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LETTER

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Abstract

Integrated assessment models are commonly used to generate optimal carbon prices based on an objective function that maximizes social welfare. Such models typically project an initially low carbon price that increases with time. This framework does not reflect the incentives of decision makers who are responsible for generating tax revenue. If a rising carbon price is to result in near-zero emissions, it must ultimately result in near-zero carbon tax revenue. That means that at some point, policy makers will be asked to increase the tax rate on carbon emissions to such an extent that carbon tax revenue will fall. Therefore, there is a risk that the use of a carbon tax to generate revenue could eventually create a perverse incentive to continue carbon emissions in order to provide a continued stream of carbon tax revenue. Using the Dynamic Integrated Climate Economy (DICE) model, we provide evidence that this risk is not a concern for the immediate future but that a revenue-generating carbon tax could create this perverse incentive as time goes on. This incentive becomes perverse at about year 2085 under the default configuration of DICE, but the timing depends on a range of factors including the cost of climate damages and the cost of decarbonizing the global energy system. While our study is based on a schematic model, it highlights the importance of considering a broader spectrum of incentives in studies using more comprehensive integrated assessment models. Our study demonstrates that the use of a carbon tax for revenue generation could potentially motivate implementation of such a tax today, but this source of revenue generation risks motivating continued carbon emissions far into the future.

1. Introduction

Most of the governments of the world have asserted that they will take additional measures aimed at reducing greenhouse gas emissions and limit global temperature increase to 2 °C and, potentially, 1.5 °C [1]. Benefits of CO₂ emissions typically accrue to the emitter, while costs of climate change are typically externalized, shared both geographically and temporally. Carbon pricing has been proposed as an effective way of internalizing these external costs. A carbon price increases the cost of CO₂ emissions and thus provides an incentive to reduce those emissions [2–4],

possibly together with other climate policies [5–9]. The so-called ‘cap-and-trade’ approach where allotted emissions are traded in a carbon market is an alternative CO₂ mitigation approach [7, 10]. It has been pointed out that carbon pricing could be more cost-effective than a quantity instrument like ‘cap-and-trade’ [10]. In addition, domestic carbon pricing in different countries can form an international climate regime to overcome the free-riding dilemma in protecting the atmospheric commons [11].

Edenhofer *et al* [8] pointed out that there could be various motivations to levy a carbon tax other than the aim to reduce CO₂ emissions, such as increasing

public financial income, improving air quality, and insuring energy security. Recent studies have noticed that a carbon tax can generate an attractive fiscal income for governments [3, 8, 12]. Pezzey and Jotzo predicted that a carbon price of 50 \$/ton CO₂ charged on all CO₂ emissions can generate a revenue that is about 2% of gross domestic product (GDP) or 12% of the central tax revenue in the US, and about 8% of GDP or 75% of the central tax revenue in China [3]. Thus, this revenue could potentially be used to reduce the tax burden of other distortionary taxes and produce a ‘double dividend’ [13]. The goal of any carbon tax scheme aimed at ultimately achieving an energy system with near-zero emissions would be to levy very high carbon taxes causing carbon emissions to fall and with them a reduction in carbon tax revenue. This raises a concern whether the desire to generate a constant stream of carbon tax revenue would introduce a perverse incentive to keep carbon tax rates lower and CO₂ emissions higher than they would be in a welfare-optimizing case. In this work, we use the phrase ‘perverse incentive’ to refer to situations in which the revenue maximization would result in a lower carbon price, but higher CO₂ emissions and more carbon tax revenue, than in the welfare maximizing case.

There has been rich literature on how to optimize the use of carbon tax revenue for realizing a revenue-neutral tax [13–16] or how to use the revenue to improve the efficiency of the tax system [17–21], but relatively little analysis of the impact of revenue maximization itself on CO₂ emissions in the future. Gago *et al* suggested that the interplay between the increasing revenue-raising motives and the environmental reasons for energy tax deserves more attention [22]. Cooper noticed that a carbon tax can raise great revenues for governments and can be appealing to ministers of finance for many decades before CO₂ emissions are greatly reduced [23, 24], but ‘*the more successful the tax is in reducing carbon emissions, the less revenue will be raised*’ [23]. However, it is unknown whether the revenue maximization will bring a perverse incentive to maintain CO₂ emissions relative to a well-known welfare-maximizing case where both CO₂ emissions and carbon tax revenue are eliminated in the next century.

