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ENERGY INSTITUTE AT HAAS

RESEARCH*review*

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How Do Rising Gas Prices Affect the Cars We Buy?

The dramatic increase in gasoline prices from below $1 in early 1999 to over $4 at their peak in 2008 made it much more expensive for consumers to operate their automobiles. For example, an average driver of a full-size SUV would have spent as little as $758 per year on gasoline at the early-1999 gasoline prices but would have spent $2,968 at the mid-2008 prices to travel the same distance in the same car!

IN THIS ISSUE

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Paying more to travel by car when gasoline prices increase, however, is not inevitable. Consumers can adjust by switching to a more fuel-efficient car. So how do consumers respond in the short run to higher gas prices? Meghan Busse (Northwestern University), Christopher Knittel (UC Davis), and Florian Zettelmeyer (Northwestern University) investigate whether the change in gasoline prices did, in fact, alter which automobiles consumers purchased and the prices they paid for cars. In their paper "Pain at the Pump: The Differential Effect of Gasoline Prices on New and Used Automobile Market" (EI @ Haas WP 201), they look at the impact of an increase in gasoline prices on the market share and prices of more and less fuel efficient automobiles in both the new and used car markets. They use detailed data on individual car transactions from a sample of 20% of all dealerships in the U.S. between September 1, 1999 and June 30, 2008 to analyze the impact of rising gasoline prices on these markets. The data include every new and used car transaction within that time period for the dealers in the sample. Only used cars sold through the dealership are included in the study.

Busse, Knittel and Zettelmeyer find that the impacts on the new and used car markets are very different. They find that a $1 increase in gasoline price increases the market share of the most fuel-efficient quartile of new cars by 20% and reduces the market share of the least fuel-efficient quartile of new cars by 24%. The used car market, in contrast, increased the market share of the most fuel-efficient cars by only 3% and reduced the market share of the least fuel-efficient cars by 7%. They also find that these changes in gasoline prices change the relative prices of the most and least fuel-efficient cars. For new fuel-efficient cars, the price increase is $127 for a $1 increase in gasoline prices; for used fuel-efficient cars it is $1,766. On the other end of the fuel spectrum, the prices of the least

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Are Appliance Standards a Necessary Part of an Effective Carbon Policy?

Many have argued that renters are less likely to have energy efficient appliances in their homes because neither the landlord nor the tenant has much incentive to purchase anything but the least expensive appliances. Landlords may not want to spend more for an energy efficient appliance if they aren't paying the utility bill and renters are unlikely to purchase their own appliance if one is already supplied by the landlord. This landlord-tenant problem, or principal-agent problem, is one argument that is used to support increasing energy efficiency standards for appliances.

Appliance standards have been used in the United States since the 1970s, and continue to be an important component of U.S. energy policy. Both the 2005 and 2007 Energy Acts included increased efficiency standards for residential appliances. Had the Waxmen-Markey bill (HR 2454) passed in 2009, it would have established stricter efficiency standards for household appliances, in addition to a cap-and-trade program for carbon emissions. The presence of both policies in the Waxman-Markey bill raises an interesting question. Does it make sense to combine efficiency standards with a cap-and-trade program? Supporters of efficiency standards argue that they address the landlord-tenant problem and other market failures that would not be addressed by a cap-and-trade program alone. The economic case for using two policies rests on those additional market failures above and beyond externalities.

TABLE 1: HOUSEHOLD CHARACTERISTICS OF HOMEOWNERS AND RENTERS

	HOMEOWNERS	RENTERS
Household Economic Characteristics		
Household Income	$55,700	$34,200
Welfare recipients	6%	24%
Household Demographics		
Age of household head	52.7	42.2
Households with children	34%	38%
Head of household non-white	21%	44%
Type of Neighborhood		
Urban	36%	57%
Town	16%	19%
Suburban	23%	14%
Rural	25%	10%
Appliance Saturation		
Refrigerator	100%	100%
Dishwasher	67%	39%
Room air conditioner	21%	38%
Clothes washer	95%	57%
Energy Efficient Technologies		
Energy Star refrigerator	24%	17%
Energy Star dishwasher	18%	7%
Energy Star room air conditioner	4%	5%
Energy Star clothes washer	23%	12%
Front loading clothes washer	9%	2%
Energy-efficient lighting (any)	41%	33%

