Financing Power: Impacts of Energy Policies in Changing Regulatory Environments

Nils May[a] *and Karsten Neuhoff*[b]

Power systems with increasing shares of wind and solar power generation have higher capital and lower operational costs than power systems based on fossil fuels. This increases the importance of the cost of financing for total system cost.

We quantify how renewable energy support policies can influence the financing costs by addressing regulatory risk and facilitating hedging. In a first assessment, we use interview data on wind power financing costs from across the EU. Large differences between countries are due to the general national circumstances for project developments like national political and financial contexts. We control for a number of potentially relevant factors, for instance whether countries have in the past retrospectively changed their support policies or whether the have implicitly, if not explicitly, abandoned all policy support.

Regression analysis reveals that feed-in tariffs and sliding premium system lead to similar financing costs. This is somewhat surprising, given that renewable energy operators are exposed to more risks under sliding premium systems. However, due to careful policy designs, they seem to be perceived as negligible. In contrast, green certificate systems are associated with significantly higher financing costs by 1.2 percentage points, or an average increase in risk premium by about a quarter. In line with part of the literature, this seems to be due to higher revenue risks under such policies. Interestingly, the implicit abolishing of all support policies is the most detrimental to low-cost investments and increases financing costs by around 2.2 percentage points.

Further, we model analytically how long-term contracts signed between project developers and energy suppliers impact financing costs in the context of green certificate schemes. The power price risk is shifted to the off-takers of long-term contracts. Rating agencies value the value of the contracts as long-term obligations without long-term hedge and impute them as debt, such that debt-equity ratios increase and credit ratings deteriorate, increasing off-takers' own re-financing costs. We parameterize the model with exemplary values for the average of large EU utilities and find that the additional costs of the long-term contracts are equal to about 21 percent of the long-term renewable energy contract.

Overall, the regression analysis and the analytical model reveal that between the support policies, the costs of renewable energy deployment differ by around 30 percent, but can lie significantly lower or higher, depending on the financial situation of energy suppliers.

a Corresponding author: German Institute for Economic Research (DIW Berlin), Berlin, Germany. Email: nmay@diw.de
b German Institute for Economic Research (DIW Berlin)

The Effect of Restructuring Electricity Distribution Systems on Firms' Persistent and Transient Efficiency: The Case of Germany

Oleg Badunenko,[a] Astrid Cullmann,[b] Subal C. Kumbhakar,[c] and Maria Nieswand[d]

One of the challenges arising subsequently to the German reunification in 1990, was to integrate the eastern and western sectors of electricity distribution. To achieve this, the East German sector was comprehensively restructured. While it was organized based on political rather than economic reasons before, the pursued strategy for this restructuring was to broadly adapt the existing structure of the western German electricity distribution sector, i.e., implementing local and regional distribution networks.

The focus of this paper is the analysis of the persistent impact of the restructuring—that followed the reunification—on the current performance of providers of electricity distribution services, i.e., DSOs. We analyze this by applying a state-of-the art stochastic frontier model that allows identifying determinants of time-variant (transient/short-run) and time- invariant (persistent/log-run) performance. We use a novel panel dataset of eastern and western German DSOs observed between 2006 and 2012. We approximate the restructuring by the location of the DSOs.

We find that overall inefficiency within the sector is driven by persistent rather than transient inefficiency. While all DSOs perform equally well in terms of transient inefficiency, DSOs located in East Germany exhibit, on average, less persistent inefficiency. We further show that, first, eastern DSOs perform uniformly well and better than most of the western DSOs, and, second, that the performance of most of the eastern DSOs are at par with best practice of their western counterparts. From this we conclude that the restructuring was beneficial to East German DSOs in terms of persistent efficiency and that today's implemented regulatory scheme successfully addresses transient inefficiency.

Our analysis shows that disentangling both types of inefficiency is an important exercise because it identifies improvement potentials, it can explain which factors actually drive short-term and long-term efficiency and, thereby, helps identifying appropriate strategies to achieve this improvement. Short- and long-term inefficiencies are likely to be issues in most public infrastructures due to the network-based technologies. Thus, we consider the applied methodology as being also relevant to other public sectors, e.g., gas distribution, water supply, sewerage, and local transportation.

a Economics and Finance Group, Portsmouth Business School, University of Portsmouth, Portsmouth, PO1 3DE, UK.

b Department of Econometrics and Statistics, TU Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany.

c Department of Economics, State University of New York, Binghamton, USA.

d Corresponding author. School of Business and Economics, Loughborough University, Loughborough, LE11 3TU, UK. Email: m.nieswand@lboro.ac.uk.

