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Simulating the impacts of imposing royalty on china's iron ore mineral resources based on a dynamic computational general equilibrium model

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Abstract. In 2017, Chinese government proposed to establish mineral resources royalty system. The unveiling of this policy will have direct impact on the price composition of mineral resources, change the supply and demand to some extent and thereby affect the total output and total consumption of the society, consequently bringing about important influence upon the Chinese economy. Taking iron resources as an example, this paper presents a prospective evaluation of the economic influences after the imposition of mineral resources royalty. By using China's dynamic energy computable general equilibrium (CDECGE) model and with the output percentage of iron ore industry in national economy as a policy constraint, the paper induces the optimal iron ore resources royalty rate and concludes with policy recommendations for the reform of China's mineral resources royalty system.

Key words. Chinese mining economy, dynamic computable general equilibrium (CGE) model, iron ore resources, royalty system.

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1. Introduction

In the context of globalized allocation of mineral resources, the Ministry of Land and Resources of the People's Republic of China officially put forward "the mineral resources royalty system" in 2017. Since mining industry is one of the important basic industries in China, the introduction of mineral resources royalty (hereinafter abbreviated as "royalty") system will bring about structural effect on the Chinese economy. The royalty issue has already caught extensive attention in the academic circles and many scholars have started researches on it, with different focuses. Cawood (2011)[1] adopted the empirical method in forecasting and evaluating the influences of South Africa's implementation of "Royalty Act" on its national revenue and industries. Ayden (2012)[2] took petroleum and natural gas as an example and analyzed the impact of royalty reform on Turkish economy. There have been lots of arguments on the nature of royalty. One viewpoint holds that royalty is a resource-based return on asset. For example, through comparative study of mineral resources rent, tax and fee systems from a global perspective, Fan and Ma. (2015)[3] as well as Gan (2012)[4] believed that royalty was the major manifestation of property rights and interests of mineral resources therefore it didn't fall into the scope of tax. Boadway (2014)[5], Zwan and Nel (2013)[6] differentiated royalty from rent tax from the viewpoint of compensation for consumable resources.

The royalty levy standard will have a direct impact on the prices of mineral products as well as the stakeholders, thus affecting the total demand and supply in the entire society and in turn having various complex implications to the macro economy of China. Therefore, we should conduct quantitative simulation and evaluation of various possible economic and social impacts of the royalty policy from macro-economic perspective.Computable general equilibrium (CGE) model is normally used to macro-economically evaluate and predict the impact of economic policy within a country or a particular region (Johansen 1960). At present, in the research of the impact on macro economy from the tax and fee policy in the mineral resources sector, CGE model is mainly used in the research of resource tax. Examples of this include: Shi, et al. (2015), Liu and Zhou (2015), Xu (2015). Rarely has CGE model been used for quantitative evaluation of royalty policy.

2. Building of China's Dynamic General Equilibrium Model

This paper uses China's dynamic energy computable general equilibrium (abbreviated as CDECGE) model for quantitative analysis. Jointly developed by Center of Energy & Environmental Policy Research, Chinese Academy of Sciences and Monash University, Australia, CDECGE model is particularly used as a single-region dynamic CGE model to analyze problems in China, as an extension of Monash model (Dixon, et al.2002). Unlike most of the CGE models, Monash model features some special suppositions. First of all, a technical change parameter is presumed to exist in all sectors, which can be used not only in discussing the impact of technological advancement on industrial output, but also in calibrating the model with historical output data. Secondly, for household consumption and government consumption, the presumption is that different consumption preference parameters exist. These parameters can be used to depict the changes in consumption trends during different years and are presumed to be endogenous variables over the historical calibration period. Thirdly, Monash model is a recursive dynamic CGE model.