Traditionally, carbon prices in integrated assessment models (IAM) are optimized to maximize net present value (NPV) of utility, namely welfare [25–29]. Income available for consumption is reduced both by the cost of emission abatement and by climate damages. In most cases considered in such models, the optimal carbon price starts out low but increases afterward. In the long term, as CO₂ emissions fall, carbon tax revenue decreases. An alternative objective function is to maximize carbon tax revenue. Early after the adoption of a carbon tax, incentives to maximize carbon tax revenue could result in a carbon price that is higher than needed to maximize welfare, resulting in

utility loss. Later, the need for carbon tax revenue generation incentivizes policy makers to tax carbon emissions at a low rate to allow CO₂ emissions and the associated carbon tax revenue stream to persist.

In the Dynamic Integrated Climate-Economy (DICE) model [25], welfare (W) is defined as NPV of utility (U) of consumption over time t :

$$W = \sum_t U[C(t), L(t)](1 + \rho)^{-t}, \quad (1)$$

where $C(t)$ is per capita consumption, $L(t)$ is the population, and ρ is the discount rate (5% in DICE). Utility (U) is a function of population size and per capita consumption [25]:

$$U[C(t), L(t)] = L(t) \cdot \frac{C(t)^{1-\alpha}}{1-\alpha}, \quad (2)$$

where α is the elasticity of marginal utility of consumption. Per capita consumption is:

$$C(t) = \frac{Y(t) - M(t) - D(t)}{L(t)}, \quad (3)$$

where $Y(t)$ is the gross output, $M(t)$ is the cost of emission abatement and $D(t)$ is the damage due to climate change. Alternatively, the NPV of carbon tax revenue (R) is defined:

$$R = \sum_t p(t) \cdot E(t) \cdot (1 + \rho)^{-t}, \quad (4)$$

where $p(t)$ is the carbon price and $E(t)$ are unabated CO₂-equivalent (equal to CO₂ hereafter unless specified) emissions.

A prime shortcoming of the conventional welfare maximizing approach is that it does not reflect incentives faced by real decision makers. Politicians engaged in writing tax law often have incentives to increase tax revenues [30, 31]. Further, they have competing incentives to satisfy constituents who seek to pay as little tax as possible to sustain consumption [32]. To bracket this range of incentives, we examine a case in which decision makers are assumed to maximize carbon tax revenue versus maximizing welfare and contrast these two cases with one where the carbon price is kept at zero. We show that, with the economic assumptions of the DICE model, the motivation to generate carbon tax revenue does not incentivize policy makers to have too low a carbon price until no later than approximately year 2085. This provides evidence that the motivation to generate revenue with a carbon tax does not risk perversely high carbon emissions for most of this century. It is to be noted that this time can be brought forward to as early as 2035 if climate damages are larger than those assumed in the model.

We aim to explore the potential consequence of maximizing carbon tax revenues and compare it to the traditional welfare-maximizing scenario. Here we use

the DICE model [25, 29, 33]; it combines a simple model of social welfare and production with an externality from climate damage caused by CO₂ emissions. While it is a gross simplification of reality, this transparent model can be easily understood by economists and non-economists. The high degree of transparency afforded by using this model allows us to communicate more clearly, and allows others to challenge our findings by performing equally transparent calculations. Further, we hope and anticipate that our work will influence others to include revenue generation as a motivation in IAM model comparison exercises that compare revenues under different climate targets and consider a broad range of factors influencing policy decisions.

2. Methodology

Here, we use the DICE model [29] (the latest version DICE-2013R) to generate three paths over the period of years 2015 to 2300 based on three different maximization targets: (1) the *welfare maximizing* case maximizes the NPV of utility of consumption equation (1); (2) the *revenue maximizing* case maximizes the NPV of carbon tax revenue (equation 4); and (3) the *zero-carbon tax* case is the business-as-usual scenario with carbon prices set to zero. Carbon tax revenue is equal to the carbon price times unabated CO₂ emissions equation (4). This revenue is zero when the carbon price is zero or it is high enough to eliminate all CO₂ emissions. Due to a negative relationship between emissions and carbon prices, carbon tax revenue increases as carbon price increases initially and decreases afterward, which is determined by the elasticity of CO₂ emissions to carbon price. We use the DICE model to predict the carbon price path that maximizes the NPV of carbon tax revenue. However, due to lack of interaction with other distortionary taxes in the DICE model, our revenue maximizing case should be distinguished from a revenue optimizing case in the literature, which addresses the impact of carbon taxation on the efficiency of the tax system [19, 20].

