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Drivers of metal consumption in China: An input-output structural decomposition analysis

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ABSTRACT

The rapid growth of metal consumption is not only the result of global processes of industrialization and urbanization but also the result of multiple drivers. Based on China's input-output tables from 1997 to 2015, this article discussed the decoupling states between metal consumption and economic growth among sectors, and then adopted structural decomposition analysis (SDA) method to analyze drivers of China's metal consumption at the national level, industrial level (agriculture, industry, construction and service industries) and sub-sectors of industry level. The results show the following: (1) from 1997 to 2015, China's total metal consumption increased by 3889.35 million tons, and the decoupling state of economic development and metal consumption presented expansive negative decoupling; thus, China's high-speed economic growth has come at the expense of high-intensity metal consumption, especially in industry; (2) capital formation is the main driver of metal consumption, increasing metal consumption by 1374.89 million tons and accounting for 35.27% of the contribution, followed by metal consumption intensity, export expansion, consumption expansion, Leontief effect and import substitution effect; (3) the metal consumption intensity and Leontief effect are potential factors for improving the efficiency of metal use and reducing metal consumption; (4) various drivers hold discrepant influence on different sectors. Based on these results, related policy recommendations are also discussed.

1. Introduction

Economic development has always been closely linked to the use of natural resources (Behrens et al., 2007). As a basic mineral resource of industrialization and urbanization, metals provide strong support for buildings, electrical appliances, machinery manufacturing, automobile manufacturing and transportation industries (Chen and Graedel, 2012; Peiró et al., 2013; Zheng et al., 2018; Feng et al., 2018) and play vital roles in economic development (Reck et al., 2010; Gong and Lin, 2018a; Feng et al., 2019). Drawing on the definition of material consumption (Pothen and Schymura, 2015) and metal footprint (Zheng et al., 2018), we define metal consumption as the amount of metal ores used by sectors, which equals the domestically extracted plus imported minus exported metal ores (Zhang et al., 2019). Due to the economic boom, metal consumption has enjoyed rapid growth (Wiedmann et al., 2015; Zheng et al., 2018; Zhang et al., 2019), especially in China. As shown in Fig. 1, China's metal consumption increased from approximately 480.36 million tons in 1997–3610.53 million tons in 2017, representing an annual growth rate of 10.61%. Moreover, the growth momentum of metal consumption has been significantly higher than GDP from 2002 to 2013; and after 2013, its growth trend was no lower than GDP, fully demonstrating the important role of metal consumption in economic development (Schandl and West, 2010; Humphreys, 2010).

Due to the acceleration of urbanization and industrialization, the demand for major metal resources, such as iron ores, copper and aluminum, will continue at a relatively high level; and the demand for rare metals, such as lithium, gallium, germanium, indium and bismuth, will continue to grow rapidly because of the new technology revolution and high-tech emerging industries (Feng et al., 2019). Furthermore, the development of a low-carbon society requires large amounts of metals (Vidal et al., 2013; Viebahn et al., 2015; Nansai et al., 2015; Ali et al., 2017; de Koning et al., 2018). However, the extensive consumption of metal resources has caused many problems. On the one hand, mining and smelting metals are polluting processes, that lead to environmental pollution (Bridge, 2004), geological conditions (Özkaynak et al., 2012; Franks et al., 2014) and greenhouse gas emissions (Van et al., 2013); on the other hand, depletion (Prior et al., 2012) and low geographical concentration of metal ore (Graedel et al., 2015) limit the supply of

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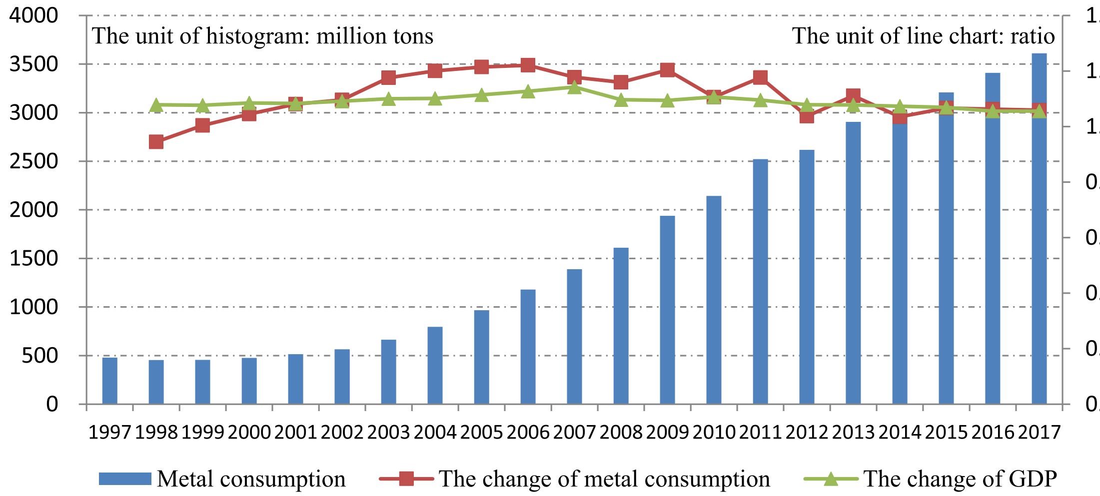

Fig. 1. China's metal consumption and changes of metal consumption and GDP from 1997 to 2017. Date sources: www.materialflows.net, UN Comtrade Database and China's National Bureau of Statistics.

metal ore. Moreover, there is a strong coupling between metal consumption and economic development (Crompton, 2015).

The new Sustainable Development Goals from the United Nations (Griggs et al., 2013) show renewed interest from the global policy community in sustainable natural resource use and impacts of economic growth (Martinico-Perez et al., 2018). The decoupling of economic development and metal consumption is the focus of the sustainable development of China's economy (Schandl and West, 2010; Steinberger et al., 2013). Policymakers in China have clearly put forward the comprehensive protection and effective utilization of mineral resources in the National Mineral Resources Planning (2016–2020) and the 13th "Five-Year Plan" (2016–2020). However, the rapid economic growth in China has increased the amount of metal ore extracted and led to an ever increasing in metal consumption (Schandl and West, 2010; Steinberger et al., 2013). With the intensive mining and rapid consumption of metals, the decline in resource carrying capacity and the environmental problems caused by large metal consumption have restricted the sustainable development of China's economy. It is crucial to understand what factors have driven such consumption patterns the most and whether these factors are consistent in different sectors. Thus, this article will decompose China's metal consumption and disentangle the main drivers of metal consumption in all sectors to suggest ways to improve the efficiency of metal use and decouple economic development from metal consumption.

Our contribution involves three main aspects. First, the decoupling statuses of metal resource consumption and economic growth have attracted the attention of researchers, producers and policymakers. Using the latest input-output table data from China, this article discusses the decoupling relationship between metal consumption and economic growth among sectors, which will help us promote the sustainable development of China's metal resources and economy. Second, the effect of economic activities on metal consumption is important, but it is more meaningful to discuss the impact of consumption, capital formation, export and other factors on metal consumption by refining economic activities. This article not only considers the terminal demand scale effect but also further decomposes it into the consumption effect, capital formation effect and export effect. Finally, according to the definition of metal consumption, the import of metal ores is an important part of metal consumption and it is necessary to explore the impact of import and export factors on metal consumption. This article applies the SRIO (single region input-output) model with the competitive imports assumption and defines the ratio of internal supply to total supply in various sectors to indicate the impact of imports on intermediate demands as well as final consumption.

The next sections are organized as follows. Section 2 presents the relevant literature. In section 3, we describe the methods and relevant data. In section 4, we analyze the decoupling states of metal consumption and economic growth and discuss the drivers of Chinese metal consumption. In section 5, we provide the final comments and propose corresponding policy recommendations.

