Co-benefits between carbon pricing and the Environmental Protection tax in China

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Abstract

China's environmental protection tax (EPT) has been implemented since the beginning of 2018 to conquer the severe air pollution problems. Meanwhile, carbon tax (CAT) has been approved as the most effective way on climate mitigation. However, the combined effects across different environmental taxes on emission reduction have not been comprehensively characterized. Besides environmental taxes, changes in trade policy between countries may also influence pollution emissions, which also needs a deeper investigation. In order to provide insights for decision-making on air pollution mitigation under an uncertain worldwide trade policy, we simulated the effects of the combinations of EPT and CAP changes on air pollutants emissions and economic activities. Utilizing a multiple-province computable general equilibrium (CGE) model, we quantify the emissions changes resulting from the individual or mixed policy components: including variating EPT from 2yuan per kilogram emissions to12yuan/kg, CAT from 50yuan per tonne CO2 emissions to 300yuan/tonne. Our results show that although CAP policy may result in greater emission reductions than that of the EPT, the EPT policy is more cost-effective to the CAP policy. Besides, CAP is most redundant to the EPT, while the EPT is complementary to a CAP policy. On province level, in most provinces, carbon pricing could increase the air pollution mitigation but also strengthen the burden of GDP at the same time, while Heilongjiang, Tianjin, Jiangsu, Hainan, Guangxi and Jiangxi provinces could result in air pollution reduction and GDP

increase. Provincial distribution is vital for regional equality. We suggest to introduce relative smaller tax rate on provinces who suffer large GDP loss, or provide subsidies to these provinces.

Key words: Carbon tax, Environmental protection tax, co-benefits

1. Introduction

Climate change and air pollution are major environmental problems, which threatening the sustainable development in China. The main response to these challenges are formulating best environmental policy [1, 2]. Market incentive tools, such as environmental taxes, trade schemes and subsidies, are widely used by policymakers as the viable way to foster economic growth while mitigating its environmental impact [3, 4]. Environmental taxes, including carbon tax [5-7], resource tax [8, 9] and environmental protection tax [10, 11] are popular tools to reduce CO_2 and air pollutants emissions. As CO_2 and a number of short-lived air pollutants share similar sources, pursing co-benefits of introducing air pollution and climate change mitigation policies are probably significant for control environmental problems with lower costs [12]. Making comparisons between these taxes is therefore an essential part of mitigation analysis.

With the urgent needs of climate change mitigation, during the 2015 Paris COP21, China released to peak its CO_2 emissions around 2030 and the carbon per unit of GDP will be reduced by 60%-65% from the 2005 level [13]. To achieve this goal, China launched the national carbon emission trading system in 2017 [14]. Comparing to the emission trading system, taxing has the advantage of creating a stable price [15], which is also the most efficient way to reach climate targets [5, 6]. The previous studies indicated that the carbon price required for limiting global mean warming to 2 °C is between US$16 and US$73 per tonne of CO_2 in 2015 [6]. Here, in this study, we evaluated the effects of a comparable carbon tax (CAT) from 50 RMB/ton to 300 RMB/ton on pollution mitigation in China.

In order to control the air pollution related haze problem, Chinese government has implemented the Environmental Protection Tax (EPT) law since the beginning of 2018 [16]. This is China's first tax clearly designed for environmental protection, which helps to establish a "green" financial and taxation system and promote pollution control. The EPT law replaced the "pollution discharge fee", and targeted enterprises and public institutions that discharge listed pollutants directly into the environment, including air, water and noise pollutants, as well as solid waste. Very few studies have been analyzed the effects of EPT law, they found that the current level of EPT can only slightly reduce air pollutants emissions in China [10], while simultaneously increasing the tax rate of EPT and reducing the household income tax might achieve the double dividend [17]. For regional inequality, the EPT might alleviate urban-rural inequality but may not improve the inter-provincial inequality [11].

