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The environmental improvement under China's 'New Normal'

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ABSTRACT

The significant environmental improvement in China has drawn much research attention in recent years. However, in exploring the factors that lead to pollution reduction, most literature has ignored the slowing economic growth under the 'New Normal' of China. This omission could lead to the overestimation of the pollution reduction effects of other factors. In this paper, we estimate the effect of the economic slowdown using a dynamic Computable General Equilibrium model, CHINAGEM. We find that the contribution of the economic slowdown to pollution reduction ranges from 10% to 30%. This indicates the importance of considering the economic slowdown when evaluating the effects of other factors related to the environmental improvement in China.

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Computable General Equilibrium model; environmental improvement; economic slowdown; New Normal

1. Introduction

With the rapid economic growth in recent decades, China has suffered severe environmental problems, including air pollution, water pollution, and rapidly growing carbon emissions (Chan and Yao 2008; Kan, Chen, and Tong 2012; Li et al. 2014; Rohde and Muller 2015; Shao et al. 2006). These environmental problems lead to serious health problems and economic losses (Kan, Chen, and Tong 2012; Li et al. 2014; Wang and Yang 2016; Wu et al. 1999). To address these problems, the Chinese government has issued a serious of policies and regulations, such as the environmental tax, the carbon trading system, and the deforestation ban. These measures have been shown to be effective in controlling polluting emissions and protecting the environment. For example, both theoretical and empirical evidence shows that the environmental tax has significantly reduced the emissions of different pollutants in China (He and Zhang 2018; Hu et al. 2018; Niu et al. 2018; Wang et al. 2018). China's environmental quality has been steadily improving in recent years (Tong et al. 2017; Zheng et al. 2019).

During the period of environmental improvement, China has experienced an economic slowdown since 2013 (Cai and Lu 2013; Cashin, Mohaddes, and Raissi 2017). The slowing growth with a more inclusive and sustainable economic structure is the New Normal status of China's economy. This New Normal plays an important role in

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pollution reduction through economic restructuring and slowing growth (Zheng et al. 2019). The effects of the diversified pollution control policies and the new economic situation are intertwined, so that it is difficult to identify the separate effects of the driving forces underlying the environmental improvement in China.

There is a large literature decomposing the contributions of the driving forces of the environmental improvement in China (Jiang et al. 2018; Tang, Yang, and Zhang 2016; Xiao et al. 2011; Xu and Lin 2016). These studies have focused on multiple driving factors, including energy efficiency, technological progress, economic development, environmental regulations, industrial upgrading, openness, and demographic structure (Chang, Li, and Lu 2015; Chen 2015; Du, Wei, and Cai 2012; Eaton and Kostka 2014; Glomsrød and Taoyuan 2005; Liu and Anbumozhi 2009; Wu et al. 2013; Zhang et al. 2000; Zhang 2011). However, most current research ignores the slowing economic growth under the New Normal, which could also slow the growth of pollution. Therefore, ignoring the economic slowdown would lead to the overestimation of the effect of environmental regulations, industrial upgrading and other positive efforts. To address this problem, this paper evaluates the environmental improvement that is due to the economic slowdown under the New Normal.

We adopt a dynamic Computable General Equilibrium model (CGE) for the analysis, considering the complicated mechanisms influencing the slower economic growth. Most CGE models do not allow for overcapacity and therefore are not suitable for the simulation of an economic slowdown. To relax the assumption of continuous full-capacity utilization of capital and to allow excess capacity, we build an excess capacity module by adding complementarity constraints to the CHINAGEM model, which is a mature CGE model. We then establish emission accounts for different pollutants and carbon, and link the emission accounts to the production functions in the CHINAGEM model. These modifications bring our simulation closer to reality.

Based on the simulation results from the CGE model, we find that polluting emissions could be 10% lower than the baseline scenario, due to many driving forces, including technological innovation, the change of energy structure, strengthened environmental regulation and other economic and social factors. The contribution of the economic slowdown to the reduction of the emissions ranges from 10% to 30%. For example, the emissions of NH3 in 2025 will be 4% lower compared to the baseline scenario, of which 1.17% is due to the economic slowdown. The effect varies across industries because industries have been affected to different degrees by the economic slowdown. The traditional manufacturing and processing industries such as Fertilizer, Pesticides, Chemistry, Clothes and Paper have had the largest reductions in emissions, and the advanced manufacturing industries and energy industries have been affected the least.