2. Literature review

To identify the driving factors of metal consumption and quantify their impacts, the research literature can be divided into two categories: research based on econometric models and research based on factor decomposition analysis.

The econometric models include STIRPAT (Dietz and Rosa, 1997), IPAT (Ehrlich and Holdren, 1971) and regression model. These methods can reflect environmental impacts to different influencing factors, e.g., population, gross domestic product (GDP), technology and energy intensity, among others (York et al., 2003; Feng et al., 2018), and specifically used to identify driving forces of energy-related carbon emission (Chertow, 2000; Ma et al., 2017; Xu and Lin, 2016), yet research areas are diverse (Vélez-Henao et al., 2019). For example, Steinberger et al. (2010) used multiple linear regressions based on the STIRPAT analysis framework to evaluate the comprehensive explanatory power of population, GDP and land area for material flows. Steger and Bleischwitz (2011) combined material flow analysis and regression analysis to identify the drivers for material use and decoupling from GDP. Wang et al. (2016) used a vector auto-regressive (VAR) model to study the effects of industrial structure, trade opening and domestic per capita extraction on raw material production efficiency from 1980 to 2010. Nasir et al. (2019) applied a structural vector auto-regression (SVAR) model to study the influences of oil price shocks on the GDP, inflation and trade balance of the Gulf Cooperation Council member countries (Bahrain, Kuwait, KSA, Oman, Qatar and UAE) from 1980 to 2016.

Decomposition analysis has been widely used to identify driving forces or determinants of historical changes of an aggregate indicator (Hoekstra and Van den Bergh, 2003; Ma and Stern, 2008; Zhang, 2009; Su and Ang, 2012). Two popular decomposition techniques are the disaggregation techniques-index decomposition analysis (IDA) and the input–output techniques-structural decomposition analysis (SDA). IDA uses the index theory in statistics to perform decomposition analysis and constructs different decomposition methods according to different indices (Ang, 1995, 2015; Dong et al., 2013). It may be grouped into five types: the Laspeyres (LASP), Shapley/Sun (S/S), arithmetic mean Divisia index (AMDI) method, logarithmic mean Divisia index (LMDI) method and other parametric Divisia methods. Ang (2004) compared these IDA methods and found the LMDI method has the most advantages. Ang (2005) provided practical guides for the LMDI method. Ang and Liu (2007) resolved the negative values in the data set of the LMDI method and expanded the application of this method. Thus, the IDA method has been widely applied to study the driving factors of energy consumption (Zhang and Lahr, 2014; Liu et al., 2019; Wang et al., 2019), energy intensity (Li et al., 2014), energy related carbon emissions (Xu and Ang, 2013; Wang and Feng, 2017a; Feng et al., 2018; Du et al., 2018; Huang et al., 2018) and material use (Hoffrén et al., 2000; Hashimoto et al., 2008; Pothen and Schymura, 2015; Wang et al., 2017). Additionally, IDA can decompose the driving factors into economic effects, structural effects, population effects, emission factor effects and energy mix effects, among others (Wang et al., 2005, 2013a; Zhang et al., 2009; Kang et al., 2014; Lin and Ouyang, 2014; Fan and Lei, 2017; Yan et al., 2016; Lin and Tan, 2017). Since the IDA method cannot reveal the influence of technology-related factors, in recent years, scholars have built a comprehensive decomposition framework (combined LMDI and PDA method) to analyze the driving factors of energy consumption (Du and Lin, 2015; Liu et al., 2018) and carbon emission (Wang and Feng, 2017b; 2018a; Song et al., 2018). Furthermore, Wang and Feng (2018b) used an extended LMDI method to reveal the impacts of investment and R&D expenditure on industrial CO_2 emissions. However, these methods consider only the direct effect, ignoring the indirect effect and final demand. At the same time, it is usually applied to a specific area, not to the whole economy (Su and Ang, 2012; Li et al., 2014; Zeng et al., 2014).

SDA is based on the input-output framework to explore the changes of economic variables (Rose and Casler, 1996; Butnar and Llop, 2011). Compared to IDA, the SDA model can distinguish between a range of Leontief effect and final demand effect (Hoekstra and Van den Bergh, 2003; Ma and Stern, 2008; Butnar and Llop, 2011) and consider both direct and indirect effects in the analysis (Rose and Casler, 1996; Hoekstra and Van den Bergh, 2003; Zhang et al., 2009). Because of these characteristics, SDA has frequently been utilized to decompose the drivers of energy consumption (Zeng et al., 2014; Zhang and Lahr, 2014; Xie, 2014; Llop, 2017; Zhong, 2018), air pollution emissions (Wang et al., 2013b, 2015; Lan et al., 2016; Xu et al., 2017; Pu et al., 2018) and material consumption (Muñoz and Hubacek, 2008; Wood and Lenzen, 2009; Weinzettel and Kovanda, 2011; Pothen, 2017).

Using the SDA method, Muñoz and Hubacek (2008) decomposed Chile's material consumption into five drivers: material intensity, structural change, changes in the mix (final demand), category (domestic final demand and export categories) and level effects (economic activities), and found that the main drivers were economic growth and increased exports. Wood and Lenzen (2009) decomposed the drivers of changes in Australian material consumption into exports, export mix, industrial structure, affluence, and population, and similar to Muñoz and Hubacek (2008), economic growth and increasing exports were particularly important to changes in material consumption. Weinzettel and Kovanda (2011) decomposed material consumption of the Czech Republic into three drivers: technology, product structure of the final demand, and volume of the final demand for individual final demand categories. Pothen (2017) decomposed the growing global raw material consumption into five factors: final demand, the mix of goods in final demand, countries supplying final demand, the input-output structure of global economy and material intensity, and found that the final demand was the main driver. Plank et al. (2018) decomposed the socio-economic driving forces of increasing global raw material consumption (RMC) into seven factors: material efficiency, production recipe, the import structure of intermediate demand, the import structure of final demand, final demand composition, total final demand per capita and population size of the respective country.

Through a literature review, we found that there are few studies on the driving factor decomposition of metal consumption. In fact, metal use and economic development are closely linked, and global processes of industrialization and urbanization consumed large amounts of metals (Wiedmann et al., 2015). On the one hand, metals are consumed by various sectors through the metal ores mining sector, and it is meaningful to study metal consumption of various sectors; on the other hand, the impact of import and export factors on metal consumption cannot be ignored. Therefore, this article chooses the SDA method based on Chinese input-output tables to clarify the driving factors of metal consumption in China's various sectors. First, the two-tier nested SDA model is used to decompose China's metal consumption into the Leontief effect, intensity effect and terminal demand scale effect. The terminal demand scale effect is further decomposed into the consumption effect, capital formation effect, export effect and import effect. The study findings enrich the analytical framework of metal consumption and provide a new research perspective for exploring the consumption law of metal resources. Second, the different characteristics and drivers of China's metal consumption are analyzed at the national level, industrial level (agriculture, industry, construction and service industries) and industrial sub-sector level, which could help policy makers understand the contribution of various industries to the consumption of metals and formulate feasible policies to improve the effectiveness of metal consumption from different levels and viewpoints. Finally, the use of comparable input-output data eliminates the influence of the price factor and makes the research method more scientific and the calculation result more accurate.

3. Methodology and data

3.1. The framework of decoupling between economic growth and metal consumption

To further understand the relationship between metal consumption and economic growth, the evaluation model of the "decoupling theory" (Tapio, 2005) has been introduced. The decoupling indicator for the base year and target year can be defined as the ratio of the rate of change in metal resource consumption to the rate of change in GDP. The specific formula is as follows:

$$D_t = \frac{\%\Delta M}{\%\Delta GDP} = \frac{\frac{M_t - M_0}{M_0}}{\frac{G_t - G_0}{G_0}} \tag{1}$$

where D_t is the decoupling indicator, M and G represent metal consumption and GDP, respectively. Subscript t and 0 represent the values of the variables in phase t (reporting period) and 0 (base period).

