labour productivity | CNY36568.5 per person | CNY 28424 per person | CNY 45210 per person |
| | Industrial contribute margin | 1.12% | 0.0078 | 0.0021 |
| | Industrial growth rate | –12.4% | 0.02 | 0.34 |
| | Income elasticity of demand | 1.658 | 1.00 | 3.00 |
| | Marketing share | 1.22% | 0.005 | 0.2 |
| | Location-based commerce | 82 | 50 | 100 |
| | Comparative profit-tax rate | 2.19% | 0.01 | 0.10 |
| | Labour absorption rate | 230 persons per CNY 100 million | 100 persons per CNY 100 million | 1000 persons per CNY 100 million |

We calculate the actual numerical value of the index system of the environmental protection industry by using the 2009 China Statistical Yearbook announced on the national statistics information network, The Research Report of the China Rubber industries Market of Year 2009, and The Research Report of the China Environmental Protection Industries Market of Year 2009. We also determined the upper and lower limits of the order parameter by consulting the datum year value, planning time value, and comparative standard value or ideal value, as shown in Table 3.

### *4.2 The evaluation of the coupling degree of the association*

We calculate the comprehensive contribute value of the environmental protection industry and rubber industry, and the coupling degree of association between environmental protection industry and rubber industry using the definitions 1–4 given previously.

#### *4.2.1 The calculation of the contribution value evaluation index layer.*

By using Table 2 and Table 3, we compute the contribution value evaluation index of environmental protection industry (Table 4: contribution value evaluation index of environmental protection industry) and the contribution value evaluation index of rubber manufacturing industry (Table 5: contribution value evaluation index of rubber manufacturing industry).

**Table 4** Contribution value evaluation index of environmental protection industry

| *Evaluation index layer* | *The international market share of the industry u11* | *Export earnings u12* | *Net export rate u13* | *Total value of out-put u21* | *Value added u22* | *Total profit u23* | *Tax amount u24* |
|---|---|---|---|---|---|---|---|
| Contribution | 0.289256 | 0.106373 | 0.010855 | 0.280627 | 0.127826 | 0.075861 | 0.042312 |
| *Evaluation index layer* | *Annual average employment u25* | *Independent patent ownership ratio u31* | *Independent brand ownership ratio u32* | *New product sales rate u33* | *R&D input rate u34* | *Technology introduction digestion fee u35* | — |
| Contribution | 0.06383 | 0.102128 | 0.1575 | 0.097765 | 0.456757 | 0.390164 | |

**Table 5** Contribution value evaluation index of rubber manufacturing industry

| *Evaluation index layer* | *Assets interest tax rate w11* | *Scale effect coefficient $w_{12}$* | *Labour productivity $w_{13}$* | *Industry contribution $w_{21}$* | *Growth rate $w_{22}$* |
|---|---|---|---|---|---|
| Contribution | 0.288889 | 0.483158 | 0.485196 | 0.257576 | −0.45 |
| *Evaluation index layer* | *Income elasticity of demand $w_{31}$* | *Market share $w_{32}$* | *Location quotient $w_{41}$* | *Contrast interest tax rate $w_{42}$* | *Labour absorption rate $w_{51}$* |
| Contribution | 0.329 | 0.036923 | 0.64 | 0.132222 | 0.144444 |

### 4.2.2 *The calculation of the operation contribution value index layer.*

By using Table 2 and Table 3, we compute the contribution value of the operation index layer of the environmental protection industry (Table 6: contribution value of the operation index layer of the environmental protection industry) and the contribution value of the operation index layer of rubber manufacturing industry (Table 7: contribution value of the operation index layer of rubber manufacturing industry).

**Table 6** Contribution value of the operation index layer of rubber manufacturing industry

| *Operation index layer* | *International competitiveness $u_1$* | *Benefit contribution $u_2$* | *Independent innovation $u_3$* |
|---|---|---|---|
| Contribution value | 0.153349 | 0.116167 | 0.44718 |

**Table 7** Contribution value of the operation index layer of rubber manufacturing industry

| *Operation index layer* | *Economic benefits $w_1$* | *Development potential $w_2$* | *Market performance $w_3$* | *Comparative advantage index $w_4$* | *Conditions of area utilisation $w_5$* |
|---|---|---|---|---|---|
| Contribution value | 0.429918 | -0.13159 | 0.135353 | 0.341427 | 0.144444 |

The integrated operational index weight with the contribution value of the operational index and the comprehensive contribute value of the environmental protection enterprises and rubber products are calculated as below.