Cap-and-trade programs work by increasing the price of energy, causing decision makers or agents to face the social costs of their choices. Principal-agent problems, like the landlord-tenant problem, reduce the effectiveness of this approach because the person experiencing these increased prices may not be the same person who is making the decision about energy use. It is important to keep in mind, however, that there is an important tradeoff inherent in efficiency standards. A standard removes goods from the market that are preferred by some buyers and may increase the cost of the appliance. These costs must be balanced against the potential benefits. Understanding the mechanisms that explain the landlord-tenant problem and the magnitude of the distortion is important for determining how to most effectively target policies.

Lucas Davis, an assistant professor at the U.C. Berkeley's Haas School of Business, provides one of the first

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Increasing Wind Production: A Game Changer for Electricity Markets

Over the past 20 years, the electric power industry has become the central focus of two extraordinary policy trends, each one significant enough to fundamentally reshape the industry. One of these is liberalization, a term that has come to encompass both privatization and regulatory restructuring, and the other is the growth of the environmental movement and its more recent focus on climate change. It is the intersection of these two trends that will dominate the economics of the electric power industry.

The impact of renewable generation on the electricity markets in which they participate has to date been relatively modest outside of regions of high concentration such as west Texas. That will almost certainly change, however, as state and federal policies considerably ramp up the amount of renewable generation throughout the country. This can have a profound impact on electricity prices and the economics of supply both for renewable and nonrenewable generation. Professor James Bushnell at Iowa State University studies this impact in his paper "Building Blocks: Investment in Renewable and Non-Renewable Technologies" (EI @ Haas WP 202R).

For the industry as a whole, the growth of nonutility generation has coincided with the expansion of renewable generation sources. To this day, the renewable industry is dominated by nonutility producers. The most commonly heard concern about the rapid expansion of renewable electricity supply is over the fact that this supply is available only intermittently. With the prospect of one-fifth or more of electrical energy coming from intermittent sources, many in the industry are confronting the fact that the traditional tools for planning and providing reliable electric service may prove inadequate. This large-scale addition of intermittent resources is taking place when the mechanisms through which generators are compensated are very much in flux.

Since the onset of market liberalization, concerns have been raised that the newly formed market regimes would fail to produce adequate investment in generation capacity.

Markets can differ greatly in the primary sources of remuneration for generators, with some relying on energy and ancillary services markets, while others have established mechanisms for compensating suppliers for their installed or available capacity. In the "energy-only" framework, suppliers receive payments for the provision of either energy or associated operating reserve service. In some markets with this approach there are no or very high price caps, however, in many markets the revenues provided through this mechanism appear to be insufficient to cover the fixed cost of new investment. Myriad reasons can be given for this, including the existence of price caps, the subtle but significant impact of the decisions of system operators on market prices, and the over investment of capacity. This and other factors have led policy makers to seek additional means to compensate suppliers. Therefore, many electricity markets provide payments for capacity "availability" that supplement revenues received for the provision of energy and ancillary services.

The power industry today therefore features two contrasting models for financing new investment: the energy-only model, which relies on periodic, extremely high prices for energy and ancillary services and the capacity payment model, whose payments are made for available capacity. The large-scale deployment of intermittent resources can imply a major paradigm shift for both investment models.

Professor Bushnell develops a long-run equilibrium model of investment to explore the ramifications of a greatly expanded supply of intermittent resources. The approach of the model is to examine actual load profiles of certain markets and then impose varying levels of intermittent wind production on those demand distributions. The model then derives the mix of thermal technologies that would be constructed to serve the resulting residual demand that is left over after accounting for wind production. The calculations are based on data from the Western Electricity Coordinating Council (WECC) for the year 2007. These data are subdivided into the four WECC subregions: California (CA), Northwest Power Pool (NWPP), Southwest (AZNM), and the Rocky Mountain Power Pool (RMPP). See Figure 1.