According to the definition of the Tapio decoupling model, the decoupling statuses of metal resource consumption and economic growth can be divided into three categories (decoupling, negative decoupling and coupling) and then further divided into eight sub-categories (shown in Table 1). In these states, strong decoupling is the most ideal state for economic growth and metal consumption, while strong negative

Table 1
Eight decoupling states of Tapio's decoupling models.

	%Δ*M*	%Δ*GDP*	D_t	States	Abbreviations
1	≤0	> 0	D_t≤0	Strong decoupling	S-D
2	> 0	> 0	0≪D_t0.8	Weak decoupling	W-D
3	< 0	< 0	D_t > 1.2	Recessive decoupling	R-D
4	> 0	> 0	D_t > 1.2	Expansive negative decoupling	E-N-D
5	< 0	< 0	0≪D_t0.8	weak negative decoupling	W–N-D
6	> 0	< 0	D_t < 0	Strong negative decoupling	S–N-D
7	> 0	> 0	0.8 < D_t≤1.2	Expansive coupling	E-C
8	< 0	< 0	0.8≪D_t1.2	Recessive coupling	R–C

Table 2
The (imports) competitive economic-metal consumption input-output table.

	Intermediate use	Final demand (Y)			Import	Total output
		Consumption	Capital formation	Export		
Intermediate input	AX	C	K	E	IM	X
Value added	V					
Total input	X^T					
Metal consumption intensity	MI					
Metal consumption	M					

decoupling is the least ideal state.

3.2. Structural decomposition analysis

The research of this article is based on an extended single region input-output table connecting economic sectors and metal consumption, and Table 2 is a simplified form of this extended table. Where $A = (a_{ij})$ denotes the direct consumption coefficient matrix ($n \times n$), representing the input of sector i needed to produce one unit of output in sector j. X represents the total output column vector and $X^T$is the total input row vector (Trepresents transposition). Y represents the final demand matrix, including consumption vector (C), capital formation vector (K) and export vector (E). IM represents the import vector. $M$and MI represent metal consumption and metal consumption intensity (metal use per unit of GDP) row vectors in the industrial sector, respectively. Furthermore, $M = M\hat{I}X$, $M\hat{I}$ represents the diagonalizable matrix of MI.

In this article, an SDA framework is adopted to decompose changes in metal consumption into its determinants.

$$\Delta M = M_1 - M_0 = M\hat{I}_1 X_1 - M\hat{I}_0 X_0 \tag{2}$$

where subscripts 1 and 0 represent the values of variables in phase t(reporting period) and 0 (base period), respectively. Δ represents the change of variables.

First, using the two-pole decomposition method (Dietzenbacher and Los, 1998), ΔM can be decomposed as follows:

$$\Delta M = (\Delta M\hat{I}X_0 + \Delta M\hat{I}X_1)/2 + (M\hat{I}_1\Delta X + M\hat{I}_0\Delta X)/2 \tag{3}$$

The extended table in Table 2 is based on the SRIO (single region input-output) model with the competitive imports assumption, which treats the imported products to be the same as those produced domestically (Su and Ang, 2013). Furthermore, the imports are used for intermediate demands and final consumption respectively, while the data cannot be obtained directly in the input-output table. To indicate the impact of imports, the ratio of internal supply to total supply (u_i) in various sectors is defined (Xu et al., 2017).

$$u_i = \frac{x_i - e_i}{x_i - e_i + m_i} \tag{4}$$

where m_i, e_i and x_i are the corresponding elements of imported column vectors IM, export column vectors E and total output column vectors X, respectively.

Based on the above assumption and the two-pole decomposition method, ΔX can be decomposed as follows:

$$X_0 = \hat{U}_0 A_0 X_0 + \hat{U}_0(C_0 + K_0) + MIX_0 \tag{5}$$

$$X_1 = \hat{U}_1 A_1 X_1 + \hat{U}_1(C_1 + K_1) + MIX_1 \tag{6}$$

where $\hat{U}$is the diagonal matrix of the ratio of internal supply to total supply (u_i). According to the input-output balance relationship, ΔX can be further decomposed into the following factors:

$$\Delta X = \tfrac{1}{2}(R_0\hat{U}_0 + R_1\hat{U}_1)\Delta C + \tfrac{1}{2}(R_0\hat{U}_0 + R_1\hat{U}_1)\Delta K + \tfrac{1}{2}(R_0 + R_1)\Delta E + \tfrac{1}{2}[R_0\Delta\hat{U}(A_1X_1 + C_1 + K_1) + R_1\Delta\hat{U}(A_0X_0 + C_0 + K_0)] + \tfrac{1}{2}(R_0\hat{U}_0\Delta AX_1 + R_1\hat{U}_1\Delta AX_0) \tag{7}$$

For convenience of description, order $R_0 = (I - \hat{U}_0A_0)^{-1}$ and $R_1 = (I - \hat{U}_1A_1)^{-1}$. Substituting the above formula into ΔM, and letting $n = \frac{1}{2}(M\hat{I}_0 + M\hat{I}_1)$, ΔM has been defined as follows:

$$\begin{aligned}\Delta M = {} & \tfrac{1}{2}\Delta M\hat{I}(X_0 + X_1) \ldots\ldots \textit{Metal consumption intensity effect} \\ & + \tfrac{1}{2}n\Delta C(R_0\hat{U}_0 + R_1\hat{U}_1) \ldots\ldots \textit{Consumption expansion effect} \\ & + \tfrac{1}{2}n\Delta K(R_0\hat{U}_0 + R_1\hat{U}_1) \ldots\ldots \text{Capital}\ \textit{formation effect} \\ & + \tfrac{1}{2}n\Delta E(R_0 + R_1) \ldots\ldots \textit{Export expansion effect} \\ & + \tfrac{1}{2}n[R_0\Delta\hat{U}(A_1X_1 + C_1 + I_1) + R_1\Delta\hat{U}(A_0X_0 + C_0 + I_0)] \ldots\ldots \textit{Import substitution effect} \\ & + \tfrac{1}{2}n(R_0\hat{U}_0\Delta AX_1 + R_1\hat{U}_1\Delta AX_0) \ldots\ldots \text{Leontief}\ \textit{effect}\end{aligned} \tag{8}$$

From equation (8), the change of China's metal consumption is decomposed into six drivers: metal consumption intensity effect (MCI), consumption expansion effect (CE), capital formation effect (IE), export expansion effect (EE), import substitution effect (IS) and Leontief effect (LE). The MCI refers to the impact of changes in metal consumption intensity on the change in metal consumption, which may cause an increase in metal consumption or a decrease in metal consumption. Next is the consumption expansion effect, which means changes in household and government consumption causing changes in metal consumption. The capital formation effect refers to changes in metal consumption caused by fixed capital formation and inventory. The export expansion effect is the impact from the exports of various products on the changes in metal consumption. The import substitution effect shows that the changes in imports products to replace domestic products used by various sectors can cause changes in metal consumption, because the competitive SRIO model treats imported products as the same as those produced domestically. The last driver is the Leontief effect, which means changes in metal consumption caused by technological advances.

3.3. Data source

According to the introduction section, metal consumption equals the domestically extracted metal ores plus the imported minus the exported. The data of China's domestic extraction metal ores are obtained from www.materialflows.net, and China's imported and exported metals are obtained from the UN Comtrade Database. Because metals are often used as components of alloys or complex assembled products, this article uses a single indicator of metal ore consumption that aggregates all groups of metals (Zheng et al., 2018).

