



Environmental Benefits From Carbon Tax in the Chinese Carbon Market: A Roadmap to Energy Efficiency in the Post-COVID-19 Era

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Because of China's global responsibilities to address climate change, the country has made a commitment to limiting the growth of future emissions using policy measures, such as funding mitigation research and regulating energy efficiency requirements directly. Extensions of these policies, such as the measures to improve energy efficiency, use of carbon taxes, and changes to the mix of electricity generation in the country, are also of interest to China. This article applied a computable general equilibrium (CGE) model to examine the effects of such energy efficiency and climate change policy options in the post-COVID-19 era in the China economy. The study findings show that even modest measures can have significant effects on emissions with marginal economic impacts, given the current level of development in the China electricity generation and transportation sectors. It is estimated that a 5 RMB per ton carbon tax will reduce emissions by 4.1% and GDP by 0.27%. Emissions drop by 8.2% and GDP drops by 0.54% when energy efficiency increases by 2% across the China economy, respectively. As a final result, a 5% shift away from burning coal would reduce emissions by 9.0%, while GDP would increase by 1.3%. It has been shown that even low carbon taxes can encourage a notable cleaner energy system.

Keywords: carbon market, carbon tax, energy efficiency, climate change, computable general equilibrium model

INTRODUCTION

Steadily increasing carbon emissions are a major threat to environmental change (Yan et al., 2021), which represents both evolving countries' main ongoing anxiety for the developed economies (Akram et al., 2020; Irfan et al., 2020; Yumei et al., 2021). Economic development in developing countries requires thorough use of oil, which may lead to environmental degradation by extra waste and residues (Zhang M. et al., 2020; Elavarasan et al., 2021b; Khan et al., 2021; Wang et al., 2022). A large proportion of CO₂ emissions come from the use of fossil fuels (Elavarasan et al., 2021a; Irfan et al., 2021a; Dagar et al., 2021; Qiu et al., 2022), for example, coal, the key energy source of car industries, which is closely linked to the economic progress (Iqbal et al., 2019a). Electricity played the most significant role throughout the cycle of economic development. Capital investment flows have been the subject of research in Asian markets over the current years (Iqbal et al., 2021b; Shao et al., 2021). This issue can also be a cause for concern due to their high

uncertainty and deficit in the financial structures linked to the turbulent situation in emerging markets and the detrimental impact of financial crises in Latin America, Asia, and Russia (Iqbal et al., 2021a; Chien et al., 2021b; Mohsin et al., 2021).

In the mid-1990s, the latter became a vital category among the three groups of private capital flows, that is, direct foreign investment, portfolio investment, or bank loans. Its proportion of private venture capital in emerging market economies has increased substantially, suggesting a more conservative stance by foreign equity investors (Baloch et al., 2020; Yu et al., 2021; Rao et al., 2022). The assistance to storing energy is seen by governments across the world and in the United States as an essential component of grid decarbonization (Iqbal et al., 2019a; Yumei et al., 2021). Government corporations in China have approved legislation designed to improve the renewable energy mix using bulk storage that often defines the surrogacy target in terms of storage capacity (MW) or power (MWh) (Irfan et al., 2021a; Hao et al., 2021; Rauf et al., 2021; Yang et al., 2021). The MEP has, along with the NDRC, adopted two process-oriented policy measures since 2014 in order to eliminate pollution causing pollutants from coal-fired power plants: 1) a regulation on volatilization (Zhao et al., 2020a), sweat reduction, and dust collection equipment, and 2) an electrical quality advantage for units that have the environmental appliance (Zhao et al., 2020b). It would make it possible for the former to introduce by raising the cost obstacles to their implementation (Li Z. et al., 2021). The required instrument suggests that the government is ready for standardized environmental equipment to be used by coal-fired power plants, but the reliability of implementation was not as high as anticipated due to the high operation and maintenance costs.