Renewable Energy Technologies and Electricity Forward Market Risks

Derck Koolen,[a] Derek Bunn,[b] and Wolfgang Ketter[c]

This paper analyses how the introduction of the same renewable technology at different parts of the electricity supply chain has different price formation effects on wholesale power markets. Across the world, the integration of renewable energy sources in power systems is taking place in various ways and paces, resulting in a fierce ongoing political combat between the various technologies. The forces at play are driven by the decarbonization of generation portfolios, moving conventional power plants toward intermittent renewable technologies, as well as the decentralization of demand and control. Digital advances in the form of smart meters and IoT devices have created opportunities for tech-savvy end-consumers and prosumers to become increasingly, but not entirely, independent from the grid.

This paper studies how the integration of renewable technologies at different parts of the supply chain may result in information asymmetries between retailers, where distributed production behind the meter may complicate prediction accuracy, and producers, who are confronted with uncertainty over intermittent production profiles. We thereby focus on the forward risk premium between short-term forward and spot electricity markets, rather than the spot market processes by itself, as the premium reveals the balance of risk-averse behaviour between producers and retailers.

We propose a multi-stage competitive equilibrium model, modelling the supply and demand side in a closed system with intermittent production capacity at both sides of the market. We find that forward prices are biased predictors of spot prices, with the emergence of risk premiums accounted to heterogeneous hedging needs of producers and retailers in relation to uncertainties from demand, intermittent production profiles and distributed production by end-consumers. We for a multi-factor propositional framework, relating the behavior of the forward premium, next to the role of technology as specified in our model, to fundamental, behavioral and dynamic market effects.

We validate the model by analyzing data in short-term forward and spot power markets in California and the Great Britain. Both markets have recently experienced a technology shift from conventional to respectively large-scale renewable energy production (e.g. wind and solar farms) and distributed renewable energy sources (e.g. rooftop solar). The results show evidence for large-scale and distributed renewable energy technologies to oppositely affect the forward premium, as asymmetries in the ability to predict and gather information on renewable energy supply heterogeneously influence risk preferences of producers and retailers.

Providing important insights on the distinctly different market price effects of renewable technologies and the role of prediction accuracy in short-term power markets, this study suggests a need for awareness by policy makers in evaluating the role of both large-scale and distributed energy sources on price formation. To the extent that the different effects of distributed and large-scale renewable facilities are due to intermittency risks being carried by retailers and generators respectively, at different ends of the supply chain, improved information transparency would help efficiency, but that would only be part of the matter. More crucially, the structural effect of small scale installations influencing retailer demand and large scale farms influencing generator produc-

a Corresponding author. Rotterdam School of Management, Erasmus University, Rotterdam, Netherlands. Send correspondence to Burgemeester Oudlaan 50, 3062PA Rotterdam, Netherlands. Email: koolen@rsm.nl.

b London Business School, London, United Kingdom.

c Faculty of Management, Economics, and Social Sciences, University of Cologne, Cologne, Germany and Rotterdam School of Management, Erasmus University, Rotterdam, Netherlands.

tion remains, and may well be a motivation in the future for increased vertical integration in the market. As competition authorities monitor the causes of mergers, technological insights from this study may therefore add a new awareness to their deliberations.

Drivers of People's Preferences for Spatial Proximity to Energy Infrastructure Technologies: A Cross-country Analysis

Jason Harold[abc], Valentin Bertsch[d‡], Thomas Lawrence[e] and Magie Hall[f]

Decarbonisation of the global energy system is an important prerequisite for the reduction of greenhouse gas emissions. Many countries plan to decarbonise their energy systems by expanding the use of renewable energy sources (RES). Such actions require significant investments in new energy infrastructures. While people are generally accepting of these infrastructures, opposition sometimes arises when these developments are sited at close proximity to people's residences.

In this context, this study examines the factors influencing people's spatial proximity preferences to a range of different energy technologies using a cross-country econometric analysis of the stated preference data from an unprecedented survey conducted on nationally representative samples of the population in Ireland, the US and Germany. Given the ordered nature of the dependent variable (distance) a generalised ordered logit model is estimated for each energy technology (wind turbines, solar power technology, biomass power plant, coal-fired power plant and natural gas power plant).

