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Abstract

Cutting the overcapacity in coal industry is a current critical issue in China and is a matter for the world. However, inappropriate capacity cut policies may induce huge fluctuations of energy price, creating a threat to energy security and even economic stability. This paper designs a capacity permit trading scheme to minimize the compliance cost of production capacity cut, and proposes the operational details of capacity permit trading scheme using China's coal industry as an example. We also construct a simple partial equilibrium model to examine the benefits and firm behaviors when adopting the permit trading scheme. The results demonstrate that the permit trading scheme will generate overall positive social welfare as well as reduce firms' cheating incentives. The results confirm that the more heterogeneous of the firms in terms of compliance costs, the higher the social welfare gains and the trade volume there will be. Our findings show that the proposed permit trading scheme is feasible and beneficial in achieving the capacity cut target in China.

Key words: Overcapacity; Individual Transferable Quotas; Permit trading scheme; China；Coal;

1 Introduction

While the overcapacity issues in China had happened in the early 2000s, the transition to 'new normal' economic development model creates a renewed and unprecedented challenge: the weakening China's demand for the traditional energy products may be permanent due to the lower economic growth than that in history. While the China's government has paid significant attention to production capacity issues in the past decade, the capacity policies become more aggressive after the global financial crisis and the current 'new normal' growth period.

The capacity cut policy and its implementation in China's coal industry could have significant implications on energy security from the perspective of acceptability and affordability. First, overcapacity leads to abnormally low prices of coal and energy in general, resulting in energy inefficiency (Pan et al., 2017), over-consumption of fossil fuels and associated over-emission of carbon. Capacity cut prevents these outcomes that contribute to the acceptable dimension of energy security (Li et al., 2016; Yao et al., 2018). Second, capacity cut in coal sector will reduce the heavily coal dominance energy mix in China and create the space for the transition to more eco-friendly renewable energy. A permit trading scheme has been found effectively in expediting the retirement of coal fired power plant (Jotzo and Mazouz, 2015). A low carbon energy mix is a key aspect of energy security (Li et al., 2016; Yao and Chang, 2014). Third, proper implementation of capacity cut polity can avoid man-made price volatility and enhance affordability. One of the major problems for the current coal capacity cut policy in China is huge fluctuations of coal price, which is evidenced by a dramatic increase in price of coal in 2016 (CEIC, 2019). Even worsen, the price fluctuation in some provinces, such as Henan and Xinjiang, are more significant than the national average. The most dramatic surge of price occurred in Xinjiang where coal price could be tripped (Shi et al., 2018). These documented price surges reduce the affordability of coal, a main indicator of energy security (Li et al., 2016; Yao et al., 2018; Yao and Chang, 2014). The increased energy price volatility also threats food and economic stability (Cheng et al., 2019; Taghizadeh-Hesary et al., 2019, 2016). In sum, proper implementation of the capacity cut policy will not only save transition costs, but also can enhance energy security, facilitate energy transition and minimize welfare loss.

How to introduce a market mechanism which ensures economic stability and energy security into the current policies is a real challenge that the China's policy makers are facing. Although the China's government leadership aspires to use market instruments (18th Central Committee of the Communist Party of China, 2013), most of the existing policies of cutting overcapacity, or capacity cut, are based on the command and control method (State Council, 2016a, 2016b). The current discussions on market mechanism for controlling the overcapacity are either non-academic (Song, 2016) or lack of operational details (NDRC et al., 2016a, 2016b). Among many studies on overcapacity issues in China's industries such as coal (Shi et al., 2018; Wang et al., 2018b, 2018a; Zhang et al., 2018), power generation (Yuan et al., 2016; Zeng et al., 2017), chemicals (Li et al., 2017) and PV (Wang et al., 2014; Xiong and Yang, 2016), there is no discussion on how to set a market mechanism in addressing the overcapacity issues. Only Shi et al. (2018) briefly mentioned the need to introduce capacity permit trading and other market instruments to control capacity or facilitate "energy transition". As alternatives to the current command and control policy, a capacity permit trading and other market instruments for the capacity cut are believed to able to reduce price volatility, and thus facilitate "energy transition" (Shi et al., 2018; Taghizadeh-Hesary and Yoshino, 2019). For example, with revenue from selling production capacity, the closed mines now can afford to start alternative business, such as renewable energy projects, so they can have smooth transition away from fossil fuel production activities.

To fill these gaps, the first objective of this paper is to specify how a permit trading scheme could be introduced to manage capacity control. We take China's coal industry as an example and present the operational details of the permit trading scheme, including the definition of trade boundary, the scope of producers, determination of total allowed production, the initial allocation of permits and trading of the permits. The coal industry is selected because it accounts for a half of the global production and consumption and it is the major source of emissions. Compared with other sectors that only have a few companies, the coal industry has a large number of companies that are belonged to different levels of governments. The large number of firms and complicated hierarchy makes the sector the ideal subject to study the complication of policy implementation in China.

We construct a simple partial equilibrium model to theoretically illustrate how this capacity permit trading scheme can facilitate the capacity cut. In particular, we investigate benefits of the permit trading scheme compared to the traditional command and control methods in terms of social welfare maximization, and examine how the firms change their behaviors due to the introducing of the permit trading scheme. The simulation results demonstrate that such a permit trading scheme will generate overall positive social welfare as well as reduce cheating behaviors of firms. The benefits, along with the trade volume of permit, will depend on the heterogeneity among firms. Moreover, with the permit price as a signal, the central government can collect the information from the market and stabilize the price by market-based policy interventions.

The study has both academic and policy contributions. The major academic contribution is investigating the impact of applying a well-established market mechanism to a brand-new area, the overcapacity control case. We show such a market instrument is a feasible solution to improve the economic welfare and ensures economic stability and energy security in the process of capacity control. A companion work of Shi et al. (2019) provides the empirical evidence of welfare gains when introducing the trading scheme in China's coal industry. This paper complements it by providing a more general theoretical foundation as well as simulation results. Based on our model, we are allowed to further trace out the firm behaviors and discuss the market-based government intervention in the permit trading. Given China's dominant role in the production of coal, steel, cement and a few other products, a market instrument incapacity cut policy and its effectiveness will even reduce price volatility in the global coal markets. The study can also inform policy debates in sectors with excess capacity in other countries, such as fisheries, agriculture (Guan et al., 2009), forest (Lee and Jang, 2012), infrastructure (Haralambides, 2002), steel (OECD, 2015)and automobiles in other countries.