As a provisional instrument for providing economic incentives, the electricity pricing premium works. Both instruments are a mix of “carrots and sticks,” but as the climate is widespread among potential carbon-fired power plants, price premium opportunities may appear excessive and be slowly reduced in order to increase the cost-effectiveness in general (Hou and Xu, 2020; Wu B. et al., 2021; Irfan et al., 2021b). Environmental tax can enable the electricity price premium to be implemented effectively by providing additional incentives to install environmental equipment for power stations (Wang L.-W. et al., 2019; Yam et al., 2019). Increased renewable energy (wind and solar) has reduced savings (Irfan et al., 2019a, 2019b; Iqbal et al., 2019b; Nuvvula et al., 2022), with overall lower prices and thus low cutting levels leading to a reduction in financial benefits both for centralized and distributed cases (Li et al., 2018; Wang L.-W. et al., 2019). Improved thermal storage efficiency also contributed to increased savings on the network as a whole, although they were smaller on the consolidated case per unit of energy (Majumder et al., 2019; Zhang J. et al., 2020). The errors in the thermal environment may be triggered. Improved electric car efficiency contributes to lower savings for the dispersed case, but a modest improvement for core cases. Greatly increased CO₂ emissions contribute to higher commodity costs under both the concentrated and localized management systems, thereby offering a marginal gain for production (Fang et al., 2021; Islam et al., 2021). Greater demand indicates that the model is

limited since capacity generation for specific scenarios is established, thereby increasing the demand (Rivera, 2017; Dolter and Rivers, 2018). The model is not significant. Reducing demand in both instances significantly reduced savings, while the effect was much stronger for distributed cases, and that is due to the fact that consumers flatten irrespective of the system; when the price differentials are not sufficiently large, they lose out because of operating stock losses; that is, additional energy needed for storage operations is more costly than the ripples (Fahria et al., 2021). Increases in gas and coal fuel prices lead to increased cash reserves both in centralized and distributed situations, while centralized modification is reduced. One exception is the distributed gas increase scenario case that can be stated by consumer herding.

Previous studies suggest that system emissions tend to increase profit or value trying to maximize income (Yi et al., 2018; Asbahi et al., 2019; Wang S. et al., 2019). Nevertheless, shifts in the carbon dioxide process operating approaches and practices have not been studied (Ahmad et al., 2021; Ali et al., 2021; Li Y. et al., 2021; Jinru et al., 2021; Tanveer et al., 2021; Elavarasan et al., 2022). We address this idea directly by assuming that the well-established decreases in carbon emissions associated with generating income and reducing pollution might be attenuated by alternative operating strategies aimed at reducing emissions. To check that, a computable general equilibrium (CGE) model is used to maximize the trade-offs among the emissions, energy usage, and pollution intensity by calculating the carbon tax to fund energy efficiency and climate change mitigation programs.

Carbon tax and energy efficiency measures are being compared to show how they affect the Chinese industrial sector, as well as CO₂ emissions reduction. Thus, this work contributes to the discussion on how to design policies and strategies that can be implemented in the fields of energy, environment, and sustainability.

This article is organized as follows: *Literature Review* outlines the methodology, *Method and Data* summarizes the findings and sparks discussion, and *Results and Discussion* summarizes the implications for policy-makers.

LITERATURE REVIEW

Carbon taxes are the subject of the earliest scholarly investigation in this area. Standard taxation and collection methods are at the heart of the carbon tax policy design as a useful resource management and environmental tool (Liu et al., 2020). Scholars have devised the carbon tax user cost theory in an effort to improve the framework for theoretical analysis of carbon taxes (Ding et al., 2020). Many studies have shown that a fair tax on resources not only ensures that consumers pay their fair share of the costs but also has the potential to improve the environmental impact of resource use (Liu Z. et al., 2021). According to Boadway and Keen, 2010, the user cost of resources in South Africa was calculated, and a discussion was held about the country's resource tax rate. Even though resource taxes can reduce CO₂ emissions and improve resource utilization efficiency, economic growth suffers as a result (Zhou et al., 2018).

In addition, the effectiveness of China's carbon regulation is being examined, as are the country's carbon intensity, scale, and performance (Chen et al., 2020; Wu H. et al., 2021). SOEs' performance will suffer more if the central government sets a higher carbon intensity reduction target than they already have (Liu et al., 2018). The output size and carbon intensity are the two most important determinants of changes in CO₂ emissions, and the mining industry as a whole should put forth more effort to meet the peak target.