In general, German and Irish citizens are more willing to accept different energy technologies at smaller distances to their homes than their US counterparts. For the five energy technologies examined, people from Germany are shown to be much more willing to accept any of the power generating technologies at distances of 0–1km/miles to their residences compared to people from the US. Thus, it could be argued that people's preferences for spatial proximity are embedded in the broader social, economic and geographic environments of their respective countries.

Moreover, this study finds that attitudinal factors shape people's preferences more consistently than any of the socio-demographic characteristics. People who value environmental sustainability as more important than any other national energy policy objective (economic viability, reliability of supply or social acceptance) are found to be less inclined to oppose the three renewable technologies regardless of distance. In addition, people's technology specific perceptions are also found to be significant drivers for their preferences for spatial proximity between the separate technologies and their residences. For all five energy technologies, the perceived influence on the landscape, health and the local economy are determined to be important.

a Corresponding author. E-mail: jason.harold@nuigalway.ie
b J.E. Cairnes School of Business and Economics, and Whitaker Institute, National University of Ireland Galway, Ireland
c Economic and Social Research Institute, and Trinity College Dublin, Dublin, Ireland.
d Department of Energy Systems Analysis, German Aerospace Center (DLR), and University of Stuttgart, Germany.
e Driftmier Engineering Center, University of Georgia, Athens, Georgia, United States.
f School of Interdisciplinary Informatics, University of Nebraska Omaha, Omaha, Nebraska, United States.

Asymmetric Information on the Market for Energy Efficiency: Insights from the Credence Goods Literature

Bruno Lanz[a] *and Evert Reins*[b]

Many countries actively promote the adoption of energy efficient technologies in an effort to reduce energy consumption and related environmental externalities. The existing literature emphasizes that policies should target informational failure that affect investment behavior, including imperfect information about and inattention to future energy savings. We argue that many energy efficient technologies share characteristics of credence goods, as consumers do not directly observe how much savings can be achieved with alternative technologies, both before and after purchase/installation. Consumers may therefore need to rely on information provided by the supply-side of the market in order to identify which technology best suits their needs. In line with this, the sources of market inefficiencies studied in the credence goods literature can provide valuable insights for policies targeting the adoption of energy efficient technologies.

The objective of this paper is to link the literature on credence goods with that on energy efficiency investments. We start by developing a simple framework to study supply-side incentives related to the provision of energy efficient technologies. The framework predicts that the difficulty to verify realized energy savings may incentivize expert-sellers to manipulate information, and ultimately reduce the number of trades in markets for energy-transforming technologies. Next, we discuss potential remedies by reviewing empirical results from the credence goods literature, and relate these results to an empirical literature on energy efficiency. Concretely, we consider four important domains that affect supply-side behavior in markets for credence goods: (i) the degree of asymmetric information, (ii) separating diagnostic and treatment, (iii) third party reimbursements, and (iv) reputation.

The implications of our work for energy efficiency policies can be summarized as follows. First, certification schemes and labels involve a trust component, which implies that third party verification and strict liability rules are necessary for this information to be decision-relevant. Second, the provision of independent diagnostic (e.g. in the form of audits) can mitigate supply-induced inefficiencies, although the associated cost can potentially harm overall welfare. Third, the credence component of energy efficiency implies that subsidies are likely to affect pricing behavior by the supply-side of the market, which may again reduce the overall welfare of the policy. Fourth, reputational mechanisms could foster trust and improve market efficiency, and could be leveraged through independent information on realized energy and/or financial savings, for example through ex-post audits. Finally, we conclude that researchers in the energy economics literature could themselves contribute to a broader literature on credence goods by slightly re-framing their research questions.

a Department of Economics and Business, University of Neuchâtel; Center for Integrative Risk Management and Economics, ETH Zürich; Center for Energy and Environmental Policy Research and Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology.

b Corresponding author: Department of Economics and Business, University of Neuchâtel. Institute of Economic Research, Abram-Louis Breguet 2, CH-2000 Neuchâtel, Switzerland. E-mail: evert.reins@unine.ch

Global Oil Export Destination Prediction: A Machine Learning Approach

Haiying Jia,[a] Roar Adland,[b] and Yuchen Wang[c]

The geographical separation of oil consuming and producing nations means that oil needs to be transported at great distances, with forty percent of the annual global oil production transported via the oceans in specialized oil tankers. The objective of this paper is to predict the destination of oil exports at the micro level in a data-driven framework by utilizing actual oil shipment information and training machine learning algorithms based on supervised classification techniques. We contribute to the academic literature by providing the first machine learning application to oil shipment data, and by providing new knowledge on the determinants of global crude oil flows.