Carbon tax is designed for CO_2 mitigation, while EPT is levied for air pollution control. However, either policy may lead to significant co-benefits from mitigating both air pollutants and CO_2 emissions. Hu et al. has pointed that the EPT in China has even a higher reduction rate on CO_2 emissions than other short-lived air pollutants [10]. Other studies also indicated that carbon policies also have co-benefit to air quality improvement and human health benefits [18-20]. This paper intends to integrate both policies and analyze the impacts of the mixed EPT and CAT policies.

The assessment of China's EPT and CAT, as well as the tariffs on pollution emissions are done based on the multi-region and multi-sector dynamic Computable General Equilibrium (CGE) model. The simulations are conducted from 2007 to 2020. The EPT is introduced from 2018, and carbon tax will be collected in 2020. The 25% tariffs changes for all goods are set in 2020. Firstly, we compare the effects from individual policies of EPT, CAT and TAR. We then combine these three policies together and examine its advantages and disadvantages over a single policy.

The paper is organized as follows. Section 2 describes the CGE model and data that we used for the analysis of distributive impacts. Section 3 presents the results and analysis. Section 4 draws concludes and discusses policy implications.

2. Methodology

2.1 CGE model

We employ a multi-region multi-sector CGE model for China. CGE model is the vital tool to assist environmental policymaking, which attempts to capture interactions between environment and society. In this study, we extend the earlier CGE model to include both CAT module and the EPT module. A detailed algebraic description of the model and the relative parameters are provided in Hu et al. [10], we here briefly provide an overview of the model.

The CGE model is based on the principles of general equilibrium theory. It integrates rational economic agents' behavior with the equilibrium conditions assumption, which describes the interactions of the price-dependent market, economic agents and income spending based on microeconomic theory. Firms minimize production costs with the inputs of intermediate goods from other sectors and the primary factors of production from households. Consumers maximize welfare under the reward from their supply to firms of factors of production (labor, capital and resources) and income from government transfers. Income earned thus is spent on goods, services and savings. The government collects tax revenues used for consumption, investment and household transfers. Energy resources are included in the CGE model as primary factors whose use is associated with the emissions of carbon dioxide (CO_2) and air pollutants. Nested constant-elasticity-of substitution cost functions are applied to characterize substitution possibilities between inputs in production, consumption and trade of goods. In this model, the labor is intersectorally mobile but immobile across regions. Capital is both intersectorally and interregionally mobile.

There are three tax modules in this model, including CAT module, EPT module and TAR module. The tariffs are levied on all import goods to increase or decrease the import prices. The CAT and EPT module are described as follows.

2.2 Carbon tax module

As most of human-produced CO_2 emissions come from the burning of fossil fuels [29], in this study, carbon tax are levied on CO_2 emissions from fossil energy consumption in production process [30, 31]. We model the provincial energy-related industrial CO_2 emissions as

$$E_{R,A} = QA_{R,A} * \varepsilon_{R,A}$$

where $E_{R,A}$ represents the total emissions from sector A in region R; $\varepsilon_{R,A}$ represents the carbon emission coefficient per production activity. The carbon emission coefficient is calculated based on regional and sectoral emissions and production activities, and then capture technology improvement with the parameters of energy efficiency and total productivity factor following Liu [32] and Lou [33] in each year.

Thus, we can calculate the carbon tax rate for each sectors in each region as

$$ctax_{R.A} = E_{R.A} * TAX/(QA_{R,A} * PA_{R,A})$$

where TAX is the specific duty rate of the carbon tax in RMB/tonne and it is an exogenous policy variable. In this study, 50-300 RMB/ton of carbon tax will be levied on industrial sectors without covering agriculture, transportation and residential sector; $QA_{R,A}$ is the production for sector A in region R; $PA_{R,A}$ is the market price of the products in sector A. Therefore, we convert the specific duty rate into ad valorem tax rate $ctax_{R,A}$, and the market price of fossil energy will be $\left(1 + ctax_{R,A}\right) * PA_{R,A}$. Then, the carbon tax would directly affect the cost of fossil energy, which would affect the production and the whole market.