Since the 1980s, a lot of scholars have studied carbon taxes (Lin and Jia, 2018; Fremstad and Paul, 2019; Hájek et al., 2019). According to academics, the green and blue dividends of carbon taxes are mutually reinforcing (Carattini et al., 2019; Hagmann et al., 2019; Razzaq et al., 2021). A carbon tax's revenue can be used to offset other business taxes, improving the economy and spurring more employment and investment (Metcalf and Weisbach, 2009). In addition to this, it can improve environmental quality (the "green dividend"). Energy conservation and efficiency can be improved by carbon taxes based on these findings (Ojha et al., 2020). Reduced CO₂ emissions can be achieved through the use of carbon taxes (Zhu et al., 2020). When the level of GDP per capita is high (Yu, 2020), environmental taxes may have a positive impact on economic growth (An and Zhai, 2020). Taxes on carbon have been shown to have a negative impact on energy production (Cheng et al., 2021). Reducing pollution through a fee on polluting goods and services (Rathore and Jakhar, 2021), increasing capital (Sabine et al., 2020), and decreasing pollution using a premium or subsidy are all possible outcomes of a pollution tax (Wang et al., 2021). However, because of the benefits carbon taxes provide, Tiwari et al., 2021 believe that the negative impact on GDP caused by carbon taxes is acceptable. Similar and wide-ranging studies have been conducted in the United Kingdom (Jiang and Yang, 2021), the United States of America (Carroll and Stevens, 2021), China (Ma et al., 2020), and India (Liu Y. et al., 2021).

In resource and environmental policy analysis, the CGE model is widely used (Chen et al., 2020; Mehleb et al., 2021; Sun and Yang, 2021). As a result of taxation, a variety of macroeconomic variables are affected (Li and Yao, 2020). Many academics build national-level CGE models to find the best resource tax rate (King et al., 2019; Li L. et al., 2021; McAusland, 2021). China's dynamic macro CGE model, for example, was developed by Liu and Hu (2015), and it investigated the effect of carbon tax on the rural economy of China. Liu et al. (2018) developed China's dynamic CGE model to examine the macroeconomic and resource environment's impact on resource tax policies. A consequence of this is that some researchers are now concentrating more on local issues rather than more global ones. Researchers in China's Guangdong Province have developed an energy computable general equilibrium (CGE) model, and found that a carbon tax is more effective at cutting emissions and saving energy than a similar consumption tax. According to Hu et al., 2021, a carbon tax in Shanxi Province could affect employment by using the dynamic CGE model.

Comparative analyses of carbon taxes can be seen from the earlier research review, but few of these previous comparisons are

available (Denstadli and Veisten, 2020; Runst and Thonipara, 2020; Fu et al., 2021). The use of energy, emissions of carbon dioxide (Luo et al., 2021), and macroeconomic effects have all been the subject of numerous studies (Li et al., 2020; Tovar Reaños, 2020); however, only a few studies have examined the environmental impact of carbon taxes. Using data from China's input-output table and the computable general equilibrium (CGE) model, we examined the effects on energy efficiency and environmental protection of increasing carbon taxes. China's carbon tax reforms can be aided by this study's findings, and it can also serve as a model for other countries.

METHOD AND DATA

It is easy to understand how economic factors act and react when using the general equilibrium model, which provides a simplified depiction of the economy (Bourgeois et al., 2021). For the general equilibrium model, prices and values are simultaneously adjusted to establish the equilibrium and optimization conditions, unlike traditional macro-level models such as linear programming models or input-output models (i.e., the income equilibrium condition, market clearing condition, and zero-profit condition) (Nie et al., 2020). In other words, prices and values in general equilibrium models are both endogenous variables, unlike in linear programming and input-output models (Boonmee et al., 2021). In other words, finding the endogenous variables was the primary goal of solving the general equilibrium model (i.e., equilibrium prices, values, and incomes) (Chien et al., 2021a). General equilibrium models, unlike econometric models, require data and fewer statistics, and use data from a reference year instead of a wide range of data and periodic statistics. Other econometric studies' statistics and data on elasticity can be used. According to the calibration method, the general equilibrium model's parameters are derived from the data and statistics of the reference year.

Model Selection

This article applied a general equilibrium model that incorporates a carbon tax policy module in order to evaluate the economic effects of carbon tax policies, emission reduction, and energy-saving (Dumortier and Elobeid, 2021). Assuming the market factor flow and clearing, the model is constructed. In order to improve the standard CGE model, we make the following modifications: 1) the factor accounted energy components are divided into subgroups. The CGE model does not break down the energy elements. It was decided to separate energy from fuel oil and natural gas for this article based on China Energy Statistical Yearbook (2018) and data from those sources. The energy components were analyzed separately from the fuel oil and natural gas components. Energy is supplied by the Cobb-Douglas function. Subdividing the energy sector is necessary for tracking changes in energy consumption and simulating the effects of carbon tax policies. The mining industry is divided up in the production module. Input-output data from China cover the coal and oil and gas industries, as well as the mining and processing industries for ferrous, non-ferrous,

TABLE 1 | China macro-SAM 2017 (billion RMB).

