From negative to positive carbon pricing in Mexico

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1. Motivations underlying the research

Over the course of a decade, Mexico transitioned from a peak of 1.8% of GDP given as fuel subsidies in 2008 to generating positive fuel tax revenues equivalent to 1.6% of its GDP in 2018. In this paper, we analyze Mexico's carbon pricing experience and its effects on the country's carbon emissions. The policy changes that were embedded in its mid 2010s energy and fiscal reforms have been described as containing "valuable lessons for other emerging countries wishing to carry out a broad-based reform of the energy sector" (OECD 2017; OECD/IEA 2021). Yet, scholarly work on Mexico's experience with graduality, fiscal innovation, and market structural changes in the transition from negative to positive carbon pricing, is scarce, especially the one linking it to their effects on reducing greenhouse gas emissions and advancing its Climate Change goals and commitments. This paper seeks to find out what are precisely those lessons that can help other countries overcome their fuel subsidy challenges, using politically feasible and resilient strategies, and then transition to a robust positive carbon pricing policy that supports a decoupling of GHG emissions from economic growth.

This paper contributes to the literature in three ways: First, it describes a subsidy reform that was followed by a strong positive carbon pricing in an emerging economy in Latin America. Given that the success of reforms elsewhere has been mixed (Clements, et al. 2019), Mexico stands out as a relevant example of how to circumvent its challenges (OECD 2017; OECD/IEA 2021). Second, uses an institutional economics lens to analyzes the features that are thought to have made the Mexican strategy successful; among them are its graduality, its ability to generate a long-term price signal, and its capacity to weave the momentum of the final stage of its subsidy phase-out into the strategy for structural change that made explicit and implicit carbon taxing a resilient element of Mexico's fiscal and environmental policy. Finally, this paper searches for the evidence of the outcomes of this transition. The substantial and sustained price increase experienced over the period analyzed was, theoretically, enough to alter significatively the carbon intensity of the Mexican economy through changes in its consumption of gasoline and diesel, and that needed to be documented.

2. A short account of the research performed

This paper follows a double path: first, it reviews changes to the institutional framework in Mexico, and its specific energy pricing and tax policies that allowed the subsidy phase-out and the introduction of a carbon tax and other fuel excise taxes to be established. Secondly, it estimates the effect this carbon pricing had on carbon emissions in Mexico, specifically the carbon intensity of its transportation sector, by developing policy counterfactual scenarios based on previously observed policy behavior and applying to the resulting price counterfactuals the estimates of price elasticities of demand for fuels previously obtained by the authors. Fossil fuel prices increases, brought on by carbon pricing policies, would have influenced firms and households' decisions to reduce the quantity of fuel demanded, caeteris paribus, via a diverse combination of actions taken both with a short and long term perspective, and these decentralized actions would be captured in the estimated price elasticities of demand for each fuel. By comparing the results to the country's NDC baseline, and reviewing other significant convergent policies, the paper estimates of the most likely effect of carbon pricing on the Mexican economy.

3. Main conclusions and policy implications of the work

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Mexico's government was giving, on average, *subsidies* of US$ 13 per ton of CO_2 to consumers these fuels in 2010; by 2019 *positive carbon prices* through a carbon tax and other excise taxes had changed the situation to imposing net taxation between US$ 91 and US$ 98 per ton of CO_2. The authors find evidence that this transitioning from negative to positive carbon pricing helped Mexico reduce the gasoline and diesel *carbon intensity* of its economy by 29% between 2010 and 2019. These changes were both gradual and structural, and the analysis points to these features as responsible for making positive carbon pricing politically feasible in its inception and resilient to political and economic change later on, including to the effect of the diverse price shocks experienced from 2020 onwards.

The paper approximates the magnitude of the avoided emissions using counterfactual scenarios and concludes that, in 2014, after the subsidy phase-out had been completed, the country was already emitting nearly 28.6 $MtCO_2$ less per year from the use of gasoline and diesel. By 2019, the avoided emissions were larger, approximately 39.8 $MtCO_2$ per year less than if the subsidy policy had remained in place. This reduction represents between 17% and 20% of Mexico's NDC baseline projection for transportation fuels for the period. The estimations show that 33% of the emissions reductions for gasoline and diesel can be attributed to the subsidy phase-out, 2% would be attributable to the explicit carbon tax, and the remaining 65% come from the carbon price implicit in the excise tax. Despite having different names, all carbon pricing instruments converge in Mexico to reduce fuel consumption and emissions, both in absolute and per unit of GDP.