The remainder of the paper is organized as follows. Section 2 introduces background on the environmental improvement and the New Normal in China. Section 3 presents the CGE model and the simulation. Section 4 reports the results. Section 5 concludes.

2. The environmental improvement and the New Normal

2.1. The environmental improvement

China has made significant progress in environmental protection in recent years, and the environmental quality has improved gradually and steadily. As shown in Figure 1, the total emissions of the main pollutants in both air and water decreased over the past decade in China. Specifically, the total emissions of sulfur dioxide (SO2) dropped from 20.2 million tons in 2011 to 15.6 million tons in 2015, and the total emissions of nitrogen oxide (NOX) were reduced from 17.3 million tons in 2011 to 11.8 million tons in 2015; the total emissions of Chemical Oxygen Demand (COD) in China dropped from 3.5 million tons in 2011 to 2.9 million tons in 2015, and the total emissions of ammonia nitrogen (NH3) were reduced from 0.28 million tons in 2011 to 0.22 million tons in 2015. In addition, the growth rate of carbon emissions declined dramatically from 10.9% in 2011 to 0.33% in 2014.

2.2. The New Normal

During the period of the environmental improvement discussed above, China's economy slowed down. As shown in Figure 2, the economic growth rate was always above 7% during 1998–2012, although there were large fluctuations. However, since 2013, growth has slowed considerably, to a level of around 6–7%, and this is believed to be a permanent shift.

There has been much discussion about the factors driving the slowing growth. Most of the arguments come from the supply side of the national economy (Chen and Groenewold 2019). One argument is that the disappearing demographic dividend has

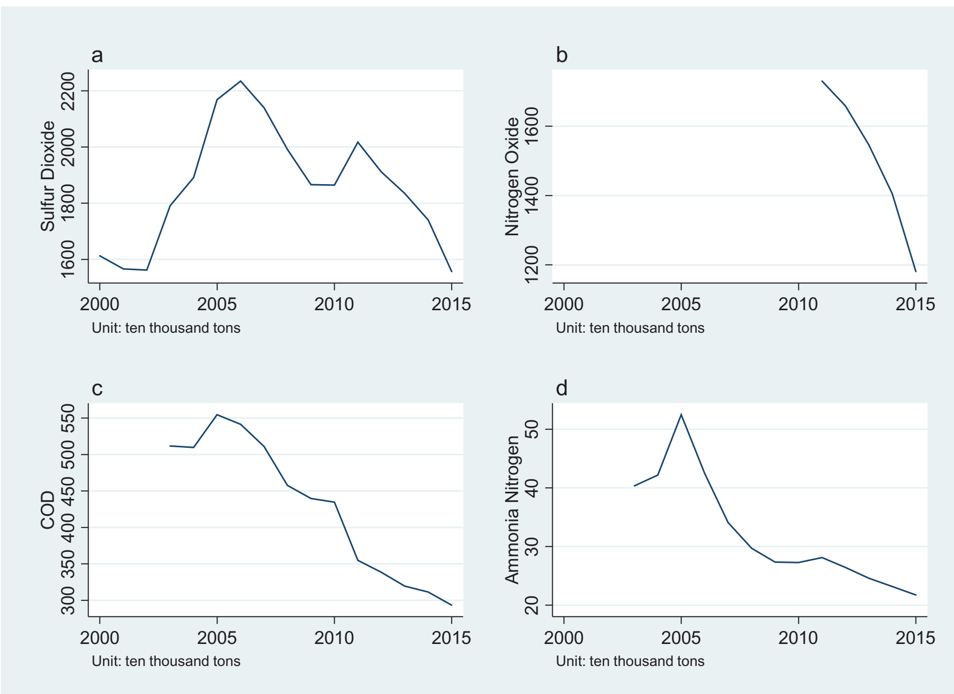

Figure 1. The total emissions of sulfur dioxide in China from 2000 to 2015 (a); the total emissions of nitrogen oxide in China from 2011 to 2015 (b); the total emissions of COD in China from 2003 to 2015 (c); the total emissions of ammonia nitrogen in China from 2003 to 2015 (d).

