Lurking in the shadows: The impact of CO_2 emissions target setting on carbon pricing and environmental efficiency.

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Abstract

This paper studies the impact of CO_2 emissions target setting. We empirically investigate the targets set during the Kyoto Protocol period using a convex non-parametric least squares system, quantile regressions, and a comprehensive data set of 125 countries. Our findings reveal CO_2 marginal abatement costs, which: (1) are significantly higher for target setting countries; (2) increase over the sample period; (3) and are an order of magnitude greater than the prevailing emissions pricing mechanisms. The results provide insights into the consequences of policies to curb unwanted by-products in a regulated system and shed light on the price efficiency of carbon markets. Furthermore, we contribute to the debate on emission reduction standard-setting and highlight the importance of shadow price estimates when regulating market instabilities in an emission trading scheme.

Introduction

The World Health Organization predicts significant health risks associated with climate change. Their analysis estimates around 250,000 additional deaths per year from 2030 to 2050, assuming the status quo of current abatement practices and global economic growth[1]. The reduction of greenhouse emissions and the impact on climate change are existential challenges of the 21st century. Many countries have adopted emissions reductions targets since the dawn of the Kyoto Protocol (hereafter KP)[2] in response to this challenge. The nature and efficacy in response to this challenge of these targets have attracted considerable conceptual debate (for example, see Angelis, Di Giacomo, and Vannoni (2019)), but few empirical studies on the impact of explicit target setting.

We attempt to solve this puzzle by testing the differences between target-setting and non-target-setting countries. We use an identification strategy that more accurately estimates the impact of target setting on carbon pricing and environmental efficiency. Specifically, we focus on the KP target setting period and analyse CO_2 emissions for 125 countries. Considering only CO_2 emissions allow for a representative sample of non-target setting Countries (non-annexed 1 Countries) and more meaningful group comparisons in our statistical tests. We use quantile system of convex nonparametric least squares regressions (CQR) to estimate shadow prices (see equation (1) in Kuosmanen and Zhou (2021a)) and an improved marginal abatement cost (MAC) of CO_2 emissions (Xian et al. 2022; Dai, Zhou, and Kuosmanen 2020; Kuosmanen, Zhou, and Dai 2020; Kuosmanen and Zhou 2021b). Convex nonparametric least squares has recently been found to admit a causal interpretation between inefficiency and productivity (Tsionas 2022). Moreover, our method allows for an examination of the factors which help explain relative (in)efficiencies.

We find that target setters during the first KP commitment period were more environmentally inefficient than non-target setters, an unintended consequence of the regulation. We also note that countries with a higher degree of industrialisation and those with more urban populations exhibit lower environmental efficiency. Our results also assert that the marginal cost of CO_2 reduction during the first KP period was an order of magnitude higher than the trading price of CO_2 in the EU-ETS. This result suggests considerable price inefficiency in the emissions market.

Our findings have important implications for international carbon regulation. Authors have highlighted potential gains in CO_2 mitigation from emission trading schemes (for example, Kumar, Managi, and Jain (2020)). Our findings add to this debate. We show that the shadow prices and market prices of CO_2 diverge in the KP period, suggestive of a consistent

[1] These statistics are taken from the WHO factsheet on climate change and health https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

[2] The KP was principled on the idea of hard targets for emissions reduction for industrialised nations and the EU. These were developed in tandem with carbon trading mechanisms, the largest of which is the EU Emissions Trading System (EU-ETS). These developments brought not just matters of environmental production efficiency to the fore but also those relating to carbon price discovery.

misallocation of the traded allowances in the EU emissions trading scheme (ETS). Our results also show an imbalance in shadow pricing due to target setting. These significant frictions in the price discovery of an ETS market may result in a surplus of allowances, exacerbating market instability, and a lower carbon price. The latter likely weakened the incentives to lower emissions. We argue that when policymakers debate structural measures to promote market stability, such as predefined rules to place unallocated allowances in a market stability reserve, shadow price imbalances due to target setting must be considered[3].

In the next section, we review the literature on the impact of the KP on emissions and productive efficiency. Next, we describe the frontier models and data used. We follow with a discussion of our findings and conclusions.

Literature Review

The academic inquiry into the effective management of climate change has a rich history. Historically, holistic models seek to understand how human development, societal choices, and the natural world integrate and influence each other. At a simplistic level, they can estimate the social cost of carbon pollutants. This top-down approach to the economics of climate change has been at the forefront of the discipline (Vale 2016). However, such a global approach may prove dated in the face of stalled international coordination on climate change policy.

Against the bedrock of climate science, the KP agreement was an ambitious attempt to coordinate across borders on targets for emissions reduction. The KP set out to differentiate reduction targets equitably in terms of a nation's industrial development, a comparable level of pollution, and the ability to mitigate the ecological damage of global emissions levels. Specifically, countries were categorised into two Annexes. Annexe 2 countries, which set explicit targets, were mostly developed nations, with higher industrial production. Annexe 1 countries, defined as developing, were not subject to targets, although most ratified the Protocol.

In the run-up to the end of the first commitment period of the KP, there were political moves to create second commitment period targets. The Doha amendment in 2012 extended the scope of the protocol targets to cover the period until 2020. The Doha Amendment was a bridge arrangement up to 2020 until a new global agreement; the Paris Agreement came into force. The Paris agreement has attracted considerable criticism. Commentators cite a lack of explicit targets, ambiguity in regard to sanctions for failing to meet targets, and a more explicit international focus as a critical weakness to country policymakers taking direct ownership of their emissions targets.