One of the conclusions is that, if all elements of the current carbon pricing policy are maintained and supported with new regulations and investment in transportation and linked economic sectors, such that it allows consumers to be equally or even more fuel-price responsive, Mexico will be able to fully deliver on its updated transportation sector NDC commitments by 2030. Any higher ambition will require higher carbon prices.

Moving forward, Mexico can increase its carbon pricing via a revision of the rates of its federal taxes (carbon and excises): increasing the rate, phasing-out exemptions, and setting a uniform rate per tCO_2 for all fossil fuels. Similarly, the development of Mexico's Emission Trading System, plus the nascent state-level environmental taxation, are key policy instruments to further increase net carbon prices and their efficiency.

Mexico's phase-out of fuel subsidies, followed by the introduction of positive carbon pricing, is helping the country transition to a low-carbon growth path. Its experience, with graduality, fiscal and market structural changes, and a carbon pricing structure responsive to international markets, can provide important lessons for other countries, especially those that still have mounting fuel subsidy challenges and require a politically feasible strategy to overcome them.

A Global South perspective on stranded regions: insights from the decline of coal mining in Cesar, Colombia

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1. Motivations underlying the research

This research was motivated by our interests in understanding what are the specific challenges that the global energy transition with the decline in demand for coal can create locally in regions economically dependent on coal extraction in the Global South. The goal of this project was to fill a gap in the academic literature on economic decline in extractive regions, a body of work widely used in current debates about just transitions in coal regions, which has tended to focus on cases located in the Global North without fully capturing the specific dimensions of Global South producing regions. This research

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was also motivated by our interest on reflecting about the implications for the economic decline in extractive regions of the implementation of climate policies globally, something that has also not been the focus of most research on economic decline in extractive regions. To address this, we drawn on the burgeoning literature on the notion and risks of stranded fossil fuels assets, which however has focused on the risks and implications for private sectors (financial actors and fossil fuel firms) and with a lower degree to national economies, without considering the risks for subnational regions.

By putting into conversation the literatures on economic decline in extractive regions and debates on stranded fossil fuel assets, we analyzed the empirical case of Cesar, a region located in the north of Colombia. Cesar is Colombia's second most important coal producer region and 40% of its regional GDP is associated with coal production. However, this activity declined by 33% in 2020. The decline in demand during the pandemic also involved the unexpected idling of some of Cesar's largest coal mines. The following research question guided this study: What were the main economic impacts that the region of Cesar faced during 2020 with the drop in coal production and stranding of some of its most important coal mines?

2. A short account of the research performed

This paper is based on a case study of the decline in coal production in Cesar. Choosing this case, and 2020 as the key year to analyze the risk of the region becoming stranded, are relevant for three reasons. First, Cesar is highly dependent on coal exports, which makes the region vulnerable to changes in international coal markets, and therefore a useful case to understand the risks of stranded regions. Second, high market concentration in Cesar, dominated by multinational extracting firms, is useful to show how the decision power on the economic future of the region relies on very few and mostly foreign hands. Finally, the unexpected shock in production created by the pandemic, which catalysed the early surrendering of mining titles from the company Prodeco, provided a 'natural experiment' to understand the impacts that an increase in stranded coal mining assets can create regionally.

Qualitative primary data was produced through 26 semi-structured interviews conducted in Cesar during February 2021. The list of interviewees includes direct employees of coal companies (both from management and operational positions), local workers and business owners not directly related to the coal industry, and representatives from local governments, trade unions, civil society organizations, NGOs, and universities (see article's appendix for complete list). Sampling was based on a stakeholder's map, created through the review of secondary literature and contacts gained in previous research projects. Interviews were conducted in Spanish and lasted between 15 and 125 minutes. Some interviews took place online due to pandemic-related restrictions. This case study also included the analysis of statistical data and extensive review of secondary literature, including academic articles, company reports, press releases, policy documents, and the grey literature.

