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RESEARCH ARTICLE

Modeling and assessing international climate financing

Jing WU[1], Lichun TANG[2], Rayman MOHAMED[3], Qianting ZHU[4], Zheng WANG (✉)[1,5]

1 Institute of Policy and Management, Chinese Academy of Sciences, Beijing 100190, China
2 Accounting School, Capital University of Economics and Business, Beijing 100070, China
3 Department of Urban Studies and Planning, Wayne State University, Detroit, MI 48202, USA
4 School of Business Administration, China University of Petroleum, Beijing 102249, China
5 East China Normal University, Key Laboratory of Geographical Information Science, Ministry of State Education of China, Shanghai 200062, China

Abstract Climate financing is a key issue in current negotiations on climate protection. This study establishes a climate financing model based on a mechanism in which donor countries set up funds for climate financing and recipient countries use the funds exclusively for carbon emission reduction. The burden-sharing principles are based on GDP, historical emissions, and consumption-based emissions. Using this model, we develop and analyze a series of scenario simulations, including a financing program negotiated at the Cancun Climate Change Conference (2010) and several subsequent programs. Results show that sustained climate financing can help to combat global climate change. However, the Cancun Agreements are projected to result in a reduction of only 0.01°C in global warming by 2100 compared to the scenario without climate financing. Longer-term climate financing programs should be established to achieve more significant benefits. Our model and simulations also show that climate financing has economic benefits for developing countries. Developed countries will suffer a slight GDP loss in the early stages of climate financing, but the long-term economic growth and the eventual benefits of climate mitigation will compensate for this slight loss. Different burden-sharing principles have very similar effects on global temperature change and economic growth of recipient countries, but they do result in differences in GDP changes for Japan and the FSU. The GDP-based principle results in a larger share of financial burden for Japan, while the historical emissions-based principle results in a larger share of financial burden for the FSU. A larger burden share leads to a greater GDP loss.

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E-mail: wangzheng@casipm.ac.cn

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1 Introduction

Climate financing refers to resources that promote low-carbon and climate-resilient development by covering the costs and risks of actions that influence climate; creating circumstances that support adaptation and mitigation; and encouraging research, development, and deployment of new technologies (Buchner et al., 2011). The aim of climate financing is to facilitate the adaptation and mitigation of climate change in developing countries and to support sustainable development (UN, 2010). In the Copenhagen (2009) and Cancun (2010) Climate Change Conferences, countries pledged to provide developing countries with $30 billion of immediate short-term funding from 2010 to 2012, an amount that would rise to $100 billion per year by 2020. The Durban Climate Change Conference (2011), which established a green climate fund, represented a pivotal moment in international climate financing when countries agreed to adopt a universal legal agreement on climate change.

Although many developed nations made climate financing commitments at the Cancun Conference, exactly how they plan to share the burden remains unclear. At the Doha climate conference (2012), the UK, France, Denmark, Sweden and the EU Commission announced that they would provide $6 billion through 2015 for long-term climate financing. Jotzo et al. (2011) determined that Australia's share could be around 2.4% of the Cancun financing pledge, or $2.4 billion a year through 2020. Houser and Selfe (2011) concluded that the US is unlikely to meet its pledge due to its unfavorable fiscal environment. However, such studies are still preliminary, and it is unknown how much countries like the US, Canada and others will actually contribute.

To implement international climate financing, countries must agree on how to share the financing burden. According to the Polluter Pays Principle, countries with greater emissions should pay compensation for the damage they have caused (UN, 1992). Many burden-sharing principles have been proposed based on that premise. Klinsky and Dowlatabadi (2009) summarized different criteria for burden sharing, including equal per capita emission allotment, cumulative GHGs, subsistence/luxury emissions, etc. Dellink et al. (2009) described principles based on capacity to pay, GDP, and historical emissions per capita in assigning shares of the financial burden to individual developed countries.

However, many unanswered questions surround these burden-sharing principles: Will they have an effect on global climate change? How will donor countries and recipient countries be affected by different principles? Which principle is most effective in limiting global temperature increases and least harmful to regional economies? These questions have important policy implications, and answering them will require studies of the interactions between climate change and the economy.

Modeling is one approach that can be used to help understand the implications of climate change policies. Climate change modeling generally falls into two categories: the Integrated Assessment Model (IAM) and the Computable General Equilibrium (CGE) model (Tol, 1997; Leimbach, 1998; Pizer, 1999; Tol, 2002; Wang et al., 2010). IAM is recognized as a broad, integrated model that can analyze the scientific and socioeconomic aspects of climate change (Kelly and Kolstad, 1999). It is also much more flexible than the CGE model and is capable of incorporating new modules when necessary. Typical IAM models include DICE (the Dynamic Integrated Climate-Economy model), RICE (the Regional Integrated Climate-Economy model; Nordhaus, 1992; Nordhaus and Yang, 1996; Nordhaus and Boyer, 2000), FUND (the climate Framework for Uncertainty, Negotiation and Distribution model; Tol, 1997), MERGE (the Model for Estimating the Regional and Global Effects of greenhouse gas reductions; Manne et al., 1995), and FEEM-RICE (Fondazione Eni Enrico Mattei- Regional Integrated Climate-Economy model; Buchner et al. 2005).

Several researchers have demonstrated the utility of IAM for assessing climate policies. Buonanno et al. (2003), Popp (2006) and van der Zwaan (2002) extend the basic RICE model and simulate the effects of technological innovations on climate change. Buchner et al. (2005) use the FEEM-RICE model to understand the effect of several mitigation policies.

However, models of climate financing are still in their infancy. The latest and most comprehensive model of climate financing was developed by Hof et al. (2011), who simulated four proposals for climate financing based on the FAIR (Framework to Assess International Regimes) model: 1) auctioning emission allowances, 2) a global carbon tax, 3) an emissions trading levy, and 4) a tax on international aviation and bunker emissions. His results demonstrate that the global carbon tax and bunker fuel emissions tax are the most promising financing proposals. Aside from Hof's paper, however, few studies model the implications of different climate change policies. Moreover, Hof's work focuses on determining the best way to generate funds for climate financing; he does not examine the effects of climate financing on the global climate and economic system. With this paper, we aim to help fill this gap in the research.