Because metal ores enter the entire value chain only through the extraction process, to obtain the amount of metal consumed in each sector, we first assume identical prices (Wang et al., 2017). A certain value of goods and services from the metal extraction sector will always contain an identical amount of metals (Zhang et al., 2019). Then calculate the complete consumption coefficient (D) based on the input-output table:

$$D = (I - A)^{-1} - I \tag{9}$$

Where A is the matrix of the technical coefficients and I is the unit matrix. The original data come from the basic flow table of China's input-output table in the years 1997, 2000, 2002, 2005, 2007, 2010, 2012 and 2015. To eliminate the impact of inflation in different years, the original input-output tables have been adjusted to comparable price input-output tables (with constant 1997 prices) based on GDP deflators. Since the sectors utilized in I–O tables are inconsistent in different years, and the data of each sector can only be merged, there is no way to split out. To facilitate comparison, the sectors have been merged into 23 sectors according to the close relationships between certain sectors. According to Zhang et al. (2019), the aggregations shown in Appendix A include agriculture (m_1), industrial sectors (from m_2 to m_{21}), construction (m_{22}) and services (m_{23}).

Thus, sectoral metal consumption (M_j) can be expressed as follows:

$$M_j = M \times D_{4j} \tag{10}$$

Where M denotes total metal consumption (referring to domestic metal consumption) and D_{4j} represents the metal extraction sector consumption coefficient.

4. Results and discussion

4.1. Holistic analysis

4.1.1. The decoupling analysis of China's metal consumption and economic growth

As shown in Table 3, the decoupling state of economic development and metal consumption is expansive negative decoupling (E-N-D) from 1997 to 2015. This means that China's economic growth and metal consumption are absolutely linked; that is, high-speed economic growth comes at the expense of high-intensity metal consumption. Furthermore, the value of $\%\Delta M$ is greater than $\%\Delta GDP$, and the growth rate of metal consumption was greater than the rate of economic growth. In the long run, the relationship between economic growth and metal consumption follows an inverted "U" shape, and China remains on the left side of the curve.

Apart from the 1997–2000 period, there was no real decoupling between economic growth and metal consumption in all years, especially between 2002 and 2005, when the value of D_t reached 2.04. This result occurred because China joined the WTO, which drove the rapid development of the domestic industrial economy, and metal consumption as an important basic resource increased sharply. During the period of the 12th Five-Year Plan, to address the serious overcapacity in the metal industry, the Chinese government set the development goals of reducing capacity and inventory, which to some extent reduced the total demand for metal consumption in economic development. Therefore, from 2012 to 2015, the rate of economic growth was greater than the rate of metal consumption, which means that metal use efficiency improved, and there was a potential for decoupling between metal consumption and economic growth.

4.1.2. Factors affecting metal consumption in China

Table 4 and Fig. 2 show the impacts of various factors on the growth of metal consumption and their contributions to the metal consumption growth in different periods. From 1997 to 2015, the effect of capital formation increased metal consumption by 1374.89 million tons, accounting for 35.27% of the contribution. Thus, capital formation was the main factor increasing metal consumption, which is consistent with the findings of Zheng et al. (2018). In all stages, capital formation has always maintained positive values, and it has always been the driving force behind the increase in metal consumption. Especially from 2007 to 2010, capital formation increased metal consumption to 652.09 million tons, which may be related to the 4 trillion (RMB) economic stimulus plan implemented in 2009 (Yuan et al., 2010; Song et al., 2018).

Next, the metal consumption intensity, export and consumption increased metal consumption by 1208.93 million tons, 659.04 million tons and 596.22 million tons, respectively, and their contributions represented 31.01%, 16.91% and 15.29% of the total increase, respectively. As shown in Fig. 2, the impact of metal consumption intensity on increasing metal consumption was inverted U-shaped from 1997 to 2015, reaching a peak of 980.24 million tons in 2007–2010. Since 2010, due to the impact of technological advancement, metal use efficiency has increased and the impact of metal consumption intensity on metal consumption has gradually weakened. Especially in 2012–2015, the effect of metal consumption intensity reduced metal consumption by 355.78 million tons. In contrast to the effect of metal consumption intensity, the effect of exports on metal consumption follows a W shape over time. When China joined the WTO, exports increased metal consumption by 169.33 million tons in 2002–2005; due to the impact of the 2008 financial crisis, metal consumption increased by only 4.86 million tons; after the crisis, metal consumption gradually increased. In contrast to the effects of metal consumption intensity and export, the effect of consumption on increasing metal consumption increased from 27.37 million tons in 1997 to 281.22 million tons in 2015, as a result of the expansion of China's domestic consumption.

In addition to the above factors, the Leontief effect and import substitution effect on China's metal consumption are not remarkable. From 1997 to 2015, they increased metal consumption by 43.12 million tons and 16.05 million tons, respectively, and their contributions were only 1.11% and 0.41%, respectively. The values of the Leontief effect were always positive and increasing from 2000 to 2010, which shows that since 2000, China's economic development has shown an increasingly "extensive" growth trend, and economic growth has become more dependent on metal resources. Although the Leontief effect had little direct impact on China's metal consumption from 1997 to 2015, it is a potential driver to improve the efficiency of metal use and reduce metal consumption. On the one hand, the trend of total metal consumption is basically consistent with the trend of metal consumption caused by the Leontief effect. On the other hand, from 2010 to 2012, the Leontief effect decreased metal consumption by 1426.17 million tons and continued to reduce metal consumption by 280.45 tons from 2012 to 2015. The influence of the import substitution effect on metal consumption

Table 3
The decoupling states of economic development and metal consumption in China from 1997 to 2015.

	1997–2000	2000–2002	2002–2005	2005–2007	2007–2010	2010–2012	2012–2015	1997–2015
	−0.01	0.18	0.71	0.44	0.54	0.22	0.23	5.68
	0.26	0.18	0.35	0.29	0.33	0.18	0.24	4.02
	−0.03	1.01	2.04	1.52	1.66	1.22	0.96	1.41
States	S-D	E-C	E-N-D	E-N-D	E-N-D	E-N-D	E-C	E-N-D

Table 4
The structural decomposition of China's metal consumption from 1997 to 2015.

		MCI	CE	IE	EE	IS	LE	Total
The growth of metal consumption (million tons)	1997–2000	−49.22	27.37	33.25	38.61	−23.09	−31.50	−4.59
	2000–2002	−24.15	14.84	42.26	26.54	−8.06	5.99	57.43
	2002–2005	211.39	29.41	113.98	169.33	−45.52	68.45	547.03
	2005–2007	363.81	49.64	171.43	122.75	122.72	101.89	932.24
	2007–2010	980.24	155.42	652.09	4.86	116.38	674.84	2583.83
	2010–2012	151.29	133.37	305.12	86.75	2.86	−1426.17	−746.77
	2012–2015	−355.78	281.22	331.39	53.06	262.82	−280.45	292.27
	1997–2015	1208.93	596.22	1374.89	659.04	16.05	43.12	3898.25
Contribution (%)	1997–2000	1073.51	−596.83	−725.21	−841.92	503.52	686.94	100
	2000–2002	−42.06	25.85	73.58	46.22	−14.03	10.43	100
	2002–2005	38.64	5.38	20.84	30.95	−8.32	12.51	100
	2005–2007	39.03	5.32	18.39	13.17	13.16	10.93	100
	2007–2010	37.94	6.02	25.24	0.19	4.50	26.12	100
	2010–2012	−20.26	−17.86	−40.86	−11.62	−0.38	190.98	100
	2012–2015	−121.73	96.22	113.38	18.16	89.93	−95.96	100
	1997–2015	31.01	15.29	35.27	16.91	0.41	1.11	100

