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Emission Taxes as a GHG Mitigation Mechanism in Agriculture: Effects on Rice Production of India

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Abstract

The effect of emission tax has been examined as a mitigation policy to reduce greenhouse gas (GHG) emissions from rice production in India. The cost of methane emissions has been internalized in the production process by taxing these emissions with carbon prices. Further, an iso-elastic supply function has been used to estimate the shift in supply of rice due to price internalization. A negative shift in the production has been observed both with market and shadow prices of carbon, which were considered as the tax levels. Although with the introduction of emission tax, the demand price increases, the higher costs and low efficiency of current mitigation measures make carbon taxation an unattractive proposition from economic and social welfare perspective. Small landholders, because of emission tax led increase in cost of production might shift from rice to other crops. This induced change in land-use would have consequence that could overpower the direct effects of emission tax. Successful implementation of emission taxation as a GHG mitigation strategy would depend on the development of cost-effective mitigation at farm level, and the instruments that can offset welfare losses for smallholders.

Key words: Rice, methane emission tax, methane mitigation, India

JEL Classification: Q56, Q53, Q18

Introduction

Climate change has become a global concern because of its negative externalities on natural, physical, biological and human systems. Global warming, caused by increasing concentrations of greenhouse gases (GHGs), is attributable to anthropogenic activities (IPCC, 2007). Among greenhouse gases, carbon di-oxide (CO_2) is emitted in the highest concentration, followed by methane, nitrous oxide and other gases. Burning of fossil fuels is the single largest human activity attributed to climate change; agriculture, deforestation, and industrial activities too make significant contributions to global warming (NRC, 2010). According to the Intergovernmental Panel on Climate Change (IPCC), the global mean temperature is likely to increase between 1.4 °C and 5.8 °C by the end of this century (IPCC, 2007).

To tackle global warming and climate change at the global level, United Nations Framework Convention on Climate Change (UNFCCC) was formed which put forth the Kyoto Protocol in 1997 (ABARE, 1999). The flexibility mechanisms or market-based approaches, such as Joint Implementation, Clean Development Mechanism (CDM) and Emissions Trading were introduced in the Kyoto Protocol as to lower the costs of achieving the emission reduction targets.

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Owing to their higher population and economic growth, developing countries, including India, could be the major emitters of GHGs in the future. India participates in global GHGs reduction by participating in CDM, and by providing low-cost options to developed countries in meeting their reduction targets. India has emerged as the second largest supplier of Certified Emission Reductions (CERs) (Capoor and Ambrosi, 2009), which shows that it has a large scope in reducing GHGs emissions.

Globally, livestock and rice production are the major sources of methane emission (Key and Tallard, 2012) sharing 63.4 per cent and 21 per cent of total agricultural emissions, respectively (INCCA, 2010). India is an agrarian economy; and agriculture sector accounts for 61 per cent of the total methane emissions (Garg, 2011). With a contribution of 17 per cent, rice cultivation (Garg, 2011) is the second most important source of methane emission in the country (Sharma, 2006). Rice, being the staple food, is an important crop in India (DES, 2009). Rice is grown on about 42.4 Mha area, and emits 3.3 Mt of methane annually (Barah, 2005; INCCA, 2010). According to Linquist *et al*. (2012), the global warming potential of methane emission from rice is four-times higher than other cultivated cereals. Therefore, methane emission from rice cultivation can be viewed as a potential contributor to global warming. On the other hand, policies targeting reduction in methane emission from rice cultivation would have an immense impact on the rural population, especially farmers, whose welfare is integrally linked with agriculture.

In contrast, there is a significant technical potential for abatement of GHGs emission from agriculture (Freibauer *et al.,* 2004; Garg, 2004; Bakam *et al.,* 2012). The scientific literature on the cost effectiveness of the GHGs mitigation options in agriculture is inconclusive. There are studies (Sathaye *et al.,* 2006; Saddler and King, 2008) which claim that agriculture can provide least cost options for GHGs mitigation. On the other hand, Smith *et al*. (2007a; 2007b) point towards economic constraints and higher transaction costs associated with implementation of mitigation measures in agriculture. Thus, the issue of how market mechanisms for GHGs mitigation in agriculture will affect farmers and food security is of great importance.

