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The Energy Paradox and the Future of Fuel Economy Regulation

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In November 2011, the Environmental Protection Agency and the National Highway Traffic Safety Administration issued a joint proposal to increase fuel economy standards to 54.5 miles per gallon by 2025, which is roughly double the 28.5 miles per gallon average of vehicles sold in 2009. This proposal builds on existing rules that raise fuel economy significantly between 2012 and 2016. The personal transportation sector accounts for roughly half of petroleum consumption and one-fifth of all greenhouse gases in the United States (Environmental Protection Agency 2007). Doubling fuel economy therefore promises to dramatically reduce our nation's demand for oil and shrink its carbon footprint.

No policy comes without costs, however, and research, development and vehicle modifications necessary to obtain these goals will be substantial. Are the benefits greater than costs? Should we pursue such aggressive targets? The answer, it turns out, may depend importantly on whether or not there is an energy paradox.

Many estimates of the costs and benefits of actions to improve energy efficiency that are left undone – including the adoption of new technologies – calculate that the costs are far outweighed by the present discounted benefits of future fuel cost savings. The failure of the

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private market to take such actions, which appear to be in their own private interest, is referred to as the energy paradox, or the "energy efficiency paradox" or the "energy gap".

For example, suppose that automotive engineers report that it would cost an additional $4,000 to turn a particular vehicle into a hybrid, and the estimated lifetime fuel cost savings from doing so was $6,000. If the market did not turn the car into a hybrid, which appears to be in the private interest of the producer and consumer, this would be a sign of an energy paradox. Improvements in fuel economy is one important area where some believe that an energy paradox exists.

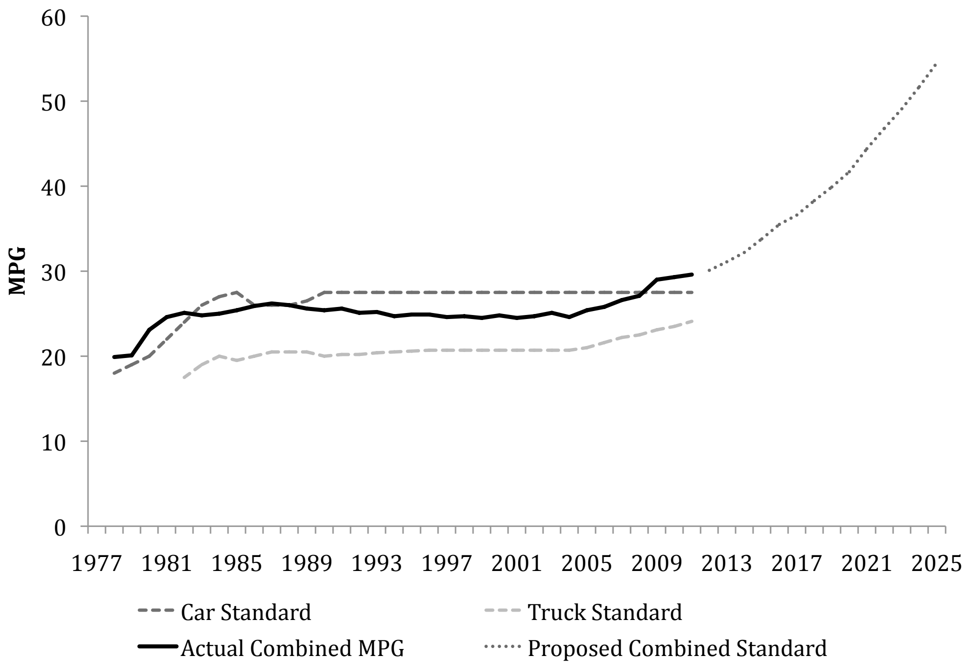
Fuel consumption generates a host of externalities, social ills whose costs are not born by the market actors making choices. We know that markets fail, that policy is warranted, when such externalities exist because market actors will not take these costs into account when deciding how much fuel to consume or how much fuel economy to demand. An energy paradox, which is sometimes called an *internality*, occurs when market actors fail to recognize the benefits that would accrue to *themselves*. The existence of a paradox can imply that, even in the absence of an externality, policy intervention is justified to improve market outcomes. When an externality exists, the presence of an internality may influence the size and shape of the ideal policy intervention.

Whether or not an energy paradox exists in the market for fuel economy is the subject of considerable debate. The goal of this paper is to discuss the importance of this debate to the evaluation of fuel economy regulations, to describe the state of our knowledge in the research community, and highlight research needs that could aid policy decisions going forward.

1 Proposed increase in fuel economy standards

Fuel economy standards first took effect in the United States in 1978, in the form of Corporate Average Fuel Economy (CAFE) standards. At that time, the National Highway Traffic Safety Administration (NHTSA), which ran the program, required that all automakers attain a fleet-

Figure 1: Past and Future Fuel Economy Standards



Data from NHTSA.

wide average of 18 miles per gallon (mpg) for passenger cars. The standard was ramped-up between 1978 and 1990, and it was made to encompass both passenger cars and light trucks, which were regulated according to a separate, less stringent standard. Between 1990 and 2012 the CAFE standard was completely flat, save for a small increase in the truck standard starting in 2005. Figure 1 shows the history of the standards for cars and trucks, as well as the actual fuel economy of both fleets combined.