2.3 Environmental Protection Tax module

According to China's EPT Law, the first three air pollutants with the largest quantity in emissions should be levied on the taxes, which are varying from 1.2 RMB to 12 RMB per pollution equivalent in difference provinces (see Table S1 in the Supplementary Information) [16]. The air pollution equivalent is calculated based on the emissions and pollution equivalent index. These indexes are provided in the EPT Law, which takes into account the harmfulness of the pollutants and the costs for controlling them. Results showed that sulfur dioxide (SO_2), nitrogen oxides (NO_X), and carbon monoxide (CO) are the first three items for each region among the pollution equivalent for SO_2, NO_X, PM, CO, non-methane volatile organic compounds (VOCs), primary organic carbon (OC), ammonia (NH_3) and black carbon (BC) [10]. We then impose the EPT as an ad valorem tax on energy input (emissions from combustion) and production output (emissions from production process). The detailed equations are described in our previous study [10].

2.4 Data

We compiled the 2007 social accounting matrix (SAM) for China's 26 provinces and 4 cities, except Tibet, Hong Kong, Macao and Taiwan. The SAM tables were compiled using interregional input-output tables, China Statistical Yearbook, China Finance Yearbook and China Taxation Yearbook. The SAM tables describe the economic linkage among activities, commodity and agents (including household, government, enterprise, investment and savings). 30 sectors are provided in the initial SAM tables, we aggregated them into 12 commodity groups for this study purpose (the definition of sector is shown in Table S2 in the Supplementary Information).

Provincial emission inventories are from PKU-Inventories and Wu et al. [34] for VOCs species. The emissions used in this study include energy-related emissions (emissions from fossil fuel combustions) and process-related emissions (emissions from production processes). Energy-related emissions are subdivided into 30 sectors based on sectoral energy consumption data, which include 8 energy types (i.e., coal, coke, gasoline, kerosene, diesel, fuel oil, liquefied petroleum gas and natural gas) [22, 35]. Process-related emissions are calculated as the activity data (industrial output) multiplied by the emission factors (emissions per output) based on previous studies [10, 17, 36].

2.5 Model Scenarios

The baseline or Business-As-Usual (BAU) scenario is simulated from 2007 to 2020, which is driven by the growth rates of capital, labor and total factor productivity. The history growth rates are obtained from national statistics, and the forward protections (including the energy efficiency) are followed other simulations [32, 33]. The robust and the uncertainties of the model have been validated in our previous studies [10, 17].

We also simulate additional policy scenarios to examined the effects of the change of individual tax, including China's environmental protection tax (EPT, tax rates ranging from 1.2 RMB/kg to 12 RMB/kg), carbon tax (CAT, tax rates ranging from 50 RMB/ton to 300 RMB/ton) and tariffs (TAR, with 25% increase or decrease for all goods between all countries and China, see Table S? in the supporting information). Each policy scenario is applied in the CGE model to constrain total air pollutants and carbon emissions from the corresponding sectors of the economy. We compare each policy scenario to the BAU, where no taxes are introduced. We calculate air pollution equivalent value as a comprehensive index to indicate the air pollution problems caused by different air pollutants. We then define the EPT efficiency and CAT efficiency as the ratio of emission reduction rate to GDP loss based on the previous study [37]. Changes in emissions and economic output under each policy scenario are evaluated for each sector and region in 2020.

3. Results and Discussion

We applied the provincial CGE model to simulate these three groups of policy scenarios over the period 2007-2020. We allow the EPT levied on 2018, and CAT and tariffs levied on 2020. We focus on the short-term responses of the economy as well as air pollution emissions to each policy and all our discussions are based on results for 2020.