We build on the RICE model to evaluate the implications of different climate financing policies. We choose this model as our starting point because it takes a multi-regional approach to examining the national implications of climate change policy. We extend this feature of the model to examine the implications of a multilateral approach to climate financing. In Section 2, we introduce our model of climate financing. In Section 3, we use the model to examine the climate financing policies proposed in the Cancun Agreements, simulating both climate and economic benefits. In Section 4, we present our conclusions.

2 Description of the model

2.1 Model construction

RICE is a representative IAM model first introduced by Nordhaus and Yang (1996). The original RICE model determines the optimal abatement rate for each region. In this paper, however, we do not aim to evaluate the effects of further abatement. Rather, our aim is to evaluate the net influence of climate financing on climate and regional economic systems. We thus remove the optimizing equations from RICE in order to use it as a policy evaluation model. We can then input exogenous policies and derive quantitative outputs. Details on the internal structure of the original RICE model can be found in Nordhaus and Yang (1996) and Nordhaus and Boyer (2000). Following RICE 1996, we divide the world into six countries/regions: China, the United States (US), Japan, the European Union (EU), the former Soviet Union (FSU), and the rest of the world (ROW).

We do not specify the instruments from which donor countries' financing will come; for simplicity, we assume that financing will be a fraction of the donor countries' GDP. The model assumes that such financing will continue after it is implemented and that recipient countries will use the financing only for emission mitigation and adaptation.

According to Buchner et al. (2011), 96% of current climate financing is used for mitigation, while only 4% is used for adaptation. For this reason, 96% of the financing will be used for mitigation. Our model does not consider the effects of adaptation. Starting from these two assumptions, we develop the model as follows.

Annual total capital flow for climate financing from donors can be stated as:

$$F_t = \sum_{i=1}^{n} F_{i,t}, \tag{1}$$

where i represents donor countries, n is the number of donor countries, F_t is the total global climate financing flow at time t, and $F_{i,t}$ is the climate finance flow from country i at time t. The capital for climate financing originates from the donor countries' production. Thus, the production expenditure of climate finance donor countries is shown in Eq. (2) as follows:

$$Y_{i,t} = C_{i,t} + I_{i,t} + F_{i,t}, \tag{2}$$

where $Y_{i,t}$ is the output, and $C_{i,t}$ and $I_{i,t}$ are the consumption and investment of each country (region).

Recipient countries obtain climate financing as shown:

$$F'_{j,t} = \lambda_{j,t} F_t, \tag{3}$$

$$\sum_{j=1}^{m} \lambda_{j,t} = 1, \tag{4}$$

where j represents recipient countries, m is the number of recipient countries, $F'_{j,t}$ is funds of climate financing gained by country j at time t, and $\lambda_{i,t}$ is the share of global climate funds received by country j at time t.

The next step is to determine each recipient country's reduction in emissions as a result of receiving funds $F'_{j,t}$. Investments in mitigation and reductions in emissions are not directly proportional because of nonlinearity in marginal mitigation costs. This means that emissions will not fall proportionally with increases in funds for emission reduction. Therefore, we have to establish the nonlinear relationship between climate financing and the reductions in emissions in terms of an increasing marginal cost.

According to the RICE model (Nordhaus and Yang, 1996), production and emissions from each country are shown in Eqs. (5) and (6), respectively.

$$Y_{j,t} = A^*_{j,t} K^{\alpha}_{j,t} L^{1-\alpha}_{j,t}, \tag{5}$$

$$E_{j,t} = \sigma_{j,t}(1-\mu_{j,t}) Y_{j,t} \frac{A_{j,t}}{A^*_{j,t}}, \tag{6}$$

where $Y_{j,t}$ is the GDP of each country; $K_{j,t}$ and $L_{j,t}$ are material capital and labor, respectively; α is capital flexibility; $E_{j,t}$ is the amount of emissions; $\sigma_{j,t}$ is the carbon emission intensity; $\mu_{j,t}$ is the emission reduction rate, which reflects the mitigation policy of the government; $A_{j,t}$ is labor productivity; and $A^*_{j,t}$ is the effective labor productivity, which describes the amount of output available for consumption and investment — after output has been reduced by control costs and climate damages (Pizer, 1999). $A^*_{j,t}$ is a function of $A_{j,t}$ as shown in the following equation (see Nordhaus and Yang, 1996), in which the expression enclosed in parentheses reflects the influence of emissions controls and damages from climate change:

$$A^*_{j,t} = \left(\frac{1 - b_{j,1}\mu_{j,t}^{b_{j,2}}}{1 + (D_0/9)T_t^2} \right) A_{j,t}, \tag{7}$$

where $b_{j,1}$ and $b_{j,2}$ are the coefficients representing emission reduction costs (Nordhaus and Yang, 1996); D_0 is the GDP loss due to a 3°C temperature increase; and T_t is the global temperature increase for the year. Eq. (7) shows that the higher the temperature is, the lower $A^*_{j,t}$ is ($A^*_{j,t}$ represents the production loss from emission reduction and the temperature increase).

