Incremental Input-Output Analysis and Empirical Study of Structural Change in China

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Abstract: The input-output method pioneered by Leontief has achieved notable success in national economic accounting, as well as in the analysis of industrial structure, industrial chains, value chains, and policy simulations. However, due to its static nature, its ability to analyze economic structural changes and their driving factors is limited. Incremental input-output analysis can capture the complex and dynamic characteristics inherent in economic activities. Nevertheless, issues such as the presence of both positive and negative values in increments, multiple forms of correlation coefficients, and the difficulty of interpreting their economic meanings remain. To address these problems, this paper proposes a fundamental identification method and its corresponding procedures for incremental input-output analysis. Specifically, we define the economic implications of four types of incremental input coefficients and incremental allocation coefficients, and establish six criteria for evaluating input-output efficiency. Using a compiled incremental input-output time series table for China from 2010 to 2020 as an example, we analyze the quality of China's input combinations and output efficiency, and reveal the drivers and characteristics of economic structural changes and economic growth. This study provides a reference for conducting incremental input-output analysis.

Keywords: Incremental input-output analysis; Principles and methods; Correlation coefficients; Economic structural change.

1. Introduction

Current comparative static analyses utilizing the input-output method pioneered by Leontief are primarily conducted using structural decomposition analysis (SDA). This method is commonly employed to examine structural changes, influencing factors of environmental indicators [1], and drivers of economic indicator changes [2-5], among others. With the implementation of high-quality economic development strategies, technological progress and total factor productivity (TFP) analysis have become issues of increasing scholarly concern. Richard R. Nelson regards technological progress and economic growth as outcomes of the operation of a complex economic system [6]. Liu Wei argues that TFP represents the comprehensive efficiency generated by the combination of multiple factors [7]. In the analysis of economic growth, the contribution of factor inputs remains a key research focus. The contribution of industrial production to economic growth is typically measured in terms of direct contribution. Zhang Shaohua et al., for example, employ an input-output model to measure the direct, indirect, and total contributions of the digital industry to tax revenue [8]. However, the above studies are all based on the assumption of constant input-output coefficients, which fails to capture scenarios of economic structural change. Therefore, it is of great significance to systematically investigate the characteristics of economic structural change, the quality of input combinations, and their associated benefits, so as to achieve a comparative static analysis with dynamic properties.

Incremental input-output analysis is an analytical method that examines the quantitative dependency between incremental inputs and incremental outputs across various sectors of a national economy. The incremental input-output model represents a dynamic refinement of traditional input-output analysis, aiming to capture the ripple effects and dynamic adjustment processes triggered by marginal changes (e.g., investment, technological progress, or policy adjustments) within an economic system. By introducing a time dimension and incremental variables, this model can reveal the quality of input combinations, structural economic changes, and the drivers of economic development quality. In 1967, Tilanus first proposed the concept of marginal (incremental) input coefficients, primarily for output forecasting, but did not delve into its underlying implications [9]. Subsequently, Li Guozhang proposed a method for compiling incremental input-output tables and highlighted the analytical advantages of the matrix of production activity coefficients [10]. However, due to the unresolved issue of the invertibility of the incremental Leontief inverse matrix, the basic model could not be fully developed; nevertheless, based on the basic model table, Li proposed a theory of soft input contributions through incremental decomposition. Later, Dong Chengzhang and Wang Shouzhen introduced general concepts of incremental direct consumption coefficients and incremental direct allocation coefficients. However, because input and output increments can take both positive and negative values, their theoretical framework failed to provide concrete interpretations or representations of these concepts, rendering the coefficients impractical for application and thereby slowing theoretical progress [11]. To address these issues, Song Hui et al. characterized the properties and concrete nature of incremental input-output coefficients, investigated incremental demand-pull and supply-push models, their assumptions, and associated production functions, and preliminarily proved the invertibility of the incremental Leontief inverse, thereby proposing a theoretical framework for basic incremental coefficients and models [12-13]. Nevertheless, the properties and types of pure income incremental direct input coefficients, as well as the properties and types of incremental allocation coefficients—particularly their manifestations in intermediate and final use structures—have not been specified, resulting in an inadequate reflection of a comprehensive incremental input-output analytical system.

Literature applying the basic coefficients and models of incremental input-output analysis remains relatively scarce. The main contributions of this paper are as follows. First, from the perspective of input structure combination quality analysis, and based on the nature of input combination elements and the pure income they generate, this paper proposes four types of incremental direct input coefficients and pure income incremental direct input coefficients, along with a discrimination method characterized by six patterns of input efficiency and contribution features. Second, from the perspective of output structural change analysis, and based on the differing nature of incremental direct allocation coefficients in use structures, this paper proposes four types of direct allocation coefficients for intermediate use and final use, along with six patterns of structural change features they exhibit. Third, using a compiled simplified incremental input-output table for China from 2010 to 2020 as an empirical example, this paper analyzes the drivers of China's economic structural changes and economic growth.

2. Incremental Input and Allocation Coefficients: Concepts, Types, and Analytical Methods

According to the studies of Li Guozhang and Chen Nanxu [14], as well as Song Hui et al. [12,15], the incremental input-output table is obtained by subtracting the base-year table at constant prices from the reporting-year table at constant prices. The row direction indicates the allocation of output increments from different sectors to various using sectors, including intermediate use increments and final use increments. The column direction indicates the changes in the consumption of different inputs by each sector during the production process, including intermediate input increments and initial input (i.e., value added) increments, as shown in Table 1.

Table 1 Incremental input-output table

		Intermediate use increments					Final use increments	Total output increments
		Sector 1	Sector 2	…	Sector n	Total		
Intermediate input increments	Sector 1	Δx_{11}	Δx_{12}	…	Δx_{1n}	ΔZ_1	ΔY_1	ΔX_1
	Sector 2	Δx_{21}	Δx_{22}	…	Δx_{2n}	ΔZ_2	ΔY_2	ΔX_2
	…	…	…	…	…	…	…	…
	Sector n	Δx_{n1}	Δx_{n1}	…	Δx_{nn}	ΔZ_n	ΔY_n	ΔX_n
	Total	ΔU_1	ΔU_2	…	ΔU_n	ΔZ	ΔY	ΔX
Initial input increments	Depreciation of fixed assets	ΔD_1	ΔD_2	…	ΔD_n	ΔD		
	Compensation of employees	ΔV_1	ΔV_2	…	ΔV_n	ΔV		
	Pure income	ΔM_1	ΔM_2	…	ΔM_n	ΔM		
	Total	ΔN_1	ΔN_2	…	ΔN_n	ΔN		
Total input increments		ΔX_1	ΔX_2	...	ΔX_n	ΔX		

Note: In the table, pure income increments include net taxes on production and operating surplus increments; final use increments include consumption, gross capital formation, and net export increments.

The incremental input-output table also satisfies, in quantitative terms, the same balancing relationships as those of a standard input-output table, with the only difference being the addition of incremental components.

The sum of intermediate use increments and final use increments equals total output increments, expressed as:

$$\sum_{j=1}^{n} \Delta x_{ij} + \Delta Y_i = \Delta X_i \tag{1}$$

The sum of intermediate input increments and initial input increments equals total input increments, expressed as:

$$\sum_{i=1}^{n} \Delta x_{ij} + \Delta N_j = \Delta X_j \tag{2}$$

Final use increments equal initial input increments, expressed as:

$$\sum_{i=1}^{n} \Delta Y_i = \sum_{j=1}^{n} \Delta N_j \tag{3}$$

Total output increments equal total input increments, expressed as:

$$\sum_{i=1}^{n} \Delta X_i = \sum_{j=1}^{n} \Delta X_j \tag{4}$$

2.1 Concepts, types, and analytical methods of incremental input coefficients

2.1.1 Basic concepts

Tilanus defined the marginal input coefficient (a_{ij}^{Δ}) as "the proportion of input change to output change" [9]. Subsequent scholars further standardized this concept as "the direct consumption of input increment from sector i per unit increment of output in sector *j*" and decomposed it accordingly [12], as shown in Equation (5).

$$a_{ij}^{\Delta}=\frac{\Delta x_{ij}}{\Delta X_j}=\frac{g_{ij}x_{ij}^{(0)}}{g_j X_j^{(0)}}=a_{ij}^{(0)}\times e_{ij} \tag{5}$$