The reminder of this paper is organized as follows. Section 2 reviews capacity control policies in China and proposes the operational details of permit trading instrument. Section 3 describes the theoretical model, followed by simulation results in Section 4. The last section concludes with policy implications.

2 Capacity control in China

2.1 Current practice of capacity control policies in China

Overcapacity generates externalities, such as investment waste, low economic efficiency, delay of low-carbon energy transition and barrier for industrial upgrading (State Council, 2013; Yuan et al., 2016). While in a perfect competitive environment, the market can rebalance through bankruptcies of firms, in China, there is significant amount of non-market factors, such as competition among government at different levels and different regions for economic growth, which lead to the difficulty to declare bankruptcy. As a result, the self-exit in the perfect market may not happen and thus the central government tends to intervene the market by designating target of capacity cap, or in other way, overcapacity cut (Lin et al., 1998; Lin and Tan, 1999).

Overcapacity in China's coal industry appeared in 1998 for the first time. Since 1998, China's coal sector has experienced a period of overcapacity and severe capacity control policies. The capacity control policy disappeared soon after 2003 when China faced high demand for coal, although the discrimination and thus elimination of small coal mines are continued (Hao et al., 2015; Shi, 2013, 2009).

After the global financial crisis and subsequent 'new normal' growth period, the overcapacity problems seem no longer be temporary and the previous capacity policies were found to be insufficient. Thus, the capacity control policies become more aggressive. In 2010, the State Council strengthened the elimination of backward production capacities in ten key industries, including coal, steel, power generation, cement, and so on (State Council, 2010). In 2013, the capacity control policies was rebranded as a part of the supply-side reforms (State Council, 2013). In early 2016, the steel industry and coal industries were further highlighted by the State Council on the overcapacity issues as potential to be harmful for the macroeconomic development in China (State Council, 2016b, 2016a).

Command and control tools are the dominant instruments to enforce the capacity cut policy in China. In the early days, policies were mild and thus the environmental and technical standards were the main tools to reduce capacity. However, since the overcapacity cannot be solved by increased standards, harsher command and control tools were proposed. For example, in 2016, State Council banned the increase of steel production capacity in all projects and required further reduce capacity through voluntary actions, merger and acquisition, relocation and international capacity cooperation and transfer (State Council, 2016b). In February 2016, the State Council declared a similar capacity frozen policy for the coal industry in the next 3 years from 2016 and went further to cut up to 1000 Mt of production capacity in the coal industry in 3-5 years from 2016. The policy also limits the working days in coal sector from 330 to 267, which is equivalent to cutting the nominal capacity by 16 percent (State Council, 2016a). Given the occasional need of the new project, the government requires project developer to conduct replacement, that is all new production capacity in the coal industry must be offset by closing down of existing capacity (hereafter 'capacity credit)' (NDRC et al., 2016b, 2016a). Even the after the State Council have required the use of market mechanisms, the common instruments that government used to address the overcapacity are still fiscal and financial ones such as policies on tax, accounting, land administration, debt restructuring, and bankruptcy reorganization (State Council, 2016a, 2016b).

The prevailing command and control method to enforce the capacity cut policy will incur significant efficiency loss, which has been well-documented in the literature, on coal industry (Shi et al., 2018; Wang et al., 2018a), power generation (Zeng et al., 2017) and other sectors (Li et al., 2017).

2.2 Market instruments as an aspiration

The past experience has demonstrated that market instruments, such as individual transferable quota (ITQ) in the fisheries and cap and trade in emission trade scheme (ETS), could do better than the command and control method. First proposed by (Dales, 1968), the use of ITQs was first seen in 'pollution quotas', which are now widely used to manage carbon emissions from power utilities. The most famous application of the cap and trade scheme is the carbon trading scheme. For both air and marine resources ITQs use a 'cap-and-trade' approach by setting annual limits on resource exploitation (TAC in fisheries) and then allowing trade of quotas between industry users (Chu, 2009). The neoliberalism believes the profit-driven market mechanisms can lead to more innovative and efficient environmental solutions than those devised and executed by states (Mansfield, 2004a, 2004b). ITQs have been proved to be effective in preventing collapses and restore declining fisheries despite controversies exist (Acheson et al., 2015). Most of the studies find that the EU emission trading scheme helps achieve the emission reduction (Anderson and Di Maria, 2011; European Commission, 2012; Meleo, 2014).

The China's government has also decided to introduce market instruments to its capacity control policy as the current target for overall capacity is similar to the cap in an emission trade scheme. According to current economic system reform agenda set at the Third Plenary Session of the 18th Communist Party of China (CPC) Central Committee in November 2013, the current reform will strengthen the decisive role of the market in allocating resources (18th Central Committee of the Communist Party of China, 2013). The State Council's policy in capacity cut in the coal industry that was issued in February 2016, also set market mechanisms and by law-based controls as basic principles (State Council, 2016a). In its August 2016 notice (NDRC et al., 2016b), the government agencies encourage local governments to set trade platforms for the capacity credits trading.

However, there is a lack of operational design and thus the market mechanisms have not been worked well. Even there are capacity replacements in the power generation sector (Yuan et al., 2016), the capacity credit is not transferable across the regions. While the central government agencies have allowed capacity credits that are generated from closing down of coal mines, or voluntary writing off capacity, to be traded across regions (NDRC et al., 2016b, 2016a), the management of the transaction of credits has not been specified. Besides, the existing trading platform, such as that in Shanxi (Shanxi Provincial Economy and Information Commission, 2015), only supports the private trading and auction, but not allow exchange-based trading.