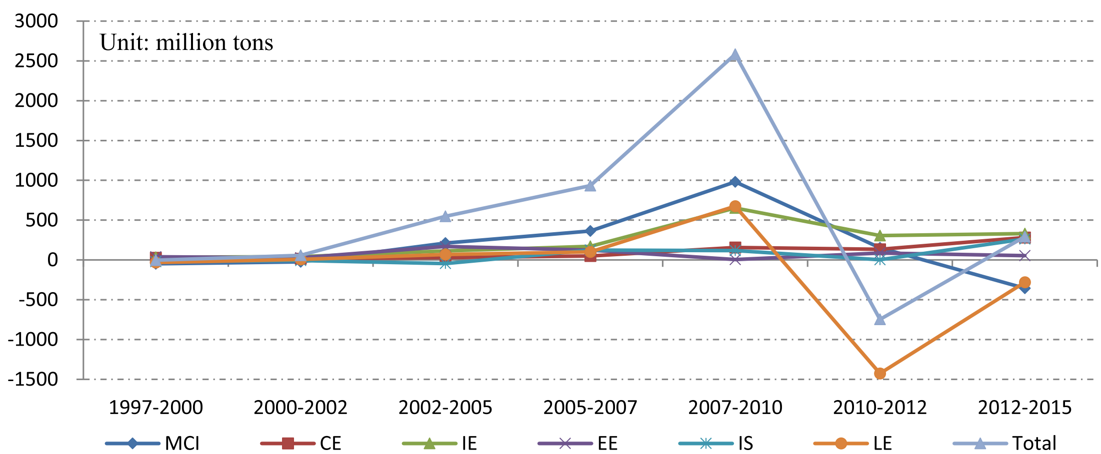

Fig. 2. Changes in the decomposition factors of China's metal consumption.

can be divided into two stages. From 1997 to 2005, it somewhat suppressed the growth of metal consumption. From 2005 to 2015, the import substitution effect changed from negative to positive, particularly leading to an increase in metal consumption by 262.82 tons in 2015, which shows that China's import structure of metals is also in a process of “deterioration".

4.2. Sector analysis

4.2.1. The decoupling analysis of metal consumption and economic growth in four sectors

As shown in Table 5, from 1997 to 2015, the decoupling states of economic development and metal consumption in agriculture (Ag-), industry (In-), construction (Con-) and services (Se-) present expansive negative decoupling (E-N-D). However, from 2010 to 2012, agriculture and service present strong decoupling; from 2012 to 2015, there is a strong decoupling state between economic development and metal consumption in all sectors apart from industry. Thus, the decoupling of economic development and metal consumption has been achieved in agriculture, construction and services.

The decoupling state of economic development and metal consumption in the industrial sector is basically consistent with the overall situation in China. Since 2000, China's rapid industrialization has brought about a large amount of metal consumption, thus leading economic development and metal consumption to change from strong decoupling to expansive negative decoupling. There are two reasons for this phenomenon. First, China's infrastructure construction has been accelerating and metal consumption has been increasing rapidly. Second, China's technological level was relatively backward in the early 21st century, so the use of resources was inefficient and wasteful. The two factors overlap, resulting in a strong coupling between economic growth and metal consumption. Industry is the basic industry of the national economy and it consumes the most metals. Thus, the decoupling of industry from metal consumption determines the efficiency of metal use in the whole national economy.

4.2.2. Factors affecting metal consumption in four sectors

Table 6 shows the impacts of various factors on the growth of metal consumption and their contributions in agriculture (Ag-), industry (In-), construction (Con-) and service (Se-) from 1997 to 2015. The increases of metal consumption in agriculture, industry, construction and services were 14.29, 3618.52, 171.57 and 93.87 million tons, respectively. This finding indicates that the metal consumption in industry far exceeds that in all other sectors, and it has a decisive effect on China's metal consumption. In contrast, agriculture has the least impact on metal consumption.

From 1997 to 2015, the metal consumption intensity effect (MCI), consumption expansion effect (CE), capital formation effect (IE), export expansion effect (EE) and Leontief effect (LE) have positive values in all sectors and are the main factors in the increase of metal consumption, but they play different roles in different industries. In agriculture, metal consumption intensity contributed 58.48% of the increase in metal

Table 5
The decoupling states of economic development and metal consumption in sectors.

		1997–2000	2000–2002	2002–2005	20005-2007	2007–2010	2010–2012	2012–2015	1997–2015
Ag-		0.08	0.40	1.67	0.65	0.96	−0.14	−0.03	9.86
		0.04	0.06	0.22	0.11	0.23	0.17	0.16	1.48
		2.02	6.77	7.70	5.96	4.21	−0.83	−0.20	6.68
	States	E-N-D	E-N-D	E-N-D	E-N-D	E-N-D	S-D	S-D	E-N-D
In-		−0.01	0.17	1.49	0.95	0.94	0.10	0.07	11.87
		0.23	0.11	0.42	0.37	0.26	0.10	0.07	2.92
		−0.05	1.54	3.56	2.58	3.67	1.04	0.98	4.07
	States	S-D	E-N-D	E-N-D	E-N-D	E-N-D	E-C	E-C	E-N-D
Con-		0.07	0.53	0.86	1.96	0.71	0.25	−0.05	17.15
		0.19	0.08	0.35	0.28	0.60	0.25	0.23	4.40
		0.36	6.50	2.47	7.04	1.19	1.00	−0.23	3.90
	States	W-D	E-N-D	E-N-D	E-N-D	E-C	E-C	S-D	E-N-D
Se-		−0.01	0.19	1.90	0.72	0.91	−0.04	−0.05	9.26
		0.34	0.71	0.28	0.25	0.42	0.29	0.37	8.25
		−0.02	0.27	6.68	2.88	2.14	−0.14	−0.14	1.12
	States	S-D	W-D	E-N-D	E-N-D	E-N-D	S-D	S-D	E-N-D

Table 6
The structure decomposition of China's metal consumption in sectors from 1997 to 2015.

	The growth of metal consumption (million tons)				Contribution (%)			
	Ag-	In-	Con-	Se-	Ag-	In-	Con-	Se-
MCI	8.36	1124.11	68.11	8.35	58.48	31.07	39.70	8.89
CE	3.28	546.05	2.72	44.18	22.95	15.09	1.59	47.06
IE	1.36	1255.05	98.96	19.53	9.53	34.68	57.68	20.80
EE	0.92	646.64	1.40	10.09	6.43	17.87	0.81	10.75
IS	−0.05	16.54	−0.04	−0.41	−0.32	0.46	−0.02	−0.44
LE	0.42	30.14	0.41	12.15	2.94	0.83	0.24	12.94
Total	14.29	3618.52	171.57	93.87	100	100	100	100

consumption, presenting the greatest contribution. The effects of import and export are not obvious, and their contribution rates are 6.43% and −0.32%, respectively. In industry, the capital formation effect is greater than the metal consumption intensity effect and export expansion effect. In construction, the metal consumption intensity effect and capital formation effect dominate, while the export expansion effect and Leontief effect are very small. For services, the consumption expansion effect and capital formation effect increase metal consumption by 44.18 and 19.53 million tons, respectively. Generally, the metal consumption intensity effect, consumption expansion effect and capital formation effect lead to a relatively larger increase in metal consumption in various industries. In contrast, the Leontief effect and import substitution effect contribute the least to the growth of metal consumption in various sectors. Moreover, the import substitution effect even has a positive effect on the reduction of metal consumption in various sectors except for the industry sector.

As shown in Fig. 3, various effects play different roles in different industries in different periods. In the four sectors, the metal consumption intensity effect gradually decreases, and its coefficient even becomes negative during the 2010–2012 period, which means that the efficiency of the use of metal resources per unit of output in China has been improved in the four sectors and played a positive role in reducing metal consumption. The consumption expansion effect exhibits a fluctuating increasing trend in all four sectors, and it contributes the most to the growth of metal consumption in the industrial sector. In recent years, although China's metal consumption growth has slowed down, the total amount is still increasing (as shown in Fig. 1). Therefore, the effect of consumption expansion on all sectors, especially the industrial sector, is still increasing. Investment also has the largest impact on metal consumption in industrial sector, and the capital formation effect tends to first increase and then decrease in industry and agriculture, while it continues to increase in construction and services. In contrast, the negative effect of imports on agricultural and industrial metal consumption is increasing, while the negative impact on the metal consumption of construction and services first increases and then decreases. In addition, the Leontief effect on the reduction of metal consumption in industrial sector is the most obvious, especially since 2010, while the effect on other sectors is not significant. This finding means that technological progress in industrial sector plays a positive role in improving the efficiency of the use of metal resources.

