An optimal TEC model with input-Output analysis and its application for reducing CO2 emission in China

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Abstract. In managing regional environmental-economic systems, it is significant to design a comprehensive total emission control (TEC) policy. In this paper, an optimal TEC model with an input-output analysis is established to maximize the total production profit of all the economic sectors. With an empirical application of the model on reducing total CO2 emission in China, a TEC policy scheme is approximately calculated by using the national input-output table to give optimal solutions respectively for total production, final use and the corresponding CO2 emission of each sector. Finally, the key sectors most responsible for total emission reduction are identified, and then the impacts of improving emission intensity coefficient of the sector with the highest emission share are analysed quantitatively on the allocations of total CO2 emissions set as the TEC target by policy maker.

1. Introduction
The global warming has recently been becoming a serious problem with great concerns in the world. It is actually a big challenge for human survival and development. Climate change is mainly resulted from combustion of fossil fuel and other human living activities, which make a great increase in emission of greenhouse gases (GHG), such as CO2, specifically. In the past decades China has experienced energy and environmental problems. In 2010 China became the world’s largest energy consumer and then has the largest CO2 emission in the world. According to the statistics released at the 2015 Paris Conference on Climate Change, China’s greenhouse gas emissions account for about 20% of world emissions [1]. With the background, early in 2009, Chinese government made the CO2 emission intensity reduction commitment that during the period of years 2005-2020, the emission intensity per GDP in China must be decreased by 40-45% of the value based on year 2005. Later on November 12, 2014, China and the United States jointly issued the "Joint Statement on Climate Change between China and the United States", in which the Chinese government proposed that the CO2 emissions should be at peak around 2030 and China would make every effort to reach the peak as soon as possible [2]. Also, this target of controlling CO2 emission is promised by China at the Paris Climate Conference in 2015. In order to achieve this target, China has stepped up to build a nationwide carbon trading market which is expected to start in 2017 [3]. Since the time of reaching the emission peak has been determined, the key topic is becoming on how to make it realized actually. For solving such a global environmental problem, adequate environmental-economic policies are required at the regional, national and international levels. As such a policy approach, the total emission control (TEC) has been becoming a remarkable option recently because it is generally an effective means in both making a full use of the natural absorption capability and protecting the environmental quality in the region as well. In fact, in order to reach the environmental target either for the emission intensity reduction or for the emission peak control on total CO2 emission in China, it is essentially important to control the total...
emission among all industries [4]. In other word, it’s actually a problem of how to design and then enforce an effective policy of total emission control [5].

Also as a significantly useful tool, input output analysis is widely used for policy maker to analyse policy schemes in a multi-regional systems [6,7,8] or multi-sectoral systems [9,10]. Applying input-output techniques allows us to trace the direct and indirect CO₂ emissions related with energy consumption in production processes [11,12,13]. The most applications are usually focused on investigating methodological instruments for identifying the economic factors responsible for the increase of environmental emissions [14,15,16,17,18].

The aim of this paper is to develop methodologically an optimal TEC model with an input-output analysis in a multi-sectoral system to maximize the whole production profit among all the sectors and then discuss quantitatively an empirical application for reducing total CO₂ emission in China. Specifically, by using the China’s national input-output table, we first apply the model to calculate an optimal TEC policy scheme, respectively for total production, final use and the corresponding CO₂ emission by each sector. Based on the results, we also identify the key sectors most responsible for total emission reduction and finally quantitatively analyse impacts of improving emission intensity coefficient of the sector with the highest emission share on the allocations of total CO₂ emission set as the TEC target by policy maker.

2. The optimal TEC model based on an input-output analysis

2.1 The basic representation of the input-output model

We assume that there are n sectors in a given regional environmental-economic system and each sector i produces product i (goods and services) as total output (production) Pᵢ (in monetary units) to meet the final use (demand) Fᵢ, and thus generates the environmental emission Xᵢ. Then we can get the basic input-output equation below.

\[ P_i = \sum_{j=1}^{n} a_{ij} P_j + F_i \]  \hspace{1cm} (2.1)

where \( a_{ij} \) represents the direct input coefficients (technical coefficients), i.e., requirement on sector i per unit output of sector j.