2.3 Design a permit trading scheme to manage overcapacity: An example in China's coal industry

In this proposal, the government should set a permit trading scheme that is similar to ITQs and ETS. However, there is one significant difference. The production cap is on stock, differing from the cap in fishing and emission trading for which cap is often set annually and is on flow. Nevertheless, the cap concept remains the same. Under the capacity permit trading scheme, the production capacity is standardized as tradable individual capacity permits (ICPs) and the total number of allowable ICPs can be set by the government.

In particular, our proposed permit trading scheme in the coal industry can be briefly described as follows: The regulator, namely the NDRC, sets a total allowable production capacity (TAPC), or the capacity cap. Over time, the central government can reduce the TAPC, and thus achieve capacity cuts by enforcing a discount on ICP generation. For example, each one unit of closed capacity will be assigned less than one unit of permit.

The TAPC is then denominated in small standard tradable units, called individual capacity permits (ICP). Given that the capacity of a coal mine is often denominated in tons, for the convenience of trade, the minimum transaction of ICPs can be prescribed as 1,000 tons/year. The ICPs can be generated through the closing down of existing coalmines or through the writing off of operating mines' capacity. Once generated, the ICPs, will no longer be bundled in the amounts that they were when they were generated and can be traded in small quantities, such as one ICP.

Firms can purchase ICPs to increase their production capacity from firms that reduce production capacity which generated ICPs. This standardized ICP allows capacity quotas that are generated from any single closed mine to be sold to many buyers and one buyer to buy a bundle of ICPs from many sellers, thereby improving the matching efficiency in supply and demand.

The central government, through its designated agency, can buy back or sell the ICPs in the secondary market in order to cope with price volatility and other changes in response to new market development. This price control mechanism is similar to the Federal Open Market Committee (FOMC) operations in monetary policy, and is particularly important for capacity cutting since the product under control is normally the intermediate goods for other sectors. The flexible TAPC allows the government to monitor price changes without change of polices themselves.

The selling of ICPs could be either from the government's previous purchase or through an additional issue, which is equivalent to adjust the TAPC. The change in the TAPC is desirable as demonstrated in the case of capping total energy consumption. In 2014, China set a ceiling on primary energy consumption for the first time starting from 2017: the State Council allocated a 5.0 billion tone coal equivalent cap among provinces (State Council, 2016c, 2014). The frequently changes of policies and regulations, as happened in the coal industry in 2016 and 2017 (Shi et al., 2018), will damage government's creditability and undermine confidence of investors.

Considering the cost effectiveness of measurement, reporting and verification (MRV), the provincial government can be tasked to measure and verify the ICPs, which must follow a national standard and be registered to a national agency (the Register). The Register will report the ICPs in detail.

The trading platforms can take any form, anywhere. The sellers can publish information regarding available ICPs on any platform. Buyers and sellers are free to trade ICPs in any form, including bilateral negotiations (over the counter, OTC) and exchange-based trading. However, both the buyers and seller must report their prices to the Register when transferring the title of the ICPs. The Register then publish the ICP prices.

Ultimately, the trading platform could be institutionalized as an exchange, which could be virtual, whether or not the trades are conducted publicly or anonymously. The ICP trade could also be conducted through current environmental exchanges. Exchange-based trading will minimize the search costs for both buyers and sellers. Since the cap and permit are permanent, a future market could be developed in which third party players, such as financial players and professional traders, may also be allowed to participate in the ICP markets so as to increase the liquidity of the markets which is a foundation for reliable price signals (Shi et al., 2016).

At least two additional benefits could be generated from our proposed permit trading scheme. On the one hand, such a market instrument allows firms and regions turn their overcapacity cuts into revenue and thus encourage them to implement the cap more seriously. In the current regulatory model, the local government that follows command will have no benefits from cutting overcapacity and thus lack of incentive to implement the policy strictly. In contrast, in the permit trading scheme, the regions that cut capacity can benefit by selling their ICPs, which will compensate some financial losses. Take the region as a whole, the permit trading scheme policy can also smooth the shocks to different regions.

On the other hand, the permit price provides an indicator of the level of overcapacity cut and the government can adjust capacity permit to achieve targeted prices without change regulations as they are doing now. For example, the China's coal industry has suffered from U-turns in capacity cutting policy in 2016, which not only create shocks to the industries, but also damage government's creditability (Shi et al., 2018). This price control mechanism is analogues to the Federal Open Market Committee (FOMC) operations in monetary policy, and provides an additional instrument for the government to intervene the product market. Due to the nascent status of the proposal, there is no theoretical study of how the proposal may affect the firms, and this study is dedicated to investigate some direct impacts.

3 Model specification

In this section, we construct a single period partial equilibrium model to theoretically illustrate the impact of such a permit trading scheme. We extend the model built by Montgomery (1972) to the scenario of overcapacity cutting. In particular, we investigate benefits of the permit trading scheme compared to the traditional command and control methods in terms of maximizing the social welfare, and examine how firms' behavior changes due to the introducing of the permit trading scheme.

Consider the following problem of cutting overcapacity: In a certain region there is one type of overcapacity goods, which is produced by a number of independent, profit-maximizing firms. The prices of the inputs of these firms are also fixed due to the competitiveness of the market structure. These firms are represented by a set of integers, $I = 1, \dots n$.

In the absence of capacity regulation, each firm is profit maximizing without the output constraints. Consider a typical single product firm i, the firm-specific revenue function can be written as:

$$G_i(y_{i1}, \dots, y_{iR}, q_i),$$

where $(y_{i1}, \dots, y_{iR})$ denotes the inputs firm i purchases to produce the output at the capacity level of q_i. G_i is concave and twice differentiable production function. The cost function has the following form:

$$\sum_{r=1}^{R} p_r y_{ir}.$$

It represents the product-specific cost of purchasing a vector of inputs $(y_{i1}, \dots, y_{iR})$.

