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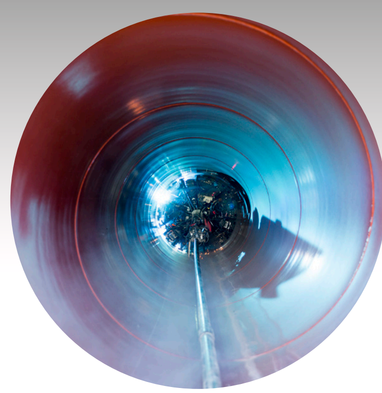
Looking back at the most recent six months, the landscape of energy and environmental policy continues to be characterized by uncertainty and dynamism, both domestically and abroad. Recent policy initiatives by the US Federal Government, such as the proposal by the Department of Energy to allow expanded baseload cost recovery ('Notice of Proposed Rulemaking for the Grid Resiliency Pricing Rule'), could fundamentally alter the structure and continued evolution of domestic electricity markets.

Meanwhile, the new leadership of the Environmental Protection Agency has shown consistency in its efforts to reverse or weaken the regulatory legacy of the previous administration. Foreign policy has not remained unaffected, with the announced US withdrawal from the Paris Agreement, but also new initiatives to strengthen exports of domestic fossil fuels.

Internationally, a growing number of countries is experiencing disruption of their energy sectors, with a combination of rapidly declining technology costs and targeted policies accelerating the transition towards renewable and distributed energy resources. There, too, unintended effects and sudden policy reversals have become increasingly common, as exemplified by the many European countries adopting abrupt phase-out timelines for conventional automobile and power generation technologies.

Taken together, these developments are compounding the difficulties of planning long-term corporate strategy and making related investment decisions. They also provide fertile ground for cutting-edge research at MIT CEEPR, where sophisticated empirical and data-driven methodologies are being deployed to analyze the complex and interrelated issues involved. Some of this research output is described in the current newsletter, and we hope you find the summaries helpful and stimulating.

CONTENTS



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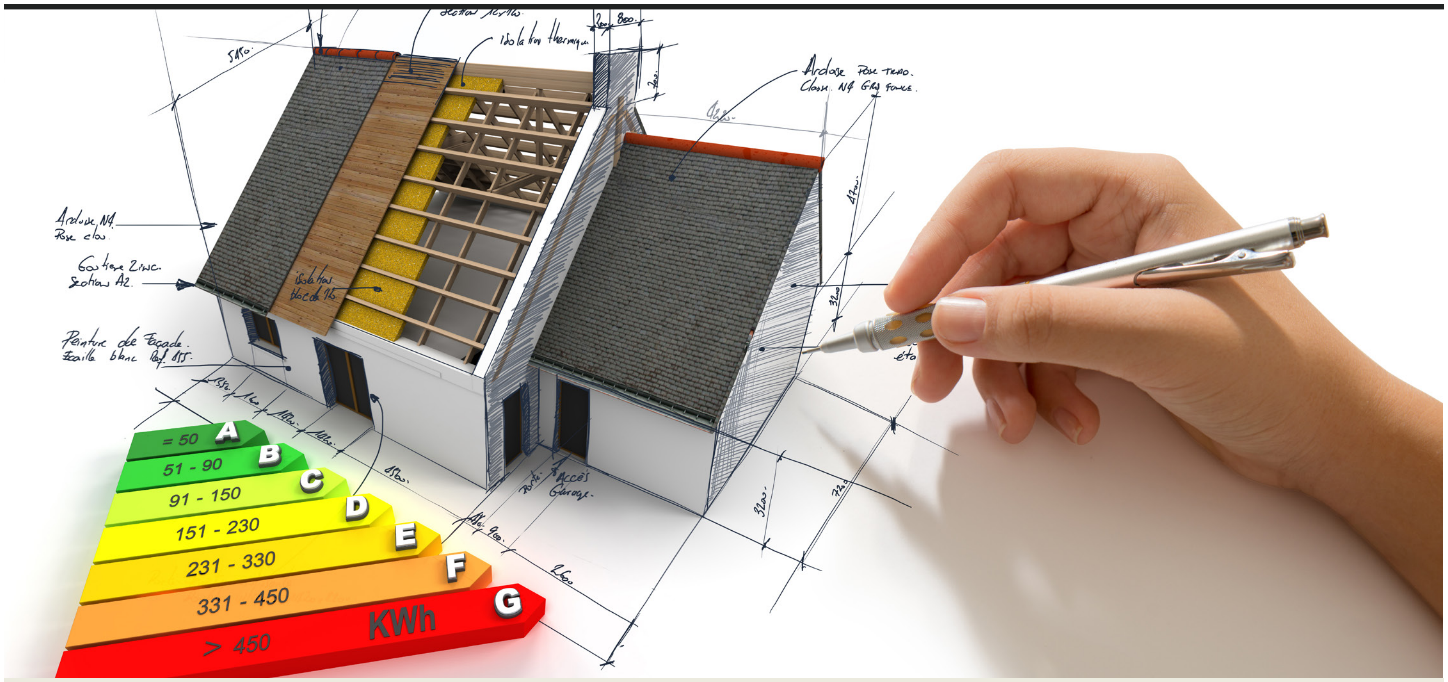
E2e Project Update: A Look at Electricity Usage

by: Leila Safavi



A new E2e paper examines whether Title 24 building codes in California reduced electricity consumption compared with rates in pre-1978 homes.

Two recent working papers[1] from E2e affiliates focus on evaluating energy-efficiency programs in the residential and commercial housing markets. The first, authored by Katrina Jessoe, Maya Papineau and David Rapson, investigates "split-incentive" problems for commercial customers. When renters are not responsible for their monthly electricity bills, there is little incentive for them to invest in energy efficiency, leading to a disconnect between the incentives of tenants and building owners. Comparing electricity usage between tenant-paid and owner-paid commercial contracts, the authors confirm that split incentives can lead to over-consumption: among the top 10% of commercial energy users, customers on owner-paid contracts used 6-14% more electricity in summer months. Interestingly, contract type did not seem to have an effect on electricity usage for the other 90% of customers, suggesting that the potential savings from changing consumption may have been too small to warrant attention from smaller firms. Jessoe, Papineau and Rapson estimate that major policy gains can be made from aligning incentives. They find that if the largest 10% of commercial customers were on tenant-paid contracts, the total energy savings would amount to 615-1,200 thousand tons of CO_2 per year and exceed the savings produced by solving the split incentives problem for the entire residential electricity sector.