Actually by using in matrix notation, the above expression (2.1) can be described as follows.

\[ (I - A) P = F \quad \text{or} \quad P = (I - A)^{-1} F = L F \]  \hspace{1cm} (2.2)

where \( P = [P_1, P_2, \ldots, P_n]^T \) stands for the column vector of total output (total production), with element \( P_i \) representing the total output of sector i; \( F = [F_1, F_2, \ldots, F_n]^T \) stands for the column vector of final use (final demand), with element \( F_i \) representing the final use of sector i; \( A = \{a_{ij}\} \) stands for the \( n \times n \) matrix of input-output coefficients, in which an element \( a_{ij} \) denotes the direct input coefficients, i.e., requirement on sector i per unit output of sector j; \( I \) stands for the identity matrix; and \( L = (I - A)^{-1} \) is the \( n \times n \) matrix of input-output multipliers or Leontief inverse matrix [20], determined by the structure of intermediate input and its elements represent the total amount of sector i’s output required both directly and indirectly to produce one unit for final use of sector j [21].

Let’s define \( \beta_i \) as the environmental emission intensity coefficient of sector i (i.e., the amount of the environmental emission generated from the per unit output of sector i). Then \( X_i \) can be calculated by \( P_i \) as follows:

\[ X_i = \beta_i P_i \quad \text{or} \quad P_i = \beta_i^{-1} X_i \]  \hspace{1cm} (2.3)

Also we can describe the expression (2.3) in matrix notation as follows:

\[ X = \beta P \quad \text{or} \quad P = \beta^{-1} X \]  \hspace{1cm} (2.4)

where \( X = [X_1, X_2, \ldots, X_n]^T \) be the column vector of total environmental emissions, and its elements \( X_i \) denote the total amount of the environmental emission driven both directly and indirectly by the final use of product in sector i; and \( \beta \) is the \( n \times n \) diagonal matrix of environmental emission coefficients, with an element \( \beta_i \) on its main diagonal and zeros elsewhere.

Now, from the expressions (2.2) and (2.4) we can describe the basic input-output model in matrix notation as follows.
2.2. The model without total emission control.

In this case, each sector can make decision independently on the production scale taking no account on the environmental emission. Therefore sector i will try to get the maximum profit as possible. i.e.

\[
\text{Max. } P_i(X_i), \quad i=1, 2, ..., n
\]

\[
\text{s.t. } F_{\text{Min}} \leq (I - A)^{-1} X \leq F_{\text{Max}}
\]

where, \( P_i(X_i) = P_i \) is the total production of Sector i; and \( F_{\text{Min}} \) and \( F_{\text{Max}} \) denote the initial values set for the final use vector \( F \).

Let \( X_i^0 \) be the optimal solution for the above model (2.6), then sector i’s maximum profit is \( P_i(X_i^0) \) and the total emission of all sectors is \( x^0 = \sum X_i^0 \). Generally, it can be supposed that \( x^0 \) is higher than the maximum of total emission allowed by the policy maker. Therefore, \( x^0 \) should be reduced to some extent to meet the target of total emission control.

2.3. The model with total emission control.

For the case of total emission control, we can describe the optimal model in the following form.

\[
\text{Max. } SB(X) = \sum_{i=1}^{n} P_i(X_i)
\]

\[
\text{s.t. } F_{\text{Min}} \leq (I - A)^{-1} X \leq F_{\text{Max}}; \quad \sum_{i=1}^{n} X_i \equiv x^{Total}.
\]

where, \( SB(X) \) means the total profit of all the sectors which is dependent of the environmental emission \( X \); and \( x^{Total} \) denotes the allowed maximum value of total emission decided by the policy maker.