4.3. Sub-sector analysis in industry

4.3.1. The decoupling analysis of metal consumption and economic growth in sub-sectors of industry

In view of the importance of industry to the growth of metal consumption, this part further analyzes the decoupling state of metal consumption of industry sub-sectors and its influencing factors. Appendix A shows the sector classification of the Chinese input-output table with the corresponding codes: there are 20 industry sub-sectors, from m_2 to m_{21}.

As shown in Table 7, the metal consumption and economic growth in most industrial sectors, except for the mining sector (from m_2 to m_5), have undergone a transition from a strong coupling state to a strong decoupling state. This transition is in line with the trajectory of China's economic development. With the rapid development of China's economy and society, the technical level of light industry and heavy industry has improved. Therefore, the utilization efficiency of metal resources also improved. As a result, the decoupling states of metal consumption and economic growth in most light industries and heavy industries presented strong decoupling during the 2012–2015 period. Notably, the metal consumption in the mining sectors has not been decoupled from economic growth, in which the decoupling states present all strong negative decoupling from 2012 to 2015. This finding means that China's mining sector is relatively backward at the technological level and coupled with serious waste, resulting in low efficiency in the use of metal mining (Chen and Cheng, 2015). In addition, the decoupling state between metal consumption and economic growth in the manufacture of non-metallic mineral products (m_{12}), smelting and processing of metals (m_{13}) and other manufacture industry (m_{20}) between 2012 and 2015 presents negative decoupling. Therefore, more attention should be paid to the input-output efficiency of the metal and non-metal manufacturing sectors. Moreover, the decoupling state of metal consumption and economic growth in the production and supply of electricity, steam and water industry (m_{21}) presents weak decoupling during the 2012–2015 period. The issue of energy efficiency has long been the focus of attention in China and even internationally. At present, although resource use in China's energy industry has made obvious progress in terms of efficiency, there is still much room for

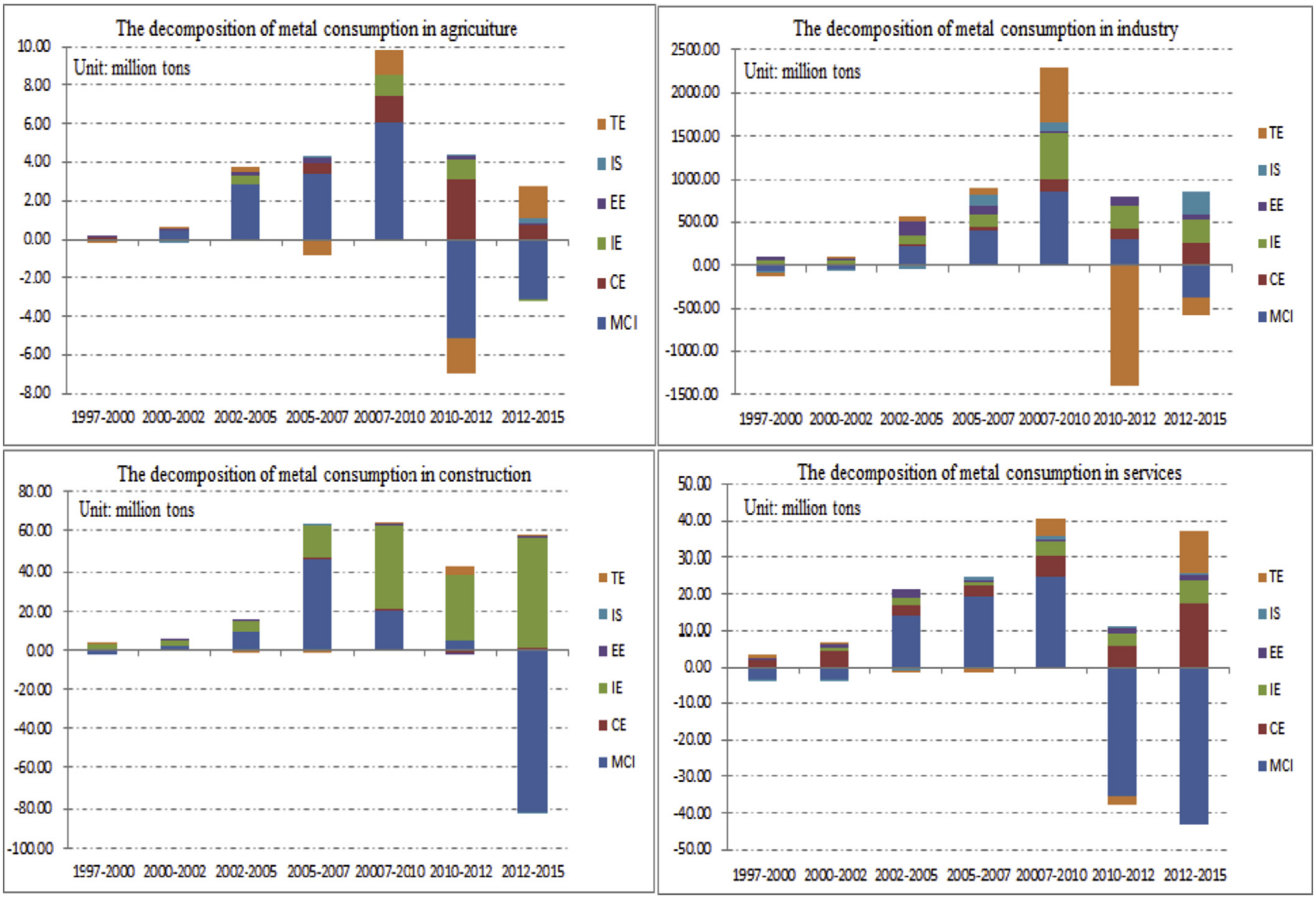

Fig. 3. China's metal consumption drivers in sectors from 1997 to 2015.

improvement.

The decoupling state of metal consumption and economic growth in most industrial sectors presents expansive negative decoupling in stages from 2002 to 2010. Since 2010, the decoupling states in most industrial sectors have shifted to strong decoupling. During the period from 2002 to 2012, China's extensive economic development model not only promoted social progress but also brought about a large amount of metal consumption, thus causing excessive mining and processing of metal resources. Therefore, the metal consumption and economic growth in this period showed a strong negative decoupling state. However, the overexploitation of metal resources was bound to lead to overcapacity. The Chinese government should take measures to reduce excess capacity and curb the overexploitation of metal resources to improve metal use efficiency. With this background, the decoupling

Table 7
The decoupling states of economic development and metal consumption in sub-sectors in industry.