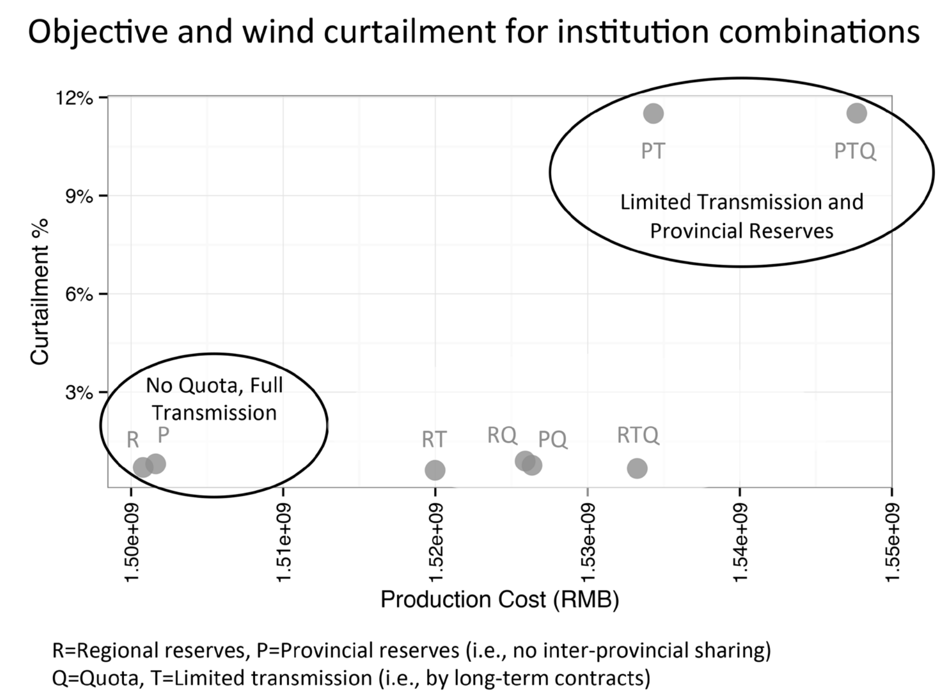
The second working paper by Kevin Novan, Aaron Smith and Tianxia Zhou examined whether Title 24, the 1977 set of building codes designed to reduce the energy required to heat in the winter and cool in the summer in California, reduced homeowner's electricity consumption. In order to determine whether building codes have an effect on electricity use, the authors tested if homes built right before and after Title 24 was passed have different responses to changes in outdoor temperatures. Using rich hourly smart meter data on electricity usage in Sacramento, they estimate that a house built just after 1978 uses on average 13% less electricity for cooling than a similar house built just before 1978. These savings alone recovered nearly half of the upfront costs of complying with the efficiency standards. Given that the natural gas cost savings were predicted to exceed the electricity costs by a factor of nine, their results support the conclusion that the policy would comfortably pass a cost-benefit test.

Furthering the discussion on energy-efficiency programs, E2e hosted a workshop in October alongside the Energy Policy Institute at the University of Chicago entitled Evaluating Residential Energy Efficiency Programs. Sponsored by the Alfred P. Sloan Foundation, the event brought together leading economists, regulators and residential energy efficiency practitioners to discuss engineering- and economics-based programmatic evaluation methods. Beyond identifying solutions to the challenges encountered when evaluating residential energy programs, the workshop aimed to foster in-depth research collaborations between practitioners and academics.

[1] For the full papers, please visit http://e2e.mit.edu/ to learn more about this project.

Modeling Unit Commitment in Political Context: China's Partially Restructured Electricity Sector

by: Michael R. Davidson and J. Ignacio Pérez-Arriaga



Wind curtailment increases when modeling existing institutional barriers to inter-provincial trading.

A wide range of countries have chosen to introduce competition into one or several segments of the traditional vertically-integrated utility (VIU) model of electricity supply. Due to differences in institutional histories, resource endowments, regulatory philosophies, and macro-economic conditions, these transitions have been often protracted and incomplete (Jamasb, 2006; Correlje & de Vries, 2008). Calculating efficiency penalties of macro market design issues, such as the choice of zonal price zones over locational marginal pricing, is an important and growing area of research (Aravena & Papavasiliou, 2017). However, the effects on outcomes of the range of observed institutional combinations are not well explored in the literature.

China is currently undergoing a decades-long transition toward competitive electricity markets – most recently reinvigorated in 2015 – while maintaining dispatch priorities that preserve quotas for coal generators and create non-physical barriers to trade. This paper[1] develops a unit commitment (UC) optimization for the northeast region of China which minimizes production cost subject to both technical constraints and political priorities. We focus on the northeast grid, which is known for its inflexible must-run cogeneration, coal overcapacity, and persistent wind curtailment (Zhao et al., 2012).

Our findings show that while the quota and must-run cogeneration in winter contribute to increased system costs, they alone do not explain the region's poor wind integration. When inter-provincial trade is constrained in both the short- and long-term – i.e., reserves cannot be shared across provincial borders and transmission is limited by long-term contractual agreements – wind integration increases several-fold (see figure). Importantly, just one of these two sources of inflexibility alone is insufficient to significantly increase wind curtailment.

A unit clustering technique is implemented (with acceptable aggregation errors in the objective of 0.02%) to deal with the long-term coupling quota constraints and to run sensitivities across uncertain policy parameters. Furthermore, our results are robust to changing the level of must-run cogeneration.

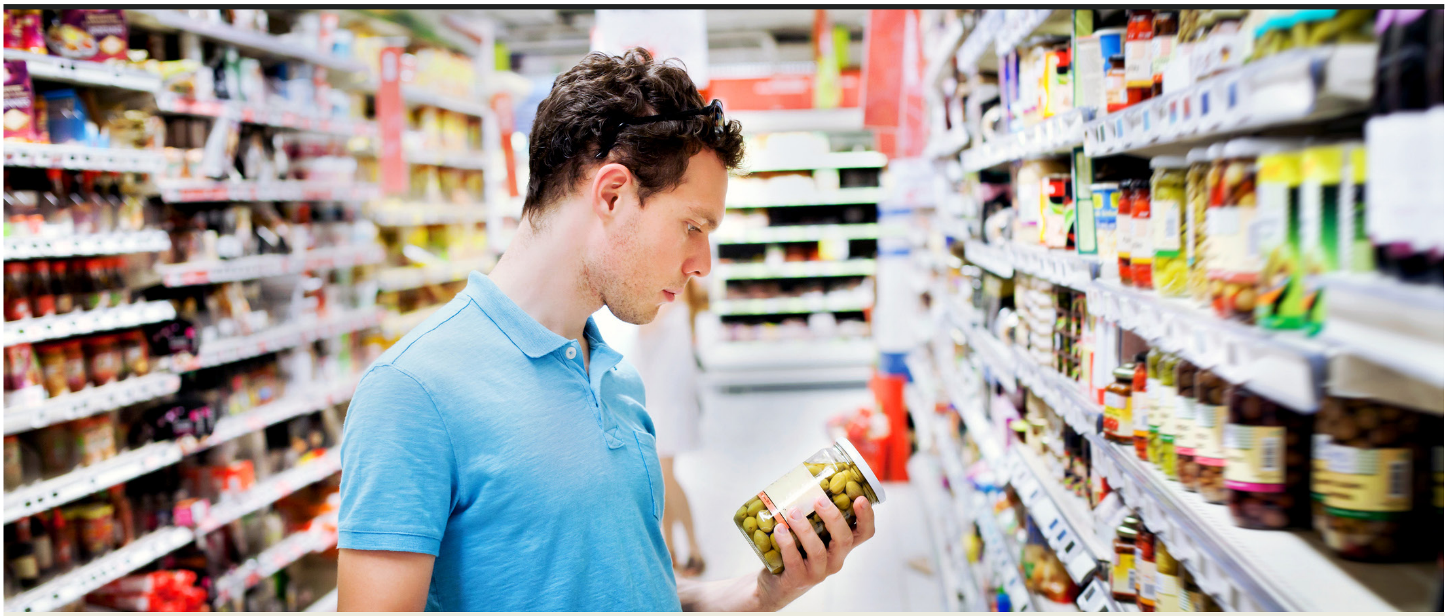
This unified model of technical and political constraints can provide guidance for reforms under consideration, in order to achieve near-efficient outcomes and other policy priorities such as renewable energy integration. For example, popular reforms of reducing the quota through long-term bilateral contracts without addressing inter-provincial trade barriers may not yield all desired benefits. Indeed, as quotas are reduced, the efficiency losses from limited transmission are enhanced.