Source: Ministry of Environmental Protection.

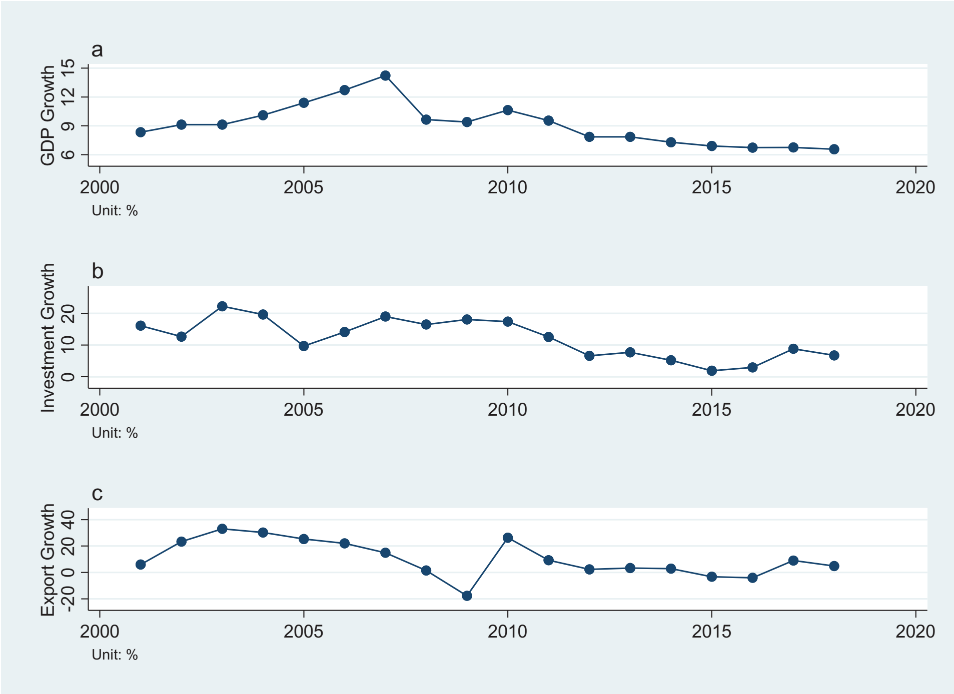

Figure 2. The GDP growth of China from 2001 to 2018 (a); the investment growth of China from 2001 to 2018 (b); the export growth of China from 2001 to 2018 (c).
Source: The National Bureau of Statistics.

dramatically raised labor costs and reduced the return on capital (Fang and Yang 2013; Zhu 2012). Another is that the long-term environmental damage, income inequality and other negative consequences constrained China's further high growth (Tyers 2014). A third idea is that the decline in Total Factor Productivity growth limited the growth potential (Lee and Hong 2010). There are also some arguments from the demand side, such as discussion of China's over-reliance on investment and exports; the point is that export growth cannot be sustained when the global economy weakens or when a trade war is looming (Lin, Wan, and Morgan 2016).

Although the reasons for the slowdown are complicated, one phenomenon is that investment and exports are weakened in an economic slowdown, no matter whether the driving forces come from the supply side or the demand side (Li, He, and Lin 2018; Lin, Morgan, and Wan 2018; Song, Wang, and Xiang 2019). As shown in Figure 2, GDP growth, investment growth, and export growth move together. During a period of low GDP, the growth rates of investment and export become low as well.

The weakened investment and exports during the slowdown are expected to decrease the number of newly registered businesses and the production of the existing industries (Bianchi, Kung, and Morales 2019; Gourio, Messer, and Siemer 2014). And the decrease in economic activities is expected to decrease the emissions of pollutants and therefore improve environmental quality, because industrial production is the main source of emissions (Schulz and Lora-Wainwright 2019).

3. Model and simulation

3.1. CGE model

We adopt a state-level Computable General Equilibrium (CGE) model for the analysis. A CGE model has the following advantages for our research. First, a CGE model better approximates the dynamics of an economic slowdown compared to an empirical method. Second, a CGE model can clarify the impacts throughout the industrial structure and extend the analysis to the sector level. Third, a CGE model can predict the long-term effects of the slowdown on the environment.