The general approach is to ask how the electricity load would have looked during 2007 under various levels of wind production. It is important to keep in mind that this is not a simulation of the incremental investment required

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INCREASING WIND PRODUCTION: A GAME CHANGER FOR ELECTRICITY MARKETS

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going forward in these markets, but rather an exercise that examines how the long-run equilibrium mix of generation and costs would change under an expansion of wind production. The goal is not to reproduce the electric system as it actually operated in 2007, but rather to assess how investment decisions would play out if the industry were starting from a completely clean slate and faced the residual demand (after existing unconventional generation) from 2007.

In the first stage of the analysis, Bushnell looks at the baseline level of estimated wind production used in a WECC study and also a level that is double that used in the WECC study. The aggregate generation levels are summarized in Table 1. As can be seen in Table 1, the wind resources are not evenly distributed throughout the WECC region; the RMPP area which includes the wind-rich areas of Wyoming has a great deal of wind potential, whereas the desert Southwest has much less. When the projected additional wind production is combined with and assumed to displace existing generation, the result is much steeper load profiles. The increasing penetration of wind resources in the WECC will create a surge of energy supply, much of which will be uncorrelated with end-use demand. The net result is a residual load shape that is more "peaky."

FIGURE 1: WECC SUBREGIONS

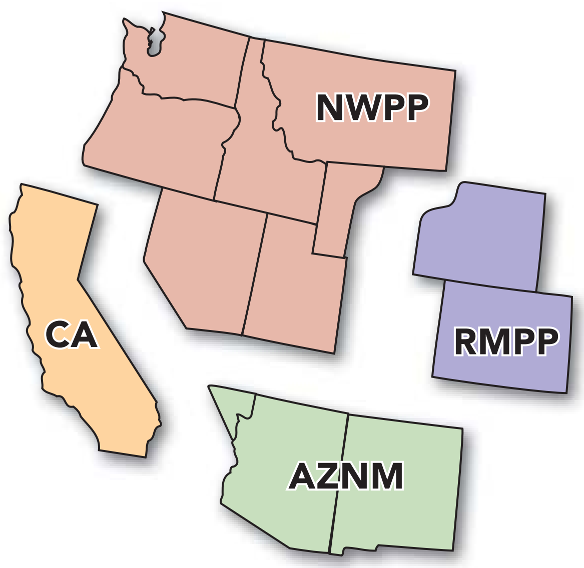

TABLE 1: AGGREGATE GENERATION LEVELS

HOURLY AVERAGES					
Region	Load (MWh)	Wind (MWh)	Share	High wind (MWh)	Share
California	13,216	1,866	14%	3,733	28%
NWPP	15,334	2,229	15%	4,458	29%
AZNM	17,942	1,445	8%	2,891	16%
RMPP	6,986	1,902	27%	3,804	54%
Totals	53,479	7,443	14%	14,885	28%

Note: MWh = megawatt-hours

To estimate the investments in additional thermal capacity spurred by increasing wind production, Bushnell examines the optimal mix of three basic generation technologies that form the backbone of most U.S. electric systems: a base load pulverized coal technology, a midmerit combined cycle gas turbine technology and a peaking gas combustion turbine (CT). Each represents different levels of the trade-off between capital costs and marginal costs. With the resulting optimal mix and level of generation capacity calculated for each of the four WECC regions, Bushnell examines the results under both an energy-only market paradigm, with no price cap and no capacity payment, and a capacity market paradigm.