2.1. Main features and specific improvements of CDECGE Model

With Chinese economy in the background, CDECGE model quantitatively depicts the action mechanism of interrelationship and mutual constraint among energy, environmental and economic systems through quantitatively modeling of them (Cui, et al.,2014). Similar to Monash model, the dynamization of CDECGE model is realized on the basis of dynamic capital accumulation and dynamic labour adjustment. The model mainly consists of historical calibration period and policy simulation period. In the historical calibration period, historical information that has already happened is adopted to calibrate the major variables of the model so as to obtain relevant technical progress parameters and share parameters; while in the period of policy simulation, it is the extrapolation of historical trend, supplemented with reasonable expectation of future macroeconomic situations. Designing the dynamization mechanism of CDECGE model enables us not only to simulate the short-term impact of certain policy but also to grasp the long-term trends of these variables.

2.2. Production module of CDECGE model

CDECGED model uses the multiple nested production structure to depict the production function (see Figure 1), in which the top layer is presumed to satisfy Leontief function, namely there is no elasticity of substitution among non-energy intermediate input, energy factor bundle and other input. Unlike Monash model, CDECGE model has adjusted the substitution relation between energy and capital labour, presuming that the elasticity of substitution satisfies CES functional form between them(Cui, et al., 2015 , Cui and Song, 2017).

First of all, non-energy commodity, energy-factor bundle and other costs satisfy the Leontief form, namely various inputs satisfy the presumption of fixed ratio in total production cost. The specific functional form is:

$$Min. \sum_j PQ_j \cdot X_{j,i} + PKLE_i \cdot KLE_i \tag{1}$$

$$s.t Z_i = \left\{ \frac{X_{1,i}}{\alpha_{1,i}}, \cdots \frac{X_{ne,i}}{\alpha_{ne,i}}, \frac{KLE_i}{\alpha KLE_i} \right\}$$

Where PQ_j refers to the output price of the jth industry, $X_{j,i}$ is the intermediate input of the jth industry into the ith industry, $PKLE_i$ is the price of labour capital-energy bundle used by the ith industry, KLE_i is the specific input, Z_i represents the total output of industry i, while $\alpha_{1,i}$, $\alpha_{ne,i}$ and αKLE_i respectively represent the technical parameters of relevant variables. Formula (1) shows that appropriate input chosen for the industry enables the maximum output level under the constraint of cost minimization.

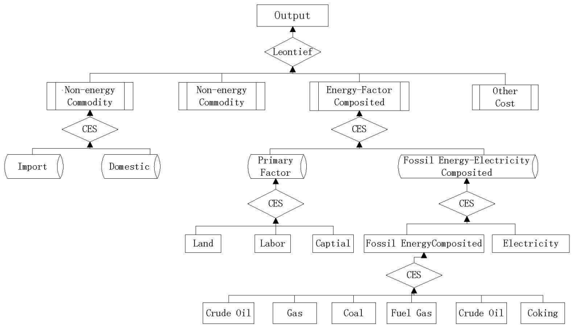

Fig. 1. Production structure of CDECGE model

Secondly, the primary production factor bundle is composited with fossil energy bundle to produce the production factor-energy bundle and it is presumed that this layer satisfies the CES functional form. Details are as follows:

$$Min.PEnergy_i \cdot Energy_i + PVA_i \cdot VA_i \tag{2}$$

$$s.t.KLE_i = A_{KLE,i} \cdot (\alpha_{energy,i} \cdot Energy_i^{\rho_{EVA,i}} + (1-\alpha_{energy,i}) \cdot VA_i^{\rho_{EVA,i}})^{\frac{1}{\rho_{EVA,i}}}$$

where $PEnergy_i$ is the price of fossil energy bundle, PVA_i is the price of primary production factor bundle, $Energy_i$ is the input of fossil energy by industry i, and VA_i is this industry's input of primary production factor bundle. Similar to Formula (1), Formula (2) contains multiple technical parameters. $A_{KLE,i}$ is a technical parameter to measure the production level, $\rho_{EVA,i}$ is the elasticity parameter of CES function, $\alpha_{energy,i}$ means the energy share, and $1-\alpha_{energy,i}$ is the input share of primary production factor.