Specifically, we use a recursive dynamic CGE model of the Chinese economy, named CHINAGEM. We perform two runs for the simulation of the slowdown shock to the economy:a baseline run and a perturbation run. The baseline run provides a plausible forecast and the perturbation run generates deviations away from the baseline caused by the shocks. In this paper, the most important features of the perturbation run concern labor and capital markets, because these two markets are the most vulnerable to the economic slowdown (Dixon and Rimmer 2011).

In the perturbation run, we assume that wage rates adjust in a sticky fashion away from their baseline path as follows:

$$\left\{\frac{W(t)}{W_b(t)}-1\right\}=\left\{\frac{W(t-1)}{W_b(t-1)}-1\right\}+\alpha_1\left\{\frac{L(t)}{L_b(t)}-1\right\} \tag{1}$$

where the subscript b indicates a baseline value, and $W_b(t)$ and $L_b(t)$ are the wage rate and the level of employment in year t in the baseline. $W(t)$ and $L(t)$ are the wage rate and the level of employment in year t in the perturbation run. α_1 is the coefficient for the change in labor.

In the perturbation run, we assume that the deviation in the wage rate from its baseline level increases at a rate that is proportional to the deviation in aggregate hours of employment from its baseline level. This labor market assumption is consistent with conventional macroeconomic modelling.

The capital market in the CGE model is modeled as Equation (2):

$$\mathrm{K(j,t+1)}=\mathrm{K(j,t)}*[1-D(j)]+I(j,t) \tag{2}$$

where $\mathrm{K(j,t)}$ is the quantity of capital available for use in industry j during year t, $D(j)$ is the rate of depreciation, and $I(j,t)$ is the quantity of new capital created for industry j during year t.

The investment is determined as an increasing function of the expected rate of return as follows:

$$\frac{I(j,t)}{K(j,t)}-D(j)=f_j[EROR(j,t),H(j,t)] \tag{3}$$

where $EROR(j,t)$ is the expected rate of return, $H(j,t)$ is investment confidence, and f_j is an increasing function.

In this dynamic CGE model, the expected rate of return is determined by the current rental rate on capital. We assume that capital cannot be transferred between industries. Thus, we have

$$EROR(j,t) = g_j[Q(j,t),\cdots] \tag{4}$$

$$Q(j,t) = n_j[K(j,t),\cdots] \tag{5}$$

where $Q(j,t)$ is the current rental rate on capital and $g_j$defines the expected rate of return on investment in industry j as an increasing function of the current rental rate on j's capital and other variables such as tax rates, depreciation rates, and the cost of new units of capital. n_j is the demand function for capital in industry j and specifies a negative relationship between capital input and rental rate, reflecting decreasing marginal productivity of capital.

With this dynamic CGE model, the simulation starts from a base year for which a detailed input-output table is available. The input-output table is used to construct a model database that portrays the economy in that year. The model database provides an initial solution for the CHINAGEM equation system. The equation system has a quantity and a price variable corresponding to every value in the input-output database. A simulation under the model moves each of the components of the input-output database, and thereby takes us to another picture of the economy.

In order to model the economic slowdown, we make some improvements on the CHINAGEM model. Firstly, we update the model database to reflect the economic structure of China in the New Normal. The original model adopts the 2007 National Input–Output Table. Due to economic development and changes in industrial structure, this database cannot meet the needs of evaluating the economic slowdown, which started around 2012. Therefore, we update the central database comprehensively by using the 2012 National Input–Output Tables of China, which were published recently by the National Bureau of Statistics. Secondly, we build a new module to simulate the excess capacity under the slowdown, as excess capacity is one of the main features of an economic slowdown or economic crisis. We discuss the Excess Capacity module in detail below.

3.2. Excess capacity module

CGE models commonly use production functions with labor and materials treated as variable inputs. Capital is treated as fixed in the short run, and the level of capital input is determined by past investments. This treatment of capital relies on the assumption of continuous full-capacity utilization. With this assumption, the main features of an economic slowdown cannot be modeled, because an economic slowdown always causes both excess capacity and low returns on capital. We therefore drop the standard full-capacity utilization assumption and allow for excess capacity. Leaving capital stock idle is a rational response under a slowdown or recession, even when capital can be substituted for other factors, because fixed costs exist for keeping plants open.