First of all, the comprehensive contribute value of the environmental protection enterprises:

$$u = \sum_{i=1}^{3} \lambda_i \cdot u_i = 0.23 \times 0.153349 + 0.42 \times 0.116167 + 035 \times 0.44718 = 0.1697$$

Secondly, the comprehensive contribute value of the rubber products:

$$w = \sum_{i=1}^{5} \delta_i \cdot w_i = 0.1992$$

Thirdly, the coupling degree of association:

$$C = \{(u \cdot w) / [(u+w)(u+w)]\}^{1/2} = 0.4985$$

Fourthly, the coupling degree of sustainable development:

$$D = \sqrt{C.T}$$

where $T = a \cdot u + b \cdot w$, $a + b = 1$, and $a$ and $b$ represent the contribution coefficients of strategic emerging industries and traditional industries, respectively. The value of $a$ and $b$ can be adjusted by the practical situation. In our study we have $a = 0.7$ and $b = 0.3$. Thus $T = a \cdot u + b \cdot w = 0.2 \times 0.1697 + 0.8 \times 0.1992 = 0.1933$, which yields the coupling degree of sustainable development as

$$D = \sqrt{C \cdot T} = \sqrt{0.4985 \times 0.1933} = 0.3104$$

## 5 Results and suggestions

### *5.1 Interpretation of results*

1 According to the calculation above, the relationship of the environmental protection industry and rubber industry is of the type of medium coupling and slight decline development.

On the one hand, the rubber industry has a close relation with the developing environmental protection industry. Raw materials for rubber include fossil energy, such as synthetic cement, carbon black and fibrous material. These raw materials determine that the rubber industry must move towards a path of energy conservation, emission reduction and low-carbon economy. Therefore these two industries have an inherent coupling relationship. On the other hand, Chinese rubber industry is actually facing dual pressure from limited and insufficient supply within the country to high cost. It can hardly vigorously develop energy saving and environmental protection products. For that reason, the coupling between rubber industry and environmental protection industry is still in an infantile stage.

2 The coupling of environmental protection industry and rubber industry is at a starting stage.

Because some of the environmental protection technologies have been used in a small amount of rubber products, a coupling relationship exists between the environmental protection industry and the rubber industry now. But overall, the coupling stops at the negative effect of the rubber products to environmental protection industry. As one of China's strategic emerging industries, the environmental protection industry has not perfected technology, products, and policies. The osmotic force and changes from the environmental protection industry to the rubber industry have just started. The coupling of these two industries is still at the primary period of fast development.

3 The coupling mechanisms of environmental protection industry and rubber product industry are not fully formed.

Coupling between different industries is affected by various integration mechanisms, such as the linkage mechanism of the industrial space organisation, transmission mechanism, superimposed and megascopic mechanism, and government promotion mechanism. There are only partial associations of production processes and recycling links between the industrial chain of environmental protection industry and the rubber industry. Also, there are no terms for networking of the industrial chain and industrial integration. The environmental protection industry adheres to new high-tech parks in industry clusters and concentrations. In contrast, the rubber industry was mainly built in the traditional industrial parks which have rich raw material and processing manufacturing industries. Therefore there is less linkage in terms of the spatial organisation of the two industries. For the past few years, the Chinese government has actively developed a low carbon economy and recycling economy, taking energy-conserving and environment-protective industry as one of the key cultivated strategic emerging industries. The government promotion mechanism is still under construction.

## *5.2 Policy suggestions*

- *Policy level:* we believe that in the coupling process of the environmental protection industry and rubber manufacturing industry, China needs to set up international views and strategic thinking, focus on growing our overall national strength and science and technology strength, and aim for triggering technology and industry evolution. Meanwhile, we should strengthen strategic planning and coordinate planning arrangements and reform mechanisms in order to combine the effects of government and the market in the development of the existing rubber manufacturing industry and environmental protection industry. Additionally, China should obtain international cooperation in supporting the growth of domestic enterprises in order to achieve planning guidance and the coordination market development and supervision. We should also actively promote demonstration of applications and vigorously develop an independent intellectual property rights technology in order to accelerate the cultivation of leading enterprises. It is needed to further improve the industrial chain by building impeccable supporting systems such as talents and technology and laws and regulations that yield a support system that includes policy, capital, and organisation. Through these mechanisms, the environmental protection industry could be promoted as the leading and backbone industry, and the rubber manufacturing industry could be optimised and upgraded in an effective and timely manner.

- *Enterprise level:* we believe that rubber companies should quicken technological progress and stick to the road of self-dependent innovation and developing characteristic products. The growth of the tire industry will be through achieving the industrialisation of a 'green tire', establishing and applying labeling rules, research and application of advanced production technologies or equipment and acceleration of the construction of tire proving grounds. The rubber goods industry needs to develop driving belts with new technology to improve their performance of technical level. Fill the gap of rubber pipe for superior automobile use and finally achieve characteristic lightweight rubber pipe by promoting its manufacturing technology and product properties. To realise any of them, they must be accompanied by accelerated research and application of infrastructure, independent research and development and progress towards trans-regional groups with product specialisation, large-scale production, efficient management and system collectivisation.

- *Supplier level:* as for raw materials, China needs to actively exploit and apply substitutes of natural rubber, such as isoprene rubber and other rubber resources. It is also needed to accelerate R&D and applications of carbon black with high-performance or low rolling resistance, which is urgently needed by market, as well as new carbon black of rubber goods for automotive use. Exploiting carbon black with better production performance and a new variety of graphitised carbon black is essential. We also have to support the R&D and application of such new materials as green auxiliary agent and dedicated carbon black.

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