The major market-based instruments in the context of GHGs mitigation are pollution charges and permit/emissions trading. Pollution charges are developed based on the '*the polluter pays principle*', where a payment must be made per unit of pollution emitted. This mechanism is designed as fertilizer tax, environmental tax or emission tax (Bakam *et al.,* 2012). Farmers pay a tax based on per unit GHG emission from their farms. Fertilizer taxes are based on the application rates of nitrogen. These mechanisms reduce on-farm emission by implementing GHGs mitigating technologies and options until marginal productivity value of an option is equal to the tax rate (Bakam *et al.,* 2012).

In emissions/permit trading, the government caps the total emissions. Farmers are allotted transferable emission permits or allowances by the government for reduction of methane emissions from cultivation. This works as an incentive for farmers to adopt GHGs mitigation strategies to minimize emissions. Farmers bear the costs of methane emission, which is indeed price internalization. As a result, a farmer can sell or buy allowances from other farmers, depending on his decision whether to implement emission reduction measures or not. Depending upon the supply and demand for credits, the price of carbon or a carbon credit is fixed.

The scientific literature indicates that GHGs abatement in agriculture (by both the methods) involves several barriers (Smith *et al.,* 2007b; Bakam *et al.,* 2012; Franks and Hadingham, 2012). The practical feasibility depends on various factors, such as measurement of GHGs emissions in the fields either directly or by using proxies, cost-effectiveness of the methods, transaction cost involved, level of input usage, and other biophysical parameters that need to be estimated. However, emission trading has been successful in sectors such as energy and forestry.

Studies addressing market mechanisms to curtail GHGs emissions in Indian agriculture are limited. Most of the published literature deals with the implementation of emission trading in energy sector. Very less attention has been given to the emission/environmental taxation in India, especially on agriculture, which clearly is a research gap. Hence, this paper examines the emission tax as an instrument to reduce methane emission from rice (paddy) cultivation in India. Even though India has a well-established position in the UNFCCC that it will not restrict its own emissions without developed countries failing to do so; by accounting for the historical responsibility and an equitable approach to fair burden-sharing (GoI, 2009), it will be interesting to know the impacts of such a policy on Indian agriculture. Specifically, the paper analyses the impact of emission taxation on the rice sector of India, and the consequent, changes in the demand and price of rice.

Methane Emissions from Rice Cultivation

Methane is mainly emitted by agricultural activities, such as enteric fermentation in domestic animals, manure management, rice production and burning of crop residues and is the second largest greenhouse gas emitted in terms of weight. Of these, rice cultivation is the second most important source of methane emission in India after enteric fermentation (Garg *et al.,* 2006; Aggarwal, 2008).

In India, rice is cultivated in different ecosystems, which maybe grouped as irrigated lowland, rainfed lowland, deep-water, and rainfed upland. Rice is grown on about 42.4 Mha, of which half is under irrigated lowland (50.5%), followed by rainfed lowland (34.1%), rainfed upland (10.0%) and deep-water ecosystem (5.4%) (Pathak *et al.,* 2005). Lowland rice ecosystems are flooded either intermittently or continuously, depending on soil texture, rainfall pattern and irrigation infrastructure. Deep-water ecosystem has paddy fields in low-lying rainfall areas, which are inundated. These two rice wetland ecosystems account for most of the rice area in India and thus for bulk of the methane emissions. Upland rice ecosystem involves no inundation or flooding, and therefore, does not contribute to methane emissions (Singh *et al.,* 1998).

The total methane emission simulated from rice area in India ranges from 1.07 to 1.10 Tg C[1] per year, under continuous flooding conditions and 0.12-0.13 Tg C per year under intermittent flooding (Pathak *et al.,* 2005). This implies that proper water management reduces the methane flux from paddy fields. There are several estimates of methane emissions and these vary widely depending on the methodology and assumptions used (Pathak *et al.,* 2005). A consensus on the estimates is difficult to arrive as the measurement of methane emission is not uniform owing to the varied nature of the rice cropping system and water management practices.