Other than changing the objective function, the set-up of the model, including economic and demographic assumptions, is identical to DICE-2013R [29]. Population growth and technological change are exogenous. From 2015 to 2250, the global population is projected to increase from 7.2 to 10.5 billion, while the cost of backstop technologies for 100% abatement decreases from 335 to 102 \$/ton CO₂ temporally (supplementary figure 1 available at stacks.iop.org/ERL/12/064001/mmedia). We fix the savings rate at 26% from an earlier version of DICE [33] and exclude the possibility of negative CO₂ emissions. This set-up allows us to focus on the difference stemming from the alternative objective functions. It should be noted that there are important efforts of improving the DICE model (e.g. [34–36]) or applying other well-developed IAMs

(e.g. [26, 27]) to represent the interaction between the energy system and economy. Further, inertia associated with energy infrastructure is not considered [37]. We use this simple version of the DICE model to show the effect of a change in the objective function. Of course, our precise numerical results depend on details of model formulation and parameter choices; nevertheless, our results point to robust qualitative conclusions. Despite its simplicity, the DICE model is useful to illustrate the difference between welfare maximizing and revenue maximizing cases and investigate factors that influence the difference (see our discussion in section 3.2).

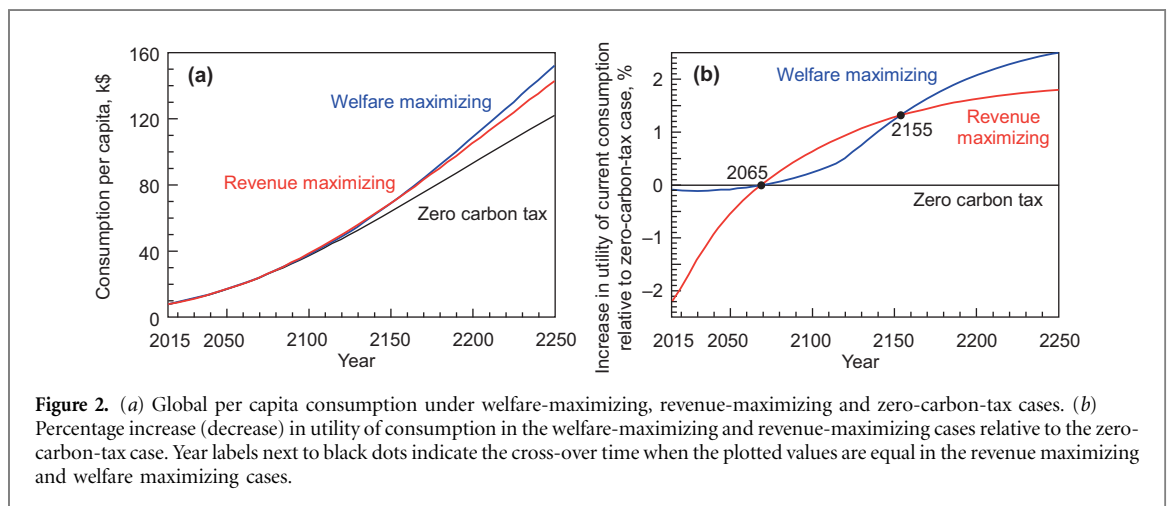
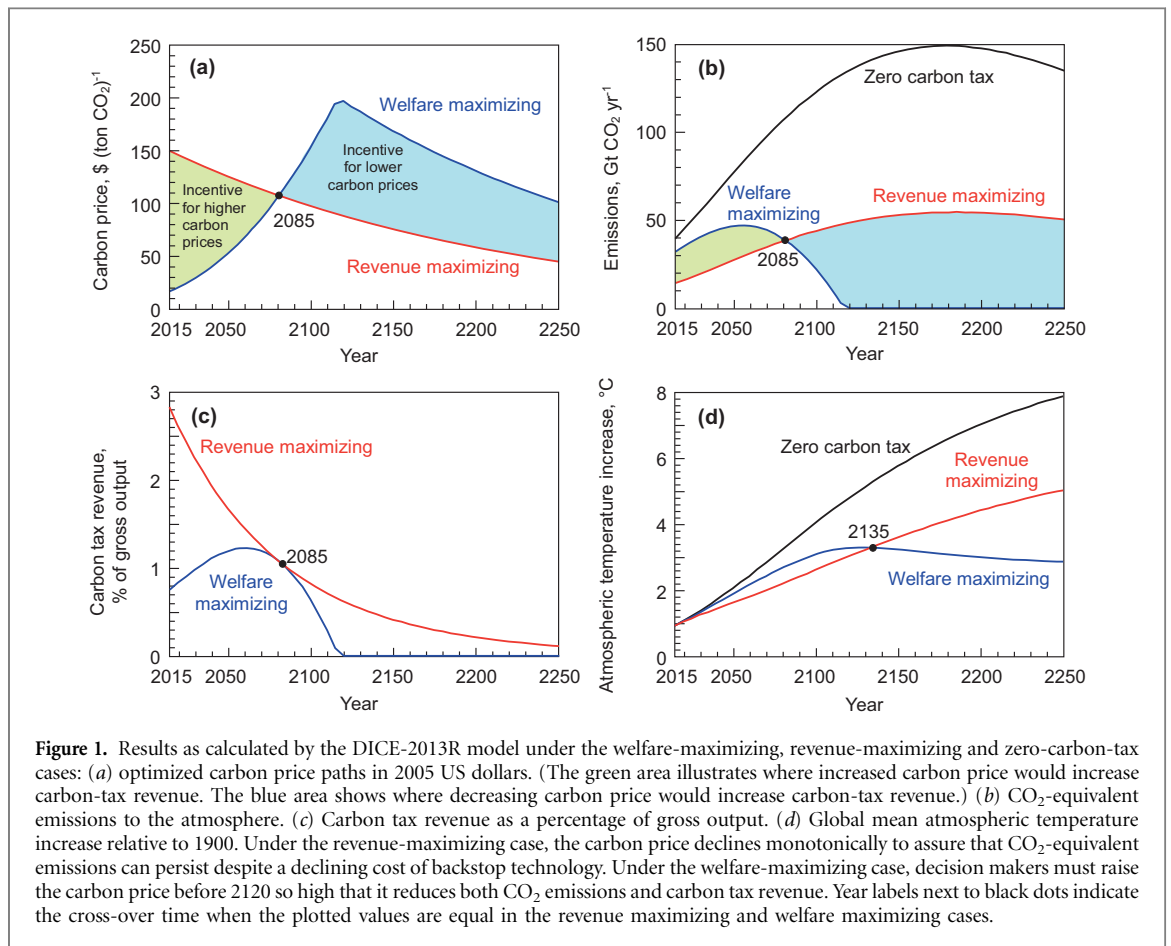
3. Results