Receipts	Activities	Labor	Commodities	Households	Capital	Tax	Enterprises	Savings-investment	Government
Activities		230397							
Labor	42,975								
Commodities	146320				32,683		12,622		37,283
Households			42,975	3,368			6,943		
Capital	31,413								
Tax	9,687				1,220	3,275			
Enterprises				28,045					
Savings-investment					19,385	24,769	5,382		
Government								14,183	

and non-metallic metals, as well as the auxiliary mining activities (2017). In China, the tax rates on various resources vary. Consequently, the mining industry was broken down to simulate China’s carbon tax policy. In order to assess the environmental impact of various tax policies, CO₂ and air pollutant emissions were included in the output module.

This article uses neoclassical closures. Commodity markets were cleaned up. At a given price and exchange rate, the quantity of goods becomes endogenous imports, and exports are quantitatively unlimited. The general equilibrium condition is satisfied as long as all domestic goods are available.

$$Q_s = \sum_a QINT_{ca} + \sum_h QINV_c + Q_{ch} + QG_c, \quad (1)$$

where Q_s indicates the commodity supply in the Chinese domestic market, INV_c is the investment demand for the commodity, and Q_{cd} is the consumer demand of commodity c of household h .

$$GDP = \sum_c \sum_h QH_{c,h} + QINV_c + \sum_c QG_c + \sum_c (QE_c - QM_c). \quad (2)$$

Data

The social accounting matrix (SAM) is the base data for the CGE model’s calculations. There are two rows and two columns in a SAM for each account. Each cell displays the transfer of funds from the column’s account to the row’s account. Consequently, the income and expenditures of an account are displayed in its column and its row, respectively. The sum of each SAM account’s revenue and expenditure is equal to its total revenue (row total and column total).

All of the economic system’s production modules are described in detail by SAM. The factor input is where the household and industrial sectors get their income in a social accounting matrix. Consumption and production are linked in an economic cycle because of the link between income and demand for consumption. The SAM was constructed using data from the “China’s input–output table” (2017), China Tax Yearbook (2018), China Statistical Yearbook (2019), Energy Statistical Yearbook of China (2018), China Environmental Statistical Yearbook (2018), and the National Bureau of Statistics. The 2017 China macro-SAM is shown in **Table 1**.

TABLE 2 | Coefficients of carbon emission from various energy sources.

Energy	Coefficient of coal	Coefficient of CO ₂ emission
Coal	0.77	2.04
Coke	1.04	3.06
Crude oil	1.53	3.24
Gasoline	1.58	3.14
Kerosene	1.58	3.24
Diesel oil	1.56	3.32
Fuel oil	1.53	3.40
Natural gas	1.42	2.31

Research questions necessitate the decomposition or aggregation of data when compiling a social account matrix. Because of China’s current energy, the mining industry status, and the available data, the production sector was divided into 35 sectors. Agriculture is the main economic activity. Farming, forestry, animal husbandry, fishery and water conservancy; coal mining and dressing; petroleum and natural gas extraction; ferrous metals’ mining and dressing; non-ferrous metals’ mining and dressing; non-metal minerals’ mining and dressing; other minerals’ mining and dressing; logging and transport of wood and bamboo; food production; beverage production; tobacco processing; textile industry; leather, furs, down, and related products; petroleum processing and coking; raw chemical materials and chemical products; medical and pharmaceutical products; chemical fiber rubber products; plastic products; non-metal mineral products; smelting and pressing of ferrous metals; metal products ordinary machinery; equipment for special purpose; transportation equipment; electric equipment and machinery; electronic and telecommunications equipment; instruments, meters, and cultural and office machinery; other manufacturing industry; scrap and waste; electric power, steam, and hot water production and supply; gas production and supply; tap water production and supply; construction; transport, storage, postal, and telecommunication services were all included in the secondary industry’s categories. Transportation, wholesale, retail, and other tertiary industries comprised the tertiary industry.

The air emission module’s relevant parameters needed to be set up, and that was a major focus of this article. We used the following methods: analyzing and contrasting the CO₂ emission

TABLE 3 | Simulation scenarios' setting.

Carbon tax policy	Tax
Case 1	5 yuan/ton of CO ₂
Case 2	10 yuan/ton of CO ₂
Case 3	40 yuan/ton of CO ₂

parameters of various energy sources. **Table 2** shows the CO₂ emission coefficients of various energy sources based on data from Zhou and Hong (2018), China's Energy Statistical Yearbook, and the 2006 IPCC national greenhouse gas inventory guidelines.

$$En_{CO_2} = \sum_i E_i \times S_i \times Ef_i. \tag{3}$$

where En_{CO_2} energy consumption is the sum of all the CO₂ emissions that result from that consumption, E_i indicates the energy consumption, S_i represents the standard coal conversion coefficient for a variety of energy sources; and Ef_i represents the emission rate of CO₂.