The program is now administered in coordination between the Environmental Protection Agency (EPA), which is mandated to regulate greenhouse gas emissions, and NHTSA. At the behest of the Obama administration, in 2009 these agencies introduced the first major change to the program in two decades. They introduced tighter regulations that raise combined fuel economy to 35.5 mpg by 2016. These new rules are in effect for vehicles in the 2012 model year, which are now being sold in the market.

In November 2011, the agencies proposed a new set of targets for 2017 to 2025, which would end with fleet-wide fuel economy at an average of 54.5 mpg. Figure 1 shows that the

Table 1: Cost and Benefits of Fuel Economy Programs ($ Billions)

	CAFE 2012-2016	CAFE 2017-2025	Heavy Trucks 2014-2018
Program Costs	346	551	8.1
Fuel Savings Benefits	1,546	1,510	50
Program Benefits	312	275	7.3
Net Benefits	1,512	1,234	49
Net Benefits without Fuel Savings	-34	-276	-0.8

Values taken from EPA regulatory impact analyses. All values are total monetized welfare impacts over program life as modeled by the EPA. Values reflect a 3% discount rate and a 5% discount rate on the Social Cost of Carbon, whose value is $21 per ton.

proposed 2025 combined standard is nearly twice the actual fuel economy of vehicles today. These recent reforms represent a dramatic change in policy. Is this change a good idea?

As it turns out, the energy paradox is central to this question. New regulations must be shown to pass key cost benefit tests. For this purpose, the EPA produces a regulatory impact assessment. Table 1 replicates analysis from the EPA's regulatory impact assessment for three programs, the 2012-2016 standards, the proposed 2017-2025 standards, and new standards for medium and heavy-duty trucks, which are discussed below. The table shows the breakdown between increased costs, largely from changes to vehicle design and technology adoption, social benefits from reduced externalities, and *private* benefits from reduced fuel costs. As the table makes clear, in all cases, the private fuel costs dominate the social benefits from reduced externalities. They are the most important factor in the calculation.

If there is no energy paradox, then economic reasoning predicts that automakers will provide any fuel economy improvements that have net private benefits *in the absence of policy*. Under this reasoning, the private benefits from the program cannot reasonably be attributed to the policy, because the improvements would be made anyway. Alternatively, if there is no energy paradox and the market still fails to generate those fuel economy improvements, it implies that there are implementation costs that are being omitted by the EPA's analysis. In either case, the regulatory impact hinges on those benefits being counted in the policy's favor, which makes sense only if there is an energy paradox.

Importantly, the EPA and NHTSA make the assumption that *none* of the fuel economy benefits are recognized by consumers, so that all of the cost savings are attributed to the policy. This is an extreme version of the paradox. With these private benefits, the policy easily passes the cost-benefit test and is expected to provide major net benefits to the economy. Without them, the policies are a net welfare loss for baseline values of other parameters. Thus, it is essential for us to know more about the paradox in order to understand and judge these policies.

Fuel economy standards have traditionally applied only to personal, light-duty vehicles, but the EPA and NHTSA have also introduced a set of standards for medium and heavy-duty trucks that are used for commercial purposes. Table 1 shows that the net benefits of these standards also hinge on an assumption about an energy paradox. As discussed below, there are a variety of reasons to suspect that consumers may not fully understand the value of fuel economy and therefore be subject to an energy paradox, but it is much more difficult to understand why commercial businesses would be subject to those same biases. As such, the EPA's decision to assume that there is an undervaluation of fuel economy in the truck market warrants scrutiny.

2 Energy paradox research and its implications

Academic economists have studied the possibility of an energy efficiency paradox for several decades (see Hausman (1979) and Dubin and McFadden (1984) for early examples). In spite of this, the existence of a paradox has not been firmly established, nor has it been resoundingly rejected. Fortunately, recent work in the specific area of fuel economy has made great strides in methodology and data quality. Nevertheless, uncertainty on many key topics remains.

The most fundamental question is whether or not there is indeed an energy paradox in the market for fuel economy. But, even if that question is resolved, many other questions require answers. Supposing there is a paradox, what is its source? There are a number of distinct reasons why people might undervalue energy efficiency, including myopia, risk aversion, framing, information or other cognitive limitations or biases. The most significant methodological research advances have come from studying how consumer behavior reacts to changes in the price of gasoline, which changes the value of fuel economy in an arguably exogenous way (Allcott and Wozny 2009; Busse, Knittel and Zettelmeyer 2009; Sallee, West and Fan 2011; Li, Linn and Muehlegger 2011). Such research cannot, however, distinguish between different *sources* of undervaluation.

This is important because the optimal policy response will generally depend on *why* there is a paradox, not just whether there is one and how large it is. For example, if consumers undervalue fuel economy because they are simply confused, the efficient policy response may be to change fuel economy labels (perhaps switching from miles per gallon to gallons per mile (Larrick and Soll 2008)). Alternatively, bias that stems from myopia likely justifies policies that influence the price of a vehicle at its time of purchase (Allcott, Mullainathan and Taubinsky 2011; Heutel 2011).