Here, a_{ij}^{Δ} (where i, j=1,2,..., n; similarly hereinafter) denotes the incremental direct input coefficient (also referred to as the incremental direct consumption coefficient), with its matrix form denoted as $\boldsymbol{A}^{\Delta}$; Δx_{ij} represents the intermediate input increment; ΔX_j represents the output increment of sector j; e_{ij} is the input elasticity coefficient, i.e., the percentage change in input directly consumed from sector i in response to a 1% change in the output of sector j; $a_{ij}^{(0)}$ and Δa_{ij} are, respectively, the direct input coefficient in the base-year table at constant prices and the increment of the direct input coefficient; and g_j is the output growth rate of sector j. For the incremental direct input coefficients of initial input components, namely the incremental direct input coefficient of depreciation of fixed assets (a_{dj}^{Δ}), the incremental direct input coefficient of compensation of employees (a_{vj}^{Δ}), and the incremental direct input coefficient of pure income (a_{mj}^{Δ}), the formulas are as follows:

$$a_{dj}^{\Delta}=\frac{\Delta D_j}{\Delta X_j}=\frac{g_{dj}D_j^{(0)}}{\mathrm{g_j X_j^{(0)}}}=a_{dj}^{(0)}\times e_{dj} \tag{6}$$

$$a_{vj}^{\Delta}=\frac{\Delta V_j}{\Delta X_j}=\frac{g_{vj}V_j^{(0)}}{g_j X_j^{(0)}}=a_{vj}^{(0)}\times e_{vj} \tag{7}$$

$$a_{mj}^{\Delta}=\frac{\Delta M_j}{\Delta X_j}=\frac{g_{mj}M_j^{(0)}}{g_j X_j^{(0)}}=a_{mj}^{(0)}\times e_{mj} \tag{8}$$

Here, ΔD_j, ΔV_j and ΔM_j denote, respectively, the increment of depreciation of fixed assets directly consumed by sector j, the increment of compensation of employees, and the increment of pure income obtained; g_{dj}, g_{vj} and g_{mj} are the corresponding input growth rates; $D_j^{(0)}$, $V_j^{(0)}$, and $M_j^{(0)}$ denote, respectively, the depreciation of fixed assets directly consumed by sector j, the compensation of employees, and the pure income obtained in the base year; and e_{dj}, e_{vj} and e_{mj} are the elasticity coefficients of depreciation of fixed assets directly consumed, compensation of employees, and pure income obtained for sector j, respectively. It can be seen that the nature of the incremental direct input coefficients a_{ij}^{Δ}, a_{dj}^{Δ} and a_{vj}^{Δ} is fundamentally different from that of the pure income incremental direct input coefficient a_{mj}^{Δ}. The former are components of input combinations, while the latter represents the pure income (i.e., economic benefits; approximately, in theory, surplus value) transformed from the combination of input factors.

From the perspective of the composition of total input increments and total output increments, there exists a "part" versus "whole" relationship. Therefore, interpreting the incremental direct input coefficients from a contribution perspective, and in conjunction with the "pull point," can also be used to analyze how changes in intermediate input and initial input drive changes in sectoral total output, as shown in Equation (9).

$$dl_{ij}=a_{ij}^{\Delta}\times g_j \tag{9}$$

Here, dl_{ij} denotes the percentage points by which the input increment of sector i directly pulls the change in total output of sector j.

2.1.2 Types and analytical methods

According to the study of Song Hui et al., this paper, from the perspective of demand-pull incremental input coefficients, proposes an analytical path consisting of Table 2, which presents four types (excluding zero) of incremental direct input coefficients (including the pure income incremental direct input coefficient) and their economic implications; Table 3, which presents a discrimination method for the six patterns of factor productivity change characteristics exhibited by the four types of incremental direct input coefficients (excluding the pure income incremental direct input coefficient); and Table 4, which presents the four types of pure income incremental direct input coefficients and a discrimination method for the six patterns of combined cost and total factor productivity change characteristics they exhibit. This provides a basis for conducting incremental input coefficient analysis.

Table 2 Four types of incremental direct input coefficients and their economic interpretations

Type	Incremental direct input coefficient	Output growth rate of sector *j*	Input growth rate of sector *i* (or value added component)	Economic interpretation
(1)	Positive value	Positive value	Positive value	The increase in direct consumption of inputs from sector *i* (or value added component) when sector *j* increases output by one unit, reflecting the positive contribution of increased input from sector *i* (or value added component) to the output increase of sector *j*. Generally corresponds to scale-expansion growth (except for the pure income incremental direct input coefficient).
(2)	Positive value	Negative value	Negative value	The increase in direct consumption of inputs from sector *i* (or value added component) when sector *j* increases output by one unit, reflecting the positive contribution of increased input from sector *i* (or value added component) to the output increase of sector *j*. Generally corresponds to scale-expansion growth (except for the pure income incremental direct input coefficient).
(3)	Negative value	Positive value	Negative value	The decrease in direct consumption of inputs from sector *i* (or value added component) when sector *j* increases output by one unit, reflecting the negative contribution of reduced input from sector *i* (or value added component) to the output increase of sector *j*. Generally corresponds to technology substitution or efficiency-improving growth (ideal structural upgrading), except for the pure income incremental direct input coefficient.
(4)	Negative value	Negative value	Positive value	The increase in direct consumption of inputs from sector *i* (or value added component) when sector *j* decreases output by one unit, reflecting the negative contribution of increased input from sector *i* (or value added component) to the output decrease of sector *j*. Generally corresponds to a "rigid demand" trap during a recessionary period (cost disease or passive inventory accumulation), except for the pure income incremental direct input coefficient.

Note: Value added components consist of compensation of employees, depreciation of fixed assets, and pure income; This table is applicable for interpreting a_{ij}^{Δ}, ,a_{vj}^{Δ} and a_{mj}^{Δ}.

The incremental direct input coefficients presented in Table 2 can be used to determine the degree of positive or negative pulling contribution of a sector's incremental direct input coefficients to its output. The characteristics of a sector's changes can be identified through the signs (positive or negative) of the output growth rate of sector *j* and the input growth rate of sector *i* (or value added component).

Table 3 Discrimination methods for six patterns of factor productivity exhibited by incremental direct input coefficients

Type No.	Type (taking the incremental intermediate input coefficient as an example)	Comparison between the input growth rate of sector *i* (or depreciation and compensation of employees) and the output growth rate of sector *j*	Increment of the direct input coefficient	Cost of sector *i* (or depreciation and compensation of employees)	Productivity of sector *i* (or depreciation and compensation of employees)	Input elasticity coefficient
(1)	$\Delta x_{ij}>0$, $\Delta X_j>0, a_{ij}^{\Delta}>0$	Input growth rate of sector *i* < Output growth rate of sector *j*	<0	Decrease	Increase	$0<e_{ij}<1$(Decoupling)
		Input growth rate of sector *i* > Output growth rate of sector *j*	>0	Increase	Decrease	$e_{ij}>1$(Negative decoupling)
(2)	$\Delta x_{ij}<0$, $\Delta X_j<0, a_{ij}^{\Delta}>0$	Input growth rate of sector *i* < Output growth rate of sector *j*	<0	Decrease	Increase	$e_{ij}>1$(Decoupling)
		Input growth rate of sector *i* > Output growth rate of sector *j*	>0	Increase	Decrease	$0<e_{ij}<1$(Negative decoupling)
(3)	$\Delta x_{ij}<0, \Delta X_j>0, a_{ij}^{\Delta}<0$	Input growth rate of sector *i* < Output growth rate of sector *j*	<0	Decrease	Increase	$e_{ij}<0$（Decoupling）
(4)	$\Delta x_{ij}>0, \Delta X_j<0, a_{ij}^{\Delta}<0$	Input growth rate of sector *i* > Output growth rate of sector *j*	>0	Increase	Decrease	$e_{ij}<0$(Negative decoupling)

Note: The intermediate input from sector *i*, depreciation of fixed assets, and compensation of employees are each single-factor inputs, corresponding to the interpretation of a_{ij}^{Δ}, a_{dj}^{Δ}, and a_{vj}^{Δ}.