[1]Tg C is Tera gram carbon (1 Tg=10^{12} gram)

Methodology

Valuing Methane Emission

To assess the impact of methane emission on rice production, methane emission is valued to internalize the costs of emission from rice fields. The internalization of emission cost is done by taxing the volume of methane emission from the paddy fields. Methane emission is valued using the concepts of global warming potential and price of carbon dioxide-equivalent. The methane emission estimate used for this analysis is the average methane emission from Indian rice paddies in kg per hectare (CH_4 kg/ha) taken from Bhatia *et al.* (2013). The concept of emission taxation requires a scale, which is adequate, and a direct measurement of GHG emission across different rice production systems. Nevertheless, this paper has used methane emissions data based on per hectare basis measured as carbon dioxide-equivalent, as this was convenient to incorporate in the analysis. The cost of emission of methane per hectare from rice fields is calculated as described below.

1. Conversion of Methane into Carbon dioxide-equivalent (CO_2-eq)

Due to their different radiative properties and lifetimes, the GHGs vary in their warming influence (radiative forcing) on the global climate. They are brought to a common footing using the concept of global warming potential.

Global warming potential (GWP) as defined by IPCC is "*an index, based upon radiative properties of well-mixed greenhouse gases, measuring the radiative forcing of a unit mass of a given well-mixed greenhouse gas in today's atmosphere integrated over a chosen time horizon, relative to that of CO_2*". The Kyoto Protocol is based on GWPs over a 100-year time frame. The GWP of methane is 25, that means, over a time period of 100 years, one metric tonne of methane and twenty five metric tonnes of carbon di-oxide trap an equal amount of heat in the atmosphere (McCarl and Schneider, 2000). IPCC uses CO_2 as a reference gas; hence, all other GHGs are converted into carbon dioxide-equivalents to ensure uniformity.

Carbon dioxide-equivalent emission is the amount of CO_2 emission that would cause the same time-integrated radiative forcing, over a given time horizon, as an emitted amount of a long-lived GHG or a mixture of GHGs. The equivalent CO_2 emission is obtained by multiplying the emission of a GHG by its GWP for the given time horizon (IPCC, 2007).

Following these descriptions and standards, the methane emissions (expressed in tonnes of CH_4 per ha) from rice fields were converted to CO_2-eq emissions by using the GWP coefficient of methane.

2. Assigning Monetary Value to Carbon dioxide-equivalent Emissions

The CO_2-eq emissions are valued employing the existing carbon pricing mechanism. The carbon price or the price of a tonne of CO_2-eq is the price that has to be paid (to public authority as a tax, or on emission permit exchange) for the emission of one tonne of CO_2 into the atmosphere, as given by IPCC in its fourth assessment. The price of carbon as traded in the market and also the shadow price of carbon is used here for valuing the methane emissions that are converted into CO_2-eq terms. The price of carbon has synonymously been used for price of CO_2-eq in this paper.

The average price of carbon in the market for the year 2008 was US$ 16.78/t (Capoor and Ambrosi, 2009) and has been considered as the market price of carbon (MPC) in this paper. The price is determined or fixed depending upon the demand and supply of carbon credits. The shadow price of carbon (SPC) implies the damage costs of climate change caused by each additional tonne of greenhouse gas emitted, converted into CO_2-eq terms. It takes into account the inflation rate and also the rate of rising damage costs due to increased emission. According to Defra[2] , the shadow price of carbon for the year 2008 was US$ 31.16[3] and it was considered in the study. The effect on the production of rice was compared considering both the prices (SPC and MPC) as proxies for emission tax, and the corresponding changes were observed.

The data on area and production of paddy used in this study were obtained from various sources like published literature and government reports. The data on cost of cultivation of rice at the national level were obtained from a representative sample, given in the report 'Cost of Cultivation of Principal Crops in India' (DES, 2007). The cost of production data were used to calculate the shift parameter that is needed to quantify the shift in the supply. The demand elasticity (-0.481) and the supply elasticity (0.374) of rice were taken from Chand (1999) and from Mittal (2007), respectively. The price of rice was taken from FAOSTAT as US$ 134.21/t. In addition to this, methane emission from rice fields was put a monetary value in order to consider it as another input in the cost of rice cultivation. This factor was the determinant for the shift in the production of rice.

Analytical Framework

The effect of emissions trading on production of rice is analysed using the concepts of iso-elastic supply function and shift parameter. The Tax_{spc} and Tax_{mpc} are used as the hypothetical tax levels on methane emissions from rice fields. The internalization of these external costs forms the basis for analysis as their consideration increases production cost and tends to bring about a shift in the supply curve. This, in turn, causes corresponding changes in the price and demand for rice in India. Assuming a single market model, the framework used was split into supply effects and demand effects.