3.1. Comparison of scenarios maximizing welfare and carbon tax revenue

Figure 1 shows the fundamental model results of the three cases. In the case without incentives to reduce emissions (*zero carbon tax*), industrial CO₂ emissions increase monotonically until late in the 22nd century. After that, the emissions start to fall because CO₂ emission intensity, defined as emissions per unit of gross output, declines at a rate of 1% per year under decarbonization [29]. It results in atmospheric CO₂ concentrations of approximately 925 ppm (supplementary figure 2) and a global warming of 3.9°C by 2100. In the model, atmospheric temperature continues to grow through 2250 reaching 7.9°C. Under the damage function used in the model, this 7.9°C temperature increase results in a decrease in utility of ~2.5% (figure 2). Use of other damage functions [36, 38] and discount rates [38, 39] would change the quantitative results derived from the standard DICE model, but all predict a high climate risk under no action to abate CO₂ emissions.

Under welfare maximization, the optimal tax rate, or carbon price, is set at a level where the NPV of the marginal utility loss due to the cost of one extra unit of abatement is equal to the NPV of the marginal utility gain due to climate change damage avoided by that last unit of abatement. The DICE model under the standard set of assumptions starts with a relatively low carbon price that continues to increase over approximately the next 100 years (figure 1). At that time, in this idealized model, the carbon price is so high that all CO₂ emissions are eliminated. From that point on, the carbon price is nominally equal to the cost of the carbon-emissions-free backstop technologies that can replace all carbon-emitting facilities. In this welfare maximizing case, global mean temperature increase relative to 1900 is 3.0°C in 2100 but returns to below 3.0°C after year 2180.

Note that the welfare-maximizing carbon price, if applied as a tax rate, would require politicians, approximately a half-century from now, to increase the carbon price so much that it would diminish carbon tax revenue. This could prove politically challenging,



as it would require that politicians place climate objectives above both the objective of raising carbon tax revenue and the objective of appeasing politically forcing seeking lower tax rates.

Alternatively, for some countries, politicians may have incentives to use carbon taxes to generate revenue [8], and thus be motivated to set the carbon price at a level that would maximize this revenue. In the DICE model, if the carbon price is set higher than the optimal value, this could greatly and rapidly reduce emissions. Further, under the revenue-maximizing case, the abatement cost is higher than the damage

caused by climate change before 2060 (supplementary figure 3). A carbon price higher than the optimal value would reduce the net economic output and capital investment and decrease the net output and finally reduce the carbon tax revenue. On the contrary, if the carbon price is set initially lower than the optimal value, the opportunity to generate additional revenue through carbon tax is not realized, and the revenue-maximizing solution is not achieved.