Based on crude oil shipment data for the period January 2013 through mid-March 2016, we investigate how destinations are determined based on four attribute clusters: cargo information (such as sellers' identity, cargo grade and cargo size), vessel information (such as vessel identity and its technical specifications), geographic information (load terminals and ports), and macroeconomic data (e.g. regional oil prices and crack spreads). We train the machine learning algorithm based on historical data and demonstrate the models' out-of-sample accuracy.

The results show that micro-level attributes of the oil shipment such as quality and cargo size dominate in the destination prediction. The machine-learning models used to predict the importing country can reach an accuracy of above 71% for the major oil exporting countries based on out-of-sample tests and outperform both naïve models and discrete regression models.

Our research is an important building block in commercial applications that deal with oil and freight market analysis. For instance, the public destination information in ship tracking data is known to be of low quality and can be easily manipulated. Accordingly, analysts that want to track cargoes as a proxy for economic activity or to estimate short-term regional supply of crude oil need a tool to benchmark such information against the likely outcome predicted from past trading patterns and micro data. Importantly, our work suggests that micro data is substantially more valuable for predictive oil trade models than observable macroeconomic data such as crack spreads and oil prices.

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a Center for Applied Research (SNF) and Department of Business and Management Science, Norwegian School of Economics, Bergen, Norway. E-mail: haiying.jia@nhh.no

b Corresponding author. Department of Business and Management Science, Norwegian School of Economics, Helleveien 30, 5045 Bergen, Norway. E-mail: roar.adland@nhh.no

c Operations Research Center, Massachusetts Institute of Technology, Cambridge, MA, USA. E-mail: yuchenw@mit.edu

d Corresponding author: German Institute for Economic Research (DIW Berlin), Berlin, Germany. Email: nmay@diw.de

e German Institute for Economic Research (DIW Berlin)

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Urban Residential Energy Demand and Rebound Effect in China: A Stochastic Energy Demand Frontier Approach

Kerui Du,[a] Shuai Shao,[b] and Zheming Yan[c]*

China is at the stage of rapid urbanization. The residential energy consumption has been dramatically increasing with the substantially rising population in urban regions. To combat climate change, China has made ambitious plans for energy demand control and energy conversion, including the control over residential energy consumption. According to those plans, one of the fundamental ideas is to improve energy use efficiency through different measures. However, the existence of the energy rebound effect might make the achievement of energy-use reduction plans in the residential sector full of uncertainty. Thus, estimating the energy rebound effect in China's urban residential sector is of importance for designing effective energy-saving policies. Also, China is a vast country with evident uneven development levels of regional economies. This motivates us to uncover the regional differences regarding the energy rebound effects, in order to understand the

a School of Management, China Institute for Studies in Energy Policy, Xiamen University, Xiamen 361005, China
b School of Business, East China University of Science and Technology, Shanghai 200237, China.
c School of Economics and Finance, Xi'an Jiaotong University, Xi'an 710049, China.
* Corresponding author. E-mail: shaoshuai8188@126.com.

rebound effect in China's residential sector more profoundly and to provide some policy references for implementing the region-specific measures of energy conservation.

Based on the pioneering contribution of Orea et al. (2015) in the methodology, we estimate the energy efficiency and rebound effect in the urban residential sector for China's 30 provincial-level regions using an adapted stochastic frontier model, i.e., the stochastic energy demand frontier approach. This approach can simultaneously estimate the energy efficiency and energy rebound effect by one step. Thus, we can be free from the restrictions in the methods using price elasticity or using the proxy of energy efficiency change to improve the estimated accuracy of the rebound effect. Furthermore, we examine the influencing factors of residential energy consumption and identify the determinants of the rebound effect.

The results show that residents' income level, temperature deviation, population scale, and household size are positively correlated with urban residential energy consumption. On the contrary, the district heating system, energy price, and technology progress contribute to reducing residential energy consumption. Regarding the energy rebound effect, an inverted U-shaped relationship between residents' income level and rebound-effect size exists. Additionally, we find that energy price is negatively correlated with the rebound effect.