CAP policy may result in greater emission reductions than that of the EPT

Figure 1 shows the CO_2 and air pollutants reductions under both CAP and the EPT policies. To enable a meaningful scenario, we set the CAP policy from CNY 50 to CNY300 per tonne based on recent studies, and the EPT vary from CNY2 to CNY12 per pollution equivalent based on the current law. We found that applying CAP in China may result in greater air pollutants' emission reduction (approach 8%) than those of EPT (less than 3%), which means that implementing a carbon tax in the context of the EPT policy could significantly increase the CO_2 and air pollutants' emission reductions.

The emission reduction rates differ across air pollutants. Results show that the largest emissions reduction rates are for SO_2, CO_2 and NO_X in both CAP and EPT scenarios. The reduction rates for SO_2, CO_2 and NO_X represent respectively 3%, 2.8% and 2.6% reductions under EPT-12 scenario (Figure 1(a)), and those air pollutants yield 2 times larger emission reduction rates (7-8%) under CAP scenario. To gain insight into the co-benefits of these two policies, we showed the changes of sectoral emissions in the supplementary information. The figure show that the target of EPT is mainly levied on SO_2 and NO_X, and thus the large reduction would occur in sectors with large SO_2 and NO_X emissions, such as the electrical power sector. The electric power sector has relative larger contributions to CO_2 emissions than air pollutants [38]. Thus, the largest reductions are for SO_2, NO_X and CO_2 emissions under EPT scenario. For CAP scenario, the carbon tax is levied on CO_2 emissions mainly contributed by electric power sector, nonmetal manufacturing sector and chemistry sector. These sectors have large emission factor for SO_2, NO_X, which result in substantial co-benefit to SO_2 and NO_X reduction. Overall, although the targets vary between CAP and ETP scenario, they both have co-benefits to CO_2 and air pollutants emission mitigation because air pollutants are usually co-emitted with CO_2 during the fossil fuel combustion.

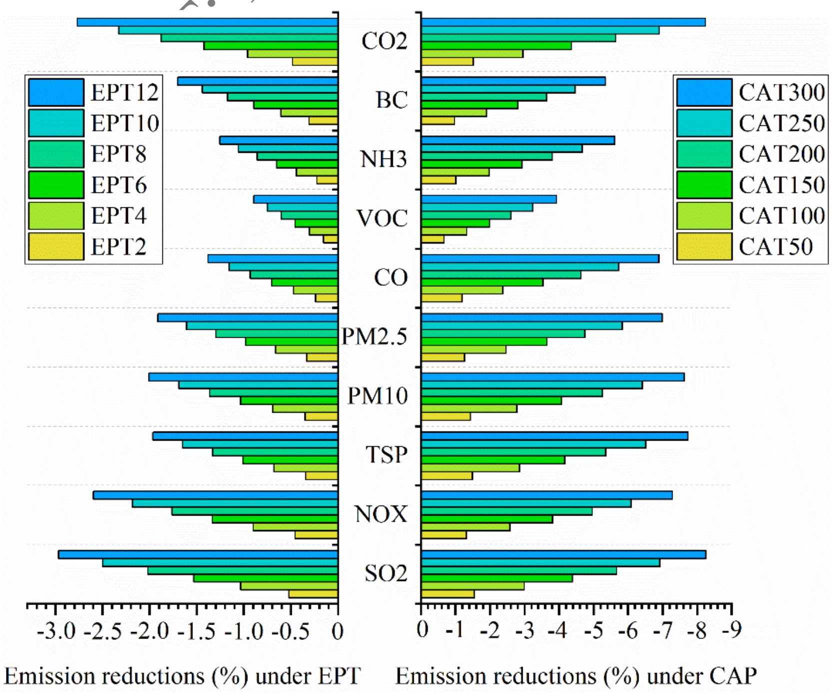


Figure 1. CO_2 and air pollutants emissions reduction under EPT and CAP scenarios

The EPT policy is more cost-effective to the CAP policy.