3. Main conclusions and policy implications of the work

We identify various economic impacts for workers, communities, and local governments caused by the structural crisis faced by this activity. Eight challenges identified can be of relevance to other coal-dependent regions in the Global South. Some of the challenges identified correspond to national challenges accentuated at the regional level (young investments, economic and fiscal dependence, high labour informality and low labour protection, weak environmental liability regulations, and environmental races to the bottom), while others correspond to more regionally-based challenges (poverty exacerbation, vulnerability of informal and low value-added activities, and direct roles of fossil fuel companies in public spending).

The main argument that we draw from this analysis is that in coal-dependent regions in the Global South, many of the impacts recognized by the literature on the Global North are exacerbated. More importantly, however, is the fact that additional challenges for a managed decline in coal production are created. Particularly important is the precariousness of local economies based on high levels of informal and low value-added activities, dependent on the role of coal companies in social spending, and with

limited institutional capacities, budgets, and available data on key policy planning variables such as employment and economic linkages.

Drawing from this analysis, two policy recommendations suitable for Cesar and other fossil fuel regions in the Global South are as follows: (1) Planning the phase-out of fossil fuels is not only important from an environmental perspective, but also to reducing the risks of stranded regions. A preventative reconversion process reduces the chances of a sudden destabilization of regional economies and offers opportunities for timely diversification efforts by taking advantages of still existing rents from the fossil fuel industry. A planned response also requires improving regulatory frameworks to deal with abrupt withdraws of mining titles, selling of operations, and drops in production levels. (2) Given the risk of a possible race to the bottom in terms of environmental and labour standards, it is fundamental to timely identify potential risks in this regard, update regulatory frameworks, and prioritize investments that ensure good-quality jobs and more sustainable economies. Moreover, accelerating investments in environmental remediation can create short- and medium-term employment as well as promote an earlier economic reconversion by ensuring appropriate ecological conditions for new productive activities.

Mexico's Energy Prospects: Gains from Renewable Sources over a Fossil Fuel-dominated Environment

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1. Motivations underlying the research

Following the energy reform in December 2013, Mexico set its priorities by pushing a more competitive electricity market and pursuing specific greenhouse gases emissions and renewable penetration goals. However, with the arrival of the new administration to the federal government on December 1, 2018, the a-priori promising future of a cleaner environment in Mexico has been seriously compromised. Specifically, the current administration aims to increase revenue from the national power company and gain control of the electricity market at the expense of consumer welfare and the environment. In the medium- and long-term (that is, within the next 10 to 30 years), however, renewable energies should become competitive and marketable energy sources due to significant technological advancements, including battery storage infrastructure. Because of this, it is interesting to analyze, and to quantify as much as possible, the potential benefits of an energy system based primarily on renewable energy compared to another scenario dominated by fossil fuels. Therefore, our analysis uses a baseline scenario that follows the energy policy agenda of the current administration which is popularly known as the "Fourth Transformation" or "4T". Throughout the paper, we contrast the 4T scenario to an alternative "green scenario". Based on our model, we can deduce the implications of changes in energy supply and demand on the rest of the economy, such as impacts on economic activity, air pollution, and, more generally, economic welfare.

2. A short account of the research performed

We develop a mathematical programming, economic equilibrium model for the fuel and electricity sectors in Mexico. The model includes imports of fuels from the rest of the world and employs the economic surplus maximization approach first introduced by Samuelson (1952) and later developed by Takayama and Judge (1964, 1971). We follow the modeling strategy of larger and well-known sectoral,

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partial equilibrium models (e.g., Beach et. al, 2012; Chen et al., 2012; Lapan and Moschini, 2012; and Núñez, 2021). Technically, we develop a static endogenous-price, mathematical programming model, emphasizing the Mexican energy sectors, which are embedded in a multi-region, multi-product, spatial partial equilibrium model of the Mexican economy.