RESULTS AND DISCUSSION

China does not have a carbon tax at this time. Carbon taxes have been advocated by a number of academics. There are more reasonable arguments in favor of such a tax based on the findings of the results. Although a 40 yuan/ton CO₂ carbon tax on production sector energy consumption is assumed, there is no carbon tax on residential sector energy emissions. It was decided to gradually raise the carbon tax because there is a widespread belief that high tax rates harm the economy (Li G. et al., 2021). All three scenarios (scenario 1, scenario 2, and scenario 3) were run in order to see how the carbon tax would affect the economy and the economy's ability to absorb CO₂ emissions. A carbon tax is a factor that reduces energy use and, as a result, CO₂ and other emissions from air pollutants. Taxes on carbon also increase the tax burden on businesses, which is detrimental to business and household income gains as well as

to economic growth in general. For businesses, household income, and national economic growth, this is not a good thing. **Table 3** displays the finalized simulation scenarios.

Carbon Tax Effect on Energy Efficiency

In the first year of implementation, by imposing a carbon tax, China's carbon emissions are reduced by 1.1%, and the cumulative reduction is 9.8%. **Table 4** shows that the decrease in carbon emissions caused by the use of coal is responsible for a large portion of the decline (8.2%). Because coal is the primary source of energy and most carbon-intensive fuel in China, this is expected. Liquefied petroleum gas (LPG), gasoline, and diesel oil will all contribute to a 2.3% reduction in greenhouse gas emissions. Regardless of the carbon tax, natural gas-related carbon emissions have increased by 5%. Natural gas and other carbon-free power generation technologies are replacing coal-fired plants in the electricity industry as a result.

Macroeconomic Effects

However, environmental benefits come at a price, as GDP shrinks and household income drops as a result of these changes. There will be a 0.1 and 0.6% decrease in real GDP growth in 2015 and 2020, respectively. **Table 5** shows how much each component of GDP contributes to the overall change in GDP. It demonstrates that falling of total consumption, investment, and government spending have all contributed to a decline in real GDP over time. The total consumption and investment will both shrink by 0.6%, while government spending will fall by 0.1%. By 0.2%, exports have grown, while imports have decreased by 0.4%. **Table 6** depicts the changes in price indices across the entire economy. Despite a cumulative drop in the CPI of 0.1%, aggregate real consumption will shrink by 0.6%. Consumption declines are linked to a 1.2% real income reduction for all households. The nominal factor returns are decreasing, which in turn reduces real household income and nominal household income, as shown at the bottom of **Table 5**. The combination of falling income and rising unemployment has a negative impact on household spending.

Though energy prices have risen due to the carbon tax, the GDP price deflator has decreased (**Table 5**). Higher energy prices

TABLE 4 | Carbon emissions from different sources of energy.

	Energy efficiency			Energy efficiency + energy mix		
	5 yuan/ton of CO ₂	10 yuan/ton of CO ₂	40 yuan/ton of CO ₂	5 yuan/ton of CO ₂	10 yuan/ton of CO ₂	40 yuan/ton of CO ₂
	% change	% change	% change	% change	% change	% change
Coal	5.05	7.9	9.15	-0.95	-2.81	-5.38
Coke	-0.09	-0.19	-0.28	-0.72	-2.13	-4.14
Crude oil	-0.11	-0.23	-0.35	-0.76	-2.24	-4.34
Gasoline	-0.14	-0.29	-0.44	-0.27	-0.83	-1.64
Kerosene	-0.15	-0.33	-0.52	-0.55	-1.61	-3.16
Diesel oil	-0.17	-0.34	-0.52	-0.34	-1.00	-1.99
Fuel oil	-0.12	-0.27	-0.39	-0.92	-2.71	-5.19
Natural gas	-0.17	-0.34	-0.51	-0.39	-1.16	-2.29
Total CO₂ emissions	-4.1	-5.91	-6.14	-4.9	-14.49	-28.16

TABLE 5 | Macroeconomic effects.