The firm's problem then will be

$$\pi_i = G_i(y_{i1}, \dots, y_{iR}, q_i) - \sum_{r=1}^{R} p_r y_{ir},$$

where π_i is the profit of firm i, p_r is the market price of inputs y_{ir}. Without the production cap set by government, we define $(\bar{y}_{i1}, \dots, \bar{y}_{iR}, \bar{q}_i)$ by

$$G_i(\bar{y}_{i1}, \dots, \bar{y}_{ir}, \bar{q}_i) \ - \sum_{r=1}^{R} p_r \bar{y}_{ir} = \max_{y_{ir}} [G_i(y_{i1}, \dots, y_{iR}, q_i) - \sum_{r=1}^{R} p_r y_{ir}] \,.$$

The bundle of $(\bar{y}_{i1}, \dots, \bar{y}_{ir}, \bar{q}_i)$ is the optimal production plan Firm i chooses after adjusting for the benefits and costs.

Now we consider the case in which the firms must adopt the production cap q_i^* and subsequently adjust its inputs in order to obtain the maximum profit under a fixed level of capacity. In this scenario, at the beginning of each period, the government imposes the production quotas on the firms. These quotas are denoted by a vector $Q^* = (q_1^*, \dots, q_n^*)$. The initial value of quotas can be determined based on the historical capacity of each firm or the economic and environmental goals the government aims to achieve. Essentially, the problem of cutting overcapacity is to minimize the economic loss b given the production quota constraints.

With the capacity regulation, for each firm i, we can define the new production plan $(\tilde{y}_{i1}, \dots, \tilde{y}_{iR}, \tilde{q}_i)$ by

$$G_i(\tilde{y}_{i1}, \dots, \tilde{y}_{iR}, \tilde{q}_i) \;-\sum_{r=1}^{R} p_r \tilde{y}_{ir} = \max_{y_{ir}}[G_i(y_{i1}, \dots, y_{iR}, q_i^*) - \sum_{r=1}^{R} p_r y_{ir}].$$

The bundle of $(\tilde{y}_{i1}, \dots, \tilde{y}_{iR}, \tilde{q}_i)$ is the optimal production plan adjusted for the benefits and costs, conditional on the capacity constraints for each firm $Q^* = (q_1^*, \dots, q_n^*)$. It is worth to point out that, in order to achieve the capacity reduction, government will set the quota q_i^* lower than the unconstrained production level $\bar{q}_i$. Therefore, after optimally adjusting for the production plan, $\tilde{q}_i$ will equal to q_i^*.

The cost of firm i to adopt the production cap is defined as the difference between its unconstrained maximum of profit and its maximum of profit with production constraint. That is,

$$F_i(q_i^a) = [G_i(\bar{y}_{i1}, .., \bar{y}_{ir}, \bar{q}_i) \;- G_i(\tilde{y}_{i1}, \dots, \tilde{y}_{iR}, \tilde{q}_i)] - \sum_{r=1}^{R} p_r\,(\bar{y}_{ir} - \tilde{y}_{ir}),$$

where $q_i^a = \bar{q}_i - \tilde{q}_i$ represents the production cut target due to the regulation. Based on the equation above, we decompose the cost of adopting production control into two parts: the change of gross income from altering the output vector and the change in costs from setting the production at a non-optimal level.

After differentiating the equation, we can show that

$$\frac{dF_i(q_i^a)}{dq_i^a} = -\frac{\partial G_i}{\partial q_i^a}.$$

It indicates that the variation of firms' profit is a function of the quantity of production cut, q_i^a. Besides, the concavity of $G_i(y_{i1}, \dots, y_{iR}, q_i)$ implies the convexity of $F_i(q_i^a)$. In sum, without the permit trading scheme, the profit-maximizing firms have to minimize the compliance cost $F_i(q_i^a)$ subject to the quota. Moreover, if G_i is concave, it follows the conditions under which $\sum_{r=1}^{R} F_i(q_i^a)$ is minimized are the same as the condition under which the total economic cost to firms of production controls is minimized.

Given the high compliance cost for firms to meet the capacity targets, one straightforward strategy the firms may adopt is to cheat or misreport. This is particularly important for the capacity cut issues in the country like China, where the regulation cost is relatively high due to the geographical and governance reasons. Meanwhile, the capacity control is usually associated with a price surge of the product under regulation, which provides the extra incentive for the firms to violate the capacity control policy.

To illustrate the cheating problem in the traditional command and control method, we specify the cheating process into our model. At each period, the firm i may choose the amount of c_i to cheat. At the same time, it also runs into the risk of getting punishment. The expectation of the cheating cost is $D_i(c_i)$, which is also a convex function since the probability of getting punishment increase disproportionally with the increase in quantity of cheating. In sum, the problem of firm i becomes:

$$\min_{c_i} [F_i(q_i^a, c_i) + D_i(c_i)].$$

Note that the idiosyncratic cheating cost can be regarded as the mean of the penalty distribution, which is subject to the location of the firms and the regulation cost of the local government. Besides, because of the existence of cheating, the quantitative target of capacity cut set by the government is not necessary equal to the real amount of production reduction of each firm. Therefore, we may denote the real quantity of the capacity cut as

$\hat{q}_i^a$, where for each firm,

$$\hat{q}_i^a = q_i^a - c_i.$$

This cheating behavior is a critical issue in cutting the overcapacity in China since it directly leads to the failure of meeting the policy target. In the extreme case that all the firms are facing the zero-cheating cost, the output level of regulated products will surge back to $\bar{q}_i$, which means that there is no effective production reduction happening in the market. Combined with the efficient loss, those are two major issues in the traditional command and control method.

To resolve the above issues, we introduce the permit trading scheme for the production control problem. Under the permit trading scheme, the capacity reduction quantity (capacity permit) can be traded at unit level freely across the different firms. The price of the capacity permit is determined by the supply and demand condition in the market. As a result, the problem of firm i becomes:

$$\min_{x_i, c_i}[F_i(q_i^a, c_i, x_i) + p_x x_i + D_i(c_i)],$$

where p_x is the market price for the capacity permits and x_i is the permits firm i trades. In the permit trading market, we have the market clear condition:

$$\sum_{i=1}^{n} x_i = 0.$$

The market is said to be equilibrium if there exists a nonnegative price p_x^*, such that x_i and c_i solves the firm's problem under the market clear condition, given the policy target of q_i^a. The strength of the permit trading schemes relies on the equalizing the marginal compliance cost across different firms. The economic benefits are immediately achieved by minimize the cost for each firm. Permit trading scheme may also mitigate the production cheating since it offers an additional channel to alleviate the compliance cost.