The carbon price in the revenue-maximizing case is initially high, resulting in lower CO₂ emissions, larger carbon tax revenue and a lower rate of

atmospheric temperature increase than in the other two cases considered (figure 1). This, in turn, reduces both per capita consumption and utility, for instance, by $\sim 1.8\%$ in 2020 relative to the zero-carbon-tax case (figure 2). However, the revenue-maximizing case maintains an amount of CO₂ emissions all the way through the end of the simulation period, rather than abating all of them, a markedly different result from the welfare-maximizing case. The revenue-maximizing carbon price is surpassed by the welfare-maximizing case in 2085. Meantime, CO₂ emissions in the revenue-maximizing case are projected by the model to exceed the welfare-maximizing case in 2085 and peak in 2185, the same as that in the zero-carbon-tax case. Cumulative CO₂ emissions in the two maximization cases intersect in around 2125, both far lower than in the zero-carbon-tax case (supplementary figure 4).

In comparison to the welfare-maximizing case, revenue maximization leads to a higher initial carbon price (150 vs. 18 \$ (ton CO₂)⁻¹) but lower later on (a maximum of 150 vs. 200 \$ (ton CO₂)⁻¹), resulting in less near-term climate damage. Under the revenue-maximizing case, the atmospheric temperature increase will reach 2.0 °C in 2075, approximately 20 or 25 years later than in the zero-carbon-tax (year 2050) or welfare-maximizing (2055) cases. In the long term, generation of carbon tax revenue requires CO₂ emissions persist, resulting in a faster rate of atmospheric temperature increase starting at the end of this century than in the welfare-maximizing case (figure 1). Consequently, per capita consumption and utility both fall below the welfare-maximizing case after 2150 (figure 2), but are still higher than in the zero-carbon-tax case.

Note that even in the revenue-maximizing case, carbon tax revenue is never greater than 3% of gross output. However, the total tax rates in most countries are collectively often an order of magnitude greater than this level (supplementary figure 5). It is unlikely that a modern economy could ever use carbon tax as a primary revenue source. Further, even if the carbon price is set at a high level to maximize carbon tax revenue, if there are offsetting reductions in other sources of distortionary taxes, the total revenues could still be neutral when viewed from the perspective of overall receipt of governmental revenues [40].

3.2. Impact of the cost of climate damage and the cost of decarbonization

A different scenario of technology developments can lead to a different abatement cost function and thus affect the optimal carbon price. The DICE model explicitly accounts for a backstop technology that can eliminate CO₂ emissions from fossil fuels. This technology can be CO₂ removal from the atmosphere, or solar energy, or wind power, or some undiscovered sources [29]. The DICE model assumes that the cost for 100% removal of annual CO₂ emissions is 344

\$ (ton CO₂)⁻¹ in 2010, which declines at a rate of 0.5% per year. Because this rate is the most important determinant of the trajectory of carbon price, here we run simulations that assume the cost for backstop technology declines at a rate of 0.25% or 1% per year, corresponding to two cases with a slower or faster pace of technology improvements (supplementary figure 6). Under a faster rate of technology improvement, CO₂ removal is less costly, leading to a lower carbon price to keep CO₂ emissions under the revenue-maximizing case. In contrast, under the welfare-maximizing case, a faster rate of technology improvements brings forward the peaking year of carbon price from year 2120 to year 2100 and leads to lower carbon price thereafter, reflecting the fact that welfare maximization prefers to a deferred mitigation. Consequently, the carbon price meets earlier in the two maximization cases under a faster rate of technology improvements, and the motivation to generate revenue can incentivize policy makers to adopt a lower carbon price earlier.

In addition to the abatement cost function, the optimal carbon price also depends on the shape of the damage function. The degree of convexity of the damage function relates directly with the incentives to address climate change. The DICE model assumes a quadratic function to estimate the damage caused by CO₂ emissions-induced global warming [25]. Here we run simulations where the damage function coefficient is doubled or halved, corresponding to a stronger or weaker sensitivity of the economy to climate change (supplementary figure 7). The results show that, if the economy is more sensitive to climate change than what is assumed in the standard DICE model, the optimal carbon price maximizing welfare would be higher due to increase in the social cost of carbon emissions. However, in the revenue-maximizing case, the carbon prices are largely unaffected by the coefficient of climate damages, changing between 0.3%–0.5% in the DICE model. Carbon tax revenue is almost unaffected by changes in economic damages because the marginal effect of carbon price on CO₂ emissions is much larger than the marginal effect of temperature on the economy. For instance, the global climate damage is only 0.17, 1.8 and 5.2% relative to global total output in 2015, 2100 and 2200 under the revenue-maximizing case.