The investment levels for an energy-only market are shown in Table 2. For each WECC region, the aggregate equilibrium thermal capacity and assumed wind capacity are given under three wind scenarios: wind at 2007 levels, the WECC-estimated level, and double the WECC-estimated level. The aggregate equilibrium thermal capacity and wind capacity are given in the first two columns. The assumed average capacity factor, taken from the wind profiles from the WECC study is given in the next column, and the share of thermal capacity that are base load and peaking are given in the last two columns. The increasing penetration of wind resources produces a clear shift of investment toward less capital-intensive peaking resources in every market. The amount of coal-fired base load production that would be an economical investment steadily declines

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HOW DO RISING GAS PRICES AFFECT THE CARS WE BUY?

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fuel-efficient new cars fall by $236, while in the used car market the prices fall by $1,073. Hence, the adjustment to changes in gasoline prices varies dramatically between new and used car markets. In the new car market, the adjustment is primarily in market shares, while in the used car market, the adjustment is primarily in prices. (See Table 1.)

The researchers argue that the dramatic difference in how usage costs affect new and used car markets can be explained by differences in how new and used cars are supplied. New cars are supplied by auto manufacturers while the supply of used cars arises ultimately from used car owners. This means that the outside options of new and used car suppliers, in the event either decides not to sell a car, differ fundamentally.

For auto manufacturers, there is no value to the car other than the profit opportunity of selling it. The manufacturer's decision to sell is unaffected by the price of gasoline. For used car owners, however, the outside option is to keep the car and drive it themselves. A used car owner's decision to sell will depend on a comparison of the gasoline costs of the current car versus a replacement car. Rising gasoline prices will increase the usage cost disadvantage of fuel-inefficient cars, increasing the incentives of their owners to sell them (and vice versa for fuel-efficient cars). This means that while rising gasoline prices should increase the demand in new and used car markets similarly, the effect on supply should differ between new and used car markets. The results of their study found just that. In the new car market, the increased price of gasoline led to more fuel-efficient cars being sold but relatively little change in the prices of the new cars. Whereas in the used car market, the gas price increase led to not much more supply of used cars but significantly higher prices paid for the fuel-efficient cars.

TABLE 1: IMPACTS OF A $1 INCREASE IN GASOLINE PRICE ON NEW AND USED CAR MARKETS

		% Change in Market Share	Car Price Change
	Fuel Efficiency		
NEW CARS	MPG Quartile 1 (least fuel efficient)	-23.9	-$236
	MPG Quartile 2	-6.6	-$74
	MPG Quartile 3	-2.74	$6.90
	MPG Quartile 4 (most fuel efficient)	20.5	$127
USED CARS	MPG Quartile 1 (least fuel efficient)	-6.64	-$1,073
	MPG Quartile 2	-9.05	-$900
	MPG Quartile 3	10.04	$118
	MPG Quartile 4 (most fuel efficient)	3.46	$1,766

With their data, the authors are also able to shed some additional light on what is happening in each of these markets. The supplementary evidence comes from looking at dealer inventories and trade-ins. The data contains information on the number of days that a specific vehicle was on a dealer's lot before it was sold and information on any cars traded in as part of a transaction.

The authors show that in the new car market, a $1 increase in gasoline prices results in the least fuel-efficient cars remaining on the lot an additional 12 days on average, while the most fuel-efficient cars leave the lot 5 days sooner on average. In contrast, for used cars, higher gasoline prices have no significant effect on the number of days on the lot for either the most or least fuel-efficient cars.

When new car deals include a trade-in, the authors find that higher gasoline prices are associated with greater fuel efficiency of the new car relative to the trade-in. The analysis implies that a $1 increase in gasoline prices leads customers to increase the fuel efficiency of the new car relative to the trade-in by 0.94 miles per gallon. For used cars, they find that the same gasoline price increase increases the fuel efficiency of the newly purchased used car relative to the trade-in by 0.48 miles per gallon. These results suggest that when gasoline prices increase, customers choose to purchase more fuel efficient cars relative to the cars that they have purchased in the past.