Variables	Base value (billion RMB)	Energy efficiency			Energy efficiency + electricity mix		
		5 yuan/ton of CO ₂	10 yuan/ton of CO ₂	40 yuan/ton of CO ₂	5 yuan/ton of CO ₂	10 yuan/ton of CO ₂	40 yuan/ton of CO ₂
		% Change	% Change	% Change	% Change	% Change	% Change
Consumption	32,779	-0.26	-0.28	-0.31	-0.01	-0.016	-0.03
GDP	84,320	-0.27	-0.45	-0.55	-0.11	-0.32	-1.02
Imports	15,270	-0.35	-0.46	-0.57	-0.11	-0.32	-1.03
Exports	16,759	-0.59	-0.96	-1.32	-0.34	-1.01	-2.19
Labor force	43,101	-0.037	-0.049	-0.061	-0.06	-0.17	-0.56
stocks	2,562	0.26	0.28	-0.29	-0.02	-0.06	-0.21
Government spendings	45,326	-0.43	-0.63	-0.82	-0.18	-0.55	-1.76
Secondary industry value-added	36,431	-0.25	-0.26	-0.29	-0.02	-0.05	-0.16

TABLE 6 | Effects on industrial-level output.

	Energy efficiency			Energy efficiency + electricity mix		
	5 yuan/ton of CO ₂	10 yuan/ton of CO ₂	40 yuan/ton of CO ₂	5 yuan/ton of CO ₂	10 yuan/ton of CO ₂	40 yuan/ton of CO ₂
	% Change	% Change	% Change	% Change	% Change	% Change
Farming, forestry, animal husbandry, fishery, and water conservancy	-0.16	-0.17	-0.18	-0.11	-0.12	-0.12
Coal mining and dressing	-0.14	-0.15	-0.15	-0.10	-0.10	-0.11
Petroleum and natural gas extraction	-5.52	-7.73	-8.83	-0.08	-0.10	-0.11
Ferrous metals' mining and dressing	-0.27	-0.28	-0.30	-0.19	-0.22	-0.25
Non-ferrous metals' mining and dressing	-0.60	-0.63	-0.66	-0.42	-0.46	-0.51
Non-metal minerals' mining and dressing	-0.40	-0.42	-0.44	-0.28	-0.31	-0.34
Other minerals' mining and dressing	1.87	1.96	2.06	-0.61	-0.67	-0.74
Logging and transport of wood and bamboo	-0.70	-0.74	-0.77	-0.49	-0.54	-0.59
Food production	1.70	1.90	2.13	-0.49	-0.52	-0.55
Beverage production	-0.17	-0.18	-0.19	-0.13	-0.13	-0.14
Tobacco processing	-0.13	-0.14	-0.14	-0.09	-0.10	-0.10
Textile Industry	-0.60	-0.63	-0.66	-0.42	-0.44	-0.47
Leather, furs, down, and related products	-0.23	-0.23	-0.24	-0.16	-0.17	-0.18
Petroleum processing and coking	-0.36	-0.37	-0.37	-0.25	-0.27	-0.28
Raw chemical materials and chemical products	-0.51	-0.57	-0.64	-0.36	-0.38	-0.40
Medical and pharmaceutical products	2.34	2.62	2.94	-0.24	-0.25	-0.27
Chemical fiber	2.60	2.91	3.26	-0.42	-0.46	-0.50
Rubber products	-0.15	-0.17	-0.19	-0.11	-0.11	-0.12
Plastic products	-0.30	-0.34	-0.38	-0.21	-0.23	-0.25
Non-metal mineral products	-0.60	-0.70	-0.82	-0.42	-0.46	-0.50
Smelting and pressing of ferrous metals	1.90	2.22	2.60	-0.63	-0.75	-0.89
Metal products	2.60	3.04	3.56	-0.42	-0.46	-0.50
Ordinary machinery	1.50	1.76	2.05	-0.35	-0.39	-0.42
Equipment for special purpose	2.60	3.04	3.56	-0.42	-0.50	-0.59
Transportation equipment	3.00	3.51	4.11	-0.21	-0.25	-0.30
Electric equipment and machinery	1.80	1.87	1.95	-0.56	-0.67	-0.79
Electronic and telecommunications equipment	-0.80	-0.83	-0.87	-0.56	-0.62	-0.68
Instruments, meters, and cultural and office machinery	1.20	1.25	1.30	-0.14	-0.15	-0.17
Other manufacturing industry	-0.70	-0.80	-0.91	-0.49	-0.54	-0.59
Scrap and waste	1.20	1.25	1.30	-0.14	-0.15	-0.17
Electric power, and steam and hot water production and Supply	-0.70	-0.73	-0.76	-0.49	-0.54	-0.59
Gas production and supply	2.40	2.50	2.60	-0.28	-0.31	-0.34
Tap water production and supply	-0.20	-0.21	-0.22	-0.62	-0.69	-0.75
Construction	-0.45	-0.47	-0.49	-0.53	-0.58	-0.64
Transport, storage, and postal and telecommunications services	-0.50	-0.52	-0.54	-0.35	-0.39	-0.42

