RESEARCH PROPOSAL

Title: Carbon Taxes and Subsidies with Electrification

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Background and Related Literature:

Standard macroeconomic models of climate change have typically relied on relatively simple representations of emissions mitigation. For example, in the DICE model (Barrage and Nordhaus (2024)), mitigation is represented by a reduced form mitigation function that maps investment in mitigation directly into emissions reduction. The parameters of the mitigation function are taken from separate engineering or energy systems model that project decarbonization pathways. A backstop technology may be assumed that eventually allows for emissions free energy production at some future date.

Alternatively, models with a structural representation of energy production typically assume that energy is generated from a composite of clean and fossil energy with a constant elasticity of substitution. A carbon tax or clean energy subsidy reduces emissions by the raising the relative price of fossil energy. Casey et al. (2024) summarize the effects of carbon taxes and clean energy subsidies with this type of energy system. Models with directed technical change include similar representations of energy production (i.e. Acemoglu et al. (2012)).

By contrast, energy systems models of decarbonization specify with greater detail the technologies needed to eliminate emissions across different sectors (i.e. Bistline, Mehrotra and Wolfram (2023) and Bistline et al. (2023)). Broadly, the path to net zero emissions in these models consists of two distinct steps: decarbonization of electric power generation and electrification of end-use sectors.

Electrification is already the lowest cost option for zero emissions surface transportation (i.e. light-duty vehicles, rail, etc.) and space and water heating (heat pumps) for residential buildings. Additionally, electrification appears feasible to displace fossil fuels for some types of commercial and industrial heating or cooling. Electrification is also required for the other major pathway to decarbonization: clean hydrogen. Electricity is needed to run electrolyzers that produce hydrogen from water that can be used for industrial heating applications (i.e. steel and cement production)

which require high temperature or for synthetic fuels needed for long distance transportation (i.e. aviation).[1]

The goal of this paper is study how decarbonization of electric power generation can have negative spillovers to end-use electrification and, paradoxically, slow down the transition to net zero emissions. The idea is simple: holding constant the cost of electricity, a carbon tax increases incentives to switch away from capital that directly combusts fossil fuels (i.e. gas furnaces, internal combustion vehicles, etc.). However, a carbon tax also raises the price of electricity. Depending on the strength of this indirect effect, electrification of end-use sectors may be delayed or even run in the opposite direction. Slow capital turnover then ensures that emissions from end-use sectors are prolonged. Possibly, a faster transition to net zero can be obtained by subsidizing clean electricity generation to keep electricity prices cheaper and enhance incentives for electrification of end-use sectors. The goal of this paper would be to both illustrate this mechanism analytically and investigate quantitatively its importance in the case of the US.

Paper Outline:

In this section, I sketch out the simple model to be analyzed and provide a brief outline of the paper. The paper will consider both a simplified discrete-choice model that can be characterized analytically and a more complex quantitative model that can be calibrated to US data to assess the optimal mix of carbon taxes and clean energy subsidies.

To illustrate the basic mechanism, the simple model will consist of a discrete choice between a clean (electrified) durable good and a durable good that burns fossil fuels. As noted earlier, this basic choice drives decarbonization for most end-use sectors. The mix of clean and fossil durable good is an initial state variable and durable goods are assumed to last for a fixed horizon. Therefore, each period, a fraction of the durable goods capital stock fully depreciates and is replaced. A unit of measure of households who's durable good has depreciated faces a discrete choice between purchasing the electrified durable good or the fossil durable good. This decision depends on the capital price of each good and the expected discounted present value of fuel costs (either

[1] Arkolakis and Walsh (2023) and Mehrotra (2024) attempt to build representations of energy production in macroeconomic models that capture some of the elements in energy systems models. The former models electricity transmission while the latter models intermittency of renewables.

electricity or fossil fuel). An idiosyncratic taste/cost shock ensures against a corner solution; a fraction of households purchase the clean good and the remainder choose the fossil durable good.

A carbon tax raises the relative price of the fossil durable relative to the clean durable, leading to a larger share of households purchasing the clean durable. Capital turnover is slow since the cost of capital is large relative to fuel cost in any given period, limiting incentives to scrap fossil fuel capital before the end of its economic lifetime. Subsidies to clean energy capital, a tax on fossil capital, or subsidies to electricity prices could induce the same pace of decarbonization as a carbon tax but must account for a potential utilization margin (i.e. higher fuel prices lower utilization and, therefore, emissions). This setup captures the salient features of end-use decarbonization: capital turnover dynamics and slow turnover, relative capital and fuel costs, and the utilization margin.