To allow for excess capacity, we introduce sticky adjustment in rental rates. Without the sticky adjustment assumption, we would view rental rates as prices that adjust instantaneously to clear the market for the services of the existing capital stock. With the sticky adjustment assumption, rental rates adjust sluggishly, implying that some of the existing capital stock is left unemployed in a downturn. Specifically, we introduce a distinction between capital in use in industry j for year t $[KU(j,t)]$ and capital in existence in industry j for year t $[KE(j,t)]$. During a slowdown, capital in use in each industry is allowed to fall below capital in existence. The sticky rental adjustment mechanism is modeled by the following equations:

$$\left\{\frac{Q(j,t)}{Q_b(j,t)}-1\right\}=\left\{\frac{Q(j,t-1)}{Q_b(j,t-1)}-1\right\}+\alpha_2\left\{\frac{KU(j,t)}{KE(j,t)}-1\right\}+S(j,t)\ for\ all\ t \quad (6)$$

$$\mathrm{Q}(j,t)=n_j(KU(j,t),\cdots)\ for\ all\ t \quad (7)$$

$$S(j,t)=0\ \text{for t}<t_c(j) \quad (8)$$

$$S(j,t)\geq 0\ \text{for t}=t_c(j) \quad (9)$$

$$KU(j,t)=KE(j,t)\ for\ t\geq t_c(j) \quad (10)$$

$$KU(j,t)\leq KE(j,t)\ for\ t \quad (11)$$

where $Q(j,t)$ and $Q_b(j,t)$ are the rental rates in industry j for year t in the perturbation and baseline runs, $S(j,t)$ is a slack variable used for complementarity, α_2 is a positive parameter, and $t_c(j)$ is the year in which industry j regains full-capacity utilization. Beyond $t_c(j)$, the full capacity is assumed to be maintained.

Equation (6) shows the sticky rental adjustment specification and Equation (7) is the capital demand equation derived from the condition that the rental on capital is the value of the marginal product of capital in use.

3.3. Pollution accounts

To link the environment with slowing growth, we set up pollution accounts in the CGE model as follows. First, we collect both national-level and industry-level pollution data from the Ministry of Environmental Protection, including data on sulfur dioxide, nitrogen oxide, COD, ammonia nitrogen and carbon dioxide. Second, we add pollution variables $\mathrm{P}(p,j,t)$ into the CGE model. p represents the type of pollutant, and $\mathrm{P}(p,j,t)$ indicates how much pollutant p industry j discharges in year t. We assign initial values for these variables according to the empirical data. For those industries that lack industry-level pollution data, we break up national-level pollution data according to energy structure and assign initial values to each industry. Third, we calculate emissions based on energy utilization:

$$\mathrm{P}(p,j,t)=\beta(e,p,j)*C(e,j,t) \quad (12)$$

where e represents the type of energy, and $C(e,j,t)$ is the quantity of energy e that industry j uses in year t. $\beta(e,p,j)$ is a parameter that defines emissions of pollutant p when industry j expends one unit of energy e.

3.4. Simulation

In the simulation, we focus on the slowdown of investment and exports, because these are the main phenomena of an economic slowdown. We make the scenarios as consistent as possible with the slowdown. To achieve this, the shocks are set as follows.

We impose a negative shock on the investment confidence variable to simulate a new investment environment under the New Normal. Though investment is endogenously determined by the economic system, investment confidence is treated as a constant and exogenous variable in CHINAGEM, as in most other dynamic CGE models.

We also impose a negative shock on the exports variable. In a global CGE model, exports are endogenously determined by many factors. However, because we are using a single-country CGE model, the exports variable can be considered exogenous. Rising labor costs, a weaker global economy, and the growing trade war between China and the U.S. are the main causes of declining exports.

4. Results

4.1. Macroeconomic impact of the slowdown

Figure 3 illustrates the real GDP growth, the simulated GDP growth in the baseline run, and the simulated GDP growth in the perturbation run. It shows that the simulated GDP growth in the perturbation run is quite close to the real GDP growth, which confirms the accuracy of our simulation.

The simulated macroeconomic results are summarized in Table 1. It indicates that the weakened investment and exports reduce the output of the economy, and the decreasing output leads to falling employment, declining wages, and shrinking household consumption. Specifically, under the slowing growth, employment in 2025 is 1.21% lower than the baseline scenario. As many as 9 million jobs in China are likely to be wiped out due to the slowing growth.