Our sensitivity analysis illustrates how assumptions regarding abatement cost and climate damage affect our results. While a faster decline of backstop cost and larger climate damage can reduce CO₂ emissions and hence lower the peak warming in the welfare-maximizing case, CO₂ emissions and global mean temperature increase associated with them are slightly influenced in the revenue-maximizing case (figure 3 and supplementary figure 8). It has been suggested that the coefficient of climate damage should be increased by a factor of 4.4 times to be consistent with a 2 °C target in the Paris Agreement [29]. We find that CO₂

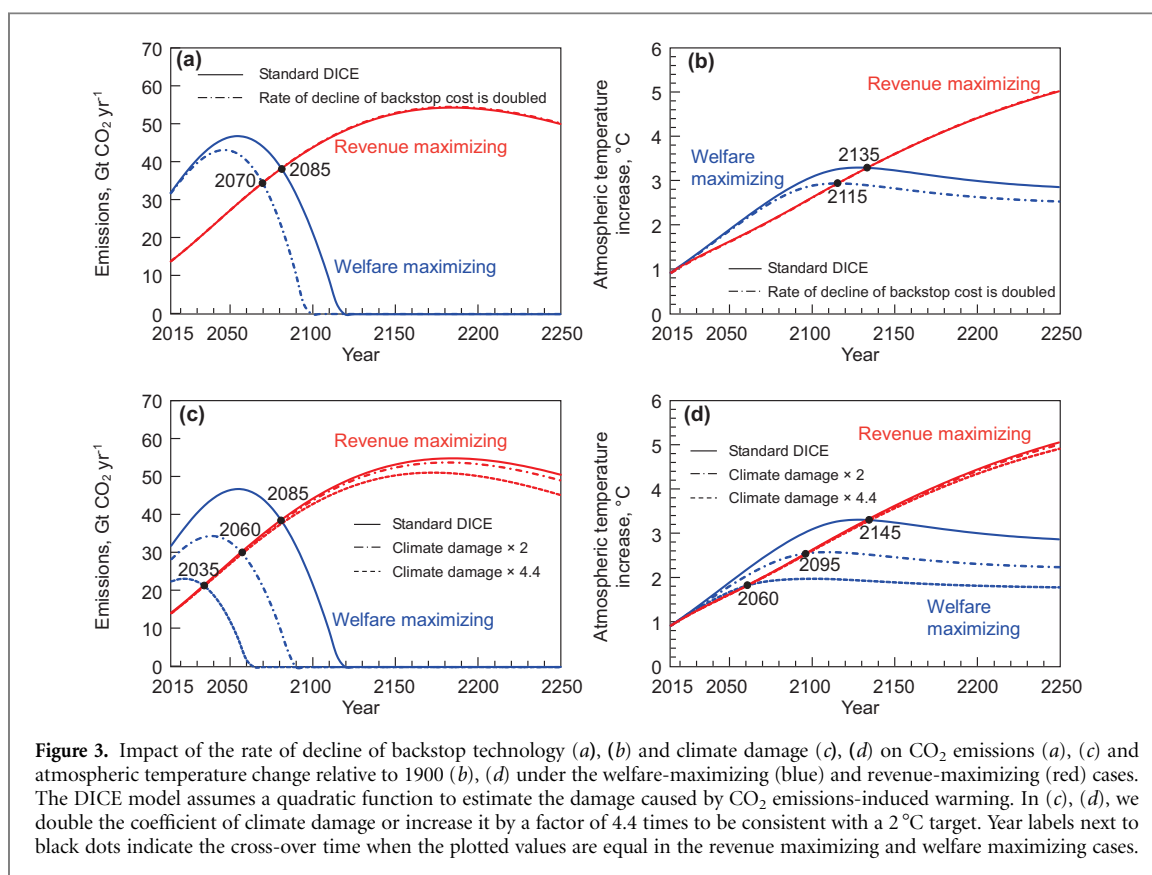


Figure 3. Impact of the rate of decline of backstop technology (a), (b) and climate damage (c), (d) on CO₂ emissions (a), (c) and atmospheric temperature change relative to 1900 (b), (d) under the welfare-maximizing (blue) and revenue-maximizing (red) cases. The DICE model assumes a quadratic function to estimate the damage caused by CO₂ emissions-induced warming. In (c), (d), we double the coefficient of climate damage or increase it by a factor of 4.4 times to be consistent with a 2 °C target. Year labels next to black dots indicate the cross-over time when the plotted values are equal in the revenue maximizing and welfare maximizing cases.