It's worth to point out that the permit trading scheme also help to control the price of the products under regulation, which is another critical issue in the capacity cut problem.

As mentioned above, to cut the overcapacity, the government must set the production cap to each firm. However, in the real world, quantifying the appropriate quantity of quota for each firm is extremely difficult. Wrongly assignment of the capacity quota may immediately lead to the dramatic fluctuations of product prices, and instability of the industries that utilize the regulation product as the intermediate goods.

In the permit trading scheme framework, we may further introduce the extra selling or buying window from the government, to control the seasonal patterns or huge fluctuations of product prices. The idea is that although the real demand of products is hard to be captured by central government, which generates the great uncertainty of products price, the permit price in the trading market is a good indicator of the demand of products. The government may intervene the ICP market by selling or buying extra permits in the market to stabilize the market. It offers an instrument from quantitative control to price control without compromising the integrity of public policy.

4 Simulation results

In this section, we experiment the simulation of the permit trading scheme. Without loss of generality, we illustrate the results in the context of two firms.[1] In order to investigate how firms' behavior changes due to the introducing of the permit trading scheme, we specify the firm's cheating in the firm's problem. As a result, we assume the firm's problem have the following form:

$$\min_{c_i, x_i}[A_i(q_i^a - c_i - x_i)^{\alpha_i} + B_i {c_i}^{\beta_i} + p_x x_i],$$

where q_i^a is the production reduction target set by the government on the firm i. It is

[1] The simulation results can be easily extended to more firms' cases.

exogenous in this model. A_i and α_i govern the marginal compliance cost and B_i and β_i govern the marginal cost of cheating of firm i.

For each firm i, it solves the following first order problems:

$$A_i\alpha_i(q_i^a - c_i - x_i)^{\alpha_i\ -1} = p_x,$$

$$A_i\alpha_i(q_i^a - c_i - x_i)^{\alpha_i-1} = B_i\beta_i c_i^{\beta_i-1}.$$

The above minimizing problem is subject to the market clear condition in the permit trading scheme:

$$\sum_{i=1}^{n} x_i = 0.$$

In a word, each firm has three instruments to achieve the capacity cut:

First, firms can achieve the production cut by simply changing their production plans. The cost of this instrument is reflected by A_i and α_i. It is convex due to the convexity of F_i, so that α_i is bigger than one. Since this channel does not rely on the cheating and the trade across different firms, we denote the cost of it as the direct compliance cost.

Second, they may cheat or misreport, and c_i represents the quantity of products misreported by the firm i. The corresponding cheating cost is governed by B_i and β_i, which represents the mean value of the penalty distribution. The cost function is convex so that β_i is greater than one. The rationale of this setting is that the probability of firms being caught increases dramatically with the increase of the cheating volume.

Third, after introducing the permit trading scheme, the production reduction target imposed on each firm can be further achieved by trading the capacity permits. The cost of this behavior is subject to the price of the permit, p_x.

In what follows we illustrate the results of the permit trading scheme by assuming both firms have the same amount production capacity to control, $q_1^a = q_2^a = 10$. Furthermore, to fix the idea, we set Firm I has the firm-specific structure which the parameter centered as $(A_1, \alpha_1, B_1, \beta_1) = (1,1.5,1,1.7)$, and Firm II as $(A_2, \alpha_2, B_2, \beta_2) = (1,1.4,1,1.6)$. We set

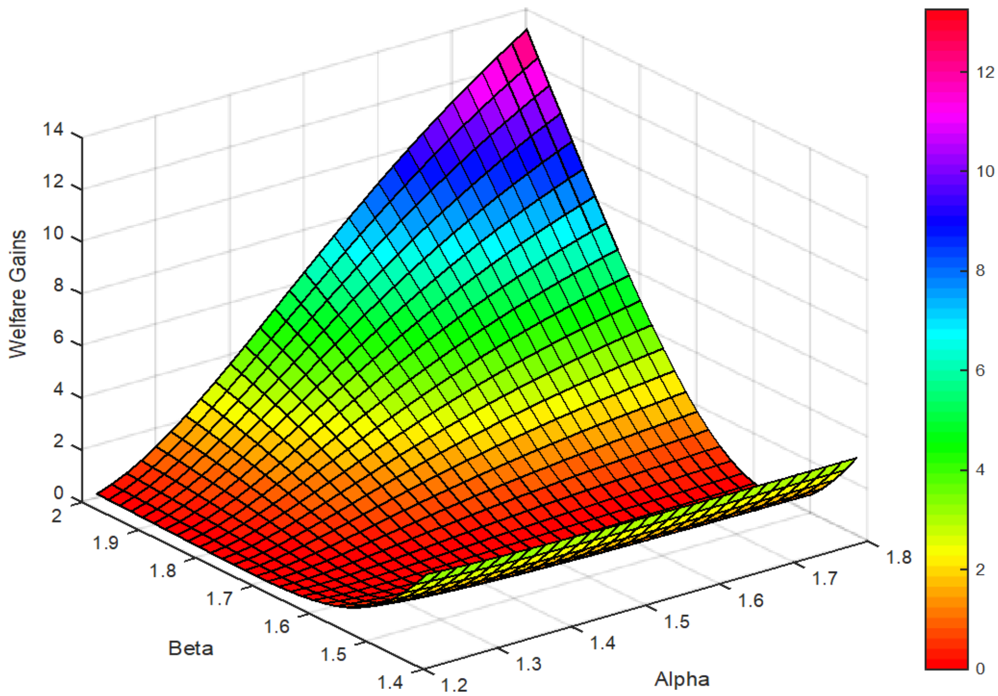
$A_i = 1$ and $B_i = 1$ for the simplicity, and letting the α_i and β_i to govern the costs of the changing of production plans and cheating respectively. To demonstrate trading, we impose the heterogeneity for two firms. As the benchmark case, we assume firm I has higher average direct compliance and cheating costs, so α_1 is bigger than α_2 and β_1 is bigger than β_2. We set β_i bigger than α_i due to the fact that the cheating cost grows normally much faster than the direct compliance cost.