Furthermore, based on the presumption of CES function, labour, capital and land are composited into primary production factor bundle and electricity and fossil energy are composited into energy bundle. Specific formulas are:

$$Min.W_i \cdot L_i + R_i \cdot K_i$$

$$s.t.VA_i = A_{VA,i} \cdot (\alpha_{L,i} \cdot L_i^{\rho_{VA,i}} + (1-\alpha_{L,i}) \cdot K_i^{\rho_{VA,i}})^{\frac{1}{\rho_{VA,i}}} \tag{3}$$

$$s.t.Energy_i = A_{energy,i} \cdot (\alpha_{fossil,i} \cdot Fossil_i^{\rho_{en,i}} + (1-\alpha_{fossil,i}) \cdot X_{elec,i}^{\rho_{en,i}})^{\frac{1}{\rho_{en,i}}} \tag{4}$$

In Formula (3), W_i is the pay level of industry i, R_i is the capital rent, L_i refers to labour input of industry i, and K_i refers to the capital input of industry i. $A_{VA,i}$ is the technical parameter of labour and capital composite while $\rho_{VA,i}$

depicts the elasticity of substitution between the two variables. $Pfossil_i$ is the fossil energy input price of industry i, PQ_{elec} is the primary electricity input price, and $Fossil_i$ and $X_{elec,i}$ respectively refer to fossil energy and primary electricity inputs of industry i. In order to reflect the effect of changes in production technology upon production level, two technical variables, $A_{VA,i}$ and $A_{energy,i}$, are introduced into Formula (3) and Formula (4) respectively.

Lastly, coal, crude oil, natural gas, refined oil, coke and fuel gas are composited into fossil energy bundle according to CES and the specific function is as follows:

$$Min. \sum_f PQ_f \cdot X_{f,i}$$

$$s.t. Fossil_i = A_{Fossil,i} \cdot (\sum_f \alpha_{f,i} \cdot X_{f,i}^{\rho_{fo,i}})^{\frac{1}{\rho_{fo,i}}} \tag{5}$$

Where PQ_f is the input price of the fth fossil energy, $X_{f,i}$ is Industry i's demand of the fth energy, $\alpha_{f,i}$ represents the share parameter of each kind of fossil energy while $A_{Fossil,i}$ represents the complex technical parameter of sub-variety of energy, and $\rho_{fo,i}$ depicts the elasticity of substitution among six kinds of fossil energy.

2.3. Demand function of CDECGE

In CDECGE model, it is presumed that government consumption satisfies the form of Cobb-Douglas function, namely the presumption of government's consumption share of each kind of commodity remains the same. As to household consumption, it is presumed that households are the price takers and they can choose to consume what kind of commodity under the restraint of disposable income so as to maximize their utility function. Disposable income of the household is the total household income minus savings while the percentage of savings in total income stays unchanged. The major sources of total household income include wages income, capital gains and transfer payment of the government. Household consumption satisfies the form of Klein-Rubin function and it becomes linear expenditure system upon linearization. Specifically,

$$s.t. \sum_{i=1}^{n} P_i^{(3)} X_i^{(3)} = W^{(3)} \tag{6}$$

In Formula (6), $W^{(3)}$ is the total disposable income and P and X represents household commodity consumption price and consumption volume. Under the presumption of Klein-Rubin function, the consumption demand of household for each commodity is shown in the following formula:

$$X_i = \theta_i + \frac{\delta_i}{P_i}(W^{(3)} - \sum_{i=1}^{n} P_i^{(3)} \theta_i) \tag{7}$$

where θ_i represents the basic demand of household for the ith kind of commodity and δ_i is the marginal budget share, namely the increasing degree of Commodity i consumption when the disposable income increases by one unit.

