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Carbon emissions in China: How far can new efforts bend the curve?

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ABSTRACT

While China is on track to meet its global climate commitments through 2020, China's post-2020 CO_2 emissions trajectory is highly uncertain, with projections varying widely across studies. Over the past year, the Chinese government has announced new policy directives to deepen economic reform, to protect the environment, and to limit fossil energy use in China. To evaluate how new policy directives could affect energy and climate change outcomes, we simulate two levels of policy effort—a continued effort scenario that extends current policies beyond 2020 and an accelerated effort scenario that reflects newly announced policies—on the evolution of China's energy and economic system over the next several decades. We perform simulations using the China-in-Global Energy Model, C-GEM, a bespoke recursive-dynamic computable general equilibrium model with global coverage and detailed calibration of China's economy and future trends. Importantly, we find that both levels of policy effort would bend down the CO_2 emissions trajectory before 2050 without undermining economic development. Specifically, in the accelerated effort scenario, we find that coal use peaks around 2020, and CO_2 emissions level off around 2030 at 10 bmt, without undermining continued economic growth consistent with China reaching the status of a "well-off society" by 2050.

1. Introduction

Recent shifts in internal policy suggest that China's policy makers are serious about transforming the country's energy system in ways that will reduce both energy-related CO_2 emissions and air pollution faster than previously expected. The Third Plenum of the Eighteenth Congress of the Chinese Communist Party, held in November 2013 in Beijing, established major new directions for reforming China's economic, political, and social system. Environmental protection took center stage at the Plenum as policy makers pledged to support slower but more sustainable economic growth, market-based approaches to pollution control, and new efforts to build an "ecological civilization" (China Daily, 2013a). To support these objectives, specific actions announced at the Plenum included liberalizing energy prices, taxing energy-intensive and highly polluting industries, and developing taxes or quotas to control emissions of CO_2 as well as locally acting pollutants. In addition to end-of-pipe controls to reduce emissions of air pollutants, the newly announced National Air Pollution Action Plan aims to reduce the share of coal in primary energy below 65% by 2017 by implementing higher resource taxes or caps on coal use (MEP, 2013). Delivered with an unprecedented sense of urgency and importance, the Chinese government's very recent energy and environmental policy announcements necessitate new analysis to understand their impact on China's energy system and CO_2 emissions trajectory.

More aggressive action at home will inform China's domestic and international commitments to mitigate climate change. At the Copenhagen climate talks in 2009, China made a commitment to reduce the nation's carbon intensity (CO_2 emissions divided by GDP) by 40–45% in 2020, relative to 2005 levels, and to have at least 15% of primary energy produced from non-fossil energy sources by 2020 (non-fossil electricity is converted to primary energy equivalent using the average efficiency of a coal-fired power plant in China). China achieved a CO_2 intensity reduction of 21% during the Eleventh Five-Year Plan (2005–2010) (Zhen et al., 2013)[1] and targets a further reduction of 17% during the Twelfth Five-Year Plan (2011–2015). If China can

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[1] We use emissions data from China from Zhen et al. (2013), which is provided by the National Bureau of Statistics (NBS) and current as of the date of publication.

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Table 1
Production sectors included in the C-GEM.

Type	Sector		Description
Agriculture	CROP	Crops	Food and non-food crops produced on managed cropland
	FORS	Forest	Managed forest land and logging activities
	LIVE	Livestock	Animal husbandry and animal products
Energy	COAL	Coal	Mining and agglomeration of hard coal, lignite, and peat
	OIL	Oil	Extraction of petroleum
	GAS	Gas	Extraction of natural gas
	ROIL	Petroleum	Refined oil and petro chemistry products
	ELEC	Electricity	Electricity and heat generation, transmission, and distribution
Energy-intensive industry	NMM	Non-Metallic Minerals Products	Cement, plaster, lime, gravel, and concrete
	I&S	Iron & Steel	Manufacture and casting of iron and steel
	NFM	Non-Ferrous Metals Products	Production and casting of copper, aluminum, zinc, and lead
Gold and silver			
	CRP	Chemical Rubber Products	Basic chemicals, other chemical products, rubber, and plastics
	FMP	Fabricated Metal Products	Sheet metal products (except machinery and equipment)
Other production	FOOD	Food & Tobacco	Manufacture of food products and tobacco
	MINE	Mining	Mining of metal ores, uranium, gems, and other mining/quarrying
	CNS	Construction	Construction of houses, factories, offices, and roads
	EQUT	Equipment	Machinery and equipment, including electronic equipment
	OTHR	Other Industries	Other industries
Services	TRAN	Transportation Services	Pipeline transport, and water, air and land transport (passenger and freight)
	SERV	Other Services	Communication, finance, public services, dwellings, and other services