Regarding the magnitude of the rebound effect, the estimated values vary to a large extent across provinces and regions, with the first, median, and third quartiles approximately equal to 40%, 70%, and 95%, respectively. By grouping provincial-level regions based on their time average values of the rebound effect, we find the group with the largest rebound effect only consists of eastern and developed provincial-level regions. In contrast, the group with the smallest rebound effect mainly consists of northwest and northeast provincial-level regions that are relatively poor. Furthermore, there is an evident "north-south" difference in the rebound effect size. For instance, the central north region and central south region are geographically nearby regions and similar in both the level and growth rate of residential income. However, the average regional size of the rebound effect increases to a large extent from the central north (42.19%) to the central south (70.32%).

Some important policy implications can be raised based on our main findings. First, energy pricing reform may be the most helpful policy tool since the marketization of energy prices in China is far from sufficient. Second, local governments should replace their GDP-based targets with sustainable development goals as proposed by the United Nations. Third, urban energy conservation in China needs the assistance of climate change mitigation policies, which aim to avoid dramatic temperature changes, to achieve a synergic outcome of these two types of policies.

Market Power and Renewables: The Effects of Ownership Transfers

Olivier Bahn,[a] Mario Samano,[b] and Paul Sarkis[c]

Over the past few years, electricity markets around the world have seen important changes in their energy portfolios as new sources have been introduced (e.g. wind and solar) and others have been retired or penalized through taxes (e.g. non-refurbished nuclear plants and coal plants). These changes continue nowadays as a number of incentives to curb the greenhouse gas emissions associated with the production of electricity have either been put in place (e.g. production subsidies

a GERAD and Department of Decision Sciences, HEC Montreal. Email: olivier.bahn@hec.ca

b Corresponding author. Department of Economics, HEC Montreal. Email: mario.samano@hec.ca Address: 3000 ch. Cote Ste. Catherine, Montreal, Canada H3T 2A7.

c Department of Economics, Boston College. Email: sarkisp@bc.edu

such as feed-in-tariffs (FiT) and mandates such as renewable portfolio standards (RPS)) or in other cases been dismantled.

We quantify the net result on wholesale electricity prices of two opposite effects: market power and the merit order effect. The latter occurs when there is an expansion of the amount of renewable energy sources (RES): in that case, the system's supply curve shifts to the right and its intersection with the demand curve occurs at a lower price than before the expansion. However, partial ownership of RES from firms with market power may counteract that effect. In fact, as we show theoretically, the best response for firms with market power is to reduce production from conventional sources, which has a positive effect on market prices. First, we quantify this market power effect on its own by measuring the effect on market prices when holding the system's capacity constant and changing the ownership structure. Second, we compare this effect to the merit order effect by expanding net capacity and allowing different firms to hold the additional capacity.

We estimate a detailed model of the Ontario electricity market to run simulations that consist of finding the new hourly equilibrium prices under different allocations of RES among market participants using the reaction functions estimated from the data. Our results show that, by keeping the total amount of RES constant in the system, transfers of that capacity from the fringe into the strategic firms give place to positive increases in prices of up to 24% relative to average prices and they increase with the amount of RES capacity transferred. These effects are net of the merit order effect because there are no additions to the system's RES capacity. As the strategic firms' portfolios include higher shares of RES, equilibrium prices increase by greater amounts. In other words, the expansion of the strategic firms' portfolios from adding RES capacity yields to more expensive electricity, contrary to the effects from a simple merit order effect. Finally, when we add RES capacity to the entire system following current policy guidelines in Canada, the merit order effect and market power combined yield lower prices relative to the equilibrium outcome with no added RES. We show that there can be a decrease of up to 30% under perfect competition but only around 7% when the largest firm is the owner of the new capacity.