Figure 2 illustrated the reduction rates and related costs in both CAP and EPT scenarios. Here, we define the consumption costs to GDP to indicate costs. The tendency of air pollution emission reductions and related costs are in line with CO_2 in both CAP and EPT scenarios, but the reduction rates of air pollution are relative smaller than that of CO_2. That is, both of CAP and EPT have greater impact on CO_2 emission mitigation.

Although CAP has greater impact on emissions reduction, the CAP is more cost-effective to the EPT policy (shown as in figure3). For the EPT policy, large number of emission reductions (reach to 60%) are burden on electricity power sector which result in more cost-effective for CO_2 emission mitigation among different sectors. In addition to electricity power sector, CAP policy also has large impact on nonmetal manufacturing sector, and chemistry sector. The costs of these sectors are relative larger than those in electricity power sector. As a consequence, CAP policy is more costly to the EPT policy. This result also indicate that the coverage of sectors will significantly impact on costs.

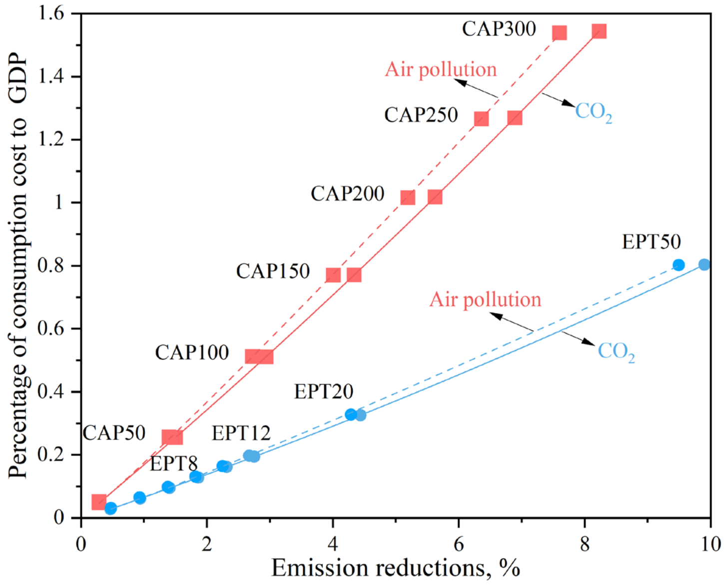


Figure 2. CO_2 (the lines) and air pollution (the dots) reduction rate and related costs (percentage of consumption cost to GDP) under CAP (carbon pricing) and ETP (environmental protection tax) policies.