achieve a carbon intensity reduction of 3% per year during the Thirteenth Five-Year Plan (2016–2020), it will accomplish a carbon intensity reduction of approximately 44% from 2005 to 2020, well within the range of its Copenhagen CO_2 intensity reduction pledge. While China is on track to meet its Copenhagen targets (China Daily, 2013b), China's CO_2 emissions trajectory after 2020 is highly uncertain. Model projections of CO_2 emissions vary significantly and are sensitive to assumptions about future economic growth, technology cost, and climate policy (Calvin et al., 2012; Paltsev et al., 2012). The objective of this analysis is to assess the impact of these recent policy announcements on China's energy system and CO_2 emissions through 2050.

Table 2
Regional aggregation in the C-GEM.

C-GEM regional aggregation	Countries and regions included
Developed economies	
United States (USA)	United States of America
Canada (CAN)	Canada
Japan (JPN)	Japan
South Korea (KOR)	South Korea
Developed Asia (DEA)	Hong Kong, Taiwan, and Singapore
Europe Union (EUR)	Includes EU-27 plus countries in the European Free Trade Area (Switzerland, Norway, and Iceland)
Australia-New Zealand (ANZ)	Australia, New Zealand, and other territories (Antarctica, Bouvet Island, British Indian Ocean Territory, and French Southern Territories)
Developing and undeveloped economies	
China (CHN)	Mainland China
India (IND)	India
Developing Southeast Asia (SEA)	Indonesia, Malaysia, Philippines, Thailand, Vietnam, Cambodia, Laos, and Southeast Asian countries not classified elsewhere
Rest of Asia (ROA)	Bangladesh, Sri Lanka, Pakistan, Mongolia, and Asian countries not classified elsewhere
Mexico (MEX)	Mexico
Middle East (MES)	Iran, United Arab Emirates, Bahrain, Israel, Kuwait, Oman, Qatar, and Saudi Arabia
South Africa (ZAF)	South Africa
Rest of Africa (AFR)	African countries not classified elsewhere
Russia (RUS)	Russia
Rest of Eurasia (ROE)	Albania, Croatia, Belarus, Ukraine, Armenia, Azerbaijan, Georgia, Turkey, Kazakhstan, Kyrgyzstan, and European countries not classified elsewhere
Brazil (BRA)	Brazil
Latin America (LAM)	Latin American countries not classified elsewhere

At the Asia-Pacific Economic Cooperation Summit in November of 2014, China and the United States jointly announced post-2020 commitments for climate change action. China's goals include reversing the rise in energy-related CO_2 emissions before 2030 and increasing the non-fossil share of primary energy to 20%, also by 2030 (in 2015, this share was just over 11%). In June 2015, China officially submitted its intended nationally determined contribution (INDC) to the UNFCCC, adding a target to cut CO_2 emissions per unit of GDP by 60–65% from 2005 by 2030 to its earlier pledge to peak CO_2 emissions and increase the non-fossil share in primary energy consumption to 20% by the same year (UNFCCC, 2015). The United States committed to reduce total CO_2 emissions by 26–28% in 2025, relative to 2005 levels. Given that China and the United States together accounted for around 41% of global CO_2 emissions in 2010 (WDI, 2014), the pledges offer substantial contributions to global mitigation efforts. China's pledge in particular may set a precedent for other large emerging countries or regions to lay out their own reduction goals ahead of global climate talks in Paris in late 2015. This analysis seeks to quantify the impact of new policies on China's future emissions trajectory, as well as the role of several sources of uncertainty.

2. Modeling China's energy and climate policies

For this analysis, we use the China-in-Global Energy Model (C-GEM), a multi-regional simulation model of the global energy and economic system. The C-GEM is an empirically calibrated global energy-economic simulation model that is capable of capturing the impact of policy through its effect on the relative prices of energy and other goods, which in turn affects fuel and technology choices, the composition of domestic economic activity, and global trade dynamics. Developed collaboratively by researchers at Tsinghua University and the Massachusetts Institute of Technology as part of the China Energy and Climate Project, the C-GEM is constructed using methods well established in the energy systems and economic modeling literatures.

The basic structure of the model reflects the circular flow of the economy in which households supply factor inputs (labor and capital) to production sectors, which are combined with energy and intermediate inputs to produce final goods and services purchased by households. The model is formulated as a mixed complementarity problem (MCP) (Mathiesen, 1985; Rutherford, 1995) in the Mathematical Programming System for General Equilibrium (MPSGE) (Rutherford, 1999) and the General Algebraic Modeling System (GAMS) modeling language (Rosenthal, 2012). The system of equations is solved using the PATH