Note that because of the data limitation, it is extremely difficult to estimate the real cost function of the direct compliance and cheating with the empirical data. To deal with this issue, in the following simulation parts, we adopt the different levels of relative direct compliance and cheating costs to explore the basic characteristics of the permit trading schemes. More specifically, while holding α_2 at 1.4 and β_2 at 1.6, we vary α_1 from 1.2 to 1.8, β_1 from 1.4 to 2.0 to approximate the different relative direct compliance and cheating cost function. While the magnitude of simulation results is subject to the above values we pick, the relationship between variables can shed light on the essential features of the permit trading scheme.

4.1 Welfare gains in the permit trading

To assess the variations of benefits of the permit trading schemes, we first examine the welfare gains by adopting the permit trading scheme, given different direct compliance and cheating costs of Firm I. Welfare gains are obtained by calculating the difference between aggregate social welfare with and without the permit trading scheme. The results show that all the values of welfare gains are positive in Figure 1, which indicates that, even with the existence of cheating channel, we can still improve the firm's welfare by introducing the permit trading scheme. Moreover, in this case, the welfare gain depends on the structure difference between the two firms. When the firms are identical, there will be no welfare gains by trading.[2] However, if the firms have considerable heterogeneities, a substantial welfare gain will be achieved.

Figure 1. Welfare gains by adopting the trading scheme



4.2 Trade volume in the permit trading

Figure 2 shows the trade volume of capacity permits. Positive values represent permit buying of Firm I, and negative values represent selling. Figure 2 reveals that permits purchasing is a positive function of total compliance costs. In particular, when Firm I is less efficient in terms of direct production reduction, it tends to buy more (or sell less) permits. Meanwhile, when Firm I is facing a higher cheating cost, it also tends to buy more

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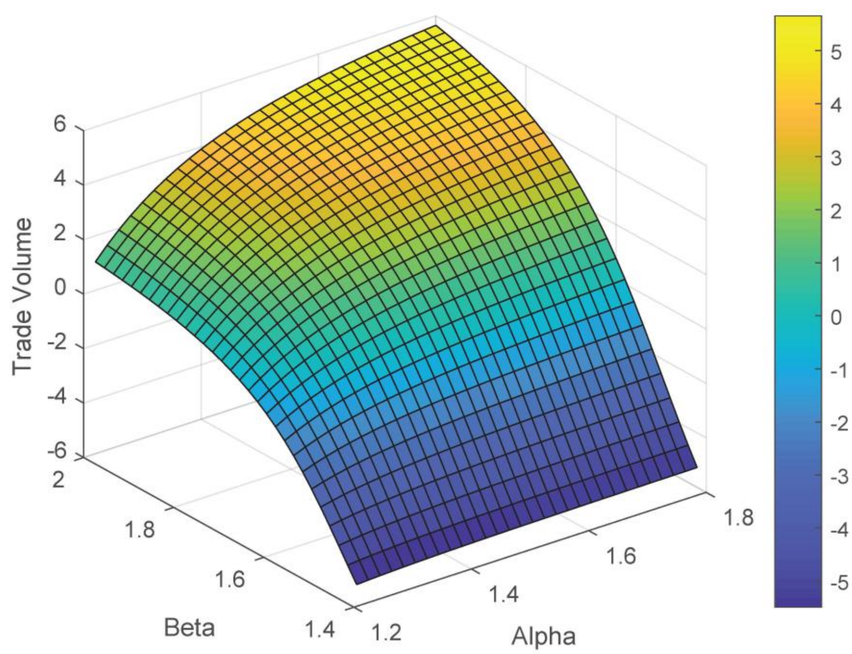
[2] Note that we set the direct compliance and cheating cost fixed for Firm II, holding α_2 at 1.4 and β_2 at 1.6. We identify 0 welfare gain when experimenting with α_1 at 1.4 and β_1 at 1.6.

(or sell less) permits. Notably, the sign of permits purchasing of Firm I depends on relative total compliance costs between two firms. Again, when there is no trading between two firms, there are no welfare gains by adopting the trading scheme, which can be verified by zero trading volume in Figure 2.

Figure 2. Trade volume when adopting the trading scheme



4.3 Firms' behaviour changes in the permit trading

A question of considerable interest is how the firm's behavior changes due to the introducing of the permit trading scheme. In particular, we focus on the impact of the permit trading scheme on the firm's cheating behavior. To answer this question, Figure 3 reveals the variations of the aggregate cheating reduction with the different levels of direct compliance and cheating costs. The aggregate cheating reduction represents the change of cheating volume due to the introducing of the permit trading scheme.