emissions in the revenue-maximizing case will be exceeded by the welfare-maximizing case in 2035, while global mean atmospheric temperature will be exceeded in 2065, manifesting the adverse effect of revenue generation on CO₂ emissions earlier than that under the standard configuration of the DICE model (figure 3). That is, the perverse effects of a revenue-maximizing policy would appear sooner if the welfare maximizing temperature is lower.

3.3. A shift from revenue maximization to welfare maximization in 2085

We notice that carbon-tax revenue maximization will result in higher CO₂ emissions after around year 2085 (figure 1), but only start to increase damage due to climate change and reduce utility of consumption after around 2150 due to reduction in CO₂ emissions in early periods (figure 2). However, carbon tax revenue is declining and no greater than 1% of gross output at the end of this century. If there is a desire to avoid persistent CO₂ emissions, revenue maximization would no longer be the basis for a carbon tax policy. At that time, ceasing reliance on carbon tax for revenue would be a formidable but perhaps not insurmountable challenge. This is further illustrated by a simulation shown in supplementary figure 9, which shows a case where the revenue-maximizing case shifts to the welfare-maximizing case after 2085, the year at which of carbon price in the two cases intersects. Consequently, the atmospheric temperature and utility both move toward the welfare-

maximizing case in the long term and reduce the welfare losses.

4. Discussion

It has been proposed that global actions to abate and eliminate CO₂ emissions as early as possible are critical to ensure that the climate change stays within a safe *planetary boundary* [41]. The goal of generating carbon tax revenue could motivate higher carbon tax rates in the near term, and provide an incentive that would result in the realization of a more ambitious near-term climate target than would otherwise be achieved. However, it is possible that a revenue neutral carbon tax may prove politically more palatable than a revenue generating carbon tax [42, 43]. If, for example, the revenue generated from a carbon tax were distributed equally on a per capita basis, due to the skewed distribution of consumption a majority of people would be net recipients of carbon tax revenue. Further, carbon tax revenue could be used to offset distortionary taxes. Thus, there could be motivation to maintain high carbon tax revenue even in the case of a revenue-neutral carbon tax.

We find that, in the DICE model, a traditional welfare-maximizing framework leads to an initially low but increasing carbon price, defers abatement actions, and decreases carbon tax revenue. In contrast, a revenue-maximizing objective leads to an initially high price, generates more revenue from carbon tax, but with increased climate damage in the long term.

Table 1. Cross-over points for instantaneous emissions and cumulative emissions in all cases considered.

Cases	Year when instantaneous emissions exceed welfare-maximizing emissions	Year when cumulative emissions exceed welfare-maximizing emissions
Central case (default configuration of the DICE model)	2085	2125
Doubling rate of decline of the backstop technology cost	2070	2105
Doubling climate damages	2060	2085
Increasing climate damages by 340% (2 °C stabilization)	2035	2050
A maximum rate of increase in carbon prices limited to no more than one doubling per decade	2085	2115

However, the rapid onset of a very high carbon price would have negative economic consequences that are not captured by the simple DICE model, since it does not represent the time it would take to replace infrastructure and allow for a more elastic response. In the real world, the sudden imposition of a very high carbon price would be expected to create substantial economic dislocations. To illustrate that ramping in higher taxes does not affect our basic conclusions, we perform a sensitivity simulation with the DICE model that maximizes carbon tax revenues with a maximum rate of increase in carbon price (no more than one doubling per decade) starting from the same year 2010 carbon price as in the welfare maximizing case. The results are shown in supplementary figure 10. It shows that the resulting carbon price and carbon tax revenue both fall between the welfare-maximizing and revenue-maximizing cases predicted by the standard DICE model. Thus, in this case too, the perverse incentives to maintain CO₂ emissions for the purposes of tax-revenue generation appear only until late in this century. More detailed studies with more comprehensive IAMs that represent dynamic infrastructure turnover can better address economic consequences of rapid increase in carbon price.