Supply Effects

The iso-elastic supply function incorporating the shift parameter is used to analyse the shift in the production of rice caused due to the internalization of emission costs of methane (Schwarz *et al.,* 2007), i.e.,

$$Q_s = c(1+f)p_s^{\varepsilon_s};\ \varepsilon_s > 0 \qquad \ldots(1)$$

where, Q_s is the new level of rice production after inclusion of the cost of methane emission through the shift parameter f, p_s is the supply price of rice in US$ per tonne, ε_s is the supply elasticity of rice, and c is the supply constant calculated as per Equation (2):

$$c = \frac{Q}{(p_s)^{\varepsilon_s}} \qquad \ldots(2)$$

where, Q is the rice production in million tonnes without emission tax.

[2] Department for Environment, Food and Rural Affairs, UK; Available at www.defra.gov.uk/environment/climatechange/research/carboncost/step2.htm#4

[3] Annual average exchange rate of British Pound (£) to US$ was 1.398 for the year 2008, taken from www.federalreserve.gov/Releases/H10/hist/dat00_eu.htm

The shift parameter, f, is the percentage change in the cost of production of rice when tax on methane emissions is included in the production costs, i.e.

$$f = \frac{C_1 - C_0}{C_0} \times 100 \quad \ldots(3)$$

where, C_1 is the cost of production in US$ per hectare that includes methane emissions tax, and C_o is the cost of production of rice in US$ per hectare without methane emissions tax.

A hypothetical shift in the supply curve due to the tax on methane emission is shown in Figure 1. The supply curve shifts from S_0 to S_1, where, S_0 is the original supply curve and S_1 is the new supply curve after external costs of methane emission are considered in the cost of production.

Demand and Price Effects

The shift in supply curve brings about corresponding changes in price and demand for rice. With this assumption of market equilibrium, the new supply curve also shifts the point of market equilibrium from E_0 to E_1 to adjust to the changes in supply (Figure 1). At the new equilibrium point E_1, the quantity of rice demanded is equal to the changed quantity of rice supplied (Q_s) consequently changing the equilibrium price to p_d.

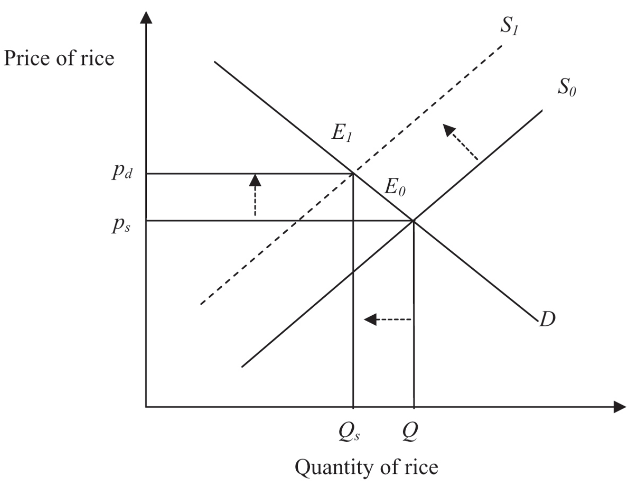

Figure 1. Hypothetical shift in the supply curve

In order to compute the new equilibrium price in the changed situation, the following expression (4) for the demand elasticity was used (Schwarz *et al.,* 2007):

$$\varepsilon_d = \frac{Q_s - Q}{p_d - p_s} \times \frac{p_s}{Q} \quad \ldots(4)$$

where, ε_d is the demand elasticity of rice, Q_s is the new level of rice production, Q is the current level of rice production, p_s is the supply price in US$ per tonne, p_d is the demand price in new market equilibrium in US$ per tonne.

The expression (4) was solved for p_d in order to obtain the new equilibrium market price at which rice will be demanded when methane emissions are taxed.

Results and Discussion

Effect of Emission Taxes on Rice Production of India

The change in rice production at different emission tax levels, such as no emission tax, Tax_{mpc} at the market price of carbon and Tax_{spc} at the shadow price of carbon are shown in Table 1. It can be inferred from the results that the production of rice reduces under both the tax situations, but a larger reduction with Tax_{spc}.