2.4. Supposition of import and export trade in CDECGE Model

CDECGE model has different presumptions of import trade and export trade. For import trade, same as many CGE models, CEDCGE model presumes that imported commodity and domestic commodity cannot completely substitute each other, that is, it satisfies Armington assumption. The two of them are composited on the basis of CES, and the composited commodity mainly flows to three channels: government consumption, household consumption and the intermediate input of enterprises. CDECGE model adopts the small-state presumption, that is, the world average price of imported product is presumed to remain the same and the import demand is determined by both domestic demand and trade situation. Imported commodities will be levied import duty upon their arrival before they go into the domestic market for circulation. The specific formula is:

$$PM_i = PW_i \cdot (1 + mtax_i) \cdot phi \tag{8}$$

PW_i is the world average price of the ith kind of commodity, PM_i is the price of the ith kind of imported commodity after it goes into the domestic market, $mtax_i$ is the import duty, and phi is the exchange rate level.

As to export trade, CDECGE model depicts the export demand as a downslope curve, satisfying the fixed price elasticity. Based on this presumption, the elasticity of export demand for China's commodities with small export volume is drawing close to positive infinity.

$$E_i = FQ_i[PE_i \cdot phi/FP_i]^{\sigma_i^4} i = 1, \cdots, n \tag{9}$$

Where E_i represents the export level of Commodity i, PE_i is the export price of Commodity i, phi refers to nominal exchange rate, FQ_i means the export amount of Commodity i calculated in US dollars, and FP is the export amount of Commodity i calculated at the world average price. σ_i^4 means the elasticity of export demand, which is negative. For bulk commodities, the value of this parameter is limited. However, for commodities with small export levels, the elasticity of their export demand goes towards negative infinity.

2.5. Setting of royalty levy in the model

The imposition of royalty on iron ore mining industry will increase the production and operating costs of enterprises, decreasing their profits and affecting their initiative in production and operation, and hence it will decrease the output level of iron ore mining industry. Although the levy of royalty is based on property ownership, which is different from taxes collected on the basis of state power, it's still a payment made to the government from the perspective of enterprises, whether it is a royalty or a tax. They will change their own production activities due to the increase of costs therefore the effects of royalty and tax are basically the same. In fact, while analyzing and evaluating the effect of royalty on economy, many scholars such as Cawood (2011)[1] , Pieter (2010) and Northey, et al.(2017) also start from the perspective of royalty's effect on production costs. Therefore, the royalty levy setting in this paper is realized through the variation of production tax. In CDECGE model, however, the formula of production tax setting in the industry is shown below:

$$100 \times \Delta viptx(i) = viptx(i) \times [pltot(i) + xltot(i)] + 100 \times vitot(i)[(1 + ptxrate(i))^2] \times \Delta ptxrate(i) \tag{10}$$

where $\Delta viptx(i)$ refers to the absolute variation of production tax in Industry i, $viptx(i)$ is the production tax level in Industry i before policy implementation, $xltot(i)$and $pltot(i)$ respectively refer to the percentages of output variation and price variation in Industry i, $vitot(i)$ is the total output level of Industry i, $ptxrate(i)$ is the direct tax rate before policy implementation, and $\Delta ptxrate(i)$ is the variation of direct tax rate.

2.6. supposition of dynamized mechanism

As far as the design of dynamized mechanism is concerned, CDECGE model uses the presumption in Monash model for reference, namely year-to-year capital accumulation and dynamic labour adjustment are used to realize the dynamization of the entire model. In terms of capital accumulation, observation is mainly focused on the relationship among capital stock, expected capital return rate and added investment. Capital stock of current period will affect the expected capital return rate. The bigger the volume of capital stock is, the lower will the expected capital return rate be.

Capital accumulation equation:

$$K_{j,t} = K_{j,t-1} \cdot (1 - D_j) + I_{j,t-1} \tag{11}$$

Where $K_{j,t}$ is the capital stock of Sector j in Period t, $K_{j,t-1}$ is the capital stock of Sector j in Period t-1, D_j is the capital depreciation rate, and $I_{j,t-1}$ is the added investment of Sector j in Period t-1.Equation of capital accumulation growth rate:

$$KGR_{j,t} = \frac{K_{j,t+1}}{K_{j,t}} - 1 \tag{12}$$

Where $KGR_{j,t}$ is the growth rate of capital stock.Capital supply equation:

$$KGR_{j,t} = h_j(E_t(ROR_{j,t})) \tag{13}$$

Where $ROR_{j,t}$ is the capital return rate of Sector j in Period t while $E_t(ROR_{j,t})$ means the expectation of capital return rate. Static equation of expected capital return rate is:

$$E_t(ROR_{j,t}) = -1 + (\frac{P_{j,t}^{(1cap)}}{P_{j,t}^{(2)}} + (1 - D_j))(\frac{1 + INF_t}{1 + r}) \qquad (14)$$