Our partial equilibrium model has the clear advantage of focusing on an accurate representation of the energy sector. In contrast, computable general equilibrium (CGE) models could be used to analyze further effects in other sectors of the economy at the expense of a less accurate fitting in the energy sector. However, even without relying on a CGE model, we adapt the energy-elasticity approach to perform complementarity calculations and assess the changes in employment and production under the two alternative scenarios. Correspondingly, we evaluate the impact that the different mixes of energy generation, and various levels of electrification in the transportation and manufacturing sectors would have on gross domestic product and the national employment level.

3. Main conclusions and policy implications of the work

The main result is that maintaining the status quo energy policy will only benefit the government-owned electricity company revenues for a limited period. Yet, an alternative green strategy will boost economic growth, reduce emissions, and ultimately benefit social welfare in a substantial way. In particular, most electricity generated under the 4T scenario will come from fossil fuels (mainly natural gas for combined cycle technology) representing 78 % of total generation in 2035 and 77 % in 2050, while the primarily renewable source will be hydropower in this context. By contrast, under the green scenario, renewables will predominate (68% in 2035 and 80% in 2050), primarily from solar and wind sources while hydropower will decline over time. As well as increasing the use of renewable energy, the green scenario will lead to a higher demand for electricity since the cost of electricity will go down, and manufacturing and transportation will become more electrified. As a result, under the green scenario which implies a larger share of renewables and higher amounts of electricity consumed, most economic sectors are better off. The economic surplus of the domestic sectors in the green scenario will be 11% (respectively, 82%) higher in 2035 (2050) than in the 4T scenario. For the projected years 2035 and 2050, GHG emissions in the green scenario will be 56% and 71% lower than in the 4T scenario, respectively. Finally, the benefits of the green scenario will translate into an increase of 1% percent in annualized GDP growth and employment level in 2035 and 1.2% in 2050.

Decision Framework for Selecting Flexibility Mechanisms in Distribution Grids

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1. Motivations underlying the research

The decarbonisation of the electricity generation mix is driving a decentralisation that requires revisiting markets, regulation, organisation, etc. of the power system. Additionally, electrification is seen as a central means to decarbonize other electricity uses in transport or heating. In this context, it becomes necessary to integrate new forms of electrical energy consumption and new forms of generation which, in turn, raises new requirements for Distribution System Operators (DSOs).

The grid needs, such as congestions management or the control of some parameters like voltage, or amperage can be met in the traditional way (i.e. investing in network assets). However, these can also be satisfied through the acquisition of flexibility services provided by the resources connected to the network. These services must be adapted to the needs of the network itself. At the same time, for that service request and delivery to occur, the necessary enabling mechanism must be in place. A flexibility

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mechanism is how the system operators acquire flexibility services from third-party providers, such as a flexibility market, dynamic tariffs, or bilateral agreements.

The Transmission System Operators (TSOs) face the challenge of managing electricity systems with decentralised generation and low inertia due to the inevitable disconnection of big synchronous fossil fuel-powered or nuclear generators that provide stability to the system. Distribution System Operators (DSOs), on the other hand, have the challenge of maintaining the quality and reliability standards of the networks in a system that is increasingly moving away from the traditional distribution function of supplying energy and are becoming energy exchange spaces, as demand is increasingly intertwined with generation and whose consumers will have more different and more unpredictable profiles.

Network needs that may occur as a result of the energy transition are therefore very diverse, and so should be the flexibility mechanisms used to address them. The objective of this research is to cover the criteria that will condition the selection of the flexibility mechanisms starting from the DSO's own needs. Thus, the applicability of the different flexibility mechanisms for each situation will be studied. In other words, the gap to fill is matching the flexibility mechanisms proposed in the literature and the real needs of the distribution network. This will help DSOs to focus on the most suitable mechanisms for their expected needs.