	1997–2000	2000–2002	2002–2005	2005–2007	2007–2010	2010–2012	2012–2015
Mining	R–C	S-D	E-N-D	E-N-D	E-N-D	S-D	S–N-D
	W-D	S–N-D	E-N-D	E-N-D	E-N-D	R–C	S–N-D
	S–N-D	S-D	E-N-D	E-C	E-N-D	E-N-D	S–N-D
	S–N-D	W-D	S–N-D	W-D	E-N-D	W-D	S–N-D
Light industry	S-D	S–N-D	E-N-D	E-N-D	E-N-D	S-D	S-D
	S–N-D	S–N-D	E-N-D	E-N-D	E-N-D	S-D	S-D
	S–N-D	W-D	E-N-D	E-N-D	S–N-D	S-D	S-D
	S–N-D	W-D	S–N-D	E-N-D	E-N-D	E-N-D	W-D
Heavy industry	S-D	S–N-D	E-N-D	E-N-D	E-N-D	S-D	S-D
	S-D	E-N-D	E-N-D	E-N-D	E-N-D	S-D	W-D
	S–N-D	E-N-D	E-N-D	E-N-D	E-N-D	W-D	E-N-D
	S-D	W-D	E-N-D	E-N-D	E-N-D	S–N-D	S–N-D
	S–N-D	W-D	E-N-D	E-N-D	E-C	S–N-D	S-D
	S–N-D	W-D	E-N-D	E-N-D	E-N-D	S-D	S-D
	S-D	E-N-D	E-N-D	E-N-D	E-N-D	E-N-D	S-D
	S-D	S–N-D	E-N-D	E-N-D	E-N-D	E-N-D	W-D
	S-D	S–N-D	E-N-D	E-N-D	E-N-D	W-D	S-D
	S–N-D	W-D	E-N-D	E-N-D	E-N-D	S–N-D	S-D
	S–N-D	E-C	E-N-D	E-N-D	E-N-D	W-D	S–N-D
Energy industry	S-D	E-N-D	E-N-D	E-N-D	E-N-D	W–N-D	W-D

Table 8
The factor decomposition of China's metal consumption in sub-sectors in industry from 1997 to 2015.

	MEI	CE	IE	EE	IS	LE	Total
m_2	35.82	20.37	27.91	10.90	0.38	0.96	96.34
m_3	33.24	17.16	15.37	6.22	−7.66	−6.71	57.62
m_4	65.23	74.84	235.90	116.43	−53.78	95.09	533.71
m_5	60.31	11.21	45.44	9.41	1.71	−29.26	98.82
m_6	6.20	6.45	1.33	0.94	−0.02	2.82	17.72
m_7	13.21	5.29	2.22	4.40	0.93	−0.95	25.1
m_8	13.74	9.27	18.40	11.10	0.78	1.81	55.1
m_9	57.11	30.43	16.06	15.93	2.93	−7.37	115.09
m_{10}	15.43	13.30	12.18	5.37	2.04	1.65	49.97
m_{11}	24.96	14.16	12.33	10.91	3.06	3.95	69.37
m_{12}	56.68	6.66	54.19	9.37	0.38	−14.72	112.56
m_{13}	217.69	90.55	310.33	150.00	30.43	77.17	876.17
m_{14}	130.42	38.22	134.77	58.98	11.76	−22.64	351.51
m_{15}	72.78	21.26	92.41	39.20	11.98	−11.46	226.17
m_{16}	27.01	47.99	76.98	20.16	0.73	4.58	177.45
m_{17}	96.80	45.32	87.44	69.25	4.88	−1.41	302.28
m_{18}	21.10	13.27	13.72	50.71	1.52	8.63	108.95
m_{19}	48.74	20.75	30.50	24.80	7.29	−1.61	130.47
m_{20}	116.84	42.36	51.22	25.22	−3.51	−82.12	150.01
m_{21}	10.79	17.20	16.34	7.34	0.72	11.74	64.13

state of metal consumption and economic growth gradually turns to strong decoupling, which indicates a very obvious positive effect of the Chinese government's policy to address overcapacity.

4.3.2. *Factors affecting metal consumption in sub-sectors of industry*

In view of the high importance of growth in metal consumption in industry, further decomposition is necessary. This section decomposes various factors of changes in the metal consumption of industry sub-sectors from 1997 to 2015. As shown in Table 8, the effect of metal consumption intensity on the increase of metal consumption in 20 industrial sectors is very significant. Among them, the metal consumption intensity effect has the greatest impact on the increase of metal consumption in sectors of m_{13}, m_{14} and m_{20}, whose values are 217.69, 130.42 and 116.84 million tons, respectively. This finding indicates that the production efficiency of the three sectors urgently needs improvement. Furthermore, the sectors of smelting and processing of metals (m_{13}) and manufacture of metal products (m_{14}) are in the middle and upper reaches of the industrial chain, and downstream production requires many these industrial products as raw materials. Due to the large demand gap and the relatively backward production technology, the effect of metal consumption intensity is obvious.

The consumption expansion effect has an obvious impact on the increase of metal consumption in sectors of m_4 and m_{13}, which have values of 74.84 and 90.55 million tons, respectively. This is consistent with the great demand for metals in China's economic development over the past two decades, and it is necessary to adjust the demand structure and improve the efficiency of metal use. Meanwhile, stimulated by the great demand for metal consumption, investment in metals has boomed. As shown in Table 8, the capital formation effect leads to increases of 235.90, 310.33 and 134.77 million tons of metal consumption in the sectors of m_4, m_{13} and m_{14}, respectively. China's investment in the mineral resources mining industry is very large. However, the decentralized investment mode of small and medium-sized enterprises has brought about many resource waste and consumption problems. The export expansion effect also has a certain impact on the increase of metal consumption in 20 industrial sectors and has a relatively large impact on the sectors of m_4 and m_{13}. China's technological level of metal mining and processing lags behind that of developed countries, and most of its export products are primary metal products. Thus, exports play a significant role in increasing the consumption of metal mining and metal processing industries.

In addition, it is worth mentioning that neither the import substitution effect nor the Leontief effect significantly influenced the increase in metal consumption in sub-sectors of industry. In contrast, they even reduced metal consumption in some sectors. The import substitution effect reduced metal consumption by 53.78 million tons in the sector of m_4, which means that the import of metal resources will reduce the amount of domestic mining of metal resources. Meanwhile, the Leontief effect increased metal consumption by 95.09 million tons in the sector of m_4 and reduced metal consumption by 82.12 million tons