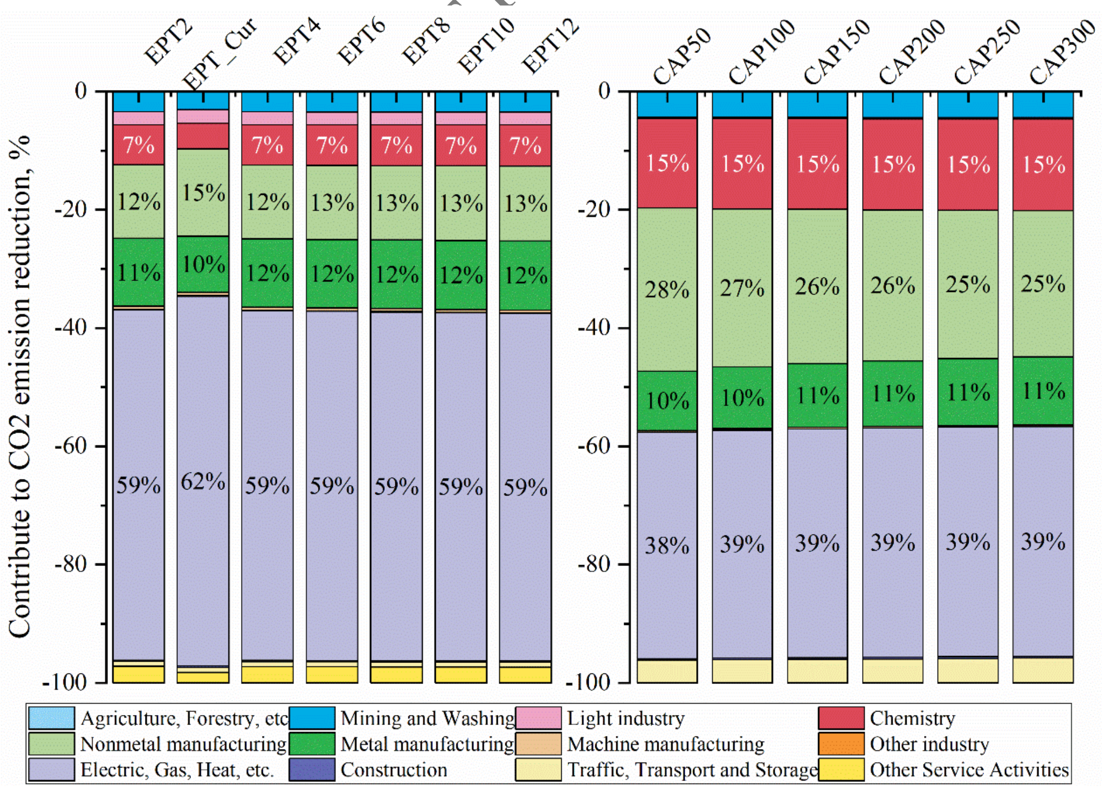


Figure 3. Contribute of sectoral CO_2 emissions reductions under both EPT and CAP

scenarios.

CAP is most redundant to the EPT, while the EPT is complementary to a CAP policy.

Layering a carbon pricing on top of the EPT policy will achieve additional emissions reductions (so it is not purely redundant), but it will increase the costs to society compared to using the EPT alone (so it is not purely complementary). As the figure 4 shows that the costs of carbon pricing are larger than that of the EPT under the same reduction target. Thus, the carbon pricing policies would be intended to reduce air pollutants and carbon emissions but would not increase the cost-effectiveness of achieving emissions reductions alongside a EPT policy. Results also show that larger the incremental carbon pricing, the higher the incremental costs, the more redundant a CAP policy is to the EPT policy on air pollution mitigation.