The modeling framework presents additional opportunities for capturing realism of operating under political context. Future work could expand to other network and generator configurations, and explore more detailed dispatch heuristics and agent coordination mechanisms to understand additional observed inflexibilities.

[1] Michael R. Davidson and J. Ignacio Pérez-Arriaga (2017), "Modeling Unit Commitment in Political Context: Case of China's Partially Restructured Electricity Sector." *CEEPR WP-2017-010*, MIT, April 2017.

The Behavioral Effect of Pigovian Regulation: Evidence from a Field Experiment

by: Bruno Lanz, Jules Wurlod, Luca Panzone, and Tim Swanson



Market-based regulations have the potential to make consumers internalize socially harmful external effects associated with their choices. Recent behavioral literature, however, suggests that explicit financial penalties/rewards may undermine willingness to behave prosocially.

Economists traditionally argue in favor of price-based instruments to regulate externalities such as climate change or local air pollution. Among these, a Pigovian approach to regulation sets up a corrective tax/subsidy to make agents internalize external effects associated with consumption or production decisions (Pigou, 1920). Introducing financial penalties/rewards associated with the externality aligns social and private interests and, in a canonical microeconomic framework, mechanically restores market efficiency.

Growing evidence from economics and experimental psychology, however, suggests that when agents are willing to voluntarily exert an effort, explicit financial incentives may have a detrimental impact on effort provision (Gneezy et al., 2011; Bowles and Polanía-Reyes, 2012). As Pigovian interventions associate an external monetary incentive with efforts to behave prosocially, behavioral effects may attenuate the effectiveness of the regulation (Frey and Oberholzer-Gee, 1997; Bénabou and Tirole, 2003). From this perspective, these behavioral traits may call for an adjustment to externality-correcting taxes/subsidies (e.g. Allcott et al., 2014; Farhi and Gabaix, 2015).

The objective of this work[1] is to shed light on the magnitude and policy relevance of these behavioral effects. We exploit experimental data gathered in a chain of UK supermarkets (see Perino et al., 2014) in which subjects make real consumption decisions about ordinary grocery products, with a set of clean and dirty alternatives as determined by their embodied carbon emissions. After an initial product choice, we randomly assign subjects to one of three treatments: (i) information about embodied emissions of each product, revealing the propensity to voluntarily contribute to the emission reduction effort; (ii) a Pigovian price change, combining a change in relative prices in proportion to external costs and information about the regulatory nature of the price changes; and (iii) a neutrally framed change in relative prices, which mimics market-driven price variations and has the exact same magnitude as the Pigovian intervention. We further consider four categories of products, for which substitutability between clean and dirty alternatives is expected to vary: cola-type sodas (in plastic bottles or in aluminum cans), spreads (margarine or butter), milk (skimmed, semi-skimmed or whole), and meat (chicken or beef).

In this setting, we quantify the impact of alternative policy interventions by observing choices before and after each intervention, and comparing how consumers of different products responded to different treatments. More formally, we use observed choices to estimate a structural demand model for differentiated products, from which we derive the following implications. First, we find that providing information about the carbon content of products induces a voluntary transition towards cleaner products, suggesting that consumers are willing to exert an effort in the form of a substitution from one of the dirty products to a cleaner one. Translated to monetary value, this effort corresponds to GBP30.69-165.15/tCO_2

depending on the product category, which is significantly above most estimates of the social cost of carbon (see e.g. Greenstone et al., 2013).

Second, we exploit the neutrally framed price change (treatment 3 above) to show that substitutability between clean and dirty alternatives varies substantially across product categories. A cross-product comparison reveals that policy interventions are more effective if a close-substitute clean alternative is available. This finding is intuitive, and it is already recognized in the literature (e.g. Bjorner et al., 2004). However, the ability to assess, in a controlled environment, how substitutability affects the behavioral impact of information vs. price interventions is novel.

Finally, experimental results show that a monetary incentive explicitly motivated by the regulation of carbon emissions is less effective as compared to a neutrally framed price change of the same magnitude. This is evidence of negative behavioral effects associated with price-based regulation of externalities. We further observe that the extent of behavioral effects varies with substitutability: for products with close substitutes (cola and milk in our setting), we observe very substantial negative behavioral effects, while for products where substitution requires more effort (spreads and meat) behavioral effects are small and statistically indistinguishable from zero.

An implication of our results is that the price signal of Pigovian regulation would need to be set above its socially efficient level (i.e. marginal damages) in order to compensate the negative behavioral effect associated with an external monetary intervention. Quantitatively, our results suggest that the compensatory increase of the Pigovian price signal (we use GBP19/tCO_2) is around GBP48.06/tCO_2 for cola products, GBP37.46/tCO_2 for milk, while for spread and meat products our point estimates (GBP6.07/tCO_2 and GBP0.22/tCO_2, respectively) are not statistically significantly different from zero. Given the growing use of market-based instruments for environmental policy, as well as the emerging literature on behavioral public finance (e.g. Chetty et al., 2009; Mullainathan et al., 2012), these results call for further research in this area, notably on the role of self-image concerns in relation to monetary incentives.

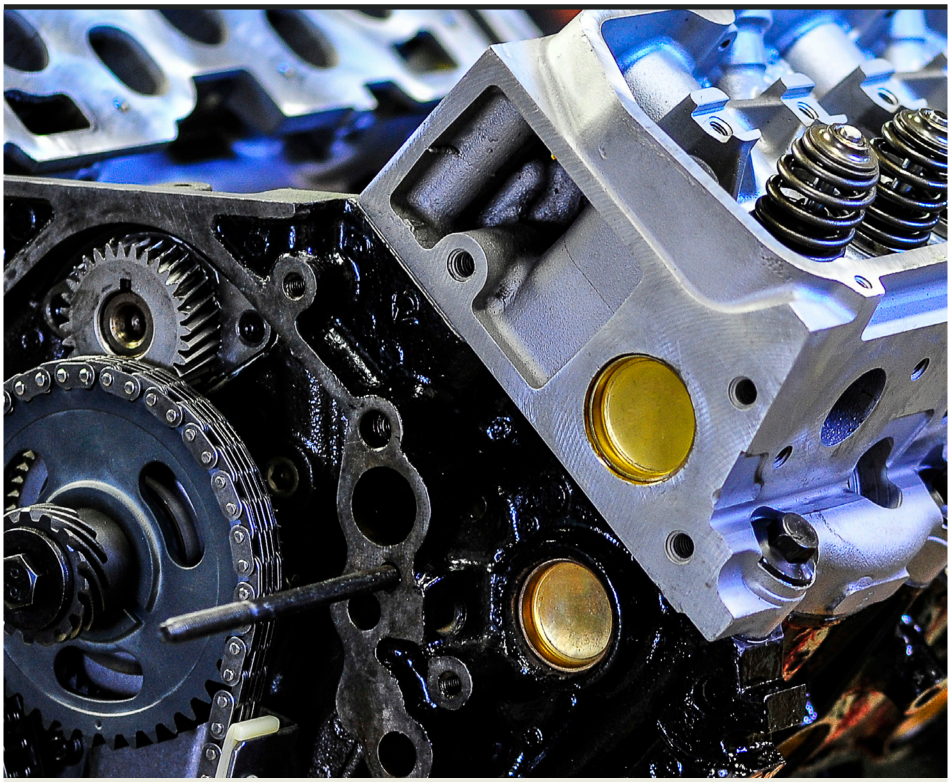
[1] Bruno Lanz, Jules Wurlod, Luca Panzone, and Tim Swanson (2017), "The Behavioral Effect of Pigovian Regulation: Evidence from a Field Experiment." *CEEPR WP-2017-011*, MIT, June 2017.