In Table 3, the incremental direct input coefficient is a comprehensive measurement indicator, closely related to variables such as the increment of the direct input coefficient (reflecting the level of technological change in factors), input growth rates, and output growth rates. A positive increment of the direct input coefficient indicates that the unit cost of inputs in that sector has risen and productivity has declined; conversely, a negative increment indicates that unit cost has fallen, productivity has increased, and factors have been saved. By comparing the input growth rate of sector *i* with the output growth rate of sector *j*, the characteristics of the increment of the direct input coefficient can also be revealed.

The input elasticity coefficient e_{ij} reflects the backward linkage changes from downstream sector *j* to upstream sector *i*. Referring to the study of industrial chain decoupling by Li Na et al. [8], it is classified into two broad categories: decoupling and negative decoupling. Decoupling indicates that the dependence of downstream sector *j*'s production on the supply from upstream sector i has weakened, and the backward coupling between industries has decreased, with the input growth rate of sector i being lower than the output growth rate of sector j. Negative decoupling indicates that the dependence of downstream sector j's production on the supply from upstream sector i has strengthened, and the backward coupling between industries has deepened, with the input growth rate of sector i being higher than the output growth rate of sector j. Furthermore, the input elasticity coefficient of input combinations (total factor) can be used to reflect sectoral production modes. For example, if the input growth rate of an input combination is lower than the output growth rate of sector j, it indicates that the production of sector j is relatively intensive; conversely, it indicates that the production of sector j is relatively extensive. This is consistent with the interpretation of the characteristics of sectoral productivity changes presented in Table 3.

Table 4 Six patterns of combined cost and total factor productivity discrimination methods for the pure income incremental direct input coefficient

No.	Type	Comparison between the pure income growth rate of sector j and the output growth rate of sector j	Increment of the pure income direct input coefficient of sector j	Total factor productivity (efficiency) of sector j	Combined cost of input combinations of sector j	Pure income elasticity coefficient
(1)	$\Delta M_j>0,\Delta X_j>0$, $a_{mj}^{\Delta}>0$	the pure income growth rate of sector j < the output growth rate of sector j	<0	Decrease	Increase	$0<e_{mj}<1$（Decoupling）
		the pure income growth rate of sector j >the output growth rate of sector j	>0	Increase	Decrease	$e_{mj}>1$(Negative decoupling)
(2)	$\Delta M_j<0,\Delta X_j<0$, $a_{mj}^{\Delta}>0$	the pure income growth rate of sector j < the output growth rate of sector j	<0	Decrease	Increase	$e_{mj}>1$(Decoupling)
		the pure income growth rate of sector j > the output growth rate of sector j	>0	Increase	Decrease	$0<e_{mj}<1$(Negative decoupling)
(3)	$\Delta M_j<0,\Delta X_j>0$, $a_{mj}^{\Delta}<0$	the pure income growth rate of sector j < the output growth rate of sector j	<0	Decrease	Increase	$e_{mj}<0$（Decoupling）
(4)	$\Delta M_j>0,\Delta X_j<0$, $a_{mj}^{\Delta}<0$	the pure income growth rate of sector j >the output growth rate of sector j	>0	Increase	Decrease	$e_{mj}<0$(Negative decoupling)

Note: In the table, the single-factor inputs are intermediate input, depreciation of fixed assets, and compensation of employees, and their input combination constitutes total factor input; Pure income reflects the effect of the input combination, corresponding to the interpretation of a_{mj}^{Δ}; When the pure income in the base year is negative, the judgment should be based on the increment of the pure income direct input coefficient.

Table 4 reflects that the nature and economic interpretation of the pure income incremental direct input coefficient are fundamentally different from those of the incremental direct input coefficient in Table 3. A positive increment of the pure income direct input coefficient indicates that the economic benefit per unit of output in that sector has risen and the combined cost of input combinations has fallen; conversely, it indicates that the economic benefit per unit of output has declined and the combined cost of input combinations has risen.

Furthermore, Song Hui et al. constructed an incremental total input coefficient of initial input (also referred to as the incremental total contribution coefficient) [12], which represents the total consumption of initial input increments resulting from changes in sectoral production, as shown in Equation (10).

$$\boldsymbol{N}_{\boldsymbol{\omega}}^{\Delta}=\boldsymbol{N}^{\Delta}(\boldsymbol{I}\text{-}\boldsymbol{A}^{\Delta})^{-1} \tag{10}$$

Here, $\boldsymbol{N}_{\boldsymbol{\omega}}^{\Delta}$ is the row vector of incremental total input coefficients of initial input, with elements$n_{\omega j}^{\Delta}$; $\boldsymbol{N}^{\Delta}$ is the row vector of incremental direct input coefficients of initial input. $n_{\omega 1}^{\Delta}$ is obtained by multiplying the row vector of incremental direct input coefficients of initial input by the first column of the incremental Leontief inverse (which holds under general conditions; see Song Hui et al. [3]), indicating the initial input increments of various sectors fully pulled by a one-unit increase in final use of sector 1. Multiplying the incremental total input coefficient by the output growth rate g_j of sector j yields the full pulling rate of initial input increments (fl_j), as shown in Equation (11).

$$fl_j=n_{\omega j}^{\Delta}\times g_j \tag{11}$$

Similarly, for the components of initial input increments, such as compensation of employees, depreciation of fixed assets, and pure income increments, their incremental total input (contribution) coefficients and full pulling rates can also be calculated using Equations (10) and (11). Moreover, there exists a quantitative relationship such that the sum of the incremental total input (contribution) coefficients of compensation of employees, depreciation of fixed assets, and pure income equals one.

2.2 Concepts, types, and analytical methods of incremental allocation coefficients

2.2.1 Basic concepts

The definitional formula and its decomposition for the incremental direct allocation coefficient are shown in Equation (12).

$$h_{ij}^{\Delta}=\frac{\Delta x_{ij}}{\Delta X_i}=\frac{g_{ij}x_{ij}^{(0)}}{g_iX_i^{(0)}}=h_{ij}^{(0)}\times r_{ij} \tag{12}$$

Here, h_{ij}^{Δ} is the incremental direct allocation coefficient, representing the increment of products directly allocated from sector i to sector j per unit increment of output in sector i, with its matrix form denoted as $\boldsymbol{H}^{\Delta}$; Δx_{ij} represents the intermediate use increment allocated from sector i to sector j; ΔX_i is the total output increment of sector i; r_{ij} is the usage elasticity, i.e., the percentage change in usage by sector j driven by a 1% change in output of sector i; $h_{ij}^{(0)}$ and Δh_{ij} are, respectively, the direct allocation coefficient in the base year and the increment of the direct allocation coefficient; and g_i is the output growth rate of sector i.

From the perspective of supply push, the intermediate use and final use of downstream sector j directly push the total output change of upstream sector i. These demands are components of total output. Therefore, the marginal direct allocation coefficient can be defined from a contribution perspective, with the types and interpretations presented in Tables 5, 6, and 7. Analogously, a "push point" based on the concept of "usage pushing total output change" is constructed, as shown in Equation (13).

$$dp_{ij}=h_{ij}^{\Delta}\times g_i \tag{13}$$

Here, dp_{ij} denotes the percentage points by which the usage (final use may also be a component) increment of sector *j* directly pushes the total output change of sector *i*.

2.2.2 Types and analytical methods

To analyze the nature and types of incremental direct allocation coefficients and to identify the manifestations of intermediate and final use structures, this paper, from the perspective of supply-push incremental direct allocation coefficients, proposes an analytical path consisting of Table 5, which presents four types of incremental direct allocation coefficients (including the final use incremental direct allocation coefficient) and their economic implications; Table 6, which presents a discrimination method for the six patterns of structural efficiency change characteristics exhibited by the four types of intermediate use incremental direct allocation coefficients; and Table 7, which presents a discrimination method for the six patterns of structural efficiency change characteristics exhibited by the four types of final use incremental direct allocation coefficients. This provides a basis for conducting incremental direct allocation coefficient analysis.

