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Carbon policy in a high-growth economy: The case of China[☆]

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ABSTRACT

There is widespread concern that a stringent international climate agreement will not be reached because it would imply too high costs for fast growing economies. To test this hypothesis we develop a general equilibrium model with fully endogenous growth and estimate the policy cost for China. The framework includes disaggregated industrial and energy sectors, endogenous innovation, and sector-specific investments. We find that the governmental target of a 65 percent carbon intensity reduction until 2030 causes a welfare reduction of 0.5 percent for China, compared to the business-as-usual scenario. Costs of carbon policy for China under an internationally coordinated emission reduction amount to 4 percent of total welfare. We highlight that lower economic growth, faster energy technology development, and stronger induced innovation reduce welfare losses significantly. Increased urbanization raises the policy costs because urban households consume more energy and energy intensive goods.

1. Introduction

China has become the world's largest greenhouse gas emitter: it consumes around fifty percent of global coal extraction and generates eighty percent of its electricity with coal. At the same time, the economic growth of China has been unprecedentedly high, with an average annual growth rate of more than ten percent over the last twenty years.[1] Future climate policies are becoming one of the top priorities for Chinese policy makers as well as for the world community, which is seeking a new policy approach based on the Paris Agreement of 2015.[2]

From the perspective of applied macroeconomics, it seems rewarding to inquire into the dynamic impact of restricted input use in a high-growth economy and to derive results on the size of its effects. Notably, if climate policy requires stabilization of future carbon use, the growth rates of fossil fuel inputs in China will contrast sharply with past and current

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[1] According to World Bank data, the average annual growth rate of China was 10.1% in the periods 1991–2001, 10.9% between 2001–2011.

[2] So far, China's position has been to offer emission intensity targets but no emission cuts; we will study the different targets and their effects in detail below. Furthermore, we notice that regional pilot cap-and-trade programs are now being implemented as part of the current Chinese climate policy. This signals that the Chinese government is making efforts for the absolute emission cuts.

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income growth rates, suggesting major welfare losses with climate policies. One may also argue that a successfully growing economy is powerful in achieving a new growth trajectory. The sky-high savings and investment rates and the associated productivity development could support the necessary transition. The nexus of energy and growth is the fundamental research issue in this field. We focus on the effects of carbon policy on the economic growth.

In this paper we develop a multi-sector endogenous growth framework, including energy inputs. We argue that the assessment of climate policies, specifically in a case like China, is only accurate when we capture economic growth in an appropriate way. We use the well-known increasing-division-of-labor framework developed by Romer (1990) as the theoretical foundation of our model. Here, endogenous innovation and capital investments increase the number of goods varieties and the stock of knowledge, which supports growth by raising productivity. We extend the original theoretical framework to a multi-sector approach with energy and foreign trade; growth of each economic sector is determined endogenously. We then use the framework as a basis for a computable general equilibrium model, i.e. we calibrate the model with Chinese input output data and study the macroeconomic effects of several potential scenarios for future climate policies.

In our model, carbon policy has a negative effect on intermediates production and a positive effect on innovation and investments. Investments entail positive learning effects which are not internalized by a specific policy. Carbon policy triggers substitution in the economy on various levels. Specifically, taxes on fossil energy increase the incentives to substitute away from energy inputs. Besides this substitution effect, firms will seek new technologies to improve the productivity (or efficiency) of using energies. Firms will then redirect their investment strategy in favor of non-energy technologies or production. In the end, investments in all parts of the economy are fostered, because capital becomes cheaper relative to energy. This brings about spillover effects for the whole economy, contributing to welfare gains of climate policy. Put differently, there are secondary effects of carbon taxes, contributing positively to innovation and technology improvement. These opportunities, however, are not exploited without climate policy lies in the nature of the knowledge spillovers which are a positive externality. Each firm contributes to public knowledge but is too small to have a sizeable impact on aggregate stocks. This is why it has an incentive to invest in capital and knowledge according to its private marginal return and costs, taking aggregate capital as given.

Our results show that the implementation of the officially announced carbon policies by the government until 2030 cause a welfare cost of 0.5 percent and a reduction in annual consumption growth of 0.4 percentage points compared to the benchmark. Welfare costs of a stringent, internationally coordinated emission target until 2050 are approximately 4 percent; the annual consumption growth rate is reduced by up to 0.5 percentage points.

The study also finds that the estimated carbon policy costs increase substantially with the stringency of the policy and the assumption on the benchmark growth rate. On average, the estimated policy cost is raised by 4 percentage points with each percentage point increase of the assumed growth rate in the benchmark without policy. We also calculate the sensitivity of the results with respect to crucial assumptions on technology and innovation. Notably, assuming a favorable technical development in the energy sector reduces welfare cost of carbon policy in the long run by at least 24 percent. Moreover, introducing energy price-induced innovation reduces the cost of climate policies by 0.6 percentage points in terms of welfare. The assumption of induced innovation has a major impact on the results: with a lower effect than in our standard model, the cost of carbon policies raises significantly, while a high effect could even entail economic benefits of climate policies in the long run. We also show that increasing urbanization will lead to slightly higher costs of carbon policies because higher income and different consumption patterns overcompensate the efficiency gains.

The paper relates to the literature in three aspects. First, it contributes to the emerging strand of literature on the integration of the *natural environment* into *endogenous growth* theory. Acemoglu et al. (2012) show that the effects and the optimal timing of environmental policy in an innovation-driven growth framework with directed technical change depend on the degree of substitution between clean and dirty inputs. The effects of carbon policies in our multi-sector approach also rely on intersectoral substitution, but contrary to most directed technical change models, we assume economy-wide and not purely sector-specific knowledge spillovers.[3] Bretschger and Smulders (2012) derive with a theoretical framework that, in a multi-sector economy, increasing energy prices do not prevent an economy from having positive innovation and growth under the conditions of poor input substitution. In a similar way, the present model implements poor input substitution in most sectors of the economy. Popp (2002) empirically estimates the effects of energy prices on energy-efficient innovations, concluding that both energy prices and existing knowledge have strongly positive effects on innovative activities. The effects of energy prices on investments will be especially modeled in our approach.

With regard to climate policies, Gans (2012) derives that policies directed at carbon emissions have an unambiguously positive impact on innovation. The results of Cullen (2013) suggest that subsidies for renewable energies are only rationalized by their environmental benefits if the social costs of pollution are sufficiently high. Huebler et al. (2012) introduce endogenous technical progress into a numerical integrated climate policy assessment framework. They find that China is a main beneficiary of early technology transfer and highlight the importance of timely international technology transfer for efficiently meeting global emission targets. Finally, Allcott and Greenstone (2012) find limited scope for "win-win" opportunities with energy policy, i.e. possibilities to consume less energy without reducing welfare by removing existing inefficiencies. We derive from this literature a consensus that climate policies are costly to a degree that depends on various

[3] Investments are also targeted at specific sectors in our model but we argue it is more general to assume that sector specific improvements also build on improvements in other sectors through learning effects.