Figure 3. Aggregate cheating reduction when adopting the trading scheme

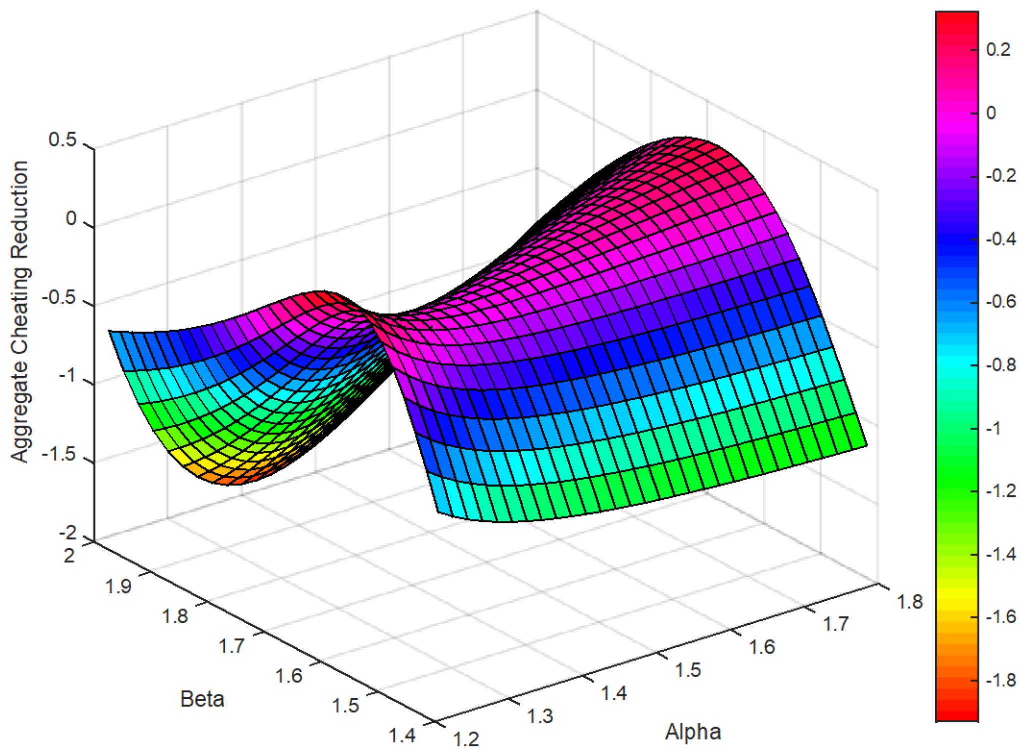
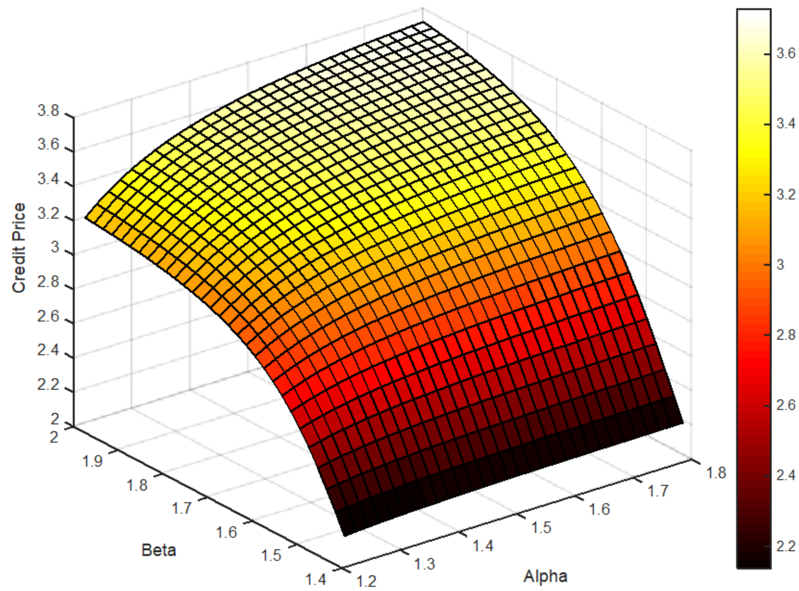


Figure 3 reveals some interesting results. First, in most of the cases, the permit trading scheme helps to mitigate the cheating, which is shown by the considerable fraction of negative values in Figure 3. It further indicates that the permit trading scheme benefits the accomplishment of the production reduction target. Second, Figure 3 also documents some positive numbers. The rationale is that, in some extreme circumstances, the firms may sell the permits in the market, and at the same time cheat much more permits to offset the permits loss. However, this may not be a critical issue when we introduce the permit trading scheme due to the limited number and magnitude of positive values in the figure. Meanwhile, in practice, this dishonest behavior can also be avoided by imposing a strict regulation on the abnormal permit buyers in the market.

4.4 Permit price in the permit trading

Figure 4 reveals the variations of permit price. Again, permit price is a positive function of the direct compliance and cheating costs. It indicates that when firm I suffers from the higher compliance cost, it has higher benefits from the permit trading, and therefore drives up the price. One point deserves further highlight is that capacity cut is usually associated with raising products prices, which can be inferred by the quota price revealed by the permit trading schemes. Based on the design of our permit trading scheme, the government can intervene the market by buying and selling the extra permits when the product price surges. In other words, the government can set the ceiling price to stabilize the market price. Note that stabilizing energy price plays a vital role in achieving energy security since it ensures the affordability of energy price in the process of capacity cut and mitigating price volatility that is damaging to the economy.

Figure 4. Permit price



4.5 Permit trade with the price ceiling

Figure 5 reveals the market equilibrium results of the permit trading scheme with a price ceiling set by government to stabilize the product markets. To illustrate the idea, we set the ceiling price as 3.6, which is around 10 percent up quantile of permit prices among all the experimental scenarios. In other words, when the market price is higher than this value, the government sells the production permits to stabilize the price. This mechanism is particularly important since the product under control is normally the intermediate goods in the other sectors.[3]

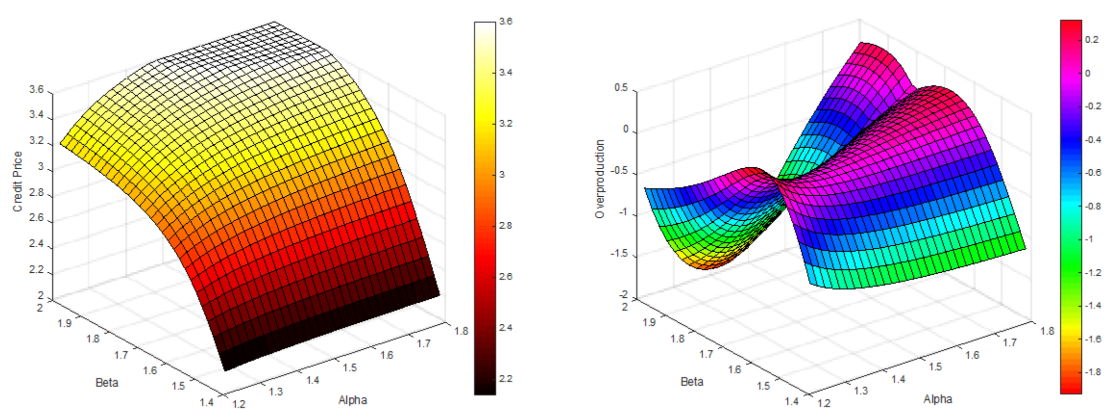
The left panel in Figure 5 shows the variations of permit price with the price ceiling. The right panel in Figure 5 shows the tradeoff between the quantity control and price control. As mentioned above, to control the price, the government has to sell the permit to the market, which leads to a higher production level. Compared to the Figure 4, the right