Table 5 Four types of incremental direct allocation coefficients and their economic interpretations

Type	Incremental direct allocation coefficient	Output growth rate of sector *i*	Usage growth rate of sector *j* (or final use component)	Economic interpretation
(1)	Positive value	Positive value	Positive value	The increase directly allocated to sector *j* (or final use component) when sector *i* increases output by one unit, reflecting the positive contribution of increased usage by sector *j* (or final use component) to the output growth of sector *i*. Corresponds to the normal marginal allocation structure during an expansionary period.
(2)	Positive value	Negative value	Negative value	The decrease directly allocated to sector *j* (or final use component) when sector *i* decreases output by one unit, reflecting the positive contribution of reduced usage by sector *j* (or final use component) to the output decrease of sector *i*. Corresponds to the symmetric marginal allocation structure during a contractionary period.
(3)	Negative value	Positive value	Negative value	The decrease directly allocated to sector *j* (or final use component) when sector *i* increases output by one unit, reflecting the negative contribution of reduced usage by sector *j* (or final use component) to the output growth of sector *i*. Abnormal allocation (inventory release, structural adjustment, import substitution effect).
(4)	Negative value	Negative value	Positive value	The increase directly allocated to sector *j* (or final use component) when sector *i* decreases output by one unit, reflecting the negative contribution of increased usage by sector *j* (or final use component) to the output decrease of sector *i*. Efficiency improvement or structural optimization (technological progress, final demand structure adjustment, self-production substitution by sector *j*).

Note: Final use components consist of consumption, gross capital formation, and net exports.

The incremental direct allocation coefficients presented in Table 5 can be used to determine the degree of positive or negative pushing contribution of a sector's incremental direct allocation coefficients to its output.

The characteristics of a sector's changes can be identified through the positive or negative growth signs of the output growth rate of sector *i* and the usage growth rate of sector *j* (or final use component).

Table 6 Six patterns of structural efficiency discrimination methods for intermediate use incremental direct allocation coefficients

Type No.	Type	Comparison between the intermediate use growth rate of sector *j* and the output growth rate of sector *i*	Increment of the intermediate use direct allocation coefficient	Intermediate use rate	Final use rate	Intermediate use elasticity coefficient
(1)	$\Delta x_{ij}>0$, $\Delta X_i>0, h_{ij}^{\Delta}>0$	the intermediate use growth rate of sector *j* < the output growth rate of sector *i*	<0	Decrease	Increase	$0<r_{ij}<1$ （Decoupling）
		the intermediate use growth rate of sector *j*>the output growth rate of sector i	>0	Increase	Decrease	$r_{ij}>1$(Negative decoupling)
(2)	$\Delta x_{ij}<0$, $\Delta X_i<0, h_{ij}^{\Delta}>0$	the intermediate use growth rate of sector *j*<the output growth rate of sector *i*	<0	Decrease	Increase	$r_{ij}>1$(Decoupling)
		the intermediate use growth rate of sector *j*>the output growth rate of sector *i*	>0	Increase	Decrease	$0<r_{ij}<1$(Negative decoupling)
(3)	$\Delta x_{ij}<0$, $\Delta X_i>0, h_{ij}^{\Delta}<0$	the intermediate use growth rate of sector *j*<the output growth rate of sector *i*	<0	Decrease	Increase	$r_{ij}<0$（Decoupling）
(4)	$\Delta x_{ij}>0$, $\Delta X_i<0, h_{ij}^{\Delta}<0$	the intermediate use growth rate of sector *j*>the output growth rate of sector *i*	>0	Increase	Decrease	$r_{ij}<0$(Negative decoupling)

In Table 6, the incremental direct allocation coefficient is closely related to the increment of the direct allocation coefficient, the usage growth rate, and the output growth rate. A high intermediate use rate indicates that the sector provides more means of production to society; a high final use rate indicates that the sector provides more consumer goods to society. Therefore, when the increment of the intermediate use direct allocation coefficient is positive, downstream sector *j* pushes sector *i*'s intermediate use rate to rise and its final use rate to fall; conversely, it pushes sector *i*'s intermediate use rate to fall and its final use rate to rise. When the increment of the final use direct allocation coefficient is positive, the increase in final use per unit of output of sector i pushes sector *i*'s final use rate to rise and its intermediate use rate to fall; conversely, it pushes sector *i*'s final use rate to fall and its intermediate use rate to rise. Similarly, by comparing the output growth rate of sector *i* with the intermediate use growth rate or final use growth rate of sector *j*, the characteristics of the increment of the direct allocation coefficient can also be revealed.

The ratio of the intermediate use growth rate to the output growth rate constitutes the intermediate use elasticity coefficient r_{ij}, which reflects the forward linkage changes from upstream sector *i* to downstream sector *j*'s demand. Decoupling indicates that the responsiveness of upstream sector *i*'s production to the market demand of downstream sector *j* has weakened, and the forward coupling between industries has decreased, with the intermediate use growth rate of sector *j* being lower than the output growth rate of sector *i*, reflecting a decline in the intermediate use rate. Negative decoupling indicates that the responsiveness of upstream sector *i*'s production to the market demand of downstream sector *j* has strengthened, and the forward coupling between industries has deepened, with the intermediate use growth rate of sector *j* being higher than the output growth rate of sector *i*, reflecting an increase in the intermediate use rate.

Table 7 Six patterns of structural efficiency discrimination methods for final use incremental direct allocation coefficients

No.	Type	Comparison between the final use growth rate of sector i and its output growth rate	Increment of the final use direct allocation coefficient	Final use rate	Intermediate use rate	Final use elasticity coefficient
(1)	$\Delta Y_i>0$, $\Delta X_i>0, y_j^{\Delta}>0$	the final use growth rate of sector *i*<the output growth rate	<0	Decrease	Increase	$0<r_{yj}<1$(Decoupling)
		the final use growth rate of sector *i*>the output growth rate	>0	Increase	Decrease	$r_{yj}>1$(Negative decoupling)
(2)	$\Delta Y_i<0$, $\Delta X_i<0, y_i^{\Delta}>0$	the final use growth rate of sector *i*<the output growth rate	<0	Decrease	Increase	$r_{yj}>1$(Decoupling)
		the final use growth rate of sector *i*>the output growth rate	>0	Increase	Decrease	$0<r_{yj}<1$(Negative decoupling)
(3)	$\Delta Y_i<0$, $\Delta X_i>0, y_i^{\Delta}<0$	the final use growth rate of sector *i*<the output growth	<0	Decrease	Increase	$r_{yj}<0$（Decoupling）

		rate				
(4)	$\Delta Y_i>0$, $\Delta X_i<0, y_i^{\Delta}<0$	the final use growth rate of sector i>the output growth rate	>0	Increase	Decrease	$r_{yj}<0$(Negative decoupling)

Note: Table 7 presents the judgment basis based on the comparison between the final use growth rate of sector i and its output growth rate; When net exports in the base year are negative, the judgment should be based on the increment of the final use direct allocation coefficient.

In Table 7, the final use elasticity coefficient r_{yj} reflects the responsiveness of changes in final use of sector i to changes in its own output, capturing the pulling efficiency of final demand on production and the output allocation structure: Decoupling indicates that the growth of final use of sector i lags behind its output growth, and the coupling between final demand and output has weakened. In this case, the final use growth rate of sector i is lower than its output growth rate, reflecting a decline in the final use rate. Negative decoupling indicates that the growth of final use of sector i leads its output growth, and the coupling between final demand and output has deepened. In this case, the final use growth rate of sector i is higher than its output growth rate, reflecting an increase in the final use rate.

From the perspective of output value formation, the formulas for the incremental total allocation (contribution) coefficient and the full pushing rate of final use increments to sectoral output changes are constructed using the incremental total supply coefficient, as shown in Equations (14) and (15), respectively.

$$\boldsymbol{Y}_{\boldsymbol{\omega}}^{\Delta}=(\boldsymbol{I}-\boldsymbol{H}^{\Delta})^{-1}\boldsymbol{Y}^{\Delta} \tag{14}$$

$$fp_i=y_{\omega i}^{\Delta}\times g_i \tag{15}$$

Here, $\boldsymbol{Y}_{\boldsymbol{\omega}}^{\Delta}$ is the column vector of incremental total allocation coefficients of final use increments, with elements $y_{\omega i}^{\Delta}$; $\boldsymbol{Y}^{\Delta}$ is the column vector of incremental direct allocation coefficients of final use increments. $y_{\omega 1}^{\Delta}$ is obtained by multiplying the first row of the incremental total supply coefficient matrix by the column vector of incremental direct allocation coefficients of final use increments, indicating the final use increments of various sectors fully pushed by a one-unit increase in the initial input of sector 1; fp_i and g_i are, respectively, the full pushing rate of final use of sector i and its output growth rate, where the former represents the degree to which changes in aggregate final use fully push the output of sector i. Similarly, the incremental total allocation coefficients of the components of final use, namely consumption, gross capital formation, and net exports, can be calculated. Moreover, there exists a quantitative relationship such that the sum of the incremental total allocation coefficients of consumption, gross capital formation, and net exports equals one.