CDECGE model has its special presumption of dynamic labour adjustment. It presumes that labour flows freely among various industries and the extent of inter-industry labour flow and the direction of its adjustment are closely related to the wage rate. CDECGE model also presumes that the wages is elastic and the adjustment of wage rate doesn't require labour supply to be equal to labour demand in current period.

Where W_t means the actual wage rate in Period t after the policy impact, $W_{f,t}$ is the actual wage rate in the base-year forecast, L_t is the actual employment level, $L_{f,t}$ is the actual employment rate in corresponding base-year forecast, α is the adjustment parameter (positive values), and f_t is the offset variable, which is presumed to be endogenous in historical calibration period but exogenous in policy simulation period. Formula (15) shows that variation of current wage rate is related not only to the previous period but also to labour variation in current period.

3. Development Status of Iron Ore Industry and Scenario Settings of the Model

3.1. Development status of iron ore industry

Iron ore is the major raw material for steel production and China is a major producer and consumer of iron ore in the world. In the past few years, China's iron ore output has accounted for about 40% of the global gross output (see Figure 2), but the dependence on import for iron ore has always been at a high level. In 2015, China imported 953 million tons of iron ore, a year-on-year increase of 2.2%. The gross import amount reached 57.62 billion US dollars, a year-on-year decrease of 38.3%. The average import price was USD 60.5/ton, a year-on-year decrease of 39.8%. The import volume accounted for 65.1% of the global volume (see Figure 3 and Figure 5).

In 2005 – 2015, the accumulated output of crude iron ore in China was 11.28 billion tons, equivalent to 3.21 billion tons of refined iron ore (Wang, et al.). In 2015, fixed asset investment in Chinese iron ore mining and dressing industry was 136.57 billion RMB yuan, which was a year-on-year decrease of 19.2%. Starting from 2012, due to influences of factors such as sluggish domestic market and imbalance between demand and supply, the price of domestic iron ore has been on a channel down in general (see Figure 4). In the meantime, the price of imported iron ore has fallen to shocks. Take 63.5% Indian fine ore in 2015 for example, the quote at the beginning of the year was 72 US dollars, but the lowest quote was 39 US dollar, declined by 45.8%, and it hasn't bounced back since the end of 2016.

Although the international price of iron ore has been continuing its decline, since 2011, China's import of iron ore has been on a steady rise, yet the gross import

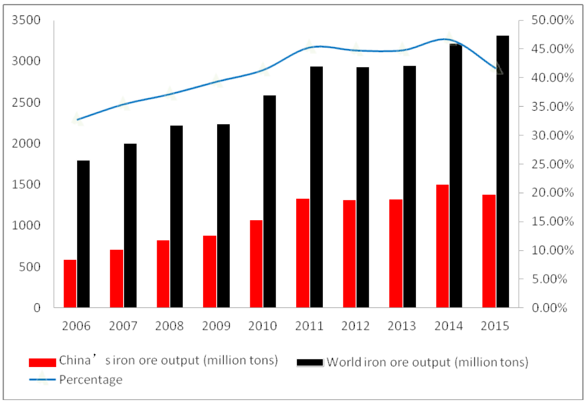

Fig. 2. Comparison of iron ore output between china and the world in 2006 - 2015

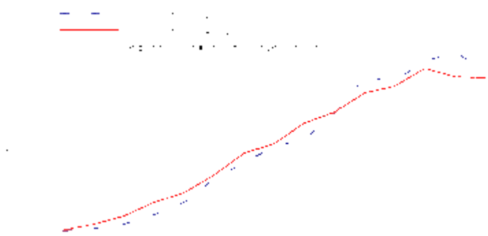

Fig. 3. Changes in china's iron ore production, consumption and degree of external dependence in 2001- 2015