Black Carbon Problems in Transportation: Technological and Governmental Policy Solutions

by: Thomas L. Brewer

A new CEEPR Working Paper[1] assesses the problems resulting from emissions of black carbon in transportation, and technologies and policies that can mitigate such emissions. The adverse effects of black carbon (BC) emissions from diverse sources are significant in human and economic terms (Shindell et al., 2012; United Nations Environment Programme and World Meteorological Organization, 2012; US Environmental Protection Agency, 2012). The health effects include annual premature deaths on the order of millions of people from lung cancer and cardiovascular problems, as well as lost work and health care costs from asthma and other disorders (World Health Organization, 2012). BC also has detrimental effects on food supplies, with the production of rice and others crops reduced by millions of tonnes per year. In addition, BC has significant climate change consequences: Its global warming impact is about 55 percent that of carbon dioxide and thus greater than other greenhouse gases (Bond et al., 2013). BC's Global Warming Potential per tonne is thousands of times greater than carbon dioxide's over a 20-year period (Inter-governmental Panel on Climate Change, 2013). BC aerosols plus BC depositions on snow and ice in the Arctic contribute to glacial melting and thus global sea level rise, and to other climate change impacts (Arctic Monitoring and Assessment Programme, 2015).

Black carbon emissions are underestimated in the transportation sector as a result of a combination of intentional under-reporting for motor vehicles and inadequate measurement methods in aviation; nevertheless, the transportation sector is estimated to be the largest source of BC emissions in developed countries and an increasing proportion in developing countries. Globally, diesel engines contribute about 90 percent of transportation's BC emissions (Sims, Gorsevski and Anenberg, 2015). Levels of BC emissions in shipping and aviation are expected to increase for the foreseeable future as a result of increases in traffic volumes. (Although diesel fuel is not used in airplanes, there are nevertheless BC



Black carbon particulates in "soot" emissions have significant detrimental impacts on public health, climate change and food production; and diesel engines are a major source of such emissions.

emissions from their engines as well as ground support vehicles. Yet, the aviation industry has not yet recognized BC emissions as a pressing issue on the International Civil Aviation Organization agenda.)

There are cost-effective technologies that can mitigate transportation sector BC emissions. Diesel particulate filter (DPF) technology has been used in motor vehicles for years and can be used in ships as well. However, the rate of technology uptake has not been sufficient to reduce the sector's BC emissions to levels consistent with global temperature targets agreed in the Paris Accord.

Governmental policies therefore need to focus on how to incentivize the uptake of mitigating technologies. The paper accordingly concludes with a wide range of policy recommendations:

- Local-level BC emission-reduction initiatives should be adopted, especially in large cities with seaports and airports. These programs should encompass all diesel engine sources of BC in maritime shipping and aviation port infrastructure areas, including off-road vehicles, loading/unloading equipment, and diesel locomotives. These initiatives could be incorporated into on-going and expanding city programs, such as the one in Paris, to reduce air pollution by prohibiting or otherwise limiting diesel-powered vehicles.

- National governments' climate change policies should include measures to reduce BC emissions, including in the transportation sector. Annual meetings of the Conference of the Parties (COP) of the UN Framework Convention on Climate Change (FCCC) as well as other climate change conferences should expand recognition that BC mitigation can be included in countries' Nationally Determined Contributions, as embodied in the Paris Accord.

- At the sectoral level, mitigating BC emissions should be an urgent objective in the International Civil Aviation Organization (ICAO) and International Maritime Organization (IMO). At the FCCC, the agenda of the Technology Transfer Mechanism should include transfers of diesel particulate filter (DPF) technologies in motor vehicles and maritime shipping. DPF tariffs and non-tariff barriers should be included in the final lists of covered items in Environmental Goods Agreement (EGA) negotiations in Geneva. National policies worldwide - and EU regional policies – concerning emissions standards and testing procedures for motor vehicles need to be strengthened.

- At the regional-international level, all maritime shipping Emission Control Areas (ECAs) should include BC emission limits. An Arctic Black Carbon Agreement in the form of a "carbon club" should be developed (Brewer, 2015).

- As for metrics, BC emission measurement deficiencies for motor vehicles and aviation need to be corrected, and a maritime shipping measurement protocol being developed at the IMO should be finalized and adopted.

As for analytic paradigms that can be used for informing technologically-relevant policymaking, the prevailing climate change paradigm should be revised to include black carbon because of its distinctive physical properties as particulate matter, its multiple detrimental impacts, its localized and regionalized impacts as well as its global impacts, and its industry-specific emission-mitigation technologies.

[1] Thomas L. Brewer (2017), "Black Carbon Problems in Transportation: Technological Solutions and Governmental Policy Solutions." *CEEPR WP-2017-012*, MIT, July 2017.

Replacing Coal by Gas: An Effective Strategy to Reduce CO_2 Emissions?

by: Julien Daubanes, Fanny Henriet, and Katheline Schubert

The trend towards greater penetration and utilization of distributed energy resources calls for re-defining traditional roles of system operators.

As a matter of fact, the ratification of the Paris Climate Agreement by President Obama commits—at least for the next four years—the US Federal Government to significantly reduce its CO_2 emissions. To meet this commitment, the plan of the US Administration has been to rely on the rapid development of the gas production from the shale resource in the aftermath of the "fracking" revolution. In the past few years, the rise of gas in the top gas producing country has induced the replacement of the steam coal input in the power generation sector. On the one hand, this replacement has significantly contributed to reducing US CO_2 emissions. On the other hand, it has released large amounts of coal that met the foreign energy demand, contributing to the recent peak in US net exports of coal and, therefore, to CO_2 emissions in the rest of the world.

The pressure towards a decrease in US CO_2 emissions is likely to persist, irrespective of the ultimate decision of the US Administration whether to be party or not to the Paris Agreement. Gas will continue to be supported, and US coal exports are likely to keep increasing. First, the current US Administration can be expected to give a favorable regulatory treatment to the projects of new coal export terminals. Second, in his June 29, 2017 speech, President Trump announced that the rise in coal exports has become an objective in itself.

In the aftermath of the Paris Climate Agreement, governments will have to rely on unilateral initiatives to meet their respective emission reduction commitments. Besides the US, other gas rich regions consider the strategy of producing more gas to reduce their domestic emissions, such as China, Russia, and the UK. In all such situations, the perspective of increasing coal exports raise the same question as to whether the unilateral strategy of producing more gas to reduce CO_2 emissions will ultimately induce world emissions to decrease or not.