3. Empirical Analysis

3.1 Analysis of the Four-Sector Incremental Input-Output Table for China

To illustrate the application of the above analytical methods, this paper conducts an analysis using the compiled four-sector incremental input-output table for China for the period 2010–2020 (with 2015 as the base year), as shown in Table 8.

Table 8 Four-sector incremental input-output table for China, 2010–2020 (100 million yuan)

		Intermediate use					Final use				
		Agriculture	Industry	Construction	Services	Total intermediate use	Total consumption expenditure	Gross capital formation	Net exports	Total final use	Total output
Intermediate input	Agriculture	-454	1200	949	1848	3543	10998	853	460	12311	15854
	Industry	-4857	-186465	19792	22406	-149125	21115	-41768	3920	-16733	-165858
	Construction	31	87	6282	-17	6383	-3758	65517	-1010	60749	67132
	Services	1515	15065	25379	151057	193018	87849	20004	-1418	106435	299453
	Total intermediate input	-3765	-170114	52402	175294	53818	116204	44606	1952	162762	216580
Value added	Compensation of employees	23744	-2931	13091	87078	120982					
	Depreciation of fixed assets	-738	6297	-143	22350	27766					
	Pure income	-3388	890	1781	14730	14014					
	Total value added	19618	4256	14729	124158	162762					
Total input		15854	-165858	67132	299453	216580					

As shown in Table 8, total output and GDP in China, together with pure income (economic benefits), increased by 21,658 billion yuan, 16,276.2 billion yuan, and 1,401.4 billion yuan, respectively. Affected by the COVID-19 pandemic in 2020, China's economy exhibited structural transformation characteristics featuring a relative contraction in industry, expansion in services and construction, consumption-led growth, and a rising share of compensation of employees. Looking at the entire period, the structural shares of the three industries in China's value added changed from 8.03:46.65:45.32 in 2010 to 8.88:39.22:51.90 in 2020, with the share of the tertiary industry in GDP increasing by 6.58 percentage points. The trajectory of this change is shown in Figure 1.

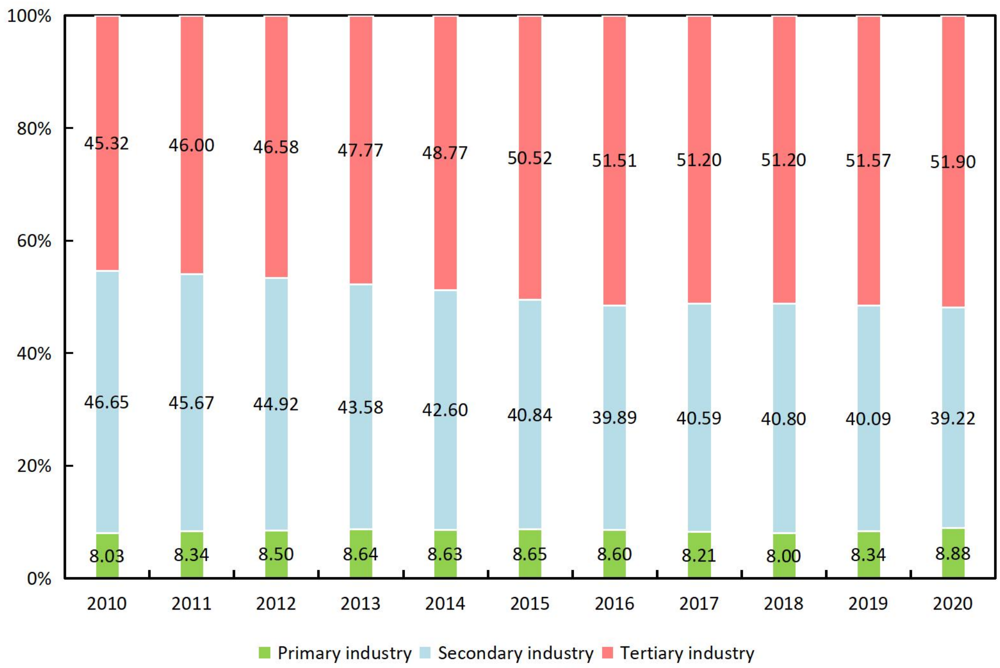

Figure 1 Share of value added of the three industries in GDP (%), 2010–2020

3.2 Structural analysis of input and use increments

Based on the compiled continuous annual incremental input-output table for China for the period 2010–2020, the input increment structural analysis table is obtained from the perspective of incremental inputs, as shown in Table 9.

Table 9 Structural analysis of input increments, 2010–2020 (100 million yuan)

Period / Sector	Intermediate input	Compensation of employees	Depreciation of fixed assets	Pure income	Input combination	Value added	Total input	Contribution rate of input combination (%)
2010-2011	73852.36	30265.16	5126.24	13229.55	109243.76	48620.96	122473.32	89.20
2011-2012	6131.71	14460.47	548.66	510.53	21140.84	15519.66	21651.37	97.64
2012-2013	51782.13	14005.21	442.76	309.76	66230.10	14757.74	66539.87	99.53
2013-2014	31705.30	10108.69	-595.31	-2212.13	41218.68	7301.25	39006.55	105.67
2014-2015	10917.70	6932.66	-1579.00	-6075.46	16271.35	-721.81	10195.89	159.59
2015-2016	-82859.27	5921.33	3034.76	512.24	-73903.18	9468.33	-73390.94	100.70
2016-2017	-57776.60	14158.93	5651.54	9639.84	-37966.13	29450.31	-28326.29	134.03
2017-2018	34832.64	13539.42	11232.73	195.04	59604.78	24967.18	59799.82	99.67
2018-2019	246.63	6762.11	2406.55	246.39	9415.28	9415.05	9661.68	97.45
2019-2020	-15014.32	4828.52	1496.73	-2342.13	-8689.07	3983.12	-11031.20	78.77
Sum of successive increments	53818.27	120982.48	27765.66	14013.64	202566.41	162761.78	216580.05	93.53
Cumulative increment	53818.27	120982.48	27765.66	14013.64	202566.41	162761.78	216580.05	93.53

Note: The sum of successive increments refers to the sum of the indicator data in the incremental tables obtained by subtracting the preceding year from the subsequent year over the period 2010–2020; the cumulative increment refers to the indicator data in the incremental table for the ten-year interval from 2010 to 2020, with

2010 as the base year and 2020 as the reporting year; the input combination increment refers to the sum of the increments of intermediate input, depreciation of fixed assets, and compensation of employees.

It can be seen that the cumulative increment of total input is 21,658.005 billion yuan, and the increments of intermediate input, value added (initial input) and its components, as well as total input, all exhibit an upward trend. Over the period 2010–2020, the contribution rate of the input combination (i.e., the input combination increment divided by the output increment) is 93.53%, indicating that the contribution of the input combination per unit of output is 93.53%. From the perspective of output direction of the incremental table, the structural analysis of input increments is shown in Table 10.

Table 10 Structural analysis of use increments, 2010–2020 (100 million yuan)

Period / Sector	Intermediate use	Consumption	Gross capital formation	Net exports	Final use	Total output
2010-2011	73852.36	28495.41	18608.09	1517.45	48620.96	122473.32
2011-2012	6131.71	12083.20	2649.92	786.54	15519.66	21651.37
2012-2013	51782.13	7877.90	4915.17	1964.67	14757.74	66539.87
2013-2014	31705.30	5301.66	388.38	1611.21	7301.25	39006.55
2014-2015	10917.70	8458.25	-10537.81	1357.76	-721.81	10195.89
2015-2016	-82859.27	14638.23	2296.89	-7466.79	9468.33	-73390.94
2016-2017	-57776.60	16982.43	15808.51	-3340.63	29450.31	-28326.29
2017-2018	34832.64	14326.80	17968.69	-7328.30	24967.18	59799.82
2018-2019	246.63	11517.71	-4862.37	2759.70	9415.05	9661.68
2019-2020	-15014.32	-3478.09	-2629.03	10090.23	3983.12	-11031.20
Sum of successive increments	53818.27	116203.50	44606.44	1951.84	162761.78	216580.05
Cumulative increment	53818.27	116203.50	44606.44	1951.84	162761.78	216580.05

During the period 2010–2020, the increase in total output has primarily relied on the rise in final use, with increases in consumption and gross capital formation being important factors driving the increase in final use, particularly consumption, which has become the main growth point driving domestic demand. This reflects a structural transformation characterized by an increasing final use rate and a decreasing intermediate use rate, indicating that China's economy has exhibited a development trend of structural upgrading and demand-driven growth.