4.2. Environmental impact of the slowdown

The simulated environmental results are also summarized in Table 1. It projects that the slowing growth will cause carbon emissions to decline by 1.51% in 2025, implying that the economic slowdown benefits the environment.

We further explore the environmental impact in the most polluting industries, including Chemistry, Paper, Plastic, Fertilizer, Pesticides and others. The results are summarized in Table 2. Take the chemical fertilizer industry as an example: its production is projected to drop by 7.92% by 2025, reducing emissions of sulfur dioxide by 32587 tons. The nitrogen oxide, COD and ammonia nitrogen produced by the chemical fertilizer industry is expected to decline by 11558 tons, 6978 tons, and 4085 tons, respectively. By contrast, the effect is not obvious for the automobile industry or the coal industry.

To evaluate the overall effects of the economic slowdown on the environment, we calculate the arithmetic mean of the growth rate of emissions from 2010 to 2015, and take this as the predicted trend of emissions. We also estimate the contribution of the economic slowdown to the reduction of emissions from 2015 to 2025 by running the simulation in the CGE model. Results are summarized in Figure 4. It shows that the

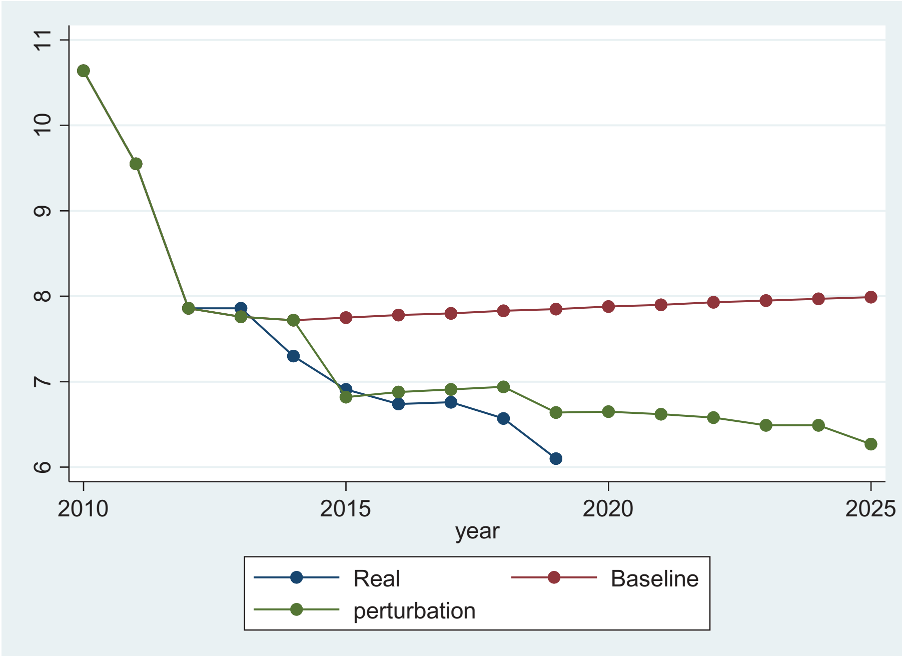

Figure 3. The real GDP growth, the simulated GDP growth in the baseline run of the CGE model, and the simulated GDP growth in the perturbation run of the CGE model.
Source: CGE model.

Table 1. The macroeconomic impact of the slowdown scenario from 2015 to 2025.

Variable	Macro variation in 2025 compared to baseline (%)	Macro variation in 2025 compared to baseline (100 million RMB)	Baseline Data in 2024 (100 million RMB)
GDP	−1.32	−15998	1211988
Employment	−1.21	−9.47	782.34#
Consumption	−1.71	−9367	547697
Foreign import	−1.72	−4067	236459
CPI	−0.44	-	-
Real Wage	−0.62	-	-
Export price	−0.03	-	-
Carbon Emission	−1.51	−192.23	12731^

The unit is one million people.
^ The unit is one million tons.
Source: The CGE model.

economic slowdown contributes between 10% and 30% to the reduction of emissions, implying that the slowing economic growth is not negligible when discussing China's environmental improvement in recent years.