have a smaller effect on output prices than lower labor and capital costs, which is the primary reason for this. Companies cut back on production as a result of rising energy costs. Due to the fact

that the primary factor demand is linked to output levels, companies reduce their employment, resulting in lower wages for the entire economy. Lower output, in turn, means lower

profitability, and lower profitability means a lower return on capital. As a result of the lower cost of capital, demand for investment goods and the production are reduced, resulting in an overall decrease in investment.

Table 5 shows the impact of the general level of prices and falling output prices on the export price index. Because of this, trade terms deteriorate and the real exchange rate depreciates, resulting in lower prices. Both of these factors make China's exports more competitive in the global market, resulting in an overall increase in exports. Exports of semiconductors, which account for about 80% of total exports, are particularly strong. This is why the semiconductor industry is expanding its output (**Table 6**). As a result of the depreciation of the real exchange rate, the demand for imports has decreased (Dorsey-Palmateer and Niu, 2020).

Most industries see their output shrink as a result of the carbon tax (**Table 5**). This is especially true for those companies, whose demand for carbon-emitting fuels decreases. Coal is the industry that has had a hardest hit. Its output drops by 0.5% in the first year and by 9.7% as a result of the carbon tax. Carbon-emitting fuel consumption will fall by 2.3% as the economy reduces its use of fossil fuels. Also, the "crude oil and natural gas extraction" industry is expected to see a 1.7% decrease in production output. Non-ferrous metals' mining and the dressing industry have the highest output decline among non-energy-producing industries. In part, this is due to the industry's reliance on carbon-emitting inputs, such as coal-intensive cement manufacturing.

That is exactly what we would expect from this. A total of 22.6% of coal-fired electricity generation's output will be reduced due to the carbon tax, which has the most significant effect on this industry. It also encourages the use of oil and natural gas as well as carbon-free sources of energy in the electricity sector such as hydropower, geothermal power, and renewables, which are less carbon-intensive than coal. Energy output from hydrothermal, geothermal, and renewable sources has increased by 20, 14.5, and 14.8% over the past few years. Additionally, electricity generated from natural gas and less carbon-intensive oil is up by 3 and 7.9%, respectively. Natural gas accounts for 28% of the electricity generated, while oil accounts for only 11.5%. As a result, the increase in electricity output from natural gas production is greater than the increase in oil production.

Discussion

For economists, policy scientists, and policy-makers who want to put a price on carbon, the issue of optimal carbon pricing mechanisms has long been hotly debated. Some researchers argue that a direct carbon tax was imposed, and others advocated the introduction of cap-and-trade. One-third of the group argued that both policies were identical (i.e., that a particular cap-and-trade system can imitate a carbon tax, and *vice versa*). Accordingly, an in-depth examination of the green economy's growth determinants is considered important. Public spending changes are viewed as a key indicator for this study. Government spending as a percentage of GDP ranges from 20 to 45%. (Aly et al., 2017). Over the last decades, a number of countries across the globe have achieved healthy economic

growth. However, such economic achievements made those countries the higher emitters of CO₂.

Based on the results of a simulation, we can see what happens to the entire economy. The findings showed that non-energy sectors and electricity generation efficiency are both improved by 2%. The efficiency gains will result in a reduction in total carbon emissions of 4.1% below 5 Yuan per ton CO₂ emissions. There is a total of 5.05% cumulative reduction in carbon emissions in the coal-burning scenario and 0.95% in the diesel, fuel oil, natural gas, and gasoline scenarios. There has been a slight increase in the emissions of LPG and other petroleum products, but greater reduction in emissions from other more carbon-intensive fuels has offset these emissions. Unlike a carbon tax, natural gas emissions fall in this scenario, whereas they rise in the latter. Real GDP increased by 0.3% compared to the baseline, and it is expected to increase by another 1.9%. Investment and consumption account for 1.7% of the GDP growth in total, making them the two main components. Exports are declining and imports are rising, which has resulted in lower real GDP growth. Wages rise in response to an increase in the supply of labor, which in turn leads to an increase in output. As output increases, rents (for both capital and land) rise, which in turn boosts industry profitability. As a result of this increased profitability, investment goods production and demand will rise by 0.8%. The export price index rises as the cost of local production rises. Increasing export prices result in a real exchange rate of 0.59% and a trade term improvement of 0.46%. Due to these two factors, cumulative exports will be 0.73% lower, imports will rise by 0.23% as the real exchange rate rises, and the cost of imported goods decreases. The well-being of families can be improved through the implementation of efficiency measures. The higher primary factor returns do help them, and it is true. Real GDP increased by 0.32% compared to the baseline, and it is expected to increase by another 1.6%. Investment and consumption account for 0.64% of the GDP growth in total, making them the two main components. Exports are declining and imports are rising, which has resulted in lower real GDP growth.