In 2009 India produced 88.43 Mt of rice under no tax situation, which reduced to 83.49 Mt with Tax_{mpc} and 79.26 Mt with Tax_{spc}. In proportionate terms, it amounts to a reduction of 10.37 per cent with SPC and 5.58 per cent with MPC. This larger reduction can be attributed to the higher price of SPC (US$ 31.16/t) than of MPC (US$ 16.78/t). Apparently, it is because the shadow price of carbon includes the damage costs of emission of each tonne of CO_2.

It can, thus, be inferred that the production of rice would reduce if the costs of emission tax were internalized in the costs of production. Hence, the results obtained corroborate the hypothetical shift of supply curve as shown in the analytical framework. The shift in the supply curve further causes the price

Table 1. Change in rice production at different tax levels

Emission tax (US$/t CO_2-eq)	Production of rice (Mt)	Change in production (%)
Tax_{mpc} (16.78)	83.49	-5.58
Tax_{spc} (31.16)	79.26	-10.37
No tax	88.43	-

of rice to adjust according to the new market equilibrium as discussed in the following section.

Effect of Taxing Emissions on Demand and Price of Rice in India

The supply shift brings about the corresponding changes in demand and price of rice to achieve new market equilibrium. The equilibrium price as a result of the shift in supply becomes US$ 149.79/t with Tax_{mpc} and US$ 163.15/t with Tax_{spc}, which is higher than the price when no tax is imposed. We can, therefore, infer that the internalized costs of methane emission from paddy fields are passed on to the product prices. In other words, there has been a clear reduction in the quantity demanded and a surge in the price of rice following supply shift due to price internalization of CO_2-eq costs. The apparent rent transfers from consumer to the producer due to price internalization are evident.

Table 2. Change in equilibrium price at various price levels

Emission tax (US$/t CO_2-eq)	Production of rice (Mt)	New price of rice (US$/t)
Tax_{mpc} (16.78)	83.49	149.79
Tax_{spc} (31.16)	79.26	163.15
No tax	88.43	134.21

The results show that there is a significant impact on the quantity of rice demanded with internalization of external costs of methane emissions. This shift can be significantly higher in the near future owing to the increased emissions from paddy fields if GHGs mitigation strategies are not undertaken. This is quite plausible because India has not agreed to bind by emission targets prescribed in the Kyoto Protocol in the first commitment period of 2008-2012.

Rice fields are one of the major sources of methane emission. There is every possibility that these emissions can rise because rice is the most important single grown crop in India and its demand is likely to increase with increase in population. Moreover, more than half of rice is cultivated under continuous or intermittent flooding conditions which are more conducive to methane emission. Consequently, rice area is going to increase in India (Anand *et al.,* 2005).

Hence, increase in methane emissions from paddy fields would invariably bring about a considerable shift in the supply of rice under the emission tax scenario. Table 3 depicts this change in the supply of rice with a gradual increase and decrease in methane emissions under the condition of environmental regulation. In a scenario where the emission taxes are implemented and the farmer fails to take up mitigation strategies, methane emissions are bound to increase, leading to a reduction in the supply (Table 3) and an increase in the price of rice. This outcome is because of the increased production costs due to the taxes that result in a leftward shift of the supply curve resulting in a price rise and a drop in the quantity demanded. It can as well happen that the consumers switch to substitutes of rice because of the price rise. Agricultural commodities, especially foodgrains being inelastic in nature, the substitution of rice is not known widely at the domestic level. It is true as in the case of fuel industry, where consumers look for cheaper substitutes for fuels. It is implicit that the price signal is passed in a right way. Rice being an export commodity, if the price of rice is higher in India than in other rice-exporting countries, then rice exports from India may decrease. It adds to the incentive to follow methane emission mitigation strategies that are cost-effective and at the same time result in no reduction in yield. On the other hand, it can be inferred from the simulation results that if the taxed emissions are reduced as a result of farm level mitigation efforts, the rice supply increases leading to a lower price of rice.