Impact of Energy Market Distortions on the Productivity of Energy Enterprises in China

Weijian Du,[a] Mengjie Li,[b] Ke Li,[c] Jiang Lin[d]

China aims to enhance the total factor productivity (TFP) to achieve sustainable development. However, the looming energy market reform, and its accompanying major energy distortions prevent the realization of this ambitious goal. Naturally, we have questions: what kinds of distortions do China's energy market face? How these distortions restrain the TFP improvement of energy enterprises in China? Investigating these issues deepens the reform of China's energy market by correcting the distortions, improving the input–output efficiency of energy factors, and further promoting the sustainable development of China's economy.

a Synergy Innovation Center for Energy Economics of Shandong, College of Economics, Shandong Technology and Business University

b Synergy Innovation Center for Energy Economics of Shandong, College of Economics, Shandong Technology and Business University

c Corresponding author: Key Laboratory of Applied Statistics and Data Science, School of Mathematics and Statistics, Hunan Normal University, Changsha, Hunan 410081, PR China. E-mail: likekent1208@163.com

d Corresponding author: China Energy Group, Lawrence Berkeley National Laboratory, Berkeley 94720, United States. E-mail: j_lin@lbl.gov

Theoretical analysis reveals that energy market distortion significantly inhibits the promotion of enterprises' TFP, and this impact has been diminishing. Furthermore, according to the data of China's energy enterprises and energy factor market (EFM) characteristics, We measures the EFM distortion and TFP to weigh the degree of distortion of the energy market and efficiency of energy enterprises. Finally, on the basis of the intensive margin of TFP change and the extensive margin of energy enterprise entry and exit, we empirically investigates the impact of EFM distortions on enterprise TFP and further verifies and extends the conclusions of the theoretical model.

The main conclusions are as follows. (1) Misallocation among China's energy enterprises and overall distortions of the EFMs in different regions have negative effects on energy enterprises' TFP. The greatest inhibitory effect is observed in state-owned enterprises. (2) The results of the panel smoothing transformation model show that the "bonus" for productivity gains can gradually increase with the continuous correction of market distortions. (3) The distortion of the energy market can inhibit enterprise entry and accelerate enterprise exit from the energy market. These results are robust for different model specifications and instrumental variable estimations. Considering the similarities in the energy market structures and the widespread distortion of energy markets in developing countries, the method and conclusions of the present study explain the ways to promote energy market reform.

ENERGY STAR Appliance Market Shares: Do They Respond to Electricity Prices, and Does It Matter?

Peter M. Schwarz,[a] Craig A. Depken, II,[b] Michael W. Herron,[b] and Benjamin Correll[b]

Energy efficiency is often cited as the lowest-cost method of reducing carbon emissions. Yet its effectiveness depends upon the degree to which consumers are willing to adopt such measures. The energy efficiency gap suggests that consumers do not fully respond to energy efficiency savings for such reasons as discounting future savings at an above-market discount rate. There is also evidence that they show limited response to rebates. Our paper focuses on an apparent paradox that the market share of energy-efficient appliances, as identified by ENERGY STAR (ES) labels, do not respond to changes in electricity prices. In contrast, we find a between-state price response for ES room air conditioners, refrigerators, and dishwashers, but not clothes washers.

Using similar data as in earlier studies for the years 2000-2009, we utilize an econometric specification that allows for both within-state and between-state impacts of state electricity prices. As did the earlier study, we find no response to within-state changes in electricity prices, but we do find a response to between-state changes in electricity prices. We interpret the insignificant within-state effect is a shorter term response by consumers, while the significant between-state effect reflects a longer term response.

In addition to non-price variables included in earlier studies, such as rebates, per capita income, and natural gas prices, we evaluate a number of additional variables, of which education and the percentage of housing that is owner-occupied, prove to increase the market share of the evaluated ES appliances. We hypothesize that additional education increases the demand for energy efficiency, either due to greater awareness of the cost savings or to a greater demand for improving

a Corresponding author: Department of Economics, Belk College of Business, University of North Carolina at Charlotte. Charlotte, NC 28223-0001, US. E-mail: pschwarz@uncc.edu

b Department of Economics, Belk College of Business, University of North Carolina at Charlotte. Charlotte, NC 28223-0001, US.

environmental outcomes. Households that own rather than rent can more easily internalize short-term energy savings and long-term benefits when they sell a home with energy-efficient appliances.

Having established a long-term price response, we evaluate the energy savings and reduction in carbon emissions from ES as compared to conventional appliances. Using the estimation results, we find that the four ENERGY STAR appliances reduce energy use by 1.9 million megawatt-hours per year with a corresponding reduction in carbon emissions of 1.4 million tons, equivalent to removing 0.1% of all U.S. vehicles. Adding a \$100/ton CO_2 tax would increase these figures to 2.1 million megawatt-hours, 1.5 million tons, and 0.11% of U.S. vehicles, equivalent to removing 275,000 vehicles from U.S. roads.