Following Pizer (1999), we combine Eqs. (5), (6), and (7), which gives the marginal cost of emission reduction $Mac_{j,t}$ at a certain emission reduction rate:

$$Mac_{j,t} = \frac{\dfrac{\partial Y_{j,t}}{\partial \mu_{j,t}}}{\dfrac{\partial E_{j,t}}{\partial \mu_{j,t}}} = \frac{b_{j,1} b_{j,2}}{\sigma_{j,t}\left(1 + \left(\dfrac{D_0}{9}\right) T_t^2\right)} \mu_{j,t}^{b_{j,2}-1}. \tag{8}$$

To determine the relationship between the marginal cost of emission reduction and the amount of emission reduction, we further transform Eq. (8) to obtain Eq. (9).

$$\begin{aligned} Mac_{j,t} &= \frac{b_{j,1} b_{j,2}}{\sigma_{j,t}\left(1 + \left(\dfrac{D_0}{9}\right) T_t^2\right)} \mu_{j,t}^{b_{j,2}-1} \frac{Eo_{j,t}^{b_{j,2}-1}}{Eo_{j,t}^{b_{j,2}-1}} \\ &= \frac{b_{j,1} b_{j,2}}{\sigma_{j,t}\left(1 + \left(\dfrac{D_0}{9}\right) T_t^2\right) E_{j,t}^{b_{j,2}-1}} D_{j,t}^{b_{j,2}-1}, \end{aligned} \tag{9}$$

$$Eo_{j,t} = \sigma_{j,t} Y_{j,t} \frac{A_{j,t}}{A^*_{j,t}}, \tag{10}$$

where $D_{j,t}$ is the reduction in emissions of country j at time t, and $Eo_{j,t}$ is the emission of country j before abatement, which can be calculated with Eq. (10). Because a recipient country may have developed mitigation actions supported by domestic capital, which is independent of climate financing, the extra reduction attributed to climate financing can be obtained by calculating the definite integral in Eq. (9) to give:

$$F'_{j,t} = \int_{D_{j,t}^{(1)}}^{D_{j,t}^{(2)}} \frac{b_{j,1} b_{j,2}}{\sigma_{j,t}\left(1+\left(\frac{D_0}{9}\right)T_t^2\right)Eo_{j,t}^{b_{j,2}-1}} D_{j,t}^{b_{j,2}-1} \mathrm{d}D_{j,t}, \quad (11)$$

where $D_{j,t}^{(1)}$ is the amount of emission reduction from domestic capital (without climate financing) in country j at time t, and $D_{j,t}^{(2)}$ is the total amount of emission reduction with climate financing. According to Eq. (11), the amount of marginal emission reduction generated from climate financing $\Delta D_{j,t}$ is

$$\Delta D_{j,t} = D_{j,t}^{(2)} - D_{j,t}^{(1)}$$
$$= \left(\frac{F'_{j,t}\sigma_{j,t}\left(1+(D_0/9)T^2\right)Eo_{j,t}^{b_{j,2}-1}}{b_{j,1}} + D_{j,1}^{b_{j,2}}\right)^{\frac{1}{b_{j,2}}} - D_{j,t}^{(1)}. \quad (12)$$

Substituting Eq. (12) into Eq. (6) gives:

$$E_{j,t}^{*} = \sigma_{j,t}(1-\mu_{j,t})Y_{j,t}\frac{A_{j,t}}{A_{j,t}^{*}} - \Delta D_{j,t}. \quad (13)$$

Eq. (13) shows the final emission of recipient countries with financing from donor countries.

Figure 1 shows the relationship between the climate financing model we develop and the RICE model. In summary, funding for climate change mitigation and adaptation comes from donor countries' investment and consumption. This funding affects the economic system of donor countries, while reducing emissions in recipient countries.

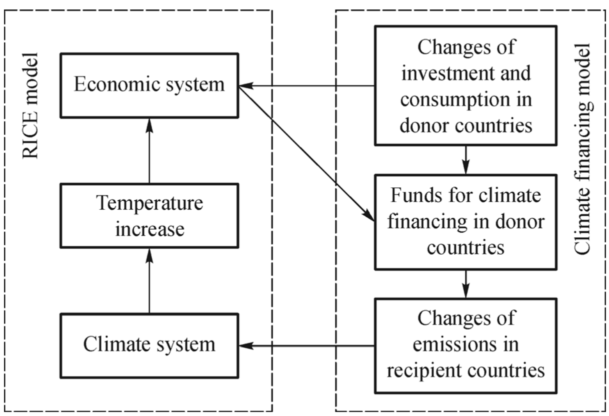

Fig. 1 Integration of the climate financing module with RICE model.

Parameter estimates for $b_{j,1}$ and $b_{j,2}$ in Eq. (12) are taken from Eyckmans and Tulkens (2003), as shown in Table 1. Furthermore, the total global climate finance flow F_t (Eq. (1)) and the share of climate financing received by country j at time t and $\lambda_{j,t}$ (Eq. (3)) are both policy-controlled parameters. Thus, we can simulate different climate financing scenarios by adjusting these parameters.

Table 1 Values of the major parameters in the technology transfer module [a)]

Regions	$b_{j,1}$	$b_{j,2}$
China	0.15	2.887
Other regions of the world	0.1	2.887

a) Taken from Eyckmans and Tulkens (2003).

2.2 Burden sharing among developed countries and sharing among recipient countries

Before proceeding with the simulations, we must settle several related issues that fall into two broad categories: those related to donor countries and those related to recipient countries.

On the donor-country side, we need to specify who will provide funding for mitigation and adaptation. In this paper, we assume that the donors are the developed countries: the US, the EU, and Japan. We also consider the former Soviet Union (FSU) to be a donor country because it is an Annex I country in the Kyoto Protocol.

A second consideration is each donor country's level of contribution. On one hand, production-based emissions are associated with the industrial revolution of the 1800s, which resulted in high GDP growth and concomitant high emissions among developed countries. We therefore use both GDP-based and historical emissions-based principles to establish a burden-sharing system among developed countries. On the other hand, consumption-based emissions that arise from the import and export of goods and services are different from production-based emissions (Lenzen et al., 2007; Chen and Chen, 2011; Chen et al., 2013). For example, Davis and Caldeira (2010) calculate that 10.8% of the US's total emissions in 2004 were consumption-based emissions due to imports. Thus, to reflect responsibility for consumption-related emissions, we also include this factor as one of the standards for burden sharing.

