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EVALUATING DIFFERENT SCENARIOS OF CHINA'S FUTURE ENERGY CONSUMPTION AND SO2-EMISSIONS - A DYNAMIC WELFARE OPTIMISATION APPROACH

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Overview

China's expected future increase of energy demand will lead to a growth of domestic energy resource extraction and – without desulphurisation devices – to an increase of sulphur dioxide (SO_2) emissions. Different studies (LI: 2003; IEA: 2004 or ZHANG ET AL.: 2000) estimate China's future primary energy consumption in 2030 to be between 2.7 bn. and 3.9 bn. standard coal equivalents (sce). This development is putting additional pressure on a variety of energy security issues such as power shortages, transport bottlenecks of coal and gas and an increasing import dependency on crude oil and oil products (SHI: 2005; SMIL: 2004; ANDREWS-SPEED, LIAO AND DANNREUTHER: 2002).

In China, the environment is gaining an increasing role on the political agenda. Consequently, environmental considerations are likely to play a more important role in China's future energy security policy. With the promotion of a "resource saving society" in the current 11th Five Year Plan (2006-2010), energy security policy is utilised as a means to improve environmental quality and a sustainable development in China (OBERHEITMANN: 2005). Over time, resource availability and, more importantly, environmental degradation have repercussions on macro-economic welfare. Under certain assumptions, future Chinese energy security strategy constitutes an inter-temporal welfare optimisation problem subject to domestic resources availability and environmental constraints.

This paper aims at formulating a dynamic optimisation model that solves the optimisation problem mentioned above and comparing the results with China's expected primary energy consumption and SO_2-emissions reductions based on the latest IEA energy consumption forecast for China. Section 1 describes the model, which is based on the application of optimal control theory (CHIANG 1992; MEYER, MÜLLER-SIEBERS AND STRÖBELE 1998). Section 2 shows the dynamic optimisation algorithm of the energy security strategy model and solves the model providing for optimal paths of resource utilisation and SO2-emissions until 2030. Section 3 takes the dynamic optimisation model results as a yardstick to evaluate the efficiency of China's expected SO_2-emissions reduction measures in the latest IEA primary energy consumption forecast in the Alternative Scenario compared to the Reference Scenario. Section 4 summarises the paper.

Methods

The model setting is as such: together with capital (K), the consumption of fossil fuel resources (R) are defined as the inputs of production. Hence, the extraction of fossil fuel resources feeds production and simultaneously reduces the stock of resources. Net investments, defined as the difference of production (Y) and consumption, (C) will feed back into the capital stock. The stock (S) of fossil fuel resources is extracted with the rate necessary for production. In this paper, a typical Cobb-Douglas production function with constant returns to scale is assumed.

Macro-economic welfare W is a positive function of consumption and environmental quality. Production induces welfare through consumption. The production side effects, however, are SO_2-emissions from fossil fuel combustion, which lead to a reduction of environmental quality (U) and welfare by the consumption of fossil resources multiplied with the SO_2-factor μ. The dynamic optimisation system consists of four components: state (U and S) and control variables (R and C), equation of motion (i.e., the rule upon which a control variable affects the state variables), the objective function (W representing the welfare maximisation goal of the Chinese government) as well as variable start- and endpoints or transversality conditions and other constraints (these describe the lower and. upper boundaries of the integral, here the time horizon of the 10^{th} to the 15^{th} Five Year Plan (2001-2030).

Chinas future SO_2-emissions are calculated by using the IEA (2004) data on primary energy consumption, SO_2-factors for oil and gas derived from State Environmental Protection Administration of China data (SEPA: 2004) and the forecasted SO_2-factor for coal using an econometric model taking the form:

$$(1)\quad \mathrm{SO2\_FACT\_COAL} = c + \alpha \cdot \mathrm{WASHEDCOAL} + \beta \cdot \mathrm{ASSETS} + \gamma \cdot \mathrm{PI\_FUELS}$$
$$+\delta \cdot d84 + \zeta \cdot d86 + \eta \cdot d94 + \theta \cdot d95 + \iota \cdot d96 + \varepsilon$$

With WASHEDCOAL = amount of washed coal produced (in Mill. t). ASSETS = stock of fixed assets (in bn. RMB in prices of 1998) and PI_FUELS = price index for fuels in China (1998=100) and dummy variables for special factors in different years, such as d84 for 1984.

Results and conclusions

In 2030 energy consumption will be well above the welfare optimal path, both in the IEA Reference (120 %) and the Alternative Scenario (94%). With an annual growth rate of investments in SO_2-emission reduction of 1% p.a., in the Reference Scenario, SO_2-emissions will be equal to the theoretically calculated optimal path by 2030. With additional investments in desulphurisation (1.5% p.a. growth rate of investments) in the Alternative Scenario (e.g., wet and dry flue gas desulphursation and slightly increasing the share of washed coal), SO_2-emissions can even be reduced to a level of about 50% below the optimality threshold.

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