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The design of renewable support schemes and CO_2 emissions in China

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HIGHLIGHTS

- Two types of FIT policies—with and without a price impact—are evaluated.
- We assess the CO_2 emissions of both schemes and their impact on economic activity.
- A support scheme with price impact is more effective in reducing CO_2 emissions.
- The price impact allows for an additional reduction of 113 Mt CO_2 in China during 2020–2035.
- Both of the FIT types have a very similar impact on coal consumption.

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ABSTRACT

The renewable energy targets put forward by the Chinese government need comprehensive incentive schemes. This paper uses a multi-regional CGE model to evaluate two types of renewable support schemes; a subsidy scheme like a feed-in tariff (FIT) with a direct price impact for final consumers and a subsidy scheme without any price impact. We assess the CO_2 consequences of both approaches, as well as their impact on economic activity in terms of GDP, industrial structure, electricity generation structure, and regional final demand elasticities of electricity. We find that a support scheme with price impact is much more effective in reducing CO_2 emissions while the difference in GDP between the two policies is small. We estimate that the price implications of the support scheme allow for an additional emissions reduction of 113 Mt CO_2—or 0.07% of total emissions—in China during 2020–2035. The support scheme with a price impact does not lead to a negative impact on the Chinese economy although there are significant differences among regions. In addition, while the whole country faces an approximately unitary electricity elasticity demand, we find significant differences in electricity demand elasticities among Chinese regions.

1. Introduction

Driven by concerns about climate change, renewable energy sources (RES) play a key role in many developed and emerging economies. As electric power generation is the most important form of renewable energy use, renewable support schemes have been introduced in various formats. Especially in Europe, feed-in tariff (FIT) systems are very attractive. As a large CO_2 emitter, China has experimented with feed-in tariff schemes since 2006. A support scheme was first introduced for wind power generation, with a FIT based on the local coal-powered generation tariff. Since then, China has put forward a series of renewable energy targets (National Development and Reform Commission, 2007; State Council, 2013, 2014). In the Intended Nationally Determined Contribution (INDC) released on June 30, 2015, the Chinese government foresees an increase of the share of non-fossil fuels in primary energy consumption up to 20% by 2030 (National Development and Reform Commission, 2015). Later at the 2015 Paris Climate Summit, this goal was further included to the new international climate agreement and has been an indispensable part of global efforts to combat climate change.

Due to the uncertain impacts of renewable support schemes on economic development, choosing the right type of FIT has been a concern in many countries (Lesser and Su, 2008; Langniß et al., 2009; Schallenberg-Rodriguez and Haas, 2012; Timilsina and Landis, 2014; Albrecht et al., 2015; Abdmouleh et al., 2015). Couture and Gagnon (2010) presented two kinds of FIT policies—fixed price and market-based price—and examined their implications

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for investors and society. Hoz et al. (2014) evaluated the costs to the Spanish electricity system caused by the old FIT policy (RD 661/2007) and a new FIT policy (RD 1578/2008) to limit the cost of renewable energy resources. Rio (2012) assessed the efficiency properties of different design elements of FITs and found significant impacts of several design elements on efficiency, of which technology-specific fixed-tariffs and floor prices are included. Relevant for the Chinese context are comments made by He et al. (2015) namely that China should adopt a dynamic adjustable FIT policy for wind power, and remarks by Liu et al. (2015) on the need to reform support schemes because of serious wind curtailment issues. Moreover, Ouyang and Lin (2014) highlighted the financial problem of renewable energy projects in China and indicated that this can be solved by providing subsidies in the short term. Hui et al. (2015) studied the crucial development thresholds of clean generation technologies in China and suggested that promotional policies such as FITs are need in the near future.

Böhringer and Behrens (2015) recently used a partial equilibrium model to investigate the interactions of emission caps and three renewable electricity support schemes in Europe, i.e. green quotas, feed-in tariffs, and feed-in premiums. They suggested that policy makers should address the overlap of emission caps and different RES policy instruments, as well as the final price consequences of the selected RES support schemes. Cho and Kim (2015) analyzed the impacts of RES policies of future Korea on environmental protection aspect and their results showed decreased CO_2 emission rates by 2040 in Korea because of the reduction of thermal power. Burtt and Dargusch (2015) linked renewable energy support schemes to emissions reductions, and compared the relative cost-effectiveness of various FIT types in Australia. However, this study did not address the social costs of the FIT policies.

The above studies show a shift of research focus from the cost of renewable support schemes to the environmental consequences. However, existing studies of FIT policy in China mostly focus on cost evaluations. In this paper, we try to fill the gap by a comprehensive analysis of the impact of FIT schemes on economic activity and on CO_2 emissions in China. In addition, this paper provides a specific multi-level perspective (national, regional and sectoral) while the above studies only focus on one or two levels.