Let \( X_i^* \) be the optimal solution for the above model (2.7), then sector i’s profit is \( P_i(X_i^*) \) and the total emission of all the sectors is \( x^* = \sum X_i^* \equiv x^{Total} \). In the case with the optimal model the policy maker can make decision over all the sectors to reach the target of total emission control as well as obtain an optimal solution for allocating the allowed total emission among all the sectors to maximize the total production profit of all the sectors [19].

3. Empirical application for CO2 emission control in China

3.1. The data preparation

3.1.1. The data of input-output table. The application study is based on the data of China’s input-output table in 2012. From the public website of National Bureau of Statistics of China, we can get the data of intermediate use, final use, total output (total production), and the direct input coefficients for input output table in 2012 [22]. It is noted that since the statistics only keep stable structure within five years, direct input coefficients will be modified in every five years. Due to the lack of similar input-output tables for years of 2013-2017, as is often done in input-output analyses, we could assume that direct input coefficients and Leontief inverse coefficients for the years of 2013-2017 are identical to the baseline year of 2012. The input-output tables encompass 17 sectors shown in Table 1.

3.1.2 The CO2 emission coefficients. We found the corresponding data for the CO2 emission coefficients shown in [24]. Since the latest data is only for years before 2007, here we can reasonably assume that the emission intensity of each sector has been improved with 5% progressive rate per year due to technological innovation during the ten years of 2007-2017. With this assumption, based on data of year 2007 [24], we calculated the CO2 emission coefficients for years of 2013 to 2017 as the empirical data. In addition, because of a lack on data for the two sectors (Sector No.15 and Sector No.16), we set the two sectors’ emission coefficients as same as that of the sector of Other Services (Sector No.17). See Table 1.
3.1.3. The target of total CO$_2$ emission control. Setting a suitable emission control target is significant in implementing the TEC policy. Here according to the policy simulation results reported in [3] (The State Information Center of China 2018) and the total emission targets suggested by Chinese Academy for Environmental Planning [5], it might be reasonable to set the allowed maximum value for the total CO$_2$ emission per year at the level of $x^{total} = 10,000$ million tons as the TEC target in this empirical application study.

3.2. Results and policy analyses
In simulating computation, $F_i^{\text{Min}}$ is set by the data of year 2012 and $F_i^{\text{Max}}$ is calculated with a growth rate per year as same as that of GDP during years 2013-2017 based on the public data from the National Bureau of Statistics of China [23].

3.2.1. The case without TEC policy. Table 2 shows the data for the case without total emission control. Here, $X_i^o$ is the amount of CO$_2$ emission that sector i should be responsible for. $P_i^o$ and $F_i^o$ are the total production and final use of sector i, respectively. It is observed that in this situation, each sector could try to reach its maximum $F_i^0$ so as to get the maximum production profit $P_i^0$ by itself, and as the result, each sector gets the maximum profit in total production independently, and the sum of all the sector’s production profits is 271,109 billion CNY (B.CNY). On the other hand, the total emission of CO$_2$ reaches 13,016 million tons (Mt), which is much more than 10,000 million tons, the maximum value of the allowed total emission of all the sectors. Thus, some kind of TEC policy strategy should be enforced for reducing CO$_2$ emission totally by about 3,016 million tons.

3.2.2. The case with TEC policy. Also in Table 2, the results can be seen for the case with a TEC policy. In the case, the CO$_2$ total emission is controlled exactly at the level of 10,000 million tons to meet the set TEC target and the total production profit of all the sectors arrives at the maximum value of 217,870 billion CNY as well. In the table, $P_i^*$ and $F_i^*$ are the total production and final use of each sector. Compared with the situation without TEC policy, the sum of the total production profit and the sum of the final use of all the sectors are decreased roughly by 53,239 billion CNY and 16,267 billion CNY, respectively. Meanwhile $X_i^*$ indicates the optimal allocation of CO$_2$ emission to each sector from the maximum total emission among all the sectors and in the case with the TEC target, about 3,016 million tons of CO$_2$ emission is reduced totally. In the table $\Delta X_i$ is the amount for each sector to be responsible for reducing and $\eta_i$ is the percentage for each sector’s share on the total CO$_2$ emission reduction.