The key endogenous price is the price of electricity. As with the durables good sector, electricity producers will supply electricity to satisfy demand from electrified durable goods. Like durable goods, capital turnover for electricity production is slow, with a limited fraction of generation capital needing to be replaced. Producers face an analogous discrete choice problem of choosing between clean and fossil fuel power generation. As with the durable good choice, an idiosyncratic taste/cost shock ensures a fraction of producers invest in clean power generation and the remainder choose fossil generation. The price of electricity is the capital cost of current and previously installed power generation capital and fuel cost, which, in the case of clean power generation, is zero.[2]

A carbon tax now raises the price of electricity and, depending, on the level of fuel prices and the relative cost share of fuel for the durable good, the indirect effect of the carbon tax via electricity price may dominate the direct effect on the lifecycle cost of purchasing the fossil durable good. As a result, a carbon tax may delay or reduce electrification even while inducing a shift towards renewable electric power generation. This shift away from electrification offsets emissions reductions from the shift to renewable power generation and locks in future emissions due to slow capital turnover.

This model can be used to assess optimal climate policy. It may be the case that a carbon tax is optimal, but it seems possible that optimal policy may require both a carbon tax and a subsidy to

[2] This assumption reflects that most clean energy generation has zero fuel cost (hydropower, solar, and wind) but could be relaxed to accommodate nuclear power or fossil fuels equipped with carbon capture.

electrification. If so, this would be distinct from the mechanisms emphasized in the directed technical change literature and learning-by-doing literature. Capital irreversibility and discrete choice are likely significant here in generating departures from the standard Piguouvian prescription. The intuition for why a carbon tax may not be optimal is because it causes electricity prices to overshoot their long-run level. During a transition, a fraction of coal/natural gas that would no longer be chosen ex ante remains in operation and passthrough the higher fuel cost to consumers. Even if a carbon tax remains optimal, one could study second-best policies. One could ask if subsidies should be provided to clean power generation, electrification or electricity prices.

The analytical model could also be used to investigate the implications of both policy uncertainty and interest rate uncertainty. Uncertainty with respect to the carbon tax would mitigate switching incentives by lowering the anticipated increase in future fuel costs. The presence of policy uncertainty with respect to a carbon tax would likely have a larger effect on switching for electric power producers given the longer capital lifetime. Interest rate uncertainty could also potentially have important implications for incentives to electrify or switch to renewable power generation.

The analytical model could also be useful in understanding how non-fuel costs such as transmission and distribution and profit rates or industry structure (deregulated or regulated markets) affect the passthrough from a carbon tax to electricity prices. While the marginal cost of electricity is the fuel cost, many fixed costs are charged on a volumetric basis, likely mitigating the degree to which a carbon tax or clean energy subsidy passes through to electricity prices. Borenstein and Bushnell (2022) point out that retail electricity prices already exceed the social marginal cost of electricity due to the inclusion of various fixed costs that need to be recovered by the utility.

The last part of the paper will seek to quantify the effect of carbon taxes versus alternative subsidy policies in the case of the US. The model will be extended to allow for different types of fossil power generation (i.e. coal and natural gas) and multiple end-use sectors (i.e. transportation, buildings, and industry). The model will also be extended to account for differences in capacity factors for different types of electric power generation and allow for an intensive margin along whereby higher fuel costs lower capital utilization rates.

Given current levels of carbon free power generation, how much does a carbon tax passthrough to electricity prices and how may that differ across regions? For this question, regional differences are

likely to be important given that some states have relatively decarbonized grids while other regions remain dependent on coal. Regional differences in heating and cooling demand and greater seasonal weather extremes may also imply higher fuel cost shares that may impact end-use electrification. For instance, electric vehicles in colder climates are less efficient and require more electricity, potentially impacting the sensitivity of the electrification decision to electricity versus gasoline prices. The quantitative model can be used to assess the emissions effects of a carbon tax v. a clean energy production credit v. investment subsidies. In practice, US decarbonization policy has focused on the latter two mechanisms instead of a carbon tax. Optimal climate policy can also be assessed in this model and compared to a carbon tax to the extent that solely relying on a carbon tax is not optimal.

Potentially, the quantitative model could also be calibrated to consider climate policy in countries like China or India that have a higher reliance on coal for electric power generation or, alternatively, countries like Brazil or France that have much lower carbon intensity of emissions in the electricity sector.

Disclosures:

The author has no ties to the energy industry or industries impacted by industrial decarbonization.

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