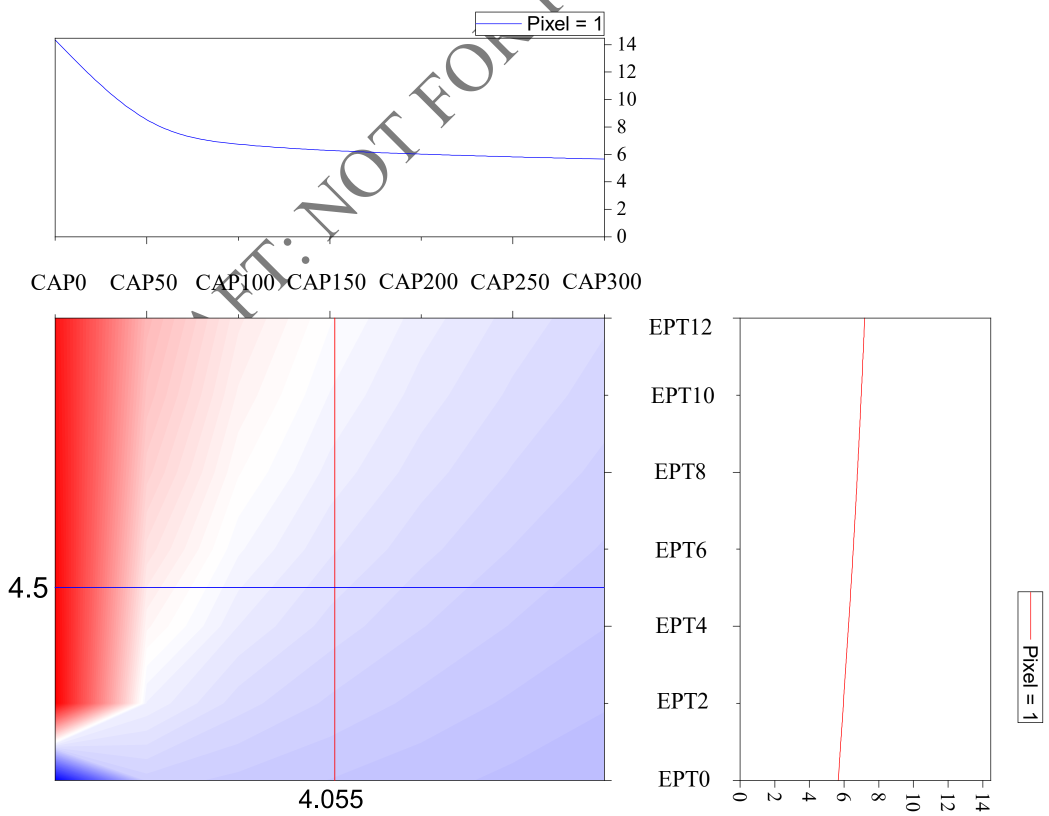
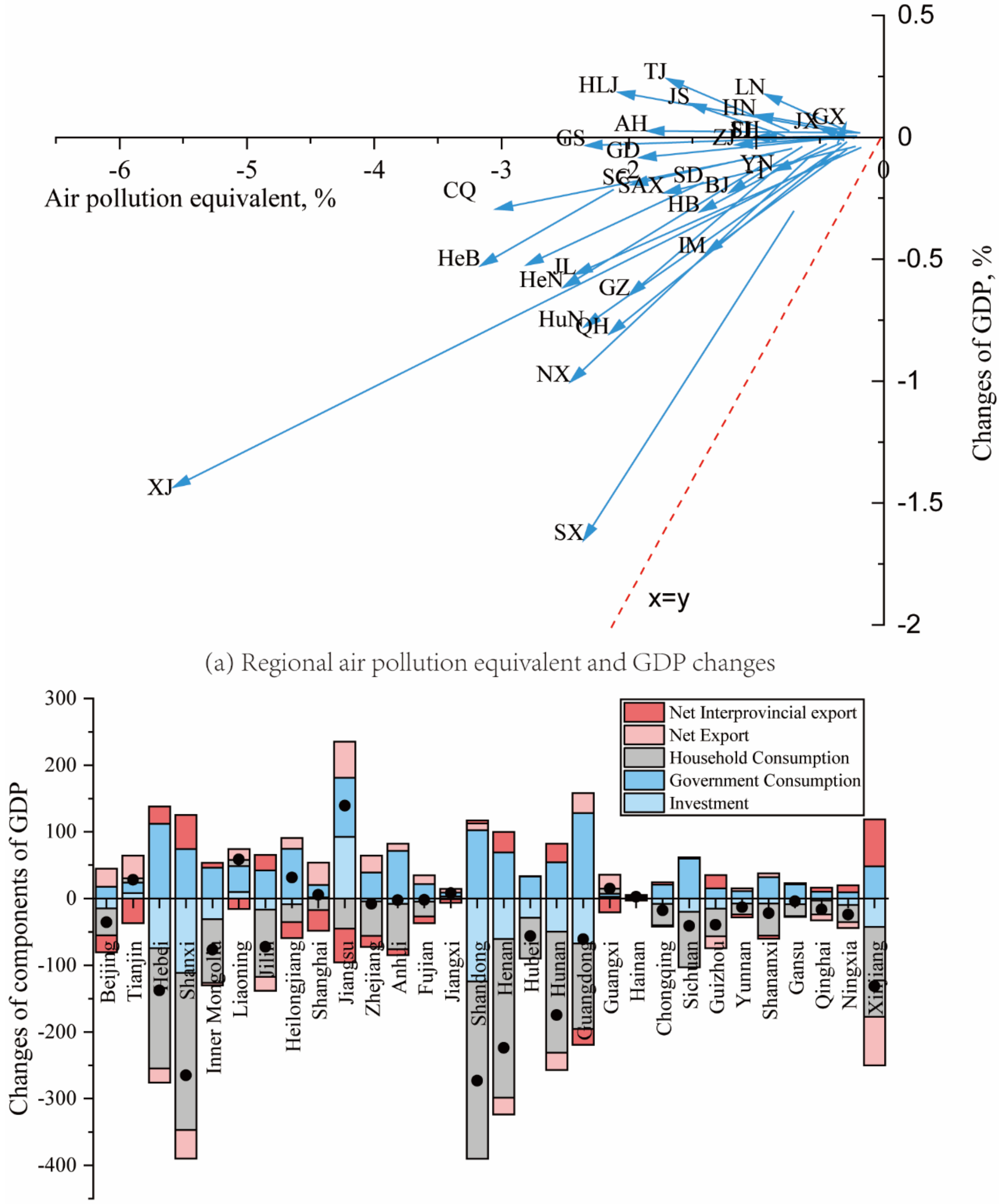