Figure 1 demonstrates visually the optimal scheme of TEC policy for each sector. It is obvious that particularly there are three key sectors, i.e., No.6, No.7 and No.10 with the much higher emission intensity, which should firstly take the greatest responsibility to control the CO$_2$ emissions. Specifically the detailed data can be checked from Table 2. The sector No.6 (Production and Supply of Electric Power, Heat Power and Water) with the highest emission intensity is supposed to cut the CO$_2$ emission from 3,693 million tons to 2,845 million tons; The sector No.7 (Coking, Gas and Processing of Petroleum) is required to decrease its emission from 2,597 million tons to 2,010 million tons; And finally the sector No.10 (Manufacture and Processing of Metals and Metal Products) is also needed to

| Sector | Xi | P/ F | Total Emission |
|--------|----|-----|----------------|
| Agriculture, Forestry, Animal Husbandry and Fishery | 1 | 0.0142 | 13,016 |
| Mining | 2 | 0.0783 | |
| Manufacture of Foods, Beverage and Tobacco | 3 | 0.0083 | |
| Manufacture of Textile, Wearing Apparel and Leather Products | 4 | 0.0074 | |
| Other Manufacture | 5 | 0.0133 | |
| Production and Supply of Electric Power, Heat Power and Water | 6 | 0.4402 | |
| Coking, Gas and Processing of Petroleum | 7 | 0.3506 | |
| Chemical Industry | 8 | 0.0428 | |
| Manufacture of Non-metallic Mineral Products | 9 | 0.0895 | |
| Manufacture and Processing of Metals and Metal Products | 10 | 0.0896 | |
| Manufacture of Machinery and Equipment | 11 | 0.0030 | |
| Construction | 12 | 0.0028 | |
| Transport, Storage, Post, Information Transmission, Computer Services and Software | 13 | 0.0500 | |
| Wholesale and Retail Trades, Hotels and Catering Services | 14 | 0.0066 | |
| Real Estate, Leasing and Business Services | 15 | 0.0039 | |
| Financial Intermediation | 16 | 0.0039 | |
| Other Services | 17 | 0.0039 | |
reduce its emission from 2,375 million tons to 1,743 million tons. The amounts of emission reductions by the three sectors are respectively 28.13%, 19.46% and 20.98% of the total emission decreased by the TEC policy. The details about other sectors’ emission reduction shares are shown in Table 2.

Table 2. Results for the case without and with TEC policy \( (X^{\text{Total}} = 10,000 \text{ Mt CO}_2) \)