The GDP-based principle and the consumption-based emissions-based principle involve similar calculations. We take all donor countries as a whole, and each country's finance burden proportion, B_i, is equal to its GDP proportion or its consumption-based emission proportion of the whole:

$$B_i = \frac{S_i}{\sum_{i=1}^{n} S_i}, \quad (14)$$

where S_i stands for GDP or consumption-based emissions of country i in the chosen base year. In existing mitigation schemes, 1990 and 2005 are commonly chosen as base years. For example, the EU pledged a reduction target of 20% below 1990 levels by 2020, and the US announced a reduction target of 17% below 2005 levels by 2020. In order to meet the targets of most countries, we choose 2005 as the base year for the GDP-based principle. For the consumption-based principle, however, we follow Davis and Caldeira (2010) and use 2004 as the base year due to issues of data availability.

The historical emissions-based principle is similar to the GDP-based principle, but using historical emissions instead of GDP introduces the following complication: During the carbon cycle mechanism (CCM), CO_2 may be absorbed by terrestrial and ocean sinks, which means that earlier emissions contribute less than later emissions to current global temperature increases. To address this concern, we consider historical emissions with and without carbon cycle absorption. We use the carbon cycle equation from the RICE model to calculate emissions with absorption by terrestrial and ocean sinks, as shown in Eq. (15):

$$M_t - 590 = \beta E_{t-1} + (1-\delta_m)(M_{t-1} - 590), \tag{15}$$

where M is the atmospheric concentration of CO_2 in GtC[1)], β is the measure of the retention rate of emissions, and δ_m is the depreciation rate of carbon in the atmosphere that reflects the absorption of CO_2 into the ocean (Pizer, 1999). We further need to account for the period in which the emissions are counted, which requires us to determine a start and end date. We use 1900, 1990 and 2000 as start dates and 2008 as the end date to calculate the historical emissions of each donor country. For each time period, we calculate the share percentage and then obtain the average financing share for each donor country.

Table 2 shows the burden shares of the US, the EU, Japan and the FSU under each principle. The US always bears the largest financing burden, with only small differences under different principles. Similarly, the burden of the EU changes little under different principles. However, there are significant differences in the financial burdens of Japan and the FSU under the GDP-based and historical emissions-based principles. In the case of Japan, the GDP-based principle results in a financial burden that is two times higher than under the historical emissions-based principle. In the case of the FSU, the financial burden under the historical emissions-based principle is almost 10 times higher than under the GDP-based principle. But the financial burdens of each country under the historical emissions-based principle with and without carbon absorption show almost no significant difference. Furthermore, when we consider consumption-based emission, we find that the shares of the US, EU and Japan are larger than they are under the historical emissions-based principle, which implies that these countries have higher consumption-based emissions than production-based emissions.

Corresponding issues on the recipient side are also critical. In particular, we have to determine how to allocate the financing among developing countries. Since China announced at the Cancun Climate Conference that it would not attempt to obtain money from international climate financing, financing from donors goes only to the ROW in our model. When financing is transferred to the ROW, the money can be used for both mitigation and adaptation. Following Buchner et al. (2011), we assume that 96% of climate financing will be used for mitigation.

3 Scenario simulation and analysis

At the Cancun Summit, developed countries committed to providing \$30 billion per year in climate financing by 2013, an amount that will rise to \$100 billion each year by 2020. However, the details of burden sharing among donors and allocation among recipients remain unclear. The overall effects of climate financing are also unclear. In this section, we develop several scenarios based on the Cancun Agreements and assess possible consequences.

Table 3 shows the scenarios we examine. In all scenarios, each country emits freely, so that we can evaluate the net influence after climate financing. In Table 3, Scenario 0 is the business-as-usual (BAU) scenario, which we take as the benchmark when assessing the effect of climate financing. Scenarios 1A, 1B, 1C, and 1D consider only the climate financing proposed in the Cancun Agreements, but we examine different burden-sharing principles for these scenarios. Scenarios 2A, 2B,

Table 2 Percent burden sharing based on different principles (%)

Regions	GDP based	Historical emissions based without CCM	Historical emissions based with CCM	Consumption-based emission based
US	42.9	41.4	41.2	43.2
EU	35.8	31.5	31.3	34.2
Japan	19.3	8.0	8.2	10.6
FSU	2.0	19.1	19.4	12.0
Totals	100	100	100	100

1) Gigatons of carbon.

Table 3 Scenario assumptions

Scenario	Climate financing by 2020	Climate financing after 2020	Burden sharing principle
Scenario 0	No financing	No financing	No financing
Scenario 1A	Rising steadily from \$30 b to \$100 b from 2013 to 2020	No financing	GDP based
Scenario 1B	Rising steadily from \$30 b to \$100 b from 2013 to 2020	No financing	Historical emissions based without CCM
Scenario 1C	Rising steadily from \$30 b to \$100 b from 2013 to 2020	No financing	Historical emissions based with CCM
Scenario 1D	Rising steadily from \$30 b to \$100 b from 2013 to 2020	No financing	Consumption-based emission based
Scenario 2A	Rising steadily from \$30 b to \$100 b from 2013 to 2020	Keeping on the \$100 b level each year	GDP based
Scenario 2B	Rising steadily from \$30 b to \$100 b from 2013 to 2020	Keeping on the \$100 b level each year	Historical emissions based without CCM
Scenario 2C	Rising steadily from \$30 b to \$100 b from 2013 to 2020	Keeping on the \$100 b level each year	Historical emissions based with CCM
Scenario 2D	Rising steadily from \$30 b to \$100 b from 2013 to 2020	Keeping on the \$100 b level each year	Consumption-based emission based

2C, and 2D extend the financing to 2100 and also assume different principles for burden sharing among developed countries.