3.3 Analysis of value added and growth rates

When analyzing growth rates, attention should be paid to the absolute levels behind the rates, because growth rates are not comparable when base values differ. Therefore, it is necessary to combine growth rates with growth amounts and calculate the absolute value of a one-percentage-point increase in growth rate. According to the formula "Absolute value of a one-percentage-point increase in growth rate = Base period development level × 1%", the calculation results are shown in Table 11.

Table 11 Value added and growth in China, 2010–2020

Year	Symbol	Value added (100 million yuan)	Cumulative growth (100 million yuan)	Fixed-base growth rate (%)	Chain growth rate (%)	Fixed-base growth speed (%)	Chain growth speed (%)	Absolute value of a one-percentage-point increase in growth rate (100 million yuan)

2010	a0	603380.40	—	—	—	—	—	—
2011	a1	652001.35	48620.96	108.06	108.06	8.06	8.06	6033.80
2012	a2	667521.01	64140.62	110.63	102.38	10.63	2.38	6520.01
2013	a3	682278.75	78898.36	113.08	102.21	13.08	2.21	6675.21
2014	a4	689580.01	86199.61	114.29	101.07	14.29	1.07	6822.79
2015	a5	688858.20	85477.80	114.17	99.90	14.17	-0.10	6895.80
2016	a6	698326.53	94946.13	115.74	101.37	15.74	1.37	6888.58
2017	a7	727776.84	124396.44	120.62	104.22	20.62	4.22	6983.27
2018	a8	752744.02	149363.62	124.75	103.43	24.75	3.43	7277.77
2019	a9	762159.06	158778.67	126.31	101.25	26.31	1.25	7527.44
2020	a10	766142.18	162761.78	126.97	100.52	26.97	0.52	7621.59

It can be seen that in 2020, China's fixed-base and chain growth rates of value added were 126.97% and 100.52%, respectively, while the fixed-base and chain growth speeds were 26.97% and 0.52%, respectively.

The absolute value of a one-percentage-point increase in the chain growth rate of value added continued to rise from 2011 to 2020, indicating that China's economic development has strong "resilience."

3.4 Analysis of incremental direct input coefficients

Based on Equations (5)–(8), Table 12 is obtained.

Table 12 Incremental direct input coefficients for four sectors in China, 2010–2020

Input sector	Agriculture	Industry	Construction	Services	Total intermediate use
Agriculture	-0.0287	-0.0072	0.0141	0.0062	0.0164
Industry	-0.3064	1.1242	0.2948	0.0748	-0.6885
Construction	0.0020	-0.0005	0.0936	-0.0001	0.0295
Services	0.0956	-0.0908	0.3781	0.5044	0.8912
Total intermediate input	-0.2375	1.0257	0.7806	0.5854	0.2485
Compensation of employees	1.4977	0.0177	0.1950	0.2908	0.5586
Depreciation of fixed assets	-0.0465	-0.0380	-0.0021	0.0746	0.1282
Pure income	-0.2137	-0.0054	0.0265	0.0492	0.0647
Total value added	1.2375	-0.0257	0.2194	0.4146	0.7515
(Input combination)	1.2137	1.0054	0.9735	0.9508	0.9353
Total	1.0000	1.0000	1.0000	1.0000	1.0000
Output growth rate (%)	17.83	-14.88	44.07	63.10	11.83

Table 12 shows that China's output growth rate is positive, reflecting that the increase in services input and the decrease in industrial input are the main positive and negative contributing factors to output growth, respectively. The former promotes the rise in total output, while the latter suppresses it. The sum of the incremental direct input coefficients of intermediate input and the incremental direct input coefficients of initial input, as well as the sum of the factor input combination and the pure income incremental direct input coefficient, both equal one, serving to reveal the characteristics of input-output efficiency changes. Based on Equations (5)–(11), the structural analysis of China's input is presented in the following table.

Table 13 Structural analysis table of China's input structure, 2010–2020

Input sector	(1) Incremental direct input coefficient	(2) Direct input coefficient in the base year	(3) Direct input coefficient in the reporting year	(4) Increment of the direct input coefficient	(5) Input growth rate (%)	(6) Output growth rate (%)	(7) Input elasticity coefficient	(8) Direct pulling rate (%)
	(1)	(2)	(3)	(4)=(3)-(2)	(5)	(6)	(7)=(5)/(6)	(8)=(1)×(6)
Agriculture	0.0164	0.0383	0.0360	-0.0023	5.06	11.83	0.4273	0.19
Industry	-0.6885	0.5010	0.3752	-0.1259	-16.26	11.83	-1.3743	-8.15
Construction	0.0295	0.0028	0.0056	0.0028	124.45	11.83	10.5166	0.35
Services	0.8912	0.1282	0.2089	0.0807	82.26	11.83	6.9516	10.55
Total intermediate input	0.2485	0.6703	0.6257	-0.0446	4.39	11.83	0.3707	2.94
Compensation of employees	0.5586	0.1533	0.1962	0.0429	43.11	11.83	3.6428	6.61
Depreciation of fixed assets	0.1282	0.0459	0.0546	0.0087	33.02	11.83	2.7904	1.52
Pure income	0.0647	0.1304	0.1234	-0.0070	5.87	11.83	0.4962	0.77
Total value added	0.7515	0.3297	0.3743	0.0446	26.97	11.83	2.2795	8.89
(Input combination)	0.9353	0.8696	0.8766	0.0070	12.73	11.83	1.0755	11.07
Total	1.0000	1.0000	1.0000	0.0000	/	/	1.0000	11.83

The quantitative relationship among the incremental direct input coefficient, the direct input coefficient in the base year, and the input elasticity coefficient presented in Table 13 is shown in Figure 2. It can be observed that the incremental direct input coefficient is proportional to the input elasticity coefficient, with the maximum value of the input elasticity coefficient occurring when the incremental direct input coefficient is greater than the direct input coefficient in the base year. The direct input coefficient in the base year is inversely proportional to the input elasticity coefficient, with the minimum value occurring when the direct input coefficient in the base year is greater than the incremental direct input coefficient. The ratio of the incremental direct input coefficient to the direct input coefficient in the base year determines the magnitude of the input elasticity coefficient. The input elasticity coefficient exhibits three peaks, with the construction sector having a relatively high elasticity, followed by the services sector.