2. A short account of the research performed

Each of the characteristics that can influence the selection of flexibility mechanisms has been studied individually. Identifying the needs faced by the DSO, their location in the network (LV, MV, HV) and the timeframe in which the need is managed. Other relevant criteria have also been studied in the choice of mechanisms, such as the impact on the TSO's responsibility, the possible generalisation of the problem or the potential market liquidity. Considering all of them, the paper proposes a clear decision framework to match DSO needs with the most suitable flexibility mechanism. Three types of situations were identified:

- Some mechanisms must necessarily be coordinated with the TSO because of their impact on balancing or TSO grid. Then depending on the timeframe and the need, different type of common or coordinated markets may be used.
- Other situations in which there is not enough market liquidity, non-market-based mechanisms are selected, such as bilateral agreements for specific needs or dynamic tariffs for generalised needs.
- And finally, for situations in which there is sufficient liquidity and there is no impact on the TSO's operation, depending on the need and timeframe, different types of local markets can be selected.

3. Main conclusions and policy implications of the work

The exclusive mechanisms for DSOs are still very unexplored in the literature and the lack of liquidity plays a key role. Market-based mechanisms, preferred by regulators, can provide optimal solutions when liquidity is high. Local DSO markets could work under those premises but illiquid situations may occur in case of lack of maturity of the market and this situation may even persist. Thus, non-market mechanisms may also have a relevant role to play in the DSO environment.

The market design options, such as the timeframe, the exchange of information, the traded product, the price formation, the cost or the barriers to entry and exit, will determine the existence of more or less liquidity and, therefore, the efficiency of a market-based mechanism. On the other hand, while products and services need to be developed to manage flexibility markets, they do not strongly influence the choice of mechanism, but it does impact liquidity.

The proposed framework aims to guide the most appropriate mechanisms, but the authors acknowledge that these mechanisms are not implemented in isolation but in a combined manner. Future research should analyse compatible combinations and apply them to real case studies.

Impact of Japanese House Insulation Subsidy System on Home Owners' Energy-Saving Awareness

Mieko Fujisawa[a] and Mika Goto[b]

1. Motivation underlying the research

Achieving a massive reduction of carbon dioxide emissions in the household sector requires consumers being made aware of the underlying issue. In other words, if consumers update their energy-saving awareness and related behaviors, the energy-efficiency effect can be expected to endure.

The Japanese government has addressed the issue of improving the thermal insulation performance of houses through various policy measures. For example, it provides subsidies and tax benefits directly to those consumers who consider a high level of insulation performance when they build their homes. This study investigates one such subsidy, the housing eco-points system, which has been in place in Japan since 2010, by focusing on its indirect effects. "Eco-points" is a Japanese–English term that combines ecological (eco) and reward (points) aspects. The basic premise of this study is that the subsidy not only directly affects the functionality of houses in terms of improving their insulation performance, but also indirectly affects consumers' behaviors by improving their energy conservation awareness.

This study thus analyzes the indirect effects of the housing eco-point system in Japan. To this end, it covers the introduction of the system from 2010 to 2012, which allows to accurately measure its newly generated indirect effects.

We develop and examine three hypotheses related to the indirect effects of energy-saving consciousness: (1) consumers exposed to the learning effects would become more conscious about energy conservation (H1); (2) a subsidy system based on self-declaration enhances consumers' energy-saving consciousness (H2); and (3) consumers living in existing houses develop greater awareness about energy saving than those living in new houses once they realize the benefits of performance improvement after insulation repairs (H3).

2. A short account of the research performed

We collected original data using a questionnaire survey on consumers who used the subsidy system. We randomly sampled those consumers who used the housing eco-point system and then collected data using a stratified sampling method that classifies them into two strata: those living in new houses and those living in existing houses. Therefore, the survey was divided into two phases.

The first phase was a preliminary investigation used to select the respondents (monitors) and the second phase was the final investigation (final survey) of the respondents who had used housing eco-points. For the final survey, we invited 1,254 monitors from the preliminary investigation to participate in the survey via e-mail. The response rate was 80.3% (1,007 responses), which was sufficient for the empirical analysis. Among the effective responses, 50.3% (507 respondents) were residents living in new houses and 49.7% (500 respondents) owned existing houses.

The final survey respondents included similar percentages of men and women, most of whom were married. The age range of the respondents varied for those who lived in new and existing houses. Respondents living in new houses were mostly in their 30s, followed by those in their 40s, while respondents living in existing houses were mostly in their 60s, followed by those in their 50s. Since the average age of the respondents living in existing houses was relatively high, they did not have live-in children. Most respondents lived in detached houses. The differences between those respondents living in new and existing houses are statistically significant—at least at the 5% significance level by the Chi-square test.