Busse, Knittel and Zettelmeyer conclusively show a contrast between how markets for new and used cars respond to changes in the price of gasoline. It is the difference in the supply of new and used cars, coupled with an efficient wholesale market for used cars, that appears to lead to rapid price adjustments for used cars, while the new car market experiences market share change instead. EI@HASS

ARE APPLIANCE STANDARDS A NECESSARY PART OF AN EFFECTIVE CARBON POLICY?

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empirical analyses of the landlord-tenant problem. In his paper "Evaluating the Slow Adoption of Energy Efficient Investments: Are Renters Less Likely to Have Energy Efficient Appliances?" (EI @ Haas WP 205), Professor Davis compares appliance ownership patterns between homeowners and renters using household-level data from a nationally-representative survey. The 2005 Residential Energy Consumption Survey (RECS) was conducted by the Department of Energy and provides detailed information about the appliances used in the home as well as information about the demographic characteristics of the household, the housing unit itself, weather characteristics, and energy prices. RECS also provides detailed information on who pays for utilities, which allows Davis to exclude those households where the landlord pays the utility bills. Those households tend to use their appliances more intensively and landlords face very different incentives to invest in energy efficient appliances when they pay the energy bill. In the 2005 RECS sample, this exclusion applied to 13.4% of all renters.

Table 1 describes average characteristics for homeowners and renters. The table reveals pronounced differences between the two groups. Homeowners have substantially higher annual household income, are less likely to receive welfare benefits, are older, are less likely to be non-white, and more likely to live in suburban and rural areas. In addition, appliance saturation levels differ substantially with homeowners more likely to have clothes washers and dishwashers but less likely to have room air conditioners. Homeowners are also significantly more likely to report having energy efficient refrigerators, dishwashers, clothes washers, and lighting. Particularly striking are the averages for front loading clothes washers, which are 50 percent more energy efficient than top loading washers. Nine percent of homeowners report having a front loading clothes washer compared to only two percent for renters. For room air conditioners the pattern is reversed, with renters reporting more energy efficient units. This primarily reflects the higher saturation levels of room air conditioners among renters. Unlike refrigerators or clothes washers, room air conditioners are relatively portable, easily installed and often owned by renters.

Although the differences in Table 1 are consistent with the landlord-tenant problem, this pattern could also be driven by other factors, such as household income, that are correlated with home ownership. Professor Davis's analysis compares the saturation level of energy efficient appliances between homeowners and renters while controlling for household income and other household characteristics. After controlling for household income, household demographics, electricity prices, heating and cooling days, Census division and available state indicators, his results show that renters are 6.7 percentage points less likely to report having energy efficient refrigerators and 9.2 percentage points less likely to report having an energy efficient dishwasher. Renters are also less likely to report having energy-efficient room air conditioners, clothes washers, and lighting though the difference is not as great.

Davis continues his analysis and poses the question: How many additional energy efficient appliances would there be in the United States if renters were equally likely as homeowners to have these technologies? His estimates imply that there would be 2.2 million more energy efficient refrigerators, 3.1 million more energy efficient dishwashers, and 6.3 million more energy efficient light bulbs. Nationwide this would reduce annual energy consumption by 9.4 trillion btus, reduce annual energy expenditures by $93 million, and reduce annual carbon emissions by 166,000 tons.

These findings provide empirical support for conventional wisdom about the landlord-tenant problem. In addition, Davis's estimates of the potential energy savings and potential reduction in carbon emissions help put this market failure in context, demonstrating what is at stake in decisions to adopt or not adopt more stringent efficiency standards. To provide a more precise measurement and evaluation of the magnitude and incidence of the impact, more research and better data are needed. EI@HASS

INCREASING WIND PRODUCTION: A GAME CHANGER FOR ELECTRICITY MARKETS

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as wind penetration increases. The reliance on the low-capital-cost combustion turbine technology increases. It is also noteworthy that less thermal capacity is needed in every market as a reflection of the fact that wind generation has lowered the residual demand required to be served by thermal sources. Figure 2 illustrates the move by subregion from less coal production toward more CT production as wind production increases.