3.1 Climate protection benefits of climate financing

Our first simulation examines the temperature rise by 2100. Under Scenario 0, the temperature rise by 2100 is 2.96°C. Since the global financing amount is the same in Scenarios 1A, 1B, 1C, and 1D, which are based on different burden-sharing principles, there is no difference in the effect on the global climate system in the three scenarios. Therefore, we integrate Scenarios 1A, 1B, 1C, and 1D into Scenario 1 and Scenarios 2A, 2B, 2C, and 2D into Scenario 2 to compare the temperature change with that of Scenario 0 (see Fig. 2). In Scenario 1, the temperature increase by 2100 is about 2.95°C. In Scenario 2, the temperature increase is about 2.84°C. The former is only 0.01°C lower than under Scenario 0, while the latter is 0.12°C lower than under Scenario 0.

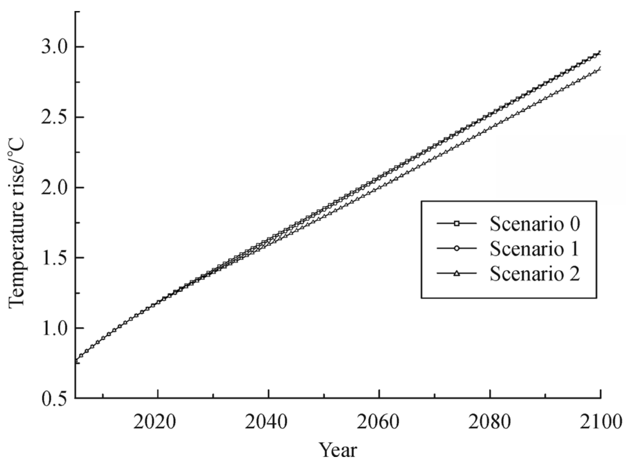

Fig. 2 Global temperature rise by 2100.

We also examine the change in atmospheric concentration of CO_2 (see Fig. 3). Results show that the CO_2 concentration is slightly lower in Scenario 1 than in Scenario 0, but there is a concentration decrease of about 22.57×10^{-6} in Scenario 2. Thus, there is little effect when climate financing is implemented only until 2020. However, longer-term financing can be more effective at restricting increases in temperature and CO_2 concentration.

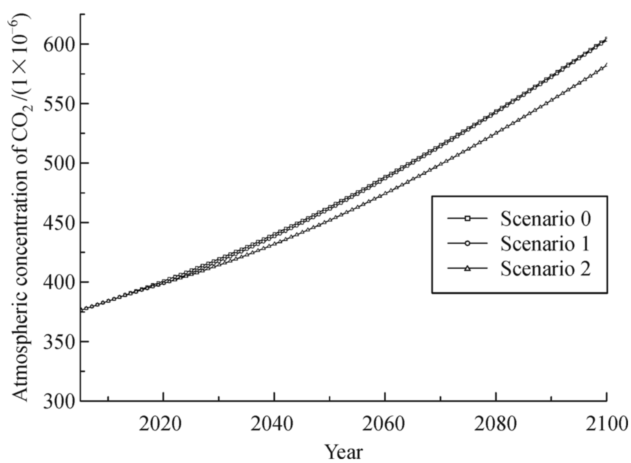

Fig. 3 Change of atmospheric concentration of CO_2 by 2100.

3.2 Analysis of the economic benefits of climate financing

In this section, we analyze the economic benefits of climate financing for both developed and developing countries under different scenarios.

3.2.1 Effect of climate financing on the GDP of recipient countries

The changes in GDP for China and the ROW between 2013 and 2100 under Scenarios 1A, 1B, 1C, and 1D as compared to Scenario 0 are shown in Fig. 4 and Fig. 5, respectively. The GDP changes of China under Scenarios 1A, 1B, 1C, and 1D are almost identical with each other, as Fig. 4 shows. The results for the ROW are similar (Fig. 5). In both instances, different burden-sharing principles do not affect changes in GDP.

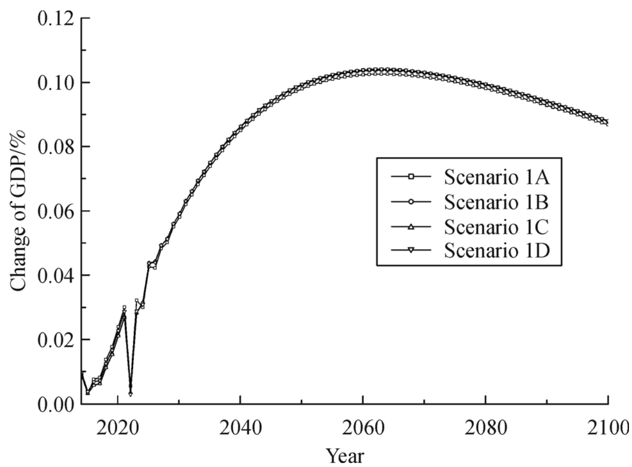

Fig. 4 GDP change of China by 2100 in Scenarios 1A, 1B, 1C, and 1D.

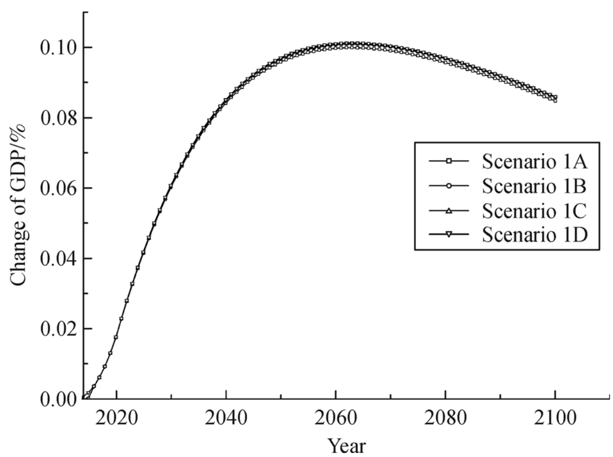

Fig. 5 GDP change of ROW by 2100 in Scenarios 1A, 1B, 1C, and 1D.