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We performed a logistic regression using the dataset from the questionnaire survey. The dependent variable was a latent variable indicating consumers' perception of changes in awareness of energy-saving—whether they began to think about energy savings or not.

The results of the logistic regression analysis reveal that the following factors exert a positive effect on energy-saving awareness: realization of the insulation-performance effect, understanding of insulation and energy conservation standards, experience of the environmentally-concerned respondents, timely receipt of the subsidy, and the self-declaration system. Further, the results show that when consumers are exposed to a learning effect through experience and understanding, they become more conscious of energy conservation. This indicates that the housing eco-points subsidy indirectly affected energy saving behaviors.

3. Main conclusions and policy implications

The results indicate that H1 (consumers exposed to the learning effect become more conscious about energy conservation) was supported, as was H2 (the design of subsidy system is important because it has the power to change consumer consciousness). However, the results do not support H3. That is, consumers gain energy-saving consciousness through experience and understanding rather than simply through financial incentives.

This study provides policymakers with useful guidance for policymaking and institutional design by proposing a novel method for reducing carbon dioxide emissions through the optimized usage of limited resources amid financial constraints.

Model-based evaluation of decentralised electricity markets at different phases of the German energy transition

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1. Motivation underlying the research

This paper has been motivated by the current discussion about the decentralisation of the energy system. This decentralisation can have different dimensions, like stronger use of small-scale technologies (e.g. PV panels and household batteries), a new distribution and localisation of power plants within the electricity grid or an implementation of decentralised markets as an option to address challenges in the transformation of the energy system (e.g. grid expansion, complexity, acceptability, costs). This paper analyses the effects of such decentralised markets, including different design options.

Scientific research on decentralised markets frequently focuses on the subsidiarity principle, i.e. the division of the energy system into geographically delimited cells that balance power generation and demand at local level before interacting with higher grid levels. There are also system modelling studies that claim to model such a decentralised energy system or even a cellular system, but focus on the decentralised allocation or deployment of renewable energy sources within a certain state or region. Other studies have their emphasis on the size of regions needed for covering the local electricity demand by using renewable electricity generation capacity, without looking at the operational side of meeting this demand in local markets. The focus in these studies is mainly on a green-field 100% renewable system and not on the current electricity system nor the transformation phase.

For the scientific and political debate on decentralised markets based on indicators like grid expansion, local energy costs or local self-supply, we have identified a research gap in the field of system-wide effects of decentralised markets. We therefore study decentralised markets not from the perspective of local effects, but in terms of their effects on the overall power system.

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2. A short account of the research performed

This paper investigates decentralised markets in the German electricity system, defined as markets in specific regions in which regional electricity demand is met primarily by regional generation and the remaining demand is met on a system-wide level in a second step. The analysis is based on reviewing the following indicators that are derived from a model-based scenario analysis: CO_2 emissions of electricity generation; regional levels of self-supply with electricity; variable costs of electricity generation; grid congestion and grid expansion needs. The research question is twofold. Firstly, how does the size of decentralised markets affect the indicators mentioned. Secondly, which effects on these indicators can be observed if only power plants of a certain size or technology are allowed to take part in the decentralised markets.

The analysis focuses on a system perspective and does not include effects on individual market players. In addition, it focuses on the electricity system with only some interactions with the heating or mobility sectors. The modelling work looks at the effects within the boundaries of a predefined scenario and for two scenario years. Dynamic effects such as a possible effect of decentralised markets on the overall deployment of RES-E technologies or storage systems is therefore not part of the analysis. The results are valid for the German electricity system and cannot necessarily be transferred to other countries or electricity systems with e.g. a weaker electricity grid or less interconnection to neighbouring countries.