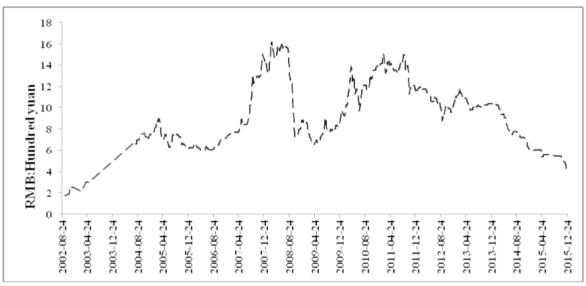

Fig. 4. Price trends of China's Qianxi iron fines (66%) in 2002 - 2015

amount has decreased. In the short run, even though the decrease of import costs for iron ore may be an advantage to certain extent in reducing the operating pressure on Chinese steel enterprises, the low ore price will lead to financing difficulties, investment decrease and scale shrinking of domestic iron mine developing enterprises and consequently huge impact on Chinese iron ore industry (see Figure 5).

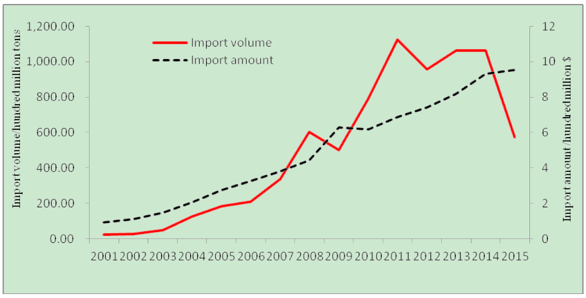

Fig. 5. Import and export trade of China's iron ore fines in 2001 - 2015

3.2. Scenario settings of the model

At current income level, the introduction of any tax and fee policy would always affect the equilibrium output of enterprises and the total utility of households and government. Although royalty is the asset-income return for the owner of mineral resources, if it is imposed substantively, it will directly affect the price composition of mineral resources, change the demand and supply to certain extent and hence affect the total output and total consumption of the society. The purpose to build CGE model in this paper is to, through comparison of total household and government utilities before and after the royalty levy, search under the constraint of cost minimization for a royalty rate, which could not only optimize the overall output of mining enterprises but also maximize the total utility of household and government.

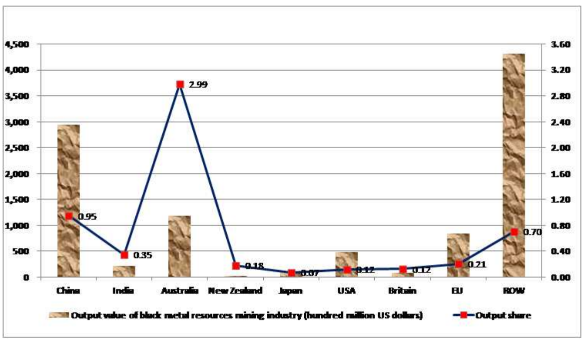

Fig. 6. Comparative analysis of global black metallicmineral resources development in Baseline Scenario (based on the accounting of GTAP 9.0 database)

Figure 6 shows the development of black metal mineral resources in major regions around the world in 2011. It is apparent from the figure that the annual output of black metallic mineral resources in China is approximately 300 billion US dollars, about 3.48 times, 6.03 times and 2.50 times of EU, USA and Australian outputs respectively and nearly 30% of the total world output. Influenced by this, the output share of China's black metallic mineral resources industry is also relatively high in all Chinese industries, approximately 0.95%, way higher than 0.12% of USA, 0.21% of EU and 0.35% of India.