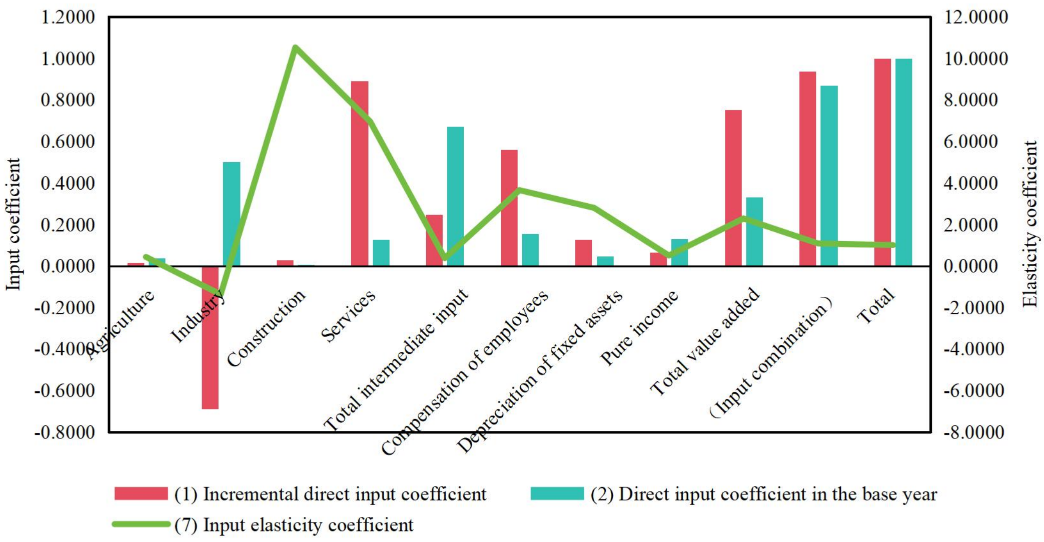

Figure 2 Comparison of key indicators of China's input structure, 2010–2020

(1) Analysis of incremental direct input and pulling coefficients. During the period 2010–2020, for each unit increase in output in China, the direct increases in inputs from agriculture, construction, services, compensation of employees, depreciation of fixed assets, and pure income were 0.0164 units, 0.0295 units, 0.8912 units, 0.5586 units, 0.1282 units, and 0.0647 units, respectively; direct input from industry decreased by 0.6885 units, reflecting that the increase in services input and the decrease in industrial input are the main positive and negative contributing factors to the increase in China's total output. It is worth noting that there is a fundamental difference between the increase in inputs of input combination components and the increase in pure income input: the former refers to the input of factor combinations, while the latter refers to the change in economic benefits caused by changes in the combination of factor inputs.

The direct pulling rate is obtained by multiplying the incremental direct input coefficient by the output growth rate. Within the 11.83% pulling of China's total output growth, inputs from agriculture, construction, services, compensation of employees, depreciation of fixed assets, and pure income pulled total output growth by 0.19%, 0.35%, 10.55%, 6.61%, 1.52%, and 0.77%, respectively; industrial input pulled total output down by 8.15%.

(2) Input-output efficiency analysis. During the period, China's total output and intermediate input increased by 11.83% and 4.39%, respectively, while value added increased by 26.97%, with the direct input of value added per unit of output increasing by 0.0446 units, reflecting the transformation of China's economic structure toward higher value added. Specifically, the input growth rates of agriculture and industry were lower than their output growth rates, indicating that their input costs per unit of output decreased by 0.0023 units and 0.1259 units, respectively, with factor productivity rising. In contrast, the input growth rates of construction, services, compensation of employees, and depreciation of fixed assets were higher than their output growth rates, indicating that their input costs per unit of output increased by 0.0028 units, 0.0807 units, 0.0429 units, and 0.0087 units, respectively, with factor productivity declining. The growth rate of the input combination formed by individual factors was higher than the output growth rate, indicating that the cost of the input combination per unit of output increased by 0.0070 units, with a corresponding decrease in benefits of 0.0070 units, revealing the quantitative transformation

relationship between the decline in input combination quality and contribution benefits (pure income). A decline in input combination quality, in turn, indicates a decline in total factor productivity. At the same time, the growth rate of pure income input was lower than the output growth rate, indicating a decline in the profitability of China's economy.

(3) Input elasticity coefficient analysis. During the expansionary period when output grew by 11.83%, China's input structure exhibited pronounced characteristics of differentiated adjustment, transformation, and upgrading. First, agriculture and industry showed divergent trends, while the construction sector experienced deep expansion, displaying a relatively high positive elasticity. Second, the services sector grew against the trend, exhibiting a high positive elasticity. Intermediate input in the services sector increased by 82.26%, with an elasticity of 6.9516, far exceeding the growth rate of total output, though still lower than the elasticity of the construction sector. This may be attributable to the fact that the services sector is in a period of superimposed expansion driven by digital transformation and consumption upgrading. Third, the components of value added generally exhibited high positive elasticities, with income distribution and capital deepening progressing in tandem. Compensation of employees increased by 43.11%, with an elasticity of 3.6428, indicating that the employment structure has been continuously optimized, and the share of employment in high-wage sectors such as services has risen. This may also be accompanied by policy effects such as upward adjustments in minimum wage standards and improvements in social security, causing the growth of compensation of employees to far exceed that of total output. Overall, during the expansionary period of total output, industry has achieved positive decoupling through declining intermediate input, and agriculture has moved toward low-dependence growth. However, the high elasticities of the construction and services sectors have placed considerable pressure on intermediate resource consumption. The high elasticities of compensation of employees and depreciation of fixed assets indicate that the economy is transitioning toward improved income distribution and capital deepening, while the relatively low elasticity of pure income reflects a structural change characterized by a declining share of profit distribution.

3.5 Analysis of incremental direct allocation coefficients

Based on Equation (12), Table 14 is obtained.

Table 14 Incremental direct allocation coefficients for four sectors in China, 2010–2020

Using sector	Agriculture	Industry	Construction	Services	Total intermediate input
Agriculture	-0.0287	0.0293	0.0005	0.0051	-0.0174
Industry	0.0757	1.1242	0.0013	0.0503	-0.7855
Construction	0.0599	-0.1193	0.0936	0.0848	0.2420
Services	0.1166	-0.1351	-0.0003	0.5044	0.8094
Total intermediate use	0.2235	0.8991	0.0951	0.6446	0.2485
Consumption	0.6937	-0.1273	-0.0560	0.2934	0.5365
Gross capital formation	0.0538	0.2518	0.9759	0.0668	0.2060
Net exports	0.0290	-0.0236	-0.0150	-0.0047	0.0090
Final use	0.7765	0.1009	0.9049	0.3554	0.7515
Total	1.0000	1.0000	1.0000	1.0000	1.0000

For each sector, the sum of the incremental direct allocation coefficient of intermediate use and the incremental direct allocation coefficient of final use equals one. The incremental direct allocation coefficient is, in essence, a contribution coefficient, reflecting the characteristics of positive or negative contribution of each sector to output increments. To reveal the characteristics of supply-push effect changes, it is necessary to apply the analytical methods based on the types and manifestations of incremental direct allocation coefficients. Based on Equations (12)–(15) and the analysis in Table 14, the structural analysis of China's use structure for the period 2010–2020 is calculated and presented in Table 15.

Table 15 Structural analysis table of China's use structure, 2010–2020

Using sector	(1) Incremental direct allocation coefficient	(2) Direct allocation coefficient in the base year	(3) Direct allocation coefficient in the reporting year	(4) Increment of the direct allocation coefficient	(5) Usage growth rate (%)	(6) Output growth rate (%)	(7) Usage elasticity coefficient	(8) Direct pushing rate (%)
	(1)	(2)	(3)	(4)=(3)-(2)	(5)	(6)	(7)=(5)/(6)	(8)=(1)×(6)
Agriculture	-0.0174	0.0221	0.0179	-0.0042	-9.30	11.83	-0.7860	-0.21
Industry	-0.7855	0.4781	0.3444	-0.1337	-19.44	11.83	-1.6428	-9.29
Construction	0.2420	0.0602	0.0794	0.0192	47.56	11.83	4.0190	2.86
Services	0.8094	0.1099	0.1839	0.0740	87.16	11.83	7.3656	9.58
Total intermediate use	0.2485	0.6703	0.6257	-0.0446	4.39	11.83	0.3707	2.94
Consumption	0.5365	0.1644	0.2038	0.0394	38.61	11.83	3.2631	6.35
Gross capital formation	0.2060	0.1563	0.1616	0.0053	15.59	11.83	1.3176	2.44
Net exports	0.0090	0.0089	0.0090	0.0000	11.92	11.83	1.0072	0.11
Final use	0.7515	0.3297	0.3743	0.0446	26.97	11.83	2.2795	8.89
Total	1.0000	1.0000	1.0000	0.0000	/	/	1.0000	11.83

Note: The comparison between the output growth rate of sector i and the growth rate of final use components differs from the judgment criteria for intermediate use sectors.

The quantitative relationship among the incremental direct allocation coefficient, the direct allocation coefficient in the base year, and the usage elasticity coefficient presented in Table 15 is shown in Figure 2, further confirming the relationship among the three. It indicates that the usage elasticity coefficient exhibits a trend consistent with that of the input elasticity coefficient, though with a slower and more lagged fluctuation, with the services sector showing a relatively high elasticity.