The GDPs of China and the ROW all increase with climate financing. This is attributable to lower global temperature changes, which are themselves a consequence of climate financing that was intended to compensate for economic losses. Still, the change in both China and the ROW is very small, with a maximum increase in GDP of about 0.1%. Furthermore, GDP change declines over time following an initial increase. This is mainly because climate financing is available only until 2020 in these scenarios. Although the temperature base in 2020 is lowered, the ripple effect from climate financing fades out gradually over time, which leads to the decline of GDP change in China and the ROW.

Figures 6 and 7 show the results of the simulations under Scenarios 2A, 2B, 2C, and 2D. The GDP increase relative to Scenario 0 keeps growing in these scenarios, reaching a maximum of about 1.28%, which is much higher than in Scenarios 2A, 2B, 2C, and 2D. The continuous GDP increase is due to the extension of climate financing to 2100. For developing countries, short-term climate financing that ends in 2020 results in only a slight increase in GDP, but long-term financing increases both the duration and the magnitude of the benefit.

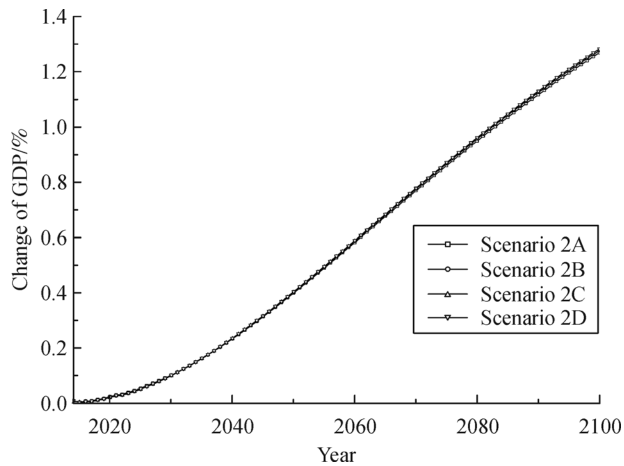

Fig. 6 GDP change of China by 2100 in Scenarios 2A, 2B, 2C, and 2D.

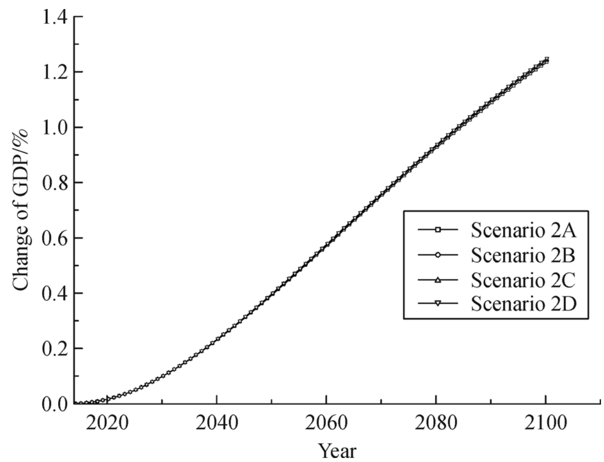

Fig. 7 GDP change of ROW by 2100 in Scenarios 2A, 2B, 2C, and 2D.

3.2.2 Effect of climate financing on the GDP of donor countries

We now analyze GDP changes in donor countries, including the US, Japan, the EU, and the FSU. Figures 8 and 9 show GDP changes in these four countries under Scenarios 1A, 1B, 1C, and 1D and Scenarios 2A, 2B, 2C, and 2D, respectively.

All donor countries experience a GDP increase after an initial decline. The reason for the initial decline is that when the countries provide climate finance to developing countries, domestic capital investment is “crowded out,” which leads to a GDP loss relative to Scenario 0. The loss will be greatest in 2020, but the magnitude is small: only 0.1% of GDP. After 2020, the GDPs of donor countries will rebound due to the cessation of climate financing in 2020 and the benefits of decreased global temperature rise. Eventually, changes in GDP will be positive, though the gains also gradually decline over time, as in the case of developing countries in Scenarios 1A, 1B, 1C, and 1D.

It is also worth noting that when we compare different burden-sharing principles (Fig. 8), GDP changes in the US and the EU are similar, but Japan and the FSU experience very different GDP changes. Specifically, the GDP-based principle leads to a larger GDP loss for Japan, while the historical emissions-based principle results in large GDP losses for the FSU (with and without carbon absorption). The GDP losses from consumption-based emission are moderate both in Japan and the FSU. The reason for the difference between Japan and the FSU can be found in Table 2. The GDP-based principle results in a larger share of financial burden for Japan, while the historical emissions-based principle results in a larger share of financial burden for the FSU. A larger burden share leads to a greater GDP loss.

In Scenarios 2A, 2B, 2C, and 2D, the initial reductions in donor countries’ GDPs also eventually turn into increases, as Fig. 9 shows. These results are similar to those in Scenarios 1A, 1B, 1C, and 1D (Fig. 8), but the points at which GDP losses cease are very different. In Fig. 9, the negative effects of climate financing on GDP continue to grow until 2030, with a maximum GDP loss of less than 0.2% in each country. From 2030 to 2040, GDP rebounds in donor countries. Finally, a steady GDP increase relative to Scenario 0 begins around 2040 in each country. The increase continues to the end of the century, even though donor countries still finance mitiga-