| Sector | The case without TEC policy | The case with TEC policy | CO2 Emission Reduction Share (%) |
|--------|-----------------------------|-------------------------|----------------------------------|
|        | Total Production (B.CNY)    | Final Use (B.CNY)        | CO2 Emission (Mt) X_i           | Total Production (B.CNY)    | Final Use (B.CNY)        | CO2 Emission Delta (Mt) \( \Delta X_i \) |
|        | P_i                         | F_i                     | X_i                           | \( P_i^* \)                  | \( F_i^* \)                  | \( X_i^* \)                  | \( \Delta P_i \)                  | \( \Delta F_i \)                  | \( \Delta X_i \)                  | \( \eta_i \)                  |
| 1      | 14,385                      | 4,043                   | 204                           | 12,169                       | 2,933                       | 173                           | 2,216                           | 1,110                       | 31                           | 1.04                           |
| 2      | 14,166                      | 176                     | 1,109                          | 10,712                       | 125                         | 839                           | 3,454                           | 51                          | 270                          | 8.97                           |
| 3      | 13,228                      | 5,956                   | 109                           | 12,485                       | 5,956                       | 103                           | 474                             | 6                           | 0                            | 0.20                           |
| 4      | 10,220                      | 3,861                   | 75                             | 9,625                        | 3,861                       | 71                             | 959                             | 0                           | 4                            | 0.15                           |
| 5      | 9,452                       | 2,202                   | 125                            | 7,286                        | 1,561                       | 97                             | 2,166                           | 641                         | 29                           | 0.95                           |
| 6      | 8,391                       | 518                     | 3,693                          | 6,464                        | 367                         | 2,845                          | 1,927                           | 151                         | 848                          | 28.13                          |
| 7      | 7,407                       | 758                     | 2,597                          | 5,733                        | 537                         | 2,010                          | 1,674                           | 220                         | 587                          | 19.46                          |
| 8      | 22,642                      | 2,267                   | 968                            | 17,901                       | 1,608                       | 765                            | 4,741                           | 660                         | 203                          | 6.72                           |
| 9      | 6,653                       | 439                     | 595                            | 4,801                        | 311                         | 429                            | 1,852                           | 128                         | 166                          | 5.49                           |
| 10     | 26,511                      | 1,742                   | 2,375                          | 19,452                       | 1,235                       | 1,743                          | 7,059                           | 507                         | 633                          | 20.98                          |
| 11     | 48,539                      | 21,312                  | 143                            | 35,644                       | 15,111                      | 105                            | 12,895                          | 6,201                       | 38                           | 1.26                           |
| 12     | 19,428                      | 18,291                  | 53                             | 13,870                       | 12,969                      | 38                             | 5,557                           | 5,322                       | 15                           | 0.51                           |
| 13     | 14,252                      | 4,383                   | 713                            | 11,025                       | 3,108                       | 551                            | 3,227                           | 1,275                       | 161                          | 5.35                           |
| 14     | 14,652                      | 5,941                   | 96                             | 13,142                       | 5,941                       | 86                             | 1,510                           | 0                           | 10                           | 0.33                           |
| 15     | 12,314                      | 5,139                   | 47                             | 11,206                       | 5,139                       | 43                             | 1,108                           | 0                           | 4                            | 0.14                           |
| 16     | 9,665                       | 1,543                   | 37                             | 8,108                        | 1,543                       | 31                             | 1,557                           | 0                           | 6                            | 0.20                           |
| 17     | 19,203                      | 14,060                  | 74                             | 18,246                       | 14,060                      | 70                             | 957                             | 0                           | 4                            | 0.12                           |

Sum    | 271,109                     | 92,631                  | 13,016                         | 217,870                      | 76,364                      | 10,000                         | 53,239                          | 16,267                      | 3,016                        | 100.00                         |

Figure 1 The results of the case with TEC target of 10,000 Mt CO2

3.2.3. Impacts of changes in emission intensity coefficients. From data of the CO2 emission reduction share in Table 2, it can be seen that the sector No.6 (Production and Supply of Electric Power, Heat Power and Water) has the highest share of CO2 emission on the total emission among the 17 sectors and is supposed to be most responsible for reducing the total CO2 emission under the TEC policy. Therefore here we choose the sector No.6 as an example in simulations to demonstrate the impacts of changes in emission intensity of the sector on the allocations of the total emission allowed by TEC target among all the sectors. It might be assumed that the CO2 emission intensity in the sector would have been declined or improved by 20%, 40%, 60% and 80% respectively. The results calculated by the
optimal model (2.5) with the same TEC target of 10,000 million tons are shown in Table 3. In the table $\Delta P_i = P_i^b - P_i^*, \Delta F_i = F_i^b - F_i^*, \Delta X_i = X_i^b - X_i^*$, where $P_i^b$, $F_i^b$ and $X_i^b$ are the results simulated with the improved emission intensity $\beta_i$ of sector No.6, and $P_i^*$, $F_i^*$ and $X_i^*$ are the results with the initial emission intensity of the sector (see Table 2). Table 3 represents, respectively, the changes on total production, final use and CO$_2$ emission allocation of each sector which resulted from changes in emission intensity coefficients of the sector No.6.