Table 3. Simulated changes in rice production and price under varying levels of emissions and constant Tax_{mpc} (16.78 US$/$CO_2$-eq) — Sensitivity analysis

CO_2-eq (t/ha)	Change in production (Mt)	Change in price (US$/t)
1.92†	83.49	149.79
2.50 (30)	82.01	154.47
2.31 (20)	82.50	152.91
2.12 (10)	83.00	151.35
1.73 (-10)	83.99	148.23
1.54 (-20)	84.48	146.67
1.35 (-30)	84.97	145.12

Notes: †Average rate of emission calculated from Bhatia *et al.,* (2013).

Figures within the parentheses denote percentage deviations from the average emissions rate

Research has been conducted on various mitigation measures in paddy cultivation to reduce methane emissions and the cost-effectiveness of those measures (Yagi *et al.,* 1997; Wassmann *et al.,* 2000; Ghosh *et al.,* 2003). For example, mid-season drainage has proved effective in reducing the methane emission (Wassmann *et al.,* 2009). The current effective methods in GHG emission abatement, such as, mid-season and multiple aeration cause yield reductions of 7 per cent and 11 per cent, respectively (Towprayoon *et al.,* 2005). However, Wassmann *et al.* (2000) also agree about the limited number of mitigation options available and the limited potential gains, especially in the rainfed and deep-water rice ecosystems, thus questioning the cost-effectiveness.

If the farmer under emissions taxes follows cost-effective method of mid-season drainage to achieve the same level of production, then it would be possible to limit the impact on production and welfare. Our results show a clear decrease in rice production, if emission taxes as mitigation measures were employed. If the tax rate is increased, it clearly brings about a considerable reduction in rice production and vice-versa. Furthermore, the price of rice also rises with increase in taxes (Table 4). The population and rice area projection for India demands an increase in rice area and production to maintain a steady economic growth (Anand *et al.,* 2005). The reductions in welfare due to decrease in agricultural productivity can have a larger negative impact on the economy than climate policy. The welfare loss from agriculture productivity reduction is estimated to be three-times higher than from the climate policies in future (Pradhan and Ghosh, 2012). The results show that the increase in production cost from mitigation strategies is passed on to the consumers, as there is a change in the price observed. Hence, a substantial portion of the loss in welfare is from the farmers who cultivate on marginal landholdings. The farmers with small and subsistence landholdings and less marketed surplus lose, as they have to bear the loss in welfare due to the extra costs.

Table 4. Simulated changes in rice production and price under varying levels of *Tax_{mpc}* and fixed rate of emissions (CO_2eq of 1.92 t/ha) — Sensitivity analysis

Tax_{mpc} (US\$/CO_2-eq)	Change in production (Mt)	Change in price (US\$/t)
16.78*	83.49	149.79
20.97 (25)	82.26	153.70
18.80 (12)	82.90	151.66
14.76 (-12)	84.08	147.92
12.58 (-25)	84.73	145.90
10.91 (-35)	85.22	144.34
8.39 (-50)	85.96	142.00

Notes: *Market price of carbon at the time of study.

Figures within the parentheses denote percentage deviations from Tax_{mpc}

In addition to the welfare loss, rice production if taxed, can result in land-use shift from rice to other crops among subsistence farmers and possibly from crops to other non-agricultural land uses. Rainfed paddy cultivation is also considered a sink that absorbs carbon di-oxide (Singh *et al.,* 1998). Hence, this induced land-use change due to the emission taxes would have emissions as well as food security consequences that could overpower the direct effects of the emissions tax.

Conclusions

The study has revealed that the taxing methane emissions from rice fields would have a negative impact on rice production. However, the magnitude of this impact would depend on food security policy, mitigation strategies and climate policy. The changes in the price of rice have indicated that the internalized methane emission costs would be passed onto the consumer. Even though the emission tax can be attractive for the rice-growing farmers due to the benefit from the increase in the price, the cost ineffectiveness and lower efficiency of current mitigation measures in rice cultivation make carbon taxation in the rice sector an unattractive option both from economic and social welfare point of view. Smallholders cultivating paddy for household consumption cannot take the advantage of the increased price from cost internalization, and hence will have to bear an increased cost on production. Further, the induced land-use change due to higher costs of production can have negative impacts on the food security. Considering the fact that agriculture can enter the carbon market, as it is a viable alternative for sequestering soil carbon, the success of such a climate policy would depend largely on the development and deployment of mitigation mechanisms, which are economically and socially viable without causing substantial reduction in the current productivity levels.

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