Figure 4. Map of CO_2 reduction efficiency under mixed carbon pricing (CAP) and environmental protection tax (EPT) policies, as well as the specific trend line.

The EPT are primarily directed at emissions of air pollutants other than carbon, including sulfur dioxide, nitric oxide, particulate matter, and many others. As noted above, these air pollution regulations have led to reductions in CO_2 emissions, for example, by reducing the amount of coal-fired power plants. As a general matter, these regulations are complementary with a carbon pricing because they achieve the reducing rates, the larger the incremental EPT price, the smaller the incremental costs, the more complementary the EPT to a carbon pricing. In summer, the EPT policy may complement a carbon tax by achieving additional CO_2 reductions and thus lowering the carbon pricing required to achieve a given emissions target.

Provincial changes in both scenarios

Figure 5 shows the relative changes of air pollution equivalent and GDP with EPT_Current and EPT_CAT50 scenarios. Heilongjiang, Tianjin, Jiangsu, Hainan, Guangxi and Jiangxi provinces could result in air pollution reduction and GDP increase, this is, a national carbon pricing in these provinces could complement to EPT policy. For most provinces, carbon pricing could increase the air pollution mitigation, but also strengthen the burden of GDP. Guangdong, Zhejiang and Gansu provinces result in large emission reductions with less GDP loss, while the provinces in Northwest (including Shanxi, Ningxia, Qinghai and Xinjiang) have large emissions reductions but also burden on large GDP loss at the same time. Provincial distribution is vital for regional equality. We could introduce relative smaller tax rate on northwest provinces which suffer large GDP loss burden, or we could provide subsidies to these provinces.



(a) Regional air pollution equivalent and GDP changes

(b) Changes of components of GDP (100 million CNY)

Figure 5. Relative changes of air pollution equivalent and GDP with EPT_Current and EPT_CAT50 scenarios.

Conclusion

The paper does not recommend which policies should be eliminated, changed, or added but intends to provide policy makers with information that will help them make decisions. The purpose is to suggest a standard framework by which policy makers can consider how to treat existing and new policies and demonstrate how one might apply that standard to the existing policy framework.

We found that although CAP policy may result in greater emission reductions than that of the EPT, the EPT policy is more cost-effective to the CAP policy. For interaction between different policies, our results show that CAP is most redundant to the EPT, while the EPT is complementary to a CAP policy. On province level, carbon pricing could increase the air pollution mitigation, but also strengthen the burden of GDP in most provinces, while Heilongjiang, Tianjin, Jiangsu, Hainan, Guangxi and Jiangxi provinces could result in air pollution reduction and GDP increase at the same time. Provincial distribution is vital for regional equality. We could introduce relative smaller tax rate on northwest provinces which suffer large GDP loss, or we could provide subsidies to these provinces.