3. Main conclusions and policy implications of the work

The results show that the greatest effects from decentralised markets are caused by an increased usage of gas-fired power plants, as they are the major dispatchable generators in the future electricity system, resulting in significantly higher CO_2 emissions and electricity generation costs, but also higher local self-supply rates. With very high RES-E shares the results hardly differ between the reference case and decentralised market models. The size of decentralised markets has a lower impact than limited access for certain fuel types or generation capacity size. Although decentralised markets can reduce the load on the grid, the need for grid expansion does not decrease. Overall, we conclude that from a system perspective decentralised markets can lead to negative effects if they are not regulated appropriately, especially during the transformation phase of the electricity system.

Should the EU ETS be extended to road transport and heating fuels?

Michael G. Pollitt[a] and Geoffroy Dolphin[b]

1. Motivations underlying the research

To achieve net zero emissions of greenhouse gases by 2050, the European Commission (EC) set out a revised emissions reduction target for 2030 of 55% compared to 1990 levels (EU, 2021). Achieving this target will require at least a quadrupling of the annual rate of GHG emissions reduction achieved by the EU over the period 1990–2018. This, in turn, calls for a strengthening of existing European Union (EU) and national climate policy instruments.

Given the magnitude of the implications implied by the emissions reduction objective, it is essential to design climate policies that (i) offer a credible and binding commitment to achieving the climate target, (ii) achieve it at least cost for society and (iii) adequately address their distributional consequences.

Against this backdrop, we analyse the proposed extension of the EU Emissions Trading System (ETS) to road transport and heating fuels. The objective of this paper is twofold. First, to highlight the value of an extension of the EU ETS to road transport and heating fuels with regard to the (credibility

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of) the achievement of the EU's emissions reduction target and the overall policy cost. Second, to shed light on the distributional implications that such a policy change might have, alongside their political economy implications and potential mechanisms to alleviate them.

This review is motivated by three observations. First, there is currently no pan-European policy instrument able to ensure that the aggregate, EU-wide, target will be met. This undermines the credibility of the EU target, especially in light of the coordination challenge that aligning individual Member States' policies targeting road transport and heating fuels with the EU target might represent. Second, the existing policy-mix induces inefficiencies raising the overall policy cost. At the EU level, inefficiencies arise mainly from (i) poorly targeted policies, (ii) lack of harmonization of incentives across countries and sectors, (iii) exclusive reliance on standards-based policies in some sectors. Third, the distributional consequences of the policies (price or non-price) implemented to achieve the EU climate objectives will be commensurate with the stringency of the objectives themselves. Existing mechanisms of redistribution between and within EU member states may not be sufficient to adequately address the consequences of raised EU-wide emissions reduction objectives.

2. A short account of the research performed

We provide a review of *how* an extension of the EU ETS would enhance EU climate policy credibility, as well as its cost-effectiveness. With regard to credibility, we highlight that the EU ETS could (i) help deliver additional (and potentially less costly) emission reductions needed to meet the EU's 1.5–2°C compatible carbon budget and not currently mandated by any of the existing policies, and (ii) deliver emissions reduction *instead* of these policies, should any of these fail to deliver their intended emissions reduction. We then discuss several ways in which an extension of the EU ETS to road transport and heating fuels could enhance the efficiency of the EU climate policy mix.

We also address the distributional implications of such an extension by between and within EU countries. To discuss the within country impacts, we follow a general equilibrium framework and analyze use-side and sources-side incidence of the extension. Finally, we provide recommendations as to how to manage the extension and address its distributional impacts.

3. Main conclusions and policy implications of the work

An extension of the EU ETS could be an effective intertemporal commitment device that sets a long-term signal shaping market participants' expectation about the stringency and credibility of EU climate policy. It represents, perhaps uniquely, a policy which could ensure delivery of the EU's overall carbon budget over the set time horizon. Together with the standard efficiency properties of emissions trading, such an extension could also deliver substantial cost savings.

Yet, successfully implementing an EU ETS extension raises significant distributional challenges that must be addressed by design. Thus, the extension must be done in a way that is consistent with Europe's climate goals, does not undermine its existing standards-based policies *and* adequately mitigates potentially severe distributional effects. A proposed extension which does not take due account of each of these elements will either face strong opposition to its implementation in the first place or be implemented with a less stringent than necessary carbon budget.