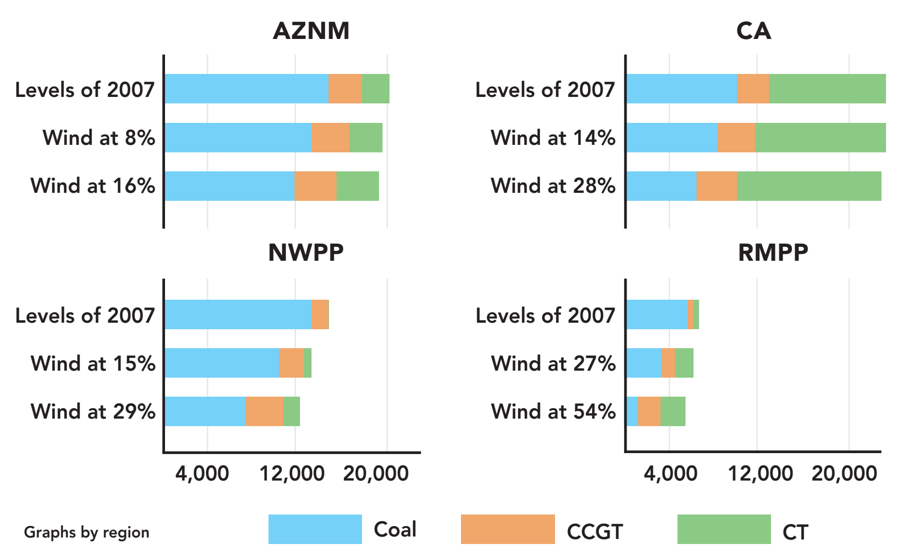
Bushnell also explores the impact of increased wind penetration on electricity market prices. The availability (or lack) of wind resources will be an important contributor to market clearing prices. The normal relationship between end-use demand levels and market prices becomes redefined as wind resources grow to take a substantial share of the market. Generally one expects high prices and revenues during high periods of demand. Under an energy-only market, the revenues for an average profile wind plant decline because prices are influenced increasingly by wind availability. An average wind plant would produce primarily during hours of glut (when most wind plants are producing) and therefore when prices are low. If revenues are based instead on a combination of capped energy market revenues and capacity payments, wind producers do a little better. This is in part because the capacity payment rewards production during high demand hours, whereas the energy-only market rewards production during high price hours. As wind penetration increases, the high price hours are relatively more focused on low wind hours than on high demand hours.

Overall increasing reliance on intermittent resources creates, or increases, costs in a fashion similar

TABLE 2: EQUILIBRIUM RESULTS FOR ENERGY-ONLY MARKET

WIND						
Region	Wind Levels	Thermal Capacity (MW)	New Wind Capacity (MW)	Wind Capacity Factor	Share Coal (Base load)	Share CT (Peaking)
	2007 level	23,208	NA	NA	43%	44%
CA	14% increase	22,753	5,670	33%	36%	50%
	28% increase	22,442	11,340	33%	28%	55%
	2007 level	14,472	NA	NA	93%	0%
NWPP	15% increase	13,188	7,890	28%	81%	4%
	29% increase	12,237	15,780	28%	64%	10%
	2007 level	20,276	NA	NA	73%	11%
AZNM	8% increase	19,691	3,840	39%	68%	14%
	16% increase	19,141	7,680	39%	62%	17%
	2007 level	6,751	NA	NA	86%	7%
RMPP	27% increase	6,000	4,650	41%	61%	20%
	54% increase	5,374	9,300	41%	26%	37%

FIGURE 2: THERMAL CAPACITY BY WIND PENETRATION LEVEL



to that caused by fluctuating end-use demand. While the added costs associated with fluctuating end use demand can be mitigated by time-varying prices, the intermittency of renewable supply is a fact of nature. In planning to serve a system with such a high degree of fluctuation of supply, firms must turn to resources that are more flexible, but also more expensive on an average cost basis. EI@HASS

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