In a recent MIT CEEPR working paper[1], Daubanes, Henriet and Schubert (2017) point out that the economic analysis of unilateral CO_2 reduction policies and the related carbon leakage is fundamentally modified in presence of more than one carbon energy source. Unlike the standard treatment with a single carbon energy source, they show that an open economy relying on an intermediate – less carbon intensive – energy source like gas to replace the domestic use of the most polluting fuels may ultimately cause a rise in world emissions. The basic difference can be explained as follows: With a single carbon energy source, any carbon penalty – be it unilateral – induces its total supply to contract; by contrast, the promotion of gas contributes to boost the total production of carbon energy sources.

To analyze the option offered by the gas intermediate energy source, Daubanes et al. (2017) examine a stylized open economy. They address the question whether the domestic rise of gas can help reduce domestic and global CO_2 emissions. The answer to these questions varies not only with the carbon intensities of coal and gas, but also with the demand and supply elasticities and market shares specific to the economy under study. For a given country, the results can be summarized in terms of the rate of pollution increase from gas to coal $(\theta c - \theta g)/\theta g$, where θc and θg are the carbon intensity of coal and gas respectively. Only when this rate is sufficiently high, as when gas is significantly less CO_2 intensive than coal, the domestic carbon penalty does warrant that more gas be produced. Despite the fact that the promotion of gas induces more coal to be exported to the rest of the world, this does not necessarily mean that world emissions are increased. However, for intermediate values of the rate of pollution increase from gas to coal, the domestic policy turns counter-productive, inducing ultimately more CO_2 emissions at the world level.

In this summary, thresholds depend on the economy's characteristics, calling for country-specific numerical applications of the results. In the case of the US, sensible empirical estimates suggest that producing more gas is justified to reduce domestic emissions, and that this strategy is effective at the world level, despite a high leakage rate. This consolidates the conclusion reached by Wolak (2016) and Knittel et al. (2017) with other methodologies under short-run assumptions on elasticities. This prediction, however, is highly sensitive to the values of coal and gas supply elasticities; admissible estimates support the case of a more-than-100% leakage rate, making the US policy counter-productive.

[1] Julien X. Daubanes, Fanny Henriet, and Katheline Schubert (2017), "More Gas, Less Coal, and Less CO_2? Unilateral CO_2 Reduction Policy with More than One Carbon Energy Source." *CEEPR WP-2017-015*, MIT, September 2017.

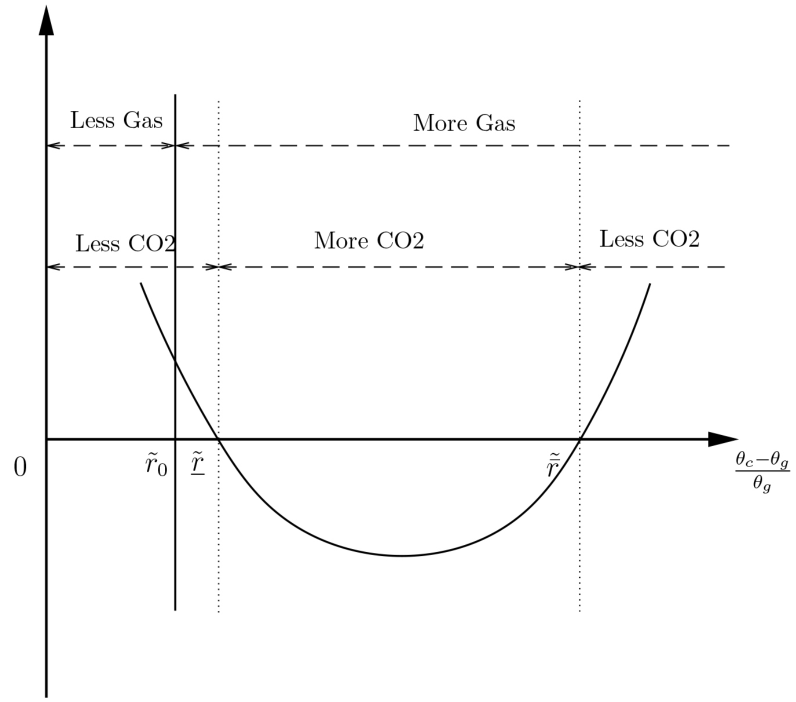


Figure: Domestic CO_2 reduction policy, domestic gas boom and world CO_2 emissions.

TSO/DSO Coordination in a Context of Distributed Energy Resource Penetration

by: Michael Birk, José Pablo Chaves-Ávila, Tomás Gómez, and Richard Tabors

Distributed Energy Resources (DERs) typically are defined as technologies that can be installed "behind the meter" on consumer premises connected to on-site loads or remote premises without on-site load. DERs are typically interconnected on distribution and lower voltage networks, and are smaller in installed capacity; ranging in the order of a few kilowatts (kW) to a few megawatts (MW) in rated nameplate capacity. A multitude of governments, transmission system or regional operators, public utility commissions and regulators, utility companies or distribution system operators, and researchers at think tanks, research laboratories, and universities have come up with slightly different definitions of DERs, covering a diversity of energy resource types, capacity, and where on the power system the resources are interconnected.

Recent technological advances and cost declines in distributed energy resources and information and communication technologies (ICT) as well as specific regional and state policies, mandates, and incentives, regulatory paradigms, and consumer trends have been major driving forces behind the increasing penetration of DERs. DERs can and do provide many services to the electric grid, and this trend will only increase as the ubiquity and ability to control these assets, for instance through management systems and smart inverters, continues to increase. However, current market designs and operational practices do not provide a level playing field for DERs to deliver services. Existing markets need to evolve, new markets need to be created, and new roles and coordination functions need to be established between distribution and transmission system operators.

A new MIT CEEPR Working Paper[1] offers an exploration into the services that DERs can provide, market structures observed in the European Union and United States, the interaction between distribution and transmission system operators, the new roles that DSOs would need to perform to unlock the most value from DERs, and certain market barriers for DERs at the transmission level. Coordinating and co-optimizing distributed, typically low-voltage assets, across jurisdictions and levels of the power system are still quite nascent. Future roles of utilities and distribution system operators, new planning and interconnection methodologies, and new wholesale market designs for DERs have been researched in theory, but not yet extensively adopted in industry. The Working Paper highlights and advocates for not only a level-playing field for DERs where their services can be valued in markets, but also for managing the complexities associated with communication, coordination, and interactions between grid operators to coordinate the services provided by DERs.

Overall, the energy sector is in a period of rapid growth and transformation unlike anything seen in the past century. Decentralization and decarbonization are driving greater penetration of distributed and renewable energy systems, and with them the subsequent need for greater system awareness, forecasting, and intelligence. Distributed energy resources can provide system services, which may enable even greater penetration of these resources. Specific responsibilities of operators, including coordination and information exchange between the operators, are of utmost importance. The European and the US electricity sectors are taking positive steps towards a decentralized paradigm for enhancing network operations as well as new tariff and market designs.