As global cooperation has stalled in the last decade, attention in the policy debate has shifted towards bottom-up strategies for climate change mitigation. Vale (2016) argues that the lack of collective political will, in turn, has shifted the nature of the associated academic enquiry. The recent focus on the economics of catastrophic risk insurance, trade and climate, and climate change adaptation represents a shift towards a more realistic investigation of climate policy in an age where the globally coordinated climate action seems illusory.

A common approach to establishing world-wide cost estimates for the reduction of polluting emissions is to establish a global production model. In such a model, based on a set of capital and human inputs, each country acts as a producer of desirable outputs such as GDP at the cost of producing undesirable outputs such as pollutants from industrial activity. Under various assumptions, such a model can reveal each country's relative (in)efficiency,calibrated against a backdrop of global optimal environmental efficiency. Furthermore, abatement of pollution output can be at the marginal cost of the desirable output foregone.

Zhang and Folmer (1998) document and critique the myriad of marginal abatement cost models. They consider both bottom-up technology-based models and top-down macroeconomic models. They conclude that combining these models best assesses the overall consequences of controlling CO2 emissions. Nordhaus and Boyer (1999) use a scenario-based approach to analyse the economics of various trading emission schemes (ETS) for Annex I countries for the KP. They find costs of the ETS's are seven times greater than the benefits, two/thirds of the net global cost of $716 billion, are borne by the US[^4] and conclude that the proposed schemes are highly cost-ineffective.

[^4]: Compared to a *so-called" efficient abatement strategy for global temperature reduction, the proposed strategy was eight times more costly.

This early work was suggestive of a broad approach to abatement cost analysis beyond the consideration of CO^2 associated pollution. Reilly et al. (1999) use the Regional Integrated Model of Climate and Economy (RICE) to show that a multi-gas control strategy could significantly reduce the costs of fulfilling the KP compared with a CO^2-only strategy. They argue that the global warming mitigation potential of the KP is limited and argue for a more comprehensive multi-gas approach. Burniaux (2000) extend previous OECD analysis to emission abatement of methane and nitrous oxide. They conclude that the economic costs of implementing the targets in the KP are lower than suggested by previous CO^2-only results. In the longer term, most abatement will likely have to come from CO^2, and the inclusion of other gases in the analysis may not substantially alter estimates of economic costs.

In the later years of the KP period, researchers considered a more statistically sophisticated approach for analysing the KP. Buonanno, Carraro, and Galeotti (2003) adapt the RICE integrated assessment model to account for endogenous technical change[^5] and shows that results are significantly impacted when modelling R&D. They find that total costs of compliance with Kyoto; are higher with induced technical change; are reduced when trading permits are introduced, and technological spillover reduces the incentive for R&D, but overall costs are higher in the presence of spillovers. McKibbin and Wilcoxen (2004) update their earlier estimates of the cost of the KP using the G-Cubed model, taking into account the new sink allowances from recent negotiations as well as allowing for multiple gases and new land clearing estimates. They perform a sensitivity analysis of compliance costs to unexpected changes in future economic conditions. The paper evaluates the policies under two plausible alternative assumptions about a single aspect of the future world economy: the rate of productivity growth in Russia. They find moderate growth in Russia would raise the cost of the KP by as much as fifty per cent but would have little effect on the cost of the alternative policy. They conclude that the KP is inherently unstable because unexpected future events could raise compliance costs substantially and place enormous pressure on governments to rescind the agreement. The alternative policy would be far more stable because it does not subject future governments to adverse shocks in compliance costs. Fischer and Morgenstern (2006) find that estimates of marginal abatement costs for reducing carbon emissions in the United States by the significant economic-energy models vary by a factor of five, undermining support for mandatory policies to reduce greenhouse gas emissions. Their meta-analysis explains which modelling assumptions are most important for understanding these cost differences and argues for developing more consistent modelling practices for policy analysis.

[^5]: They explore three formulations; technical change is endogenous and enters the production function via the domestic stock of knowledge; there is an additional effect of domestic stock of knowledge on the emission-output ratio; the output of domestic R&D spills over the other regions' productivity and emission-output ratio.

In more recent studies researchers focus on how a country's economic characteristics fluctuate with abatement challenges. Halkos and Tzeremes (2014) apply a probabilistic DEA approach to estimate conditional and unconditional environmental efficiency of 110 countries in 2007. They find that a country's environmental efficiency is influenced in a non-linear mannerby both the obliged percentage levels of emission reductions and the duration forwhich a country has signed the KP. Cifci and Oliver (2018) use regression techniques to illustrate the conflicting political strands of the climate change argument. The results show that the KP reduced Annex I countries' GHG emissions by approximately 1 million metric tons of CO2 equivalent relative to non-Annex I countries. Contrariwise, these countries experienced an average reduction in GDP per capita growth of 1-2 per cent relative to non-Annex I countries. Both findings illustrate that the international climate change agreements are fragile due to the clash of short-term political goals with long-term reduction ambitions.

Empirical Design

We model the global economy as a production machine. Capital and labour are inputs, creating economic output (desirable). However in doing so the economic "machine" also produces CO2 emissions which are undesirable. We use the concept of an efficiency frontier to model combinations of inputs and outputs. We do so not in a deterministic way, but using stochastic non-parametric methods. This affords us the advantage of not having to specify a functional form of the input-output relationship a priori and also the ability to model noise in the data. We are concerned both with measuring environmental inefficiency (distance from the frontier), but perhaps more subtly shadow costs. These shadow costs can be interpreted as opportunity