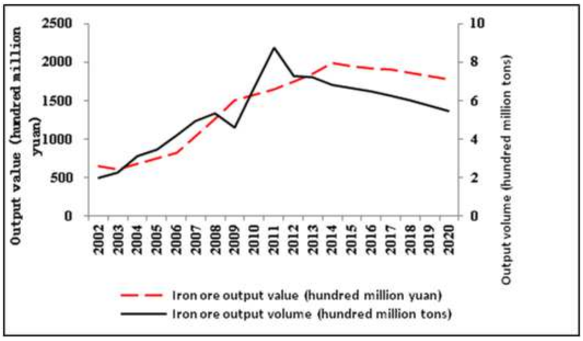

Fig. 7. Analysis of iron ore development status in Baseline Scenario

Based on the research objectives and presumptions of future economic growth scenario, two kinds of policy scenario are set: baseline scenario and scenario of royalty levy on iron ore mining industry. (1) Baseline scenario: This scenario is the trend extrapolation of historical simulation. It is presumed that China will continue its current economic growth method and maintain current industrial policies, with no attempt to seek industrial structure adjustment. As to the setting of economic growth, considering that Chinese economy has currently entered a period of new normal and it is under great pressure of economic downturn, it is presumed that China's annual average GDP growth rate during the period of the 13th Five-Year Plan is 6.5%. (2) Scenario of royalty levy on iron ore mining industry: Following existing rules of economic growth, this scenario is the trend extrapolation of future changes on the basis of historical rules. Compared to Scenario 1, it presumes that royalty will be levied in 2017, the royalty rate will cause China's iron ore output share in 2020 to decrease by 43% from 2011.

4. Empirical Findings

4.1. Development Status of iron ore industry in baseline scenario

At present, China has been under increasing pressure of economic downturn. Influenced by the economic downturn and the policy to eliminate backward production capacity, both the output volume and output value in the iron ore mining industry in China will show downward trend during the period of the 13th Five-Year Plan, as shown in Table 7. As we can tell from the figure, since the beginning of the 21st century, there are roughly two stages in the iron ore development in China. The first stage is the rapid expansion period between 2002 and 2011, during which the annual average growth rate in Chinese economy exceeded 10% and there were high and strong demands for various kinds of energy resources. The iron ore output volume in China increased to 879 million tons from 197 million tons, with an annual average increase of 18.08%. The output value of iron ore industry increased to 164.50 billion yuan from 64.93 billion yuan, with an annual increase of 10.88%. The second stage is the rapid adjustment period between 2011 and 2020. The output volume of iron ore will decrease to 545 million tons from 879 million tons, with an average annual decrease of 5.17%. As shown in Figure 8, if the current situation of economic growth continues in China, the iron ore output volume in 2020 will return to the 2008 level and the output value of iron ore will roughly return to the 2012 level."

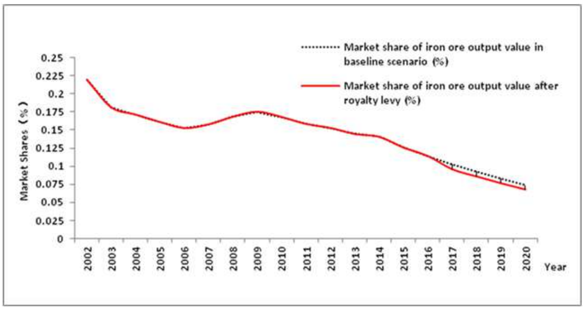

Fig. 8. Changes in iron ore market share in baseline scenario and after royalty levy