The Working Paper highlights phases of DER penetration on electric grids in the US and Europe and the interactions between the transmission and distribution system operators. At present, the penetration of DERs is still relatively small, although in many regions the yearly installed capacities are growing rapidly. In initial phases of DER integration, distribution networks are expected to be able to manage the presence of small amounts of DERs. The challenge in this initial phase is to be able to have visibility and monitor the assets on the distribution network.

In a subsequent phase, the Working Paper concludes that there could be significantly higher penetration levels of DERs in the system that provide services to the transmission and distribution system. In this subsequent phase, energy and load forecasting, scheduling, activation of resources and procedures to manage emergency situations will need to be defined and implemented. Under these conditions, the DSOs will likely need to perform new functions, such as determining prices for local constraints and coordinating those prices with those of the transmission system operator or wholesale market operator. New market rules and requirements, tariff designs, and price signals could mitigate many of the potential conflicts between services.

New wholesale market rules, requirements, and mechanisms for distributed resources to provide services should be codified, as DERs are able to provide system services. Today, there exists a lack of proper market structures, rules, and access as well as compensation mechanisms for DERs to actively provide services across the power system. Coordination between DSOs and TSOs will become increasingly salient as more and more distributed resources interconnect to the grid and provide system services.

[1] M. Birk, J. P. Chaves-Ávila, T. Gómez, and R. Tabors(2017), "TSO/DSO Coordination In A Context of Distributed Energy Resource Penetration." *CEEPR WP-2017-017*, MIT, October 2017.

With respect to electrical grids and power systems there is a trend towards a greater penetration and utilization of distributed energy resources.

Cost Pass-Through to Higher Ethanol Blends at the Pump: Evidence from Minnesota Gas Station Data

by: Jing Li and James H. Stock

A new paper examines the pass-through of wholesale costs to pump prices for E85 and finds that in Minnesota, on average, retailers pass on only half of E85's RFS implicit subsidy to consumers.

The Energy Independence and Security Act of 2007 set ambitious goals for blending renewable fuels into the US. surface transportation fuel supply. The regulatory structure for achieving these goals is the Renewable Fuel Standard (RFS). The RFS effectively provides a revenue-neutral tax on fuels with low renewable content and a subsidy to fuels with high renewable content, which operates through the market for tradable RFS compliance certificates, RINs (Renewable Identification Numbers).

For the past decade, the main renewable fuel in the United States has been ethanol made from corn kernels, and the dominant fuel blend sold at retail today is E10, which is 10% ethanol. Selling more ethanol into the fuel supply than provided through E10 requires sales of higher blends. Although there have been attempts to sell E15, the main higher blend available is E85, which is between 51% and 83% ethanol and can be used only by flex fuel vehicles. Because E85 has lower energy content than E10 and thus requires more frequent refueling, boosting sales of E85 requires providing a price incentive to flex fuel vehicle owners to buy E85. This price incentive is provided by the RIN subsidy, assuming it is passed through to the consumer in the form of lower prices in the E85 market.

A recent CEEPR Working Paper[1] studies the pass-through of wholesale prices and RIN values to pump prices in the retail market for E85. The retail market is the final of three steps in the gasoline supply chain. With considerable simplification, in the first (upstream) step importers and refiners sell bulk refined petroleum fuels on exchanges and at the bulk wholesale level. That petroleum blendstock is then transported to a regional distribution terminal, typically via pipeline. Separately, ethanol is produced then transported to the terminal, typically by rail. In the second (midstream) step, these two fuels are blended at the terminal, sold to retailers, and pumped into tanker trucks for delivery to the gas station. At the third (downstream) step, the retailer sells the fuel to the end consumer at the gas station.

Our core data are monthly observations at the retail gas station level on E85 retail prices collected by the Minnesota Department of Commerce. We augment these data with data from OPIS on retail prices for E10, matched at the month-station level. We also use OPIS rack prices for E10 and E85; by matching stations to racks, we estimate station-level wholesale prices for E10 and E85. Because we know the locations of the E85 stations, we can also compute regional station density measures, for example the number of competing E85 stations within a 10-minute drive. Our full data set spans January 2007 to March 2015, which includes the period of high ethanol RIN prices beginning in January 2013.

We have three main findings. First, consistent with a large literature on E10 pricing, we find complete pass-through in the E10 market: over the full sample period, we estimate a cumulative pass-through coefficient of 1.003 (SE = 0.003) using our sample of 247 stations for which we observe both E85 and E10 prices.

Second, we find only partial pass-through to the E85 retail price of the E85 wholesale price, controlling for the E10 wholesale price, that is, of the E85-E10 wholesale spread to the E85-E10 retail spread. This pass-through increased over the sample period from 0.323 (SE = 0.021) in 2007-December 2011 to 0.525 (SE = 0.053) in January 2012-March 2015.

Third, there is considerable heterogeneity in E85 pass-through rates. Much of this variation is explained by observable factors. In particular, we find that pass-through is higher if there are more local stations that sell E85. Moreover, the entry of a nearby station into the E85 market reduces the markup on E85 charged by an E85 retailer. We also examine whether there is variation in pass-through or markups associated with whether the retailer is affiliated with an entity that is obligated under the RFS to retire RINs with the EPA. We find no meaningful association with obligation status, consistent with the profit-maximizing incentives for marketing E85 being the same at the station level whether or not the station is affiliated with an obligated party.

Taken together, these results are consistent with the E10 market being highly competitive, but the E85 market being comprised of local markets in which participants frequently have considerable market power. Having more local E85 stations increases competition and is associated with higher pass-through. In the Twin Cities (Minneapolis-St. Paul) metro area, an area of relatively high E85 station density, we find essentially complete pass-through of the E85-E10 rack price discount to retail prices. Outside the Twin Cities, slightly less than half the E85-E10 wholesale price discount is passed along to consumers.

Returning to the RIN subsidy, we estimate that in the Twin Cities, nearly all of the RIN price subsidy for E85 is passed through the full supply chain and is received by the retail consumer. Outside the Twin Cities, however, we estimate that roughly three-fourths of the RIN value is passed through at the rack, and slightly less than half of that is passed through to retail prices. Statewide, we estimate that 0.35 (SE = 0.05) of the RIN subsidy passes through the full supply chain to retail E85 prices.

Our results suggest that, in the context of the RFS and other similar price subsidy policies, market structure and firm competition can erode the anticipated benefits and lead to higher compliance costs. Therefore, policies to increase entry and competition in the markets that policymakers want to support may make the standalone price subsidies more effective and less costly.

[1] J. Li and J. H. Stock (2017), "Cost Pass-Through to Higher Ethanol Blends at the Pump: Evidence from Minnesota Gas Station Data." *CEEPR WP-2017-020*, MIT, October 2017.