As a result of greater energy efficiency, most industries have seen an increase in output (**Table 5**). Energy-producing industries, whose output decreases as a result of increased energy efficiency, are the exception here. Oil-fired power generation will increase output by 0.2%, while renewable power generation will increase output by 3.3%, with the electricity sector expected to see the most growth. The well-being of families can be improved by implementing efficiency measures. Higher primary factor returns do help them. The final policy simulation examines an alternative electricity generation mix policy following efficiency gains in the previous simulation. Over the next 3 years, coal will be phased out in favor of renewable energy. For the most part, there are few notable differences between this and the energy efficiency simulation. Total carbon emissions will be reduced by 17.32%, which is 3.15% points more than if only efficiency improvements had been implemented. Because it reduces emissions by 8.1%, coal is to blame for the discrepancy. Electricity generated from renewable sources will rise by 12.21%, while output from coal-fired power

plants will fall by 10.18%. The output of petroleum and natural gas extraction increased by 5.52% as a result of lower natural gas prices. In comparison to the previous scenario, an identical shift in the output of alternative energy sources can be observed.

CONCLUSION AND POLICY IMPLICATION

Although the Chinese government's emissions targets are clearly ambitious, there must be some doubt as to whether it has sufficient policy instruments under its direct control to encourage businesses and households to act in a way that ensures these targets are met. This study was conducted to fill the void left by the lack of previous research on the impact of carbon taxes on China's energy, environmental, and economic sectors. The study findings show that the effects of a carbon tax on China's economy have been examined, and the results show that the country's energy efficiency will be improved, and also energy consumption and carbon dioxide emissions will be reduced under three scenarios of taxation.

Policy Implication

According to the findings of this study.

1. Carbon dioxide emissions are slightly more affected by taxation without compensation than when households receive a lump sum payment for their taxes.
2. It has been found that if a government has no budget deficit, a tax based on the carbon content of each energy carrier can better align energy pricing with the government's goal of reducing greenhouse gas (GHG) emissions.
3. Carbon taxation with revenue redistribution is therefore an effective policy for increasing social well-being and reducing emissions, even if external effects due to improved environmental quality are not taken into account.
4. For a 100% reduction in pollutant emissions, a carbon tax of 50% would be required, according to model simulations. Emissions can be reduced by as much as 50% under suggested scenarios if taxes are imposed, which is the minimum reduction.
5. Carbon taxes should be enacted regardless of the availability of a suitable basis for calculating energy prices, given the positive effects on welfare, unemployment, energy savings, and

reductions in pollutant emissions. This is true as long as the labor tax is decreased, and the total tax revenues of the government remain constant.

6. The policy of carbon tax is only recommended insofar as it reduces other taxes and revenues, such as income tax, employer-provided unemployment insurance, and social security benefits. Labor taxes can be negative in order to keep total tax revenues the same.

Research Limitation and Future Direction

Additional production inputs (instead of energy labor and capital), markets, and production sectors can be added to the selected model in future works. In this case, a more flexible production function can be an important consideration, such as translog instead of CGE. Competition and constraints, as well as uncompetitive conditions, are the starting points for the selection of equations in most general equilibrium studies. It has been performed in a similar way in the current study with Iran's economy as the only uncompetitive condition taken into account. Other uncompetitive economic conditions can be incorporated into the general equilibrium model in future studies.

A carbon tax that applies to every sector of the economy, fossil fuels of all kinds, and all regions of the country cannot achieve the goal of implementing a carbon tax policy that internalizes the external costs of emissions. As a result, this study's 30% tax rate does not imply that the earlier considerations are not important. Different tax rates can be compared in future studies, including household and production sectors, to see how they affect the economy and environment.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary materials; further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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