5. Discussion

A growing literature has studied the driving factors behind China's environmental improvement, but most of these studies neglect the effects of the economic growth slowdown called the 'New Normal.' This may overestimate the effects of other

Table 2. The environmental impact of the slowdown scenario for industries in 2025.

Industry	Output variation compared to baseline (%)	The emission reduction of SO2 (tons)	The emission reduction of NOX (tons)	The emission reduction of COD (tons)	The emission reduction of NH3 (tons)
Fertilizer	−7.92	32587	11558	6978	4085
Pesticides	−5.85	1616	681	1459	142
Clothes	−3.61	891	256	851	78
Chemistry	−3.00	600	186	359	18
Paper	−2.67	23854	9957	29917	994
Plastic	−1.59	1126	272	139	13
Automobile	−1.30	156	87	211	13
Coal	−1.21	1863	679	1826	55

Source: The CGE model.

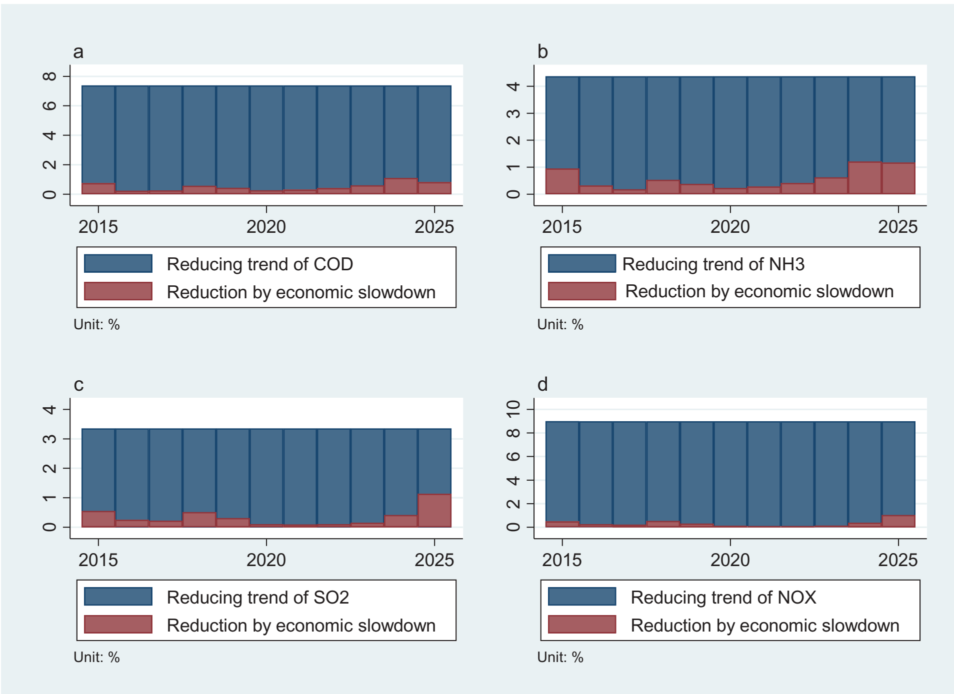

Figure 4. The predicted decreasing trend of polluting emissions and the contribution of the economic slowdown in China from 2015 to 2025.
Source: The CGE model.

contributors to the environmental improvement, such as technical progress, environmental regulations, etc. Therefore, in this paper, we use a dynamic CGE model to simulate the effect of the New Normal on polluting emissions.

We find that the economic slowdown under the New Normal is playing an important role in environmental improvement in China. The contribution of the economic slowdown to the reduction of emissions is in the 10%-30% range. The impact of the slowdown on emission reductions varies by industry. For instance, the fertilizer industry and paper industry significantly reduced emissions (Table 2), while there is not much effect for automobiles or coal.

The simulation also explores the macroeconomic impacts of the economic slowdown. The results show that the weaker investment and exports during the slowdown reduce the output of the economy. The decreasing output leads to falling employment, wage, and household consumption. As many as 9 million jobs in China are likely to be wiped out due to the slowing growth, compared to the no-slowdown scenario.

We are aware that these results are obtained under assumptions. For example, the energy structure and energy efficiency are assumed to be fixed during the simulation. That is, technological progress stimulated by the economic slowdown is overlooked in this model. Relaxing these assumptions is a direction for future research.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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