Linking Heterogeneous Climate Policies (Consistent with the Paris Agreement)

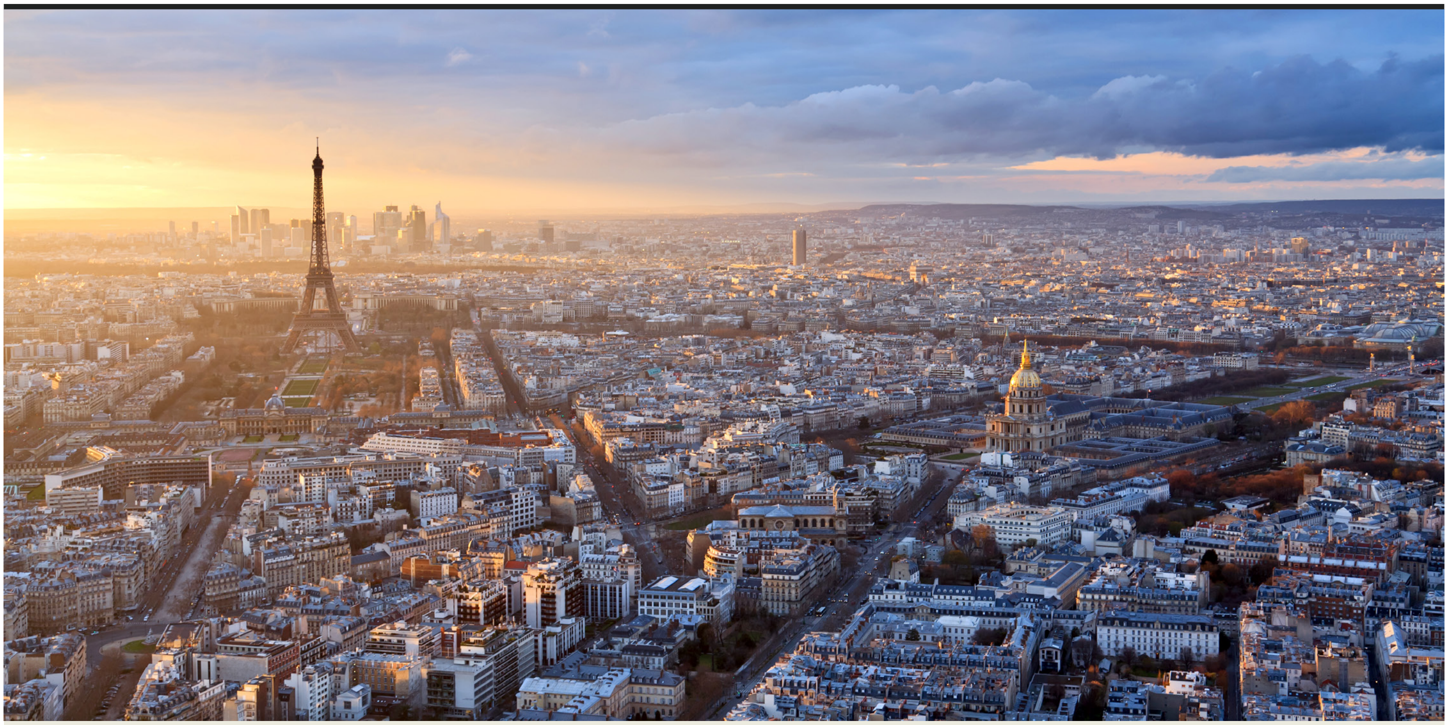
by: Michael A. Mehling, Gilbert E. Metcalf, and Robert N. Stavins

The Paris Agreement achieved broad participation by countries accounting for some 97% of global GHG emissions. As negotiations begin to elaborate key details of the Agreement, a critical question is how to create incentives for countries to increase ambition over time, to have any hope of limiting global average warming to 2° C. The ability to link different climate policies, such that emission reductions undertaken in one jurisdiction can be counted toward the mitigation commitments of another jurisdiction, may help Parties increase ambition over time. The paper[1] summarized here explores options and challenges for facilitating such linkages in light of the considerable heterogeneity that is likely to characterize regional, national, and sub-national efforts to address climate change.

Linkage is important, in part, because it can reduce the costs of achieving a given emissions-reduction objective. Lower costs, in turn, may make it politically feasible to embrace more ambitious objectives. In a world where the marginal cost of abatement – that is, the cost to reduce an additional ton of emissions – varies widely, linkage improves overall cost-effectiveness by allowing jurisdictions with relatively higher abatement costs to finance reductions from jurisdictions with relatively lower costs. In effect, linkage drives participating jurisdictions toward a common cost of carbon, equalizing the marginal cost of abatement and producing a more efficient distribution of abatement activities. These benefits are potentially significant: The World Bank has estimated that international linkage could reduce the cost of achieving the emissions reductions specified in the initial set of Nationally Determined Contributions (NDCs) submitted under the Paris Agreement 32% by 2030 and 54% by 2050.

Article 6 of the Paris Agreement provides a foundation for linkage by recognizing that Parties to the Agreement may "choose to pursue voluntary cooperation in the implementation of their" NDCs through "the use of internationally transferred mitigation outcomes" (ITMOs). In contrast to the Kyoto Protocol (which likewise included provisions for international cooperation), the voluntary and flexible architecture of the Paris Agreement allows for wide variation, not only in the types of climate policies countries choose to implement, but in the form and stringency of the abatement targets they adopt.

Linkage is relatively straightforward when the policies involved are similar. However, linkage is possible even when this is not the case: for example, when one jurisdiction is using a cap-and-trade system to reduce emissions while another jurisdiction is relying on carbon taxes. There are several potential sources of heterogeneity: type of policy instrument used (e.g. taxes vs. cap-and-trade vs. performance or technology standard); level of government jurisdiction involved (e.g., regional,



International linkage of climate policies can play an important role in ensuring adequate climate ambition under the Paris Agreement.

national, or sub-national); status under the Paris Agreement (i.e., whether or not the jurisdiction is a Party to the Agreement – or within a Party); nature of the policy target (e.g., absolute mass-based emissions vs. emissions intensity vs. change relative to business-as-usual); and operational details of the country's NDC, including type of mitigation target, choice of target and reference years, sectors and greenhouse gases covered. The full paper examines five specific cases of linkage, with various combinations of features, to identify which types of linkage are feasible, which are most promising, and what accounting mechanisms are needed to make their operation consistent with the Paris Agreement.

Most forms of heterogeneity – including with respect to policy instruments, jurisdictions, and targets – do not present insurmountable obstacles to linkage. However, some of these characteristics present challenges and call for specific accounting guidance if linkage is to include the use of ITMOs under the Paris Agreement. In particular, robust accounting methods will be needed to prevent double-counting of GHG reductions, to ensure that the timing (vintage) of claimed reductions and of respective ITMO transfers is correctly accounted for, and to ensure that participating countries make appropriate adjustments for emissions or reductions covered by their NDCs when using ITMOs. Additional issues under Article 6 include how to quantify ITMOs and how to account for heterogeneous base years, as well as different vintages of targets and outcomes.

Broader questions that bear on the opportunities for linkage under Article 6.2 include the nature of NDC targets and whether these are to be treated as strict numerical targets that need to be precisely achieved; the nature and scope of ITMOs, which have yet to be defined, let alone fully described, under the Paris Agreement; and finally, whether transfers to or from non-Parties to the Agreement (or sub-national jurisdictions within non-Parties) are possible, and if so, how they should be accounted for. Parties have differing views, however, on whether the guidance on Article 6.2 should extend to such issues.