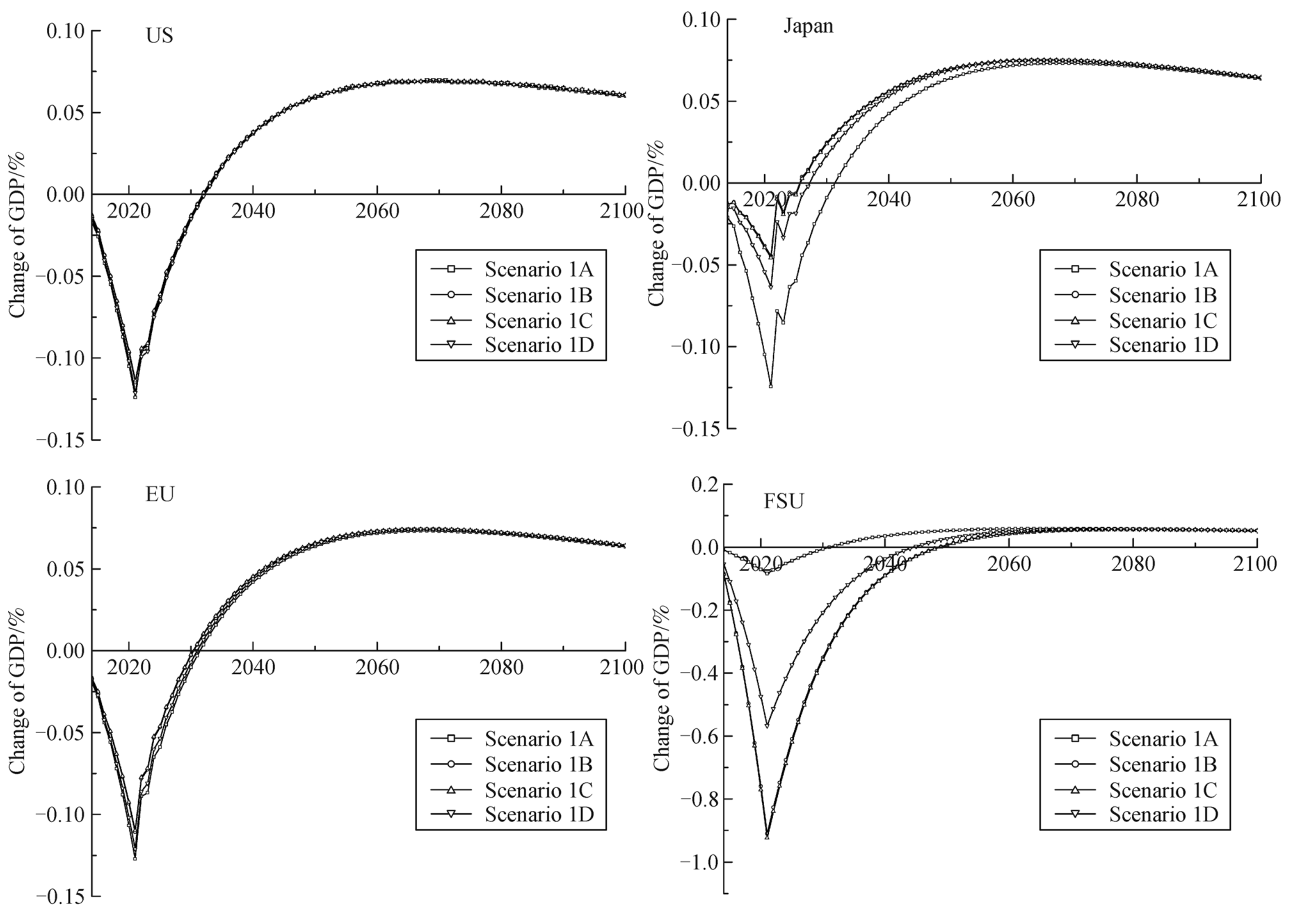

Fig. 8 GDP change of donor countries in Scenarios 1A, 1B, 1C, and 1D.