**Table 3. Impact of changes in emission intensity $\beta_i$ of Sector No.6 (Electric, heat power and Water)**

| Sector | 20% reduction in emission intensity | 40% reduction in emission intensity | 60% reduction in emission intensity | 80% reduction in emission intensity |
|--------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|
|        | $\Delta P_i$ | $\Delta F_i$ | $\Delta X_i$ | $\Delta P_i$ | $\Delta F_i$ | $\Delta X_i$ | $\Delta P_i$ | $\Delta F_i$ | $\Delta X_i$ |
| 1      | 1,619         | 1,110         | 25           | 1,803         | 1,110         | 28           | 2,008         | 1,110         | 31           |
| 2      | 634           | 53            | 14           | 1,409         | 114           | 23           | 2,346         | 187           | 3,350        |
| 3      | 345           | 4             | 5            | 477           | 5             | 594          | 0             | 6             | 739          |
| 4      | 213           | 2             | 3            | 401           | 0             | 507          | 0             | 4             | 594          |
| 5      | 1,147         | 641           | 16           | 1,484         | 641           | 21           | 1,916         | 641           | 26           | 2,162        | 641           | 30           |
| 6      | 391           | -499          |             | 825           | -988          |             | 1,294         | -1,547        |             | 1,911        | 151           | -2,175       |
| 7      | 282           | 120           |             | 582           | 225           |             | 943           | 351           |             | 1,537        | 102           | 560          |
| 8      | 1,150         | 63            |             | 2,217         | 108           |             | 3,092         | 146           |             | 4,724        | 660           | 216          |
| 9      | 109           | 11            |             | 383           | 35            |             | 1,465         | 132           |             | 1,849        | 128           | 167          |
| 10     | 1,558         | 149           |             | 3,695         | 340           |             | 5,586         | 510           |             | 7,044        | 507           | 640          |
| 11     | 4,831         | 2,646         |             | 11,253        | 6,201         | 34           | 12,121        | 6,201         | 36           | 12,875       | 6,201         | 39           |
| 12     | 13            | 0             |             | 605           | 560           | 2            | 4,901         | 4,712         | 14           | 5,557        | 5,322         | 15           |
| 13     | 426           | 28            |             | 915           | 52            |             | 1,415         | 77            |             | 3,217        | 1,275         | 167          |
| 14     | 432           | 4             |             | 895           | 0             | 7            | 1,225         | 0             | 9            | 1,503        | 0             | 11           |
| 15     | 261           | 0             |             | 561           | 3             | 835          | 0             | 4             | 1,100        | 0             | 5            |
| 16     | 349           | 2             |             | 753           | 0             | 3             | 1,166         | 0             | 5            | 1,548        | 0             | 6            |
| 17     | 214           | 7             |             | 474           | 8             | 781          | 0             | 9             | 953          | 0             | 9            |
| sum    | 13,975        | 4,397         | 0            | 28,733        | 8,512         | 0            | 42,195        | 12,664        | 0            | 52,874       | 16,148        | 0            |

$\Delta P_i$ and $\Delta F_i$: billion CNY; $\Delta X_i$: million ton

As shown in Table 3, for the sector No.6 (Production and Supply of Electric Power, Heat Power and Water), there is a huge CO$_2$ emission reduction potential, and it is basically necessary to improve the abatement technology in the sector so as to decline the CO$_2$ emission per unit of production. For instance, when the emission intensity is improved by 20% in the sector, the amount of its own emission will decrease by 499 million tons, which meanwhile will have a strong influence and result in changes on the amounts of emissions of all the other sectors. As a result, even if keeping the same TEC target at the level of 10,000 million tons, the production profit and the final use in total of all the sectors will increase by 13,975 billion CNY, and 4,397 billion CNY, respectively. For the other three situations with the emission intensity improvement by 40%, 60% or 80%, there are the similar effects on all the sectors’ emission allocations of the total emission. The more the improvement is made, the stronger the effect is.