Clear and consistent guidance for accounting of emissions transfers under Article 6 can contribute to greater certainty and predictability for Parties engaged in voluntary cooperation, thereby facilitating expanded use of linkage. At the same time, too much guidance, particularly if it includes restrictive quality or ambition requirements, might impede linkage and dampen incentives for cooperation. Given their limited mandate, Parties should exercise caution when developing guidance under Article 6.2 that goes beyond key accounting issues. This does not mean that concerns about ambition and environmental integrity should be neglected. However, if the combination of a set of common accounting rules and an absence of restrictive criteria and conditions can accelerate linkage and allow for broader and deeper policy cooperation, it can also increase the potential for Parties to scale up the ambition of their NDCs. And that may ultimately foster stronger engagement between Parties (and non-Parties), as well as with regional and sub-national jurisdictions.

[1] M. A. Mehling, G. E. Metcalf, and R. N. Stavins (2017), "Linking Heterogeneous Climate Policies (Consistent with the Paris Agreement." *CEEPR WP-2017-021*, MIT, November 2017.

Clean Power Plan Repeal Won't Save Coal

by: Rebecca Linke

The Obama-era Clean Power Plan repeal is underway. But the move from coal to cleaner energy will happen for economic, not regulatory, reasons.

The repeal of the federal Clean Power Plan will allow some states to "ride out the status quo," but it won't reverse the decline in coal consumption, CEEPR Director and MIT Sloan professor Christopher Knittel said.

"I've done analysis that suggests an 85 percent drop of coal consumption has come from lower natural gas prices. At most you can point to 15 percent coming from state level polices and minor federal level policies," Knittel, whose research focuses on environmental economics, said. In some cases, solar is also less expensive than coal, but it and wind power benefited more than natural gas from the proposed Clean Power Plan incentives.

The Clean Power Plan was an Obama-era effort to curb carbon emissions from power plants by one-third by 2030. It was never implemented and a repeal process was announced in October by Scott Pruitt, the head of the Environmental Protection Agency.

Since the plan was proposed in 2015, many utilities started shifting to natural gas or renewable energies, even though the regulation was temporarily blocked by the Supreme Court in 2016 after multiple states and industry groups challenged it. But, Knittel said, it was affordability of natural gas, not the looming federal regulation, that had many states moving away from coal.

Since some of the regulations to curb carbon emissions originated at the state level — many pledged to still implement the Paris Agreement even after the US officially pulled out of it — the repeal won't change much for them.

"Some states will be doubling down and incentivizing renewable technologies. Where we will be missing the big incentive is in red states that will be able to just ride out the current status quo," Knittel said. "But we will still see coal plants struggling."

The repeal may slow down the shift to cleaner energies — but the Trump administration is also expanding drilling for natural gas. That in turn will drive down natural gas prices, further increasing pressure on coal plants. "In many ways, the administration's goals are counter to each other," Knittel said. "I think the basic economics is pointing away from coal to natural gas."

According to Knittel, the biggest disappointment from the Clean Power Plan repeal may be the impact on health. The regulations were estimated to prevent 3,600 premature deaths from air pollution, 1,700 heart attacks, 90,000 asthma attacks, and 300,000 days of missed school and work annually. "The co-benefits alone of the Clean Power Plan outweighed its cost. The legislation would have raised welfare just through fewer asthma attacks and heart attacks and other respiratory problems that come about through burning fossil fuels," Knittel said.

With the repeal, the EPA will be asking the public to weigh in on what sort of regulations should take the place of the Clean Power Plan. But since the Supreme Court ruled in 2007 that greenhouse gases are a pollutant that the EPA must regulate, doing nothing is not an option. In the meantime, we can expect multiple lawsuits from states and environmental groups that want to keep the Clean Power Plan in place.

Notable Changes

The start of a new academic year has brought with it a number of new CEEPR personnel. CEEPR welcomes three new MIT faculty members as affiliates.

Professor **Namrata Kala** has joined the MIT Sloan faculty as an Assistant Professor of Applied Economics. She is an economist with research interests in environmental and development economics. Her current research projects include studying how firms and households learn about and adapt to environmental change and regulation, the returns to environmental technologies, and the returns to worker training and incentives.

Professor **David R. Keith** is the Mitsui Career Development Professor and an Assistant Professor of System Dynamics at the Sloan School of Management. Drawing on his experience working in the automotive industry, David studies consumer behavior, firm strategy and the formation of markets for emerging automotive technologies. His research examines issues including spatial patterns of technology adoption, supply constraints in production, platform competition, and the impact of new technologies on energy consumption and the environment.

CEEPR also welcomes Dr. **Jing Li** to MIT. Jing is currently a Postdoctoral Associate at the MIT Energy Initiative and in the Fall 2018 semester, will join the MIT Sloan School of Management as an Assistant Professor of Applied Economics. Her research interests include industrial organization and energy and environmental economics.

Finally, CEEPR has hired a number of new graduate students this semester. **Sruthi Davuluri, Bora Ozaltun, Ivan Rudnick,** and **Anthony Fratto** have joined CEEPR as new graduate research assistants.

Recent Working Papers

WP-2017-021
Linking Heterogeneous Climate Policies (Consistent with the Paris Agreement)
Michael A. Mehling, Gilbert E. Metcalf, Robert N. Stavins, November 2017

WP-2017-020
Cost Pass-Through to Higher Ethanol Blends at the Pump: Evidence from Minnesota Gas Station Data
Jing Li and James H. Stock, October 2017

WP-2017-019
The Light and the Heat: Productivity Co-Benefits of Energy-saving Technology
Achyuta Adhvaryu, Namrata Kala, and Anant Nyshadham, October 2017

WP-2017-018
Vintage-specific Driving Restrictions
Nano Barahona, Francisco Gallego, and Juan-Pablo Montero, October 2017

WP-2017-017
TSO/DSO Coordination in a Context of Distributed Energy Resource Penetration
Michael Birk, José Pablo Chaves-Ávila, Tomás Gómez, and Richard Tabors, October 2017

WP-2017-016
Attribute Substitution in Household Vehicle Portfolios
James Archsmith, Kenneth Gillingham, Christopher R. Knittel, and David S. Rapson, September 2017

WP-2017-015
More Gas, Less Coal, and Less CO2? Unilateral CO2 Reduction Policy with More than One Carbon Energy Source
Julien X. Daubanes, Fanny Henriet, and Katheline Schubert, September 2017

WP-2017-014
Using Output-based Allocations to Manage Volatility and Leakage in Pollution Markets
Guy Meunier, Juan-Pablo Montero and Jean-Pierre Ponssard, September 2017

WP-2017-013
Output-based Allocations in Pollution Markets With Uncertainty and Self-Selection
Guy Meunier, Juan-Pablo Montero and Jean-Pierre Ponssard, September 2017

WP-2017-012
Black Carbon Problems in Transportation: Technological Solutions and Governmental Policy Solutions
Thomas L. Brewer, July 2017

WP-2017-011
The Behavioral Effect of Pigovian Regulation: Evidence from a Field Experiment
Bruno Lanz, Jules-Daniel Wurlod, Luca Panzone, and Timothy Swanson, June 2017

WP-2017-010
Modeling Unit Commitment in Political Context: Case of China's Partially Restructured Electricity Sector
Michael R. Davidson and J. Ignacio Pérez-Arriaga, April 2017

All listed and referenced working papers in this newsletter are available on our website at ceepr.mit.edu/publications/working-papers

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A symphony orchestra plays before the dinner keynote session at the College des Bernardins during the 2017 European Energy Policy Conference in Paris, France on July 6, 2017.