In China, CO_2 emissions from electricity generation and heat production reached 4104.3 Mt, accounting for 50.02% of the total emissions in 2012 (IEA, 2014). Therefore, the expected transition or greening of electric power generation will inevitably affect total emissions in China. While China is committed to the achievement of its emissions reduction target (National Development and Reform Commission, 2010, 2011, 2012, 2014; State Council, 2010, 2011), we should consider the impact of various types of RES policy on the emissions reduction, as well as on macroeconomic activity.

Against this background, we contribute to the existing literature on renewable energy policy for China by focusing on the impacts of alternative renewable support schemes. We opt for a simple but transparent exercise with a FIT mechanism of which the subsidy cost is passed through to final consumers by adding a tax or surcharge on electricity consumption. This type of FIT has a direct impact on the electricity price and hence can lower demand for electricity. As an alternative, we consider a FIT policy that is financed from government fiscal expenditure, hence there is no surcharge or price impact for electricity consumers. In this paper, we compare both types of FIT policies, and investigate their impacts on the CO_2 emissions, industrial structure, and electricity market in China. In addition, we also model the reactions of households based on a discussion on the price elasticity of electricity demand in different regions of China.

The paper is structured as follows. The methodology and policy scenarios are described in Section 2. Section 3 presents our findings: CO_2 emissions, GDP, industrial structure, electricity generation structure, and households electricity demand elasticities with the two types of renewable support schemes. Finally, Section 4 concludes the findings and discusses the policy implication.

2. Methodology and policy scenarios

To assess the macroeconomic impacts of RES policy, our empirical methodology is based on the CEEP Multi-Regional Energy-Environment-Economy Modeling System (CE^3MS). This is a multi-regional computable general equilibrium (CGE) model for China and the modules in this analysis present production, commodity trading, institution, labor and capital mobility, emissions trading, and macro closure. As compared with a national CGE model, the CE^3MS is capable of capturing labor migration, capital flows, and commodity trading across regions. Hence the model can be used for regional economic planning in China. In particular, the emissions trading module and the detailed representation of power generation technologies in CE^3MS offer great advantages for climate policy assessment (e.g. on emissions trading schemes) at the national or regional level (Wu et al., 2016; Fan et al., 2016). The model is the same version that is described in Wu et al. (2016), therefore we only briefly introduce the main features in this section. In addition, we describe the modeling of RES policy in our model.

The CGE model has 30 regions and 17 production sectors in each Chinese region, including one agricultural sector, five energy sectors (*Coal*, *Crude oil and natural gas*, *Coking, gas and petroleum*, *Electric and heat power*, and *Gas and water*), seven non-energy industrial sectors, and four service sectors. The model includes one central government and 30 regional governments which all collect tax revenues from households and enterprises, and then use this income for commodity consumption, institutional transfers, government savings, or subsidies.

2.1. Feed-in tariff policy

The electric power generation in the production module is represented by eight kinds of technologies: coal-powered (*Coa*), gas-powered (*Ngs*), petroleum-powered (*Pet*), nuclear power (*Nuc*), hydropower (*Hyd*), wind power (*Win*), solar (*Sol*), and other renewable (*Oth*) technologies. A nested constant elasticity of substitution (CES) function is adopted to describe the relationship of inputs and outputs for each technology *k*. In particular, coal, natural gas, and petroleum are considered as intermediate inputs in the coal-powered, gas-powered, and petroleum-powered generation. We can summarize the model structure as follows;

$$QA_{k,r} = \alpha_{k,r}\left[\delta_{k,r}QINTA_{k,r}^{\rho_{k,r}} + (1-\delta_{k,r})QVAE_{k,r}^{\rho_{k,r}}\right]^{\frac{1}{\rho_{k,r}}},\quad k \in Coa, Ngs, Pet, Nuc, Hyd, Win, Sol, Oth \tag{1}$$

$$PP_{k,r}QA_{k,r} = PINTA_{k,r}QINTA_{k,r} + PVAE_{k,r}QVAE_{k,r} \tag{2}$$

Here, $QA_{k,r}$, $QINTA_{k,r}$, $QVAE_{k,r}$ denote the output, intermediate input, and value-added (from capital and labor) and energy input of electricity generation technology k in region r. $PP_{k,r}$ is the production cost of technology K, and $PINTA_{k,r}$ and $PVAE_{k,r}$ are the prices of its intermediate input and the use of capital, labor and energy. $\alpha_{k,r}$ and $\delta_{k,r}$ are the scale and share parameters, while $\rho_{k,r}$ is the elasticity parameters of substitution elasticity of $QINTA_{k,r}$ and $QVAE_{k,r}$.

The total electricity output is the aggregated output from all generation technologies, described by a CES function. When the