4. Conclusions and policy implications

Generally speaking, the environmental problems are mainly caused by the process of production and consumption. Environmental management is an important part of economic operations in the present society. In some meaning, either for the environmental emission intensity reduction or for the emission peak control of CO$_2$ emissions in China, it is actually significant to design and then enforce an effective policy of total emission control, which should be considered to be a comprehensive solution for solving the conflict between environment and economy [25]. In this paper, we establish methodologically a model to maximize the total production profit among all sectors and satisfy the environmental emission control target as well for a multi-sectoral environmental-economic system. The optimal TEC model is based on an input-output analysis and allows us to allocate the total emissions (quotas) to each sector as optimal TEC policy schemes while the economy is growing up. Furtherly it can be used to analyse the impacts of changes in one sector’s emission intensity coefficient on all the sectors’ emissions and identify the key sectors most responsible for reducing total environmental emission. The model mainly proposes a methodology which could be an innovation on how to design quantitatively a suitable TEC policy for a multi-

(\(\Delta P_i\) and \(\Delta F_i\): billion CNY; \(\Delta X_i\): million ton)
sectoral environmental system by pursuing an optimal balance between environmental protection and economic development.

As an application of the model, we discussed quantitatively on policy design for reducing total CO₂ emission in China. Based on the national data of Input-Output Table of China in 2012, and with a total CO₂ emission control target being set at the level of 10,000 million tons per year, we simulated the CO₂ emissions in 17 sectors and also calculated approximately the respective optimal solutions for total production and final use (demand) of each sector. The result shows, firstly, that in the existing situation without total emission control, each sector could reach its maximum production scale and get its own maximum profit independently. On the other hand, each sector’s CO₂ emission could increase as the production is growing up. As a result, the total emission of all the sectors could rise up to 13,015 million tons, which is much more than the set target value of 10,000 million tons. Thus, some TEC policy scheme for cutting total CO₂ emission by about 3,015 million tons should be enforced as each sector’s economical scale has been increasing with a growth rate per year along with the GDP in China.

In order to achieve the reduction target, we calculated an optimal set of allocations of the total emission to each sector as a possible TEC scheme for policy suggestion. The result indicates that totally in the scheme, the total emission reduction target is reached exactly at the allowed maximum value of 10,000 million tons, and also, the sum of all sectors’ production profit is maximized up to the value of 217,870 billion CNY, which is 53,239 billion CNY less than that in the case without TEC policy. This implies that some sectors make a contribution, to a certain extent, to the decrement in CO₂ total emission at a cost of decreasing their own profits. In addition, particularly, there are three key sectors with the much higher emission intensity, which should take the greatest responsibility to control the CO₂ emission at first. The sector No.6 (Production and Supply of Electric Power, Heat Power and Water) with the highest emission intensity is supposed to cut its CO₂ emission from 3,690 million tons to 2,850 million tons; The sector No.7 (Coking, Gas and Processing of Petroleum) is required to decrease its emission from 2,850 million tons to 2,010 million tons; And finally the sector No.10 (Manufacture and Processing of Metals and Metal Products) is also needed to reduce its emission from 2,380 million tons to 1,740 million tons. The shares of emission reductions by the three sectors are respectively 28.13%, 19.46% and 20.98% of the total emission reduction resulted from the TEC policy.

Furtherly in the application, we also analysed the impacts of improving the emission intensity of some sector on all other sectors’ emissions. As an example, we selected the sector No.6 (Production and Supply of Electric Power, Heat Power and Water), which has the highest share in total CO₂ emission reduction among the 17 sectors, and calculated the corresponding TEC schemes when the emission intensity of the sector is declined or improved by 20%, 40%, 60% or 80%. The result data show obviously that when the emission intensity is improved by 20% in the sector, for instance, the amount of its emission will decrease by 499 million tons and then will have a strong influence and result in changes on the amounts of emissions of all the other sectors. As a result, even if keeping the same TEC target of 10,000 million tons, the production profit and the final use in total of all the sectors will increase by 13,975 billion CNY, and 4,397 billion CNY, respectively. The results suggest that the sector No.6 (Production and Supply of Electric Power, Heat Power and Water) is the most significant one with strong influences on reducing total CO₂ emission among all sectors. Finally we recommend that with technical effects, this sector should be considered as the leading industry in which technological innovation is absolutely needed to decrease the CO₂ emission per unit of production at first while implementing the TEC policy scheme.

5. References
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