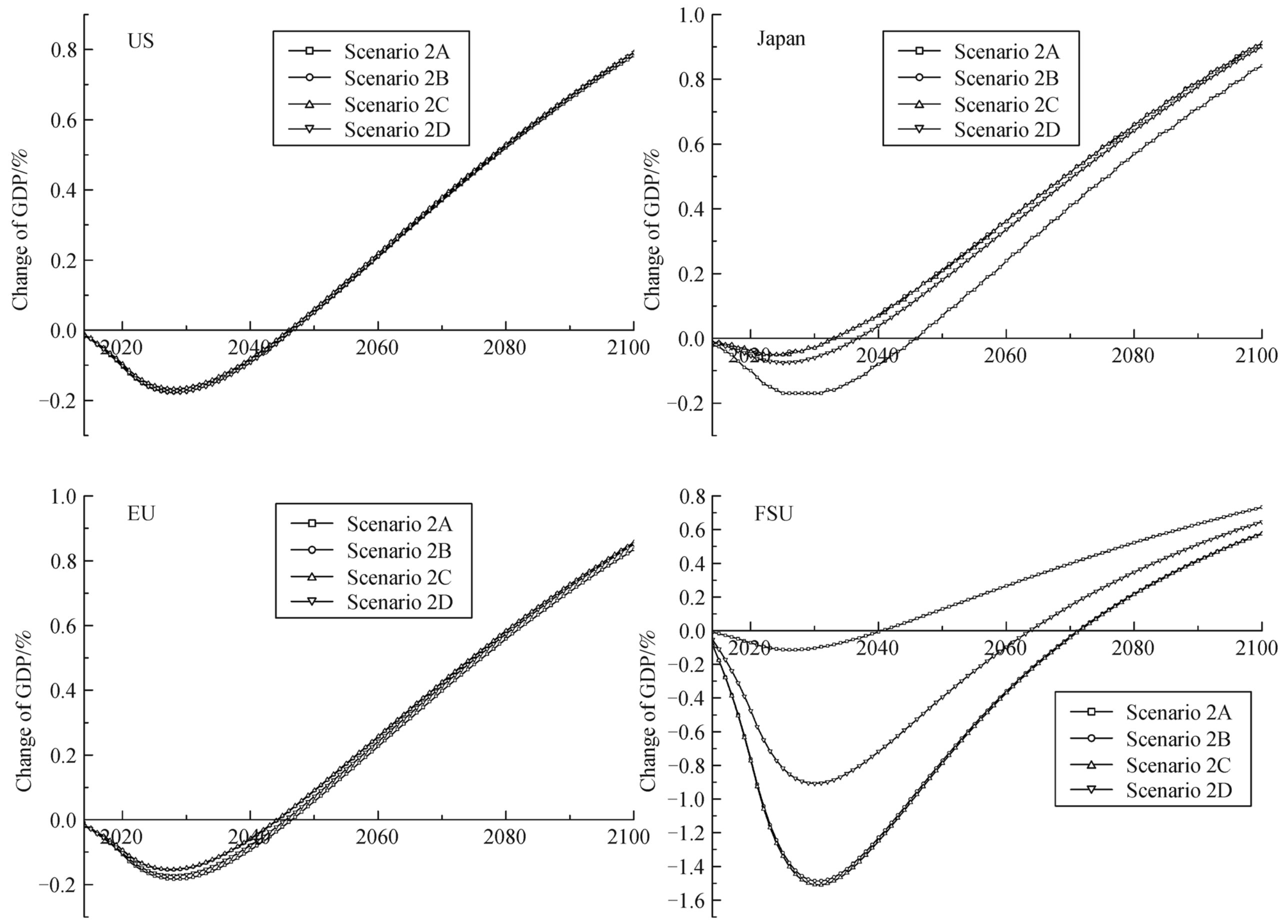

Fig. 9 GDP change of donor countries in Scenarios 2A, 2B, 2C, and 2D.

tion in recipient countries. These results imply that climate financing does not always have adverse impacts for donors; in fact, donor countries can benefit from providing financing. In addition, the GDP loss experienced by developed countries in the early stages of climate financing is less than 0.2%, while the GDP gain, which reaches 0.8% in 2100, far exceeds the initial GDP loss.

3.2.3 Effect of climate financing on global accumulated GDP

Figure 10 shows global accumulated GDP under the scenarios listed in Table 3. Note that the global GDP growth in Scenario 2 is far less than in Scenario 1. The former is only about 0.068% while the latter is about 0.55%, which implies that long-term climate financing can result in more global economic growth than short-term financing. There is no significant difference in global GDP change under the two different burden-sharing principles. Thus, global GDP change as a result of climate financing is sensitive to the duration of financing but non-sensitive to burden-sharing principle.

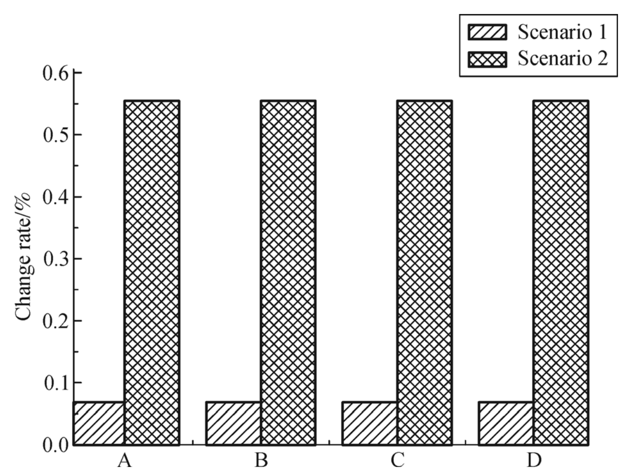

Fig. 10 The global accumulated GDP change in Scenario 1 and Scenario 2.

4 Conclusions

Climate financing from developed countries to developing countries has become an important issue in global climate negotiations. Using the framework of the RICE model, this study establishes an international climate financing model in which donor countries provide financing to promote mitigation in developing countries, and recipient countries use 96% of the money for mitigation.

In the Cancun Agreements, developed nations committed to providing \$30 billion of immediate short-term funding, an amount that will rise to \$100 billion per year by 2020. Results show, however, that the impact of this funding on global climate change and economic growth will be limited. Global temperatures will decrease by only 0.01°C as a result of this financing proposal. An extended financing program, in which the funding is maintained at \$100 billion each year between 2020 and 2100, will result in a 0.12°C temperature reduction by 2100. These results suggest that long-term financing by developed countries to support mitigation and adaptation in developing countries can have a positive impact on global temperatures.

Economically, recipient countries will always benefit from climate financing due to reduced global temperature changes. However, if financing ceases after 2020, the positive influences of financing will wear off; if, on the other hand, financing is maintained until 2100, positive economic growth will continue because of the positive influences of the financing in recipient countries. As the sources of climate financing, donor countries will experience an initial loss in GDP due to the crowding out of capital investments, but the negative effect is limited; in fact, the GDP of donor countries will eventually grow. Positive influences of long-term climate financing on GDP can be detected around 2040. By 2100, these positive influences result in a 0.8% greater GDP relative to the scenario without climate financing. This suggests that long-term climate financing can lead to a win-win outcome for donor and recipient countries.

The Cancun Agreements determined the financing amount but left unsettled how donor countries would share the burden. To examine burden sharing among developed countries, we considered a GDP-based principle, a historical emissions-based principle with and without the carbon cycle mechanism, and a consumption-based emissions-based principle. Results show that the different principles have very similar effects on the global temperature change and economic growth of recipient countries, but there are differences in GDP changes for Japan and the FSU. Specifically, the GDP-based principle leads to a larger GDP loss for Japan, while the historical emissions-based principle leads to a larger GDP loss for the FSU (whether or not the carbon cycle mechanism is considered). The consumption-based emissions-based principle leads to a moderate GDP loss in both countries. Finally, different burden-sharing principles make little difference in global GDP change. In summary, the modeling and simulations of this study suggest that climate financing can help to protect the global climate by limiting temperature changes while also contributing to economic benefits for donor and recipient countries.

However, more research is needed to assess the effects of climate change financing. For instance, the regional divisions we use in this paper are rudimentary: developed countries like Canada and Australia are considered recipient countries, when in fact they may be donor countries. Further modifications are also necessary to account for the financing instruments used by donor countries. Nonetheless, this paper makes an important contribution to our understanding of the effects of climate financing on climate change and the economies of both donor and recipient countries.

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