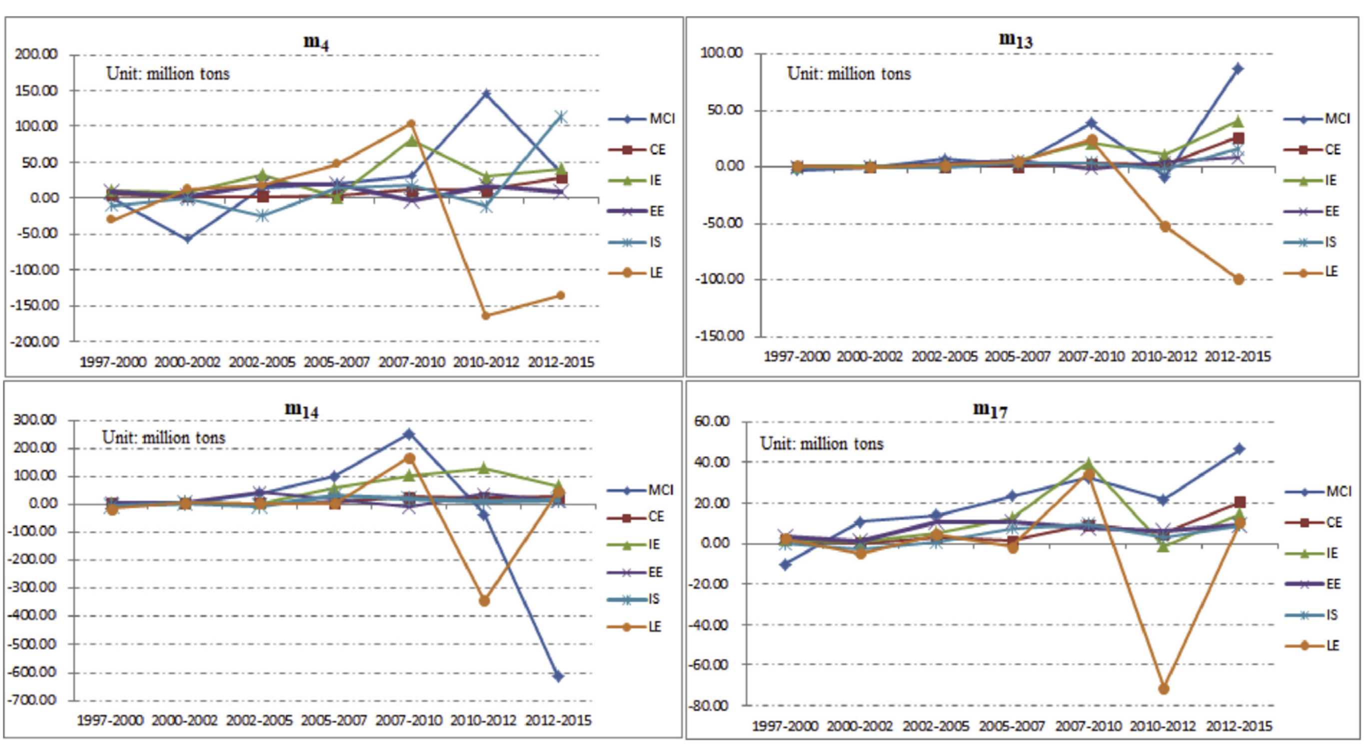

Fig. 4. Factor decomposition of metal consumption in the top four sub-sectors in different stages.

in the sector of m_{20}. This finding indicates that China's technological advances in metal mining have been modest, and technological advancement should receive more attention. However, the level of recycling and utilization in the metal industry has improved significantly.

In different stages, different factors have different effects on the metal consumption of sectors. We selected the four sectors with the largest increase in metal consumption between 1997 and 2015 and decomposed the influencing factors in different periods. The results are shown in Fig. 4. The metal consumption intensity effect leads to a significant increase of metal consumption in the sectors of m_4, m_{13} and m_{17}, while it reduces the metal consumption in the sector of m_{14}. The consumption expansion effect has a significant effect on the increase of metal consumption in these four sectors. Likewise, the capital formation effect has an obvious impact on the increase of metal consumption in these four sectors, but the increase of metal consumption in the m_4 sector is relatively small. Moreover, the export expansion effect and import substitution effect do not significantly reduce metal consumption. However, the Leontief effect has an increasingly significant effect on metal consumption reduction in the sectors of m_4 and m_{13}, but its effect on metal consumption in the sectors of m_{15} and m_{17} has been decreasing since 2012. Thus, there is more room for efficiency improvement in the metal mining and processing links.

5. Conclusions and policy implications

This article explored the decoupling relationship between metal consumption and economic growth and adopted structural decomposition analysis (SDA) to identify the driving factors of China's metal consumption, enriching and expanding the theory of metal resource demand. At the same time, to explore the characteristics and trends of metal consumption in different stages of industrialization and urbanization, this article also analyzes the contribution of driving factors to metal consumption, determines the key factors affecting metal consumption, and further deepens the study of the differences in metal consumption across sectors and the reasons for these differences.

From 1997 to 2015, China's total metal consumption increased by 3889.35 million tons, economic development and metal consumption presented expansive negative decoupling (E-N-D) from 1997 to 2015. In the long run, the relationship between economic growth and metal consumption followed an inverted "U" shape, and China is still on the left side of the curve. Thus, China's high-speed economic growth comes at the expense of high-intensity metal consumption, especially in industry. From the SDA results, the change in capital formation was the main factor of metal consumption; it increased metal consumption by 1374.89 million tons and accounted for 35.27% of the contribution, followed by metal consumption intensity, export, consumption expansion, Leontief effect and import substitution effect. Because the Leontief effect decreased metal consumption by 1426.17 million tons from 2010 to 2012 and continued to reduce metal consumption by 280.45 tons from 2012 to 2015, the effect of metal consumption intensity reduced metal consumption by 355.78 million tons from 2012 to 2015; thus, the effect of metal consumption intensity and Leontief are potential drivers of improving the efficiency of metal use and reducing metal consumption. In addition, various decomposition factors have different influences on different sectors. For example, the metal consumption intensity is the main driver of increasing metal consumption in agriculture and construction, whereas in industry and services, the capital formation and consumption expansion are the main drivers, respectively; from the sub-sector analysis in industry, the metal consumption intensity effect leads to a significant increase of metal consumption in the sectors of m_4, m_{13} and m_{17}, while it reduces the metal consumption in the sector of m_{14}; the import substitution effect and Leontief effect revealed substantial heterogeneity across different sectors.

Based on the above conclusions, related policy recommendations are also discussed. First, consumption, investment and export, served as three driving forces of China's economic growth (Zhu and Kotz, 2011), led to a sharp increase in China's metal consumption. The Chinese government needs to adjust investment orientation, optimize export structure and boost domestic demand to successful transition to a pattern of growth driven more by domestic consumption demand (Lardy, 2016). Second, the fundamental way to reduce the metal consumption intensity and improve the efficiency of metal use is continuous improvement at the technical level. On the one hand, optimizing the input structure of intermediate products and guiding the production department to improve metal use efficiency and input-output efficiency. On the other hand, increasing technical investment to encourage technological innovation and cooperate with developed countries that possess advanced technologies (He et al., 2013). Furthermore, a weak decoupling state is China's short-term expected goal. China should accelerate the transformation of economic growth mode and realize the driving of factor-driven innovation (Xiaolua et al., 2009; Lardy, 2016). For example, the steel industry should eliminate backward production capacity, actively promote the reorganization of advantageous production capacity and advantageous enterprises, improve the competitiveness of the industry, and reduce the total metal consumption of the entire economy from the base (Song et al., 2018). At the same time, the transformation of the economic growth mode by means of technological innovation and management innovation can promote the effective use of metal resources and the decoupling of metal resource consumption and economic development to achieve sustainable economic development (Zheng et al., 2018).

Our research can be further improved. First, this article has a limitation that aggregated metals into a single indicator of metal ores used. However, the unit values of different types of metals are significantly different, and there are obvious structural contradictions in metals in China. The consumption of rare metals, such as lithium, gallium, germanium, indium, bismuth, etc., should receive increasing attention. Second, this article does not consider the effects of metal prices and metal futures on metal consumption. However, the fluctuation of the price of nonferrous metals has an important influence on the industrial production of manufacturers (Gong and Lin, 2018a). The application of HAR-type volatility models with structural breaks to forecast the volatility of metal prices and metal futures and to determine its impact on metal consumption will also attract considerable attention from academia, government and investors (Wen et al., 2016; Gong and Lin, 2017, 2018b).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resourpol.2019.101421.

Appendix A. Sector classification of the Chinese input-output table with the corresponding codes

Code	Sectors	Code	Sectors
m_1	Agriculture	m_{13}	Smelting and processing of metals
m_2	Mining and washing of coal	m_{14}	Manufacture of metal products
m_3	Extraction of petroleum and nature gas	m_{15}	Manufacture of general and special purpose machinery
m_4	Mining of metal ores	m_{16}	Manufacture of transport equipment
m_5	Mining of non-metallic mineral	m_{17}	Manufacture of electrical machinery and apparatus
m_6	Manufacture of foods and tobacco	m_{18}	Manufacture of communication equipment, computers and other electronic equipment
m_7	Manufacture of textile, leather, fur, feather and its products	m_{19}	Manufacture of measuring instruments and machinery for cultural activity and office work
m_8	Processing of timbers and furniture	m_{20}	Other manufacture (including scrap and waste)
m_9	Manufacture of paper, printing and articles for culture, education and sport activity	m_{21}	Production and supply of electricity, steam and water
m_{10}	Manufacture of refined petroleum, coke products, processing of nuclear fuel	m_{22}	Construction
m_{11}	Manufacture of chemicals and chemical products	m_{23}	Services
m_{12}	Manufacture of non-metallic mineral products		

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