[3] The stabilization of coal prices has been practiced by the Chinese government in its coal sector in 2016 (NDRC, 2016).

panel documents the dramatic increase of production when the intervention occurs. We point out that the permit trading scheme provides a practical policy instrument to manage the price if the government wishes. With the further development of the future market of production quota, the price can serve as a good market signal that the government can rely on to make the policy decision. The stable public policy also increases investors' confidence in investing in more advancing technologies in energy sector and thus upgrade the industry structure for more sustainable development.

Figure 5. Trading scheme with the price ceiling

Permit price with ceiling　　　　Overproduction



Similarly, the government may also adopt the floor price in the permit trading scheme to stabilize the product markets. In other words, when the product price is lower than the floor price, the government buys permits. Since the products is determined by both supply and demand conditions, the possible weak demand of the products under control may also leads to the cheaper permits. In this case, the government may intervene the market by setting the floor price. Based on that, setting the floor price helps to accelerate the cutting overcapacity process by subtracting the production permit from the market. The simulation results are comparable to that in Figure 5.

In conclusion, based on this simple simulation, we show the benefits of the permit trading scheme. In particular, we document that the introducing of the permit trading scheme can substantially improve the total firms' welfare, given the cutting overcapacity target set by the central government. Besides, the permit trading scheme also has a huge impact on the Firms' behaviors and helps to mitigate the misreporting problem. The benefits, as well as the trade volume, will depend on the heterogeneity among firms. This implies that the more players in the permit trading scheme, the larger benefits and the more liquidity of the permit markets there will be. Therefore, a national permit trading scheme is better than a provincial permit trading one. Moreover, with the permit price as a signal, the central government can collect the information from the market and stabilize the price by market-based policy interventions.

5 Conclusion

Control and even cutting production capacity has been a practice in China for more than a decade. With the persistent low economic growth of the world economy and China's 'new normal' in economic growth, overcapacity cut has become more outstanding. The capacity cut policy and its implementation could have significant implications on energy security, energy transition and economic growth. China's overcapacity is also a global issue since China's share of production capacity in those overcapacity industries dominates the world total production.

Compared to the conventional command and control method, we propose a permit trading scheme as a market instrument to manage capacity control, which ensures the economic stability and economic security. This market instrument that is similar to the popular ITQ in fishing management and ETS in climate change mitigation, which will not only minimize capacity cut costs and reduce cheating of the firms, but also will enhance local governments' cooperation. Using China's coal industry as an example, this paper presents the operational details of the permit trading scheme, including the definition of trade boundary, the scope of producers, determination of total allowed production, the initial allocation of permits and trading of the permits.

This paper also constructs a simple partial equilibrium model to examine the benefits and firm behaviors in the permit trading scheme. The simulation results demonstrate that such a permit trading scheme will generate overall positive social welfare as well as reduce cheating behaviors of firms. This minimized welfare loss will make transition of firms away from fossil fuels more willingly and thus contribute to a fast energy transition than otherwise. The benefits of the trading scheme depend on the heterogeneity of firms: the more diversified the firms in terms of compliance costs, the higher the social welfare gains and the trade volume there will be. Mitigated price volatility through trading among heterogeneous firms will enhance energy security and mitigate negative impact on economic stability. The revealed price of permit also provides an instrument for the government to intervene the product markets without causing back-and-forth changes of public policy, which is a major barrier for investment.

The findings of this paper have important implications for the academic researchers, policy makers, and business practitioners. Frist, permit trading scheme is feasible and beneficial to be applied to achieve the capacity cut target. Based on the trading scheme, the government can stabilize the product prices through market mechanisms, which helps to enhance energy security and avoid economic instability. Given this, the China's government is suggested to introduce the capacity permit trading scheme in the current coal capacity replacement mechanism following the experience of ETS (Sun et al., 2019). Second, while the paper discusses practical issues in China, the ICP concept can also be applied in other cases. For example, a permit trading scheme could facilitate the global overcapacity issues in the steel industry. The United States and the European Union argue that excess capacity in China has distorted global steel trade and fostered unfair trade practices (Lu, 2016). With the redistribution of benefits, these economies are more likely to cooperate with each other. Third, since a larger coverage of firms is preferred to reap more benefit, a national or even worldwide capacity permit trading scheme is preferable than subnational ones when designing the trading scheme.

Despite this paper demonstrates that such a market mechanism can improve efficiency of the capacity control, it has no intention to justify the capacity cut policy itself. According to the neoclassical economics, overcapacity is a short-term phenomenon and the negative impact of overcapacity can be eliminated by market itself. However, many scholars such as Ward et al. (2004), argue that overcapacity is a long-term state and cannot be resolved by the market's own regulation and thus government intervention is required, an argument that is also held in recent publications (Zhang et al., 2019, 2017). Justification of such policies would be a good topic for the future studies. Note that the existing literature is also interested in identifying the fundamental causes of overcapacity, such as removing subsidies (Zhang et al., 2017) and correction of soft budget issues (Lin and Tan, 1999), etc. Detailed investigations on this issue, however, are beyond the scope of the current paper. In addition, a limitation of the present study is a lack of model testing with empirical data. This problem could be solved by using DSGE or CGE modelling with calibration, which are good topics for further studies.

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