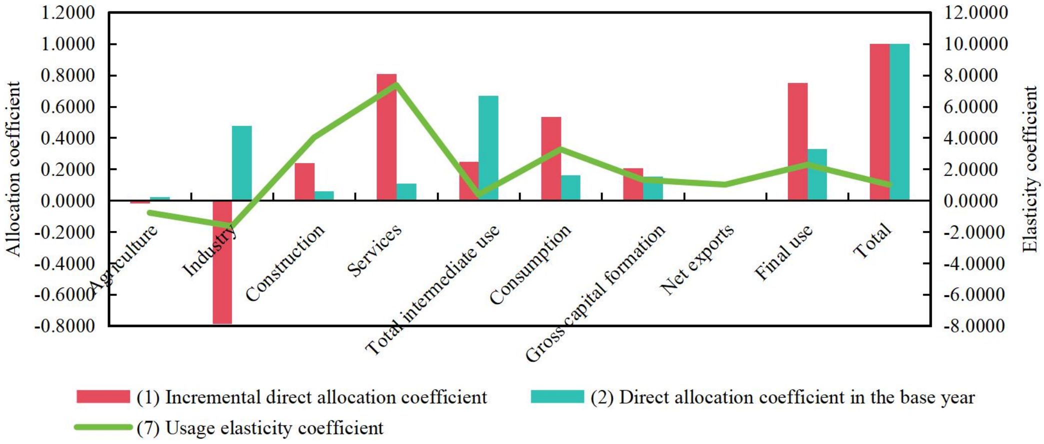

Figure 3 Comparison of key indicators of China's use structure, 2010–2020

(1) Analysis of incremental direct allocation and pushing coefficients. During the period 2010–2020, for each unit increase in output in China, direct decreases in allocation to agriculture and industry were 0.0174 units and 0.7855 units, respectively; direct increases in allocation to construction, services, consumption, gross capital formation, and net exports were 0.2420 units, 0.8094 units, 0.5365 units, 0.2060 units, and 0.0090 units, respectively, reflecting that the increase in services use and the decrease in industrial use are the main positive and negative contributing factors to China's output growth.

The direct pushing rate is obtained by multiplying the incremental direct allocation coefficient by the output growth rate. Within the 11.83% direct pushing of output growth, agriculture and industry, through their direct decreases in demand, pushed total output down by 0.21% and 9.29%, respectively, while construction, services, consumption, gross capital formation, and net exports, through their direct increases in demand, pushed total output up by 2.86%, 9.58%, 6.35%, 2.44%, and 0.11%, respectively.

(2) Use structure efficiency analysis. Intermediate use and final use increased by 4.39% and 26.97%, respectively, with the growth rate of final use far exceeding that of intermediate use, indicating an improvement in use structure efficiency. Specifically, for agriculture and industry, the growth rates of intermediate use were lower than their output growth rates, with corresponding increments of the direct allocation coefficient being negative, indicating that agriculture and industry lowered the overall intermediate use rate while the final use rate (value added) rose. For construction and services, the growth rates of intermediate use far exceeded their output growth rates, with the services sector in particular achieving high positive growth, and the corresponding increments of the direct allocation coefficient were positive, indicating that construction and services raised the intermediate use rate while the final use rate declined. For the final use components—consumption, gross capital formation, and net exports—their growth rates exceeded the output growth rate, with consumption having the highest growth rate and net exports growing at a rate similar to that of output. The corresponding increments of the direct allocation coefficient for all three components were positive, indicating that the final use rate increased while the intermediate use rate decreased. Foreign demand showed a declining trend, while consumption became a new growth driver.

(3) Use elasticity coefficient analysis. During the expansionary period when output grew by 11.83%, the economic structure exhibited pronounced characteristics of differentiated adjustment.

First, the use of agriculture and industry declined against the trend, displaying characteristics of negative elasticity decoupling. Second, construction, services, consumption, gross capital formation, and net exports all exhibited high positive elasticities, with their use growth rates exceeding the total output growth rate. Third, the growth of consumption and the expansion of the services sector formed a synergistic pushing effect. The rapid growth of services use is closely related to the consumption elasticity being as high as 3.2631. The upgrading of the household consumption structure (e.g., online retail, catering, cultural tourism, and information technology services) directly drove a substantial increase in the intermediate use of services sectors such as commerce, transportation, and communications. Furthermore, the high growth of the construction sector and the elasticity of gross capital formation (1.3176) mutually reinforce each other, reflecting that the investment-driven growth model remains significant, with demand for the use of building materials, energy, transportation, and the like from infrastructure construction and real estate development remaining strong.

4. Conclusions and Future Research

4.1 Conclusions

1. The proposed systematic analytical method for incremental coefficients provides a basis for revealing the drivers of economic structural change. Starting from the demand-pull incremental input coefficients and the supply-push incremental allocation coefficients, this paper presents their four types (excluding zero), along with their economic implications, manifestations, and judgment criteria, through two sets of three analytical tables each. This makes the analytical principles clearer and facilitates comparative analysis. By compiling incremental input-output tables, input-output tables for different years and sector classifications can be transformed into continuous annual or interval-based time series tables [16], enabling time series analysis. The correlation coefficients calculated from incremental input-output tables are directly related to dynamic statistical indicators such as contribution rates, pulling rates, growth rates, and elasticity coefficients. Moreover, total contribution rates, total pulling rates, and total pushing rates can also be calculated. This represents an extension and significant development of input-output theory, deepening the analysis from reflecting economic operation to capturing the process of economic change.

2. Empirical evidence shows that during the period 2010–2020, China's total output, GDP, and pure income (economic benefits) all increased, with notable achievements in economic structural transformation. Despite shocks such as the COVID-19 pandemic, China's total output and intermediate input grew by 11.83% and 4.39%, respectively, while value added increased by 26.97%, with the direct input of value added per unit of output increasing by 0.0446 units, reflecting the transformation of China's economic structure toward higher value added. The increase in total output primarily relied on the rise in final use, with increases in consumption and gross capital formation being important factors driving the increase in final use, particularly consumption, which became the main growth point driving domestic demand. During the expansionary period when output grew by 11.83%, China's input structure exhibited pronounced characteristics of differentiated adjustment, transformation, and upgrading. This reflects a structural transformation characterized by an increasing final use rate and a decreasing intermediate use rate, indicating that China's economy has exhibited a development trend of structural upgrading and demand-driven growth. However, the quality and efficiency of

input-output combinations across sectors still need further improvement, mainly reflected in the increased consumption cost of input combinations per unit of output.

3. The study finds that the savings in input combinations per unit of output in each sector are entirely transformed into pure income per unit of output, revealing the quantitative transformation relationship between the improvement in input combination quality and the contributed pure income. This indicates that an improvement in the quality of input combinations, which consist of the three single factors—intermediate input, depreciation of fixed assets, and compensation of employees—implies an increase in total factor productivity. Under the unified framework of incremental input-output analysis, it is possible to simultaneously analyze the productivity of the three single factors and their composition into total factor productivity for the analysis of intermediate input plus value added as total output, as well as the productivity of the two single factors (depreciation and compensation of employees) and their composition into total factor productivity for the analysis of value added as output.

Due to space limitations, this paper does not analyze the incremental total input coefficients and incremental total allocation coefficients.

4.2 Future Research

It can be seen from the calculation formulas of incremental input-output coefficients that the fluctuations in the growth rates of various sectors within the economic system originate from both demand-side pulling, primarily transmitted through the intermediate input elasticity coefficient, and supply-side pushing, primarily transmitted through the intermediate use elasticity coefficient, resulting from the joint action of both. On the basis of the base-year technology level, the elasticity coefficient determines the magnitude of fluctuations in incremental input or allocation coefficients.

Due to the complex and dynamic nature of economic system changes, research on incremental input-output analysis for revealing its characteristics remains preliminary, and potential biases may exist. Further research is still needed. By combining the decoupling and negative decoupling reflected in the elasticity coefficients calculated in this paper with supply chain resilience, indicators such as the incremental fluctuation resilience coefficient can be calculated to reveal the degree of structural stability of the economic system. As the incremental analysis system matures, further research is needed on issues such as incremental non-competitive tables, incremental interregional tables, incremental environmental governance, and incremental CGE models, in order to enhance the explanatory power of economic and social changes.

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