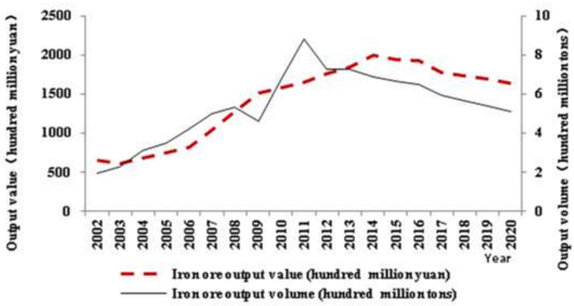

Fig. 9. Analysis of post-royalty-levy iron ore development

4.2. Development status of iron ore industry in royalty-levy scenario

The imposition of royalty on the iron ore mining industry in China will affect its operating profits, reduce its motivation for production and result in further decrease in the output volume of iron ore. As shown in Figure 9, the iron ore output in China will experience certain degree of decrease in the royalty-levy scenario. For example, the iron ore outputs in 2017 and 2020 are 592 million tons and 519 million tons respectively, a decrease of 5.31% and 6.47% compared with the baseline scenario. Due to the decrease in output volume, the output value in the iron ore mining industry will also experience decrease to a certain extent. The output value of iron ore mining industry in 2017 is approximately 176.98 billion yuan, a decrease of 13.25 billion yuan compared with the baseline scenario. The output value in 2020 is estimated to be 163.76 billion yuan, a decrease of 13.69 billion yuan compared with the baseline scenario.

4.3. Effect of iron ore industry royalty levy on actual GDP

Iron ore is the important raw material for infrastructure construction and the decrease of its output volume would bring about certain negative influences on the economy, yet to a limited degree. As shown in Figure 9, in the baseline scenario, the actual GDP of China in 2016 is 52.33 trillion yuan (2002 constant price, the same below), 0.01 trillion yuan higher than 52.32 trillion yuan in the royalty scenario. As we can tell that the levy of royalty has caused the actual GDP in 2017 to decrease by 0.19%. The negative influence of royalty policy on the economy will ease off as time goes by and the actual GDP of China in 2020 is approximately 63.21 trillion yuan, decreased by 0.01 trillion yuan in comparison with the baseline scenario, a decrease close to 0.11%.

4.4. Sharing of iron ore profits in policy scenario

Figure 9 shows the percentage of royalty in output value of iron ore mining industry. We can tell from the figure that, influenced by the continuously increasing pressure of economic downturn and production capacity adjustment policy implemented in high-energy-consumption industries in China in recent years, the annual output value of iron ore mining industry decreases form 176.98 billion yuan in 2017 to 163.76 billion yuan in 2020. In the meantime, the royalty amount decreases from 14.884 billion yuan to 13.77 billion yuan. From this, it is known that the percentage of royalty in iron ore output value remains at 8.41% or so. This means that it would be appropriate to set the royalty levy limit to 8.41% in the output value of iron ore industry in order to guarantee the smooth development of iron ore industry in China and decrease the share of output value in iron ore industry to the average level of countries (excluding China) in the world.

5. Conclusion and Discussion

This is great significance in reality. By building and applying CDECGE model, the present paper conducts simulation analysis on the economic and social impacts of launching royalty policy in the iron ore mining industry. Year 2020 is used as the target year for the policy to explore the royalty levy standard for the reasonable development of the iron ore industry. The empirical research mainly results in the following findings:

1) In the context of new normal of economy where there is an increasing downward pressure on Chinese economy, the iron ore output in China will experience some decrease during the period of the 13th Five-Year Plan (on the premise of 6.5% average annual growth rate). The output will decrease to 545 million tons in 2020, from 666 million tons in 2015. The output value will decrease to 177.45 billion yuan from 194.71 billion yuan. 2) In the scenario of royalty levy in the iron ore industry, the iron ore output in China will be about 510 million tons in China and the output

value close to 163.76 billion yuan, which respectively represent 6.42% and 7.71% decrease compared with the baseline scenario. It is likely that the output level of iron ore in China may be even further decreased.

As a matter of fact, there is not much quantitative research on the royalty levy standard at present, although China has been promoting the reform for the pay-for-use of the mineral resources and has recently put forward the proposal to develop the royalty system. The present research uses the percentage of iron ore output value in the national economy as a policy restraint and introduces the optimal royalty rate. Due to the rapid economic development, the iron ore output value in China accounts for a much higher percentage in the national economy compared with many developed countries. The mineral resources are heavily over-explored.

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