Our goal is to examine whether and when the incentive to generate revenue would oppose the incentive to mitigate climate change, not to provide an analysis of fiscal policy. Nevertheless, the interaction of carbon taxes with the fiscal system has been receiving increasing attention [44]. According to Goulder [45], there are at least two macro-economic effects of carbon taxes. First, carbon tax revenues can be used to reduce other distortionary taxes and produce a ‘double dividend’ as a revenue-recycling effect [13, 46]. However, carbon taxes cannot become a major component of government tax in a modern economy. Figure 1c shows that the carbon tax revenue can contribute to up to 2.8% of GDP in the revenue-maximizing case, and this contribution is declining over time. supplementary figure 5 shows that marginal tax rates are often an order of magnitude greater than this level. Second, the carbon tax may interact with pre-

existing market distortions. Edenhofer *et al* [8] suggested that double dividend can be used to offset the negative impact of a carbon tax on labor demand and hence unemployment. Markandya *et al* [20] showed that a carbon tax can reduce the pre-existing inefficiency of the tax system in a shadow economy and enhance the possibility of benefiting from a double dividend.

In all our cases, the use of a carbon tax for revenue generation could produce a perverse incentive to continue instantaneous emissions as time goes on, leading to higher cumulative emissions in the long term. However, there are many factors that can influence the timing of this cross-over point. Table 1 lists the cross-over points in terms of instantaneous emissions and cumulative emissions for each of our cases. It shows that CO₂ emissions in the welfare maximizing case are sensitive to the rate of decline of the cost of net-zero-emission backstop technologies and the specification of the climate damage function. However, the revenue maximizing case is relatively insensitive to these factors, therefore the time when revenue maximization provides perverse incentives is earlier if the welfare-maximizing emission rate is lower. In addition, if the carbon price is ramped up more slowly to avoid the economic dislocations due to a sudden imposition of a very high carbon price, CO₂ emissions in early periods will be higher than predicted by the DICE model, leading to an earlier manifestation of the adverse effect of the revenue maximization strategy. Therefore, the time when the revenue maximizing motive imposes welfare losses depends on the optimal temperature in the welfare maximizing case and the rate at which a carbon price can be ramped in without producing excessive economic dislocations due to a sudden imposition of high carbon price. These two factors deserve further investigation.

It has been widely noticed that current emission pledges stated by the Paris Agreement are unlikely to hold the global peak warming below 2 °C [47, 48]. Under the default configuration of the DICE model, the revenue maximizing case predicts lower temperatures over the 21st century than in the welfare maximizing case, while the global temperature increase exceeds 2 °C in 2075. This suggests that

policy to meet the 2°C target in the Paris Agreement will need to have either effective carbon price higher than in the revenue maximizing case or a more rapid decline in the cost of net-zero-emission backstop technologies.

5. Conclusion

Integrated assessment models are used to investigate optimal carbon price paths and thus emissions trajectories. However, the conventional objective function that maximizes the social welfare does not reflect all incentives faced by real decision makers. To explore the implications of non-climate incentives to increase carbon tax revenue, we consider an extreme idealized case in which maximizing carbon tax revenue is the only goal. We present this case to understand consequences of the goal of increasing revenue; we do not expect that real decision-makers will ever see revenue maximization as their sole objective. Revenue maximization, relative to welfare maximization, gives a higher carbon price at the beginning and a lower one late in the 20th century and beyond with a lower maximum carbon price. Over the next half century or more, the revenue-maximizing carbon price leads to lower CO₂ emissions than the welfare-maximizing carbon price. The climate and welfare benefits under the revenue-maximizing case are closer to those under the welfare-maximizing case than those under no carbon tax.

A carbon tax can never become the primary revenue source for a modern economy. Because there are social forces opposing higher taxes, a conflict between those who want to maximize revenue and those who want to minimize taxes might result in a tax level that lies between these two extremes. The qualitative conclusion is that, for at least the next half-century, incentives to generate tax revenue motivates a higher carbon price than would be justified by a welfare maximizing objective, and thus would result in less climate damage. However, incentives to generate revenue are projected to oppose the incentives to reduce CO₂ emissions as time goes on, leading to higher cumulative emissions and greater climate damage in the next century. At that time, improving welfare and mitigating climate damage will depend on having political leadership that is willing to increase carbon tax rates so high that both carbon emissions and carbon tax revenue approach zero.

Politicians are driven by opposing incentives, including incentives to generate tax revenue and to minimize taxes for constituents. Over the next half century, these twin incentives to both raise revenue and avoid politically unpopular taxation could motivate carbon prices that are close to the welfare-maximizing optimum. A central conclusion of our work is that the incentive to raise revenue is not a threat to mitigating CO₂ emissions for the immediate

future, but this incentive could pose a threat to CO₂-mitigation in the long term.

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