Research is only now beginning to grapple with questions of how policy should be designed if there is an energy paradox. The traditional debate in this policy area is between a fuel tax and a regulatory standard. In a standard model, a fuel tax is significantly more efficient than a fuel economy standard because it does not induce an inefficient rebound effect, it affects new and used cars alike, and it creates equal marginal incentives for all automakers (see Anderson, Parry, Sallee and Fischer (2011a) for a review). If there is an energy paradox, then the fuel price increase that results from a gas tax might not generate the efficient response, because, for instance, consumers undervalue future savings and therefore react too little to a gasoline price hike.

Nevertheless, the existence of an energy paradox does not immediately overturn the traditional finding that gasoline taxes are more efficient than regulation. Fischer, Harrington and Parry (2007) demonstrate that undervaluation needs to be severe: if consumers recognize less than half of the value of fuel economy, then regulation may be preferred. Even mild undervaluation, however, can justify some other policy *in addition to* a gasoline tax. Research is now seeking to explore exactly how to design such policies, and in particular how to deal with heterogeneity across consumers. Fully efficient policies typically require additional policy instruments that treat different individuals differently (Allcott et al. 2011; Heutel 2011), something that does not fit naturally into regulation. These modeling efforts require that the source of the energy paradox be specified. Information and myopia, for example, will enter such a model differently and may generate different policy prescriptions.

All of this is simply to say that, even if we know that there is an energy paradox, there are still many questions that need to be answered before we can confidently guide policy. Unfortunately, the existence of the paradox is itself unsettled. Research has documented very clearly that people do value fuel economy. This is apparent from the numerous studies showing that the market share and prices of high fuel economy vehicles rise when the gasoline price rises (Linn and Klier Forthcoming; Klier and Linn 2010; Langer and Miller 2011; Li et al. 2011; Li, Timmins and von Haefen 2009; Busse et al. 2009; Allcott and Wozny 2009; Sallee et al. 2011). On the other hand, behavioral economics has clearly documented many cases where people make mistakes, even in large purchases. Moreover, laboratory evidence has shown that consumers are confused about the nonlinearity of fuel costs in mpg ratings (Larrick and Soll 2008), and survey evidence shows that consumers are poor at articulating the building blocks of a fuel economy valuation calculation (Turrentine and Kurani 2007).

The most methodologically sound research has used changes in gasoline prices to try to tease out tests of whether or not consumer valuation of fuel economy is large enough to rule out an energy paradox (Allcott and Wozny 2009; Busse et al. 2009; Sallee et al. 2011; Li et al. 2011). The research findings across these projects are somewhat disparate, but recent versions appear to be converging on a conclusion that while there may be some undervaluation, it is not severe. Consumers account for roughly three-quarters, or more, of the value of fuel economy. (See the Backgrounder: Energy Paradox, as well as Helfand and Wolverton (2009) and Greene (2010) for more extensive reviews.) If it holds up, such a finding would indicate that, even though there may be some bias, it is not large enough to justify regulation instead of fuel taxes. It would also be qualitatively important for regulatory impact assessments, as it would imply that large private fuel savings benefits may actually be a signal that the true costs of implementation are greater than expected.

3 Research needs and policy evaluation

Given the aggressive plans for future fuel economy standards, the stakes are high. If there is no energy paradox, then conventional estimates suggest that these regulations are inefficient, or perhaps even harmful. On the other hand, if there is a large energy paradox, then future fuel economy regulation could generate dramatic social benefits. Even then, however, a better understanding of the nature of the paradox could lead to more efficient policy design.

Conventional research topics

More research is still needed to resolve the fundamental question of whether or not there is a systemic undervaluation of energy efficiency in the market for fuel economy. One particular research need is the incorporation of heterogeneity in potential biases into existing models, as has been pointed out by Bento, Li and Roth (2010). Heterogeneity, if ignored, can cause researchers to erroneously find evidence of a paradox. Along with this, improved estimates of the size of any undervaluation on the part of consumers is essential for making policy choices, because, as discussed above, small biases and large ones justify different policy interventions.

The need to reach a research consensus on those issues is clear, but what seems to be receiving less attention is the question of the source of a paradox. Is it myopia, or risk, or information, or what? This matters too because of the influence it has on the design of policy. For example, it is plausible that car buyers are simply confused about the value of fuel economy and fail to make an accurate present discounted value calculation because of limited information. If so, then the right policy response may be to modify the information that consumers have. The EPA, attentive to such concerns, has redesigned the fuel economy labels that are placed on cars. Research determining whether or not these new labels, or some alternative, actually changes consumer purchases would be very valuable. It is challenging to find compelling tests for whether or not a paradox exists, and it is more difficult still to distinguish among possible sources of it. Research is needed to meet this challenge.

More research is also still needed to fully flesh out the policy implications of a paradox, as a function of its size and the heterogeneity of any bias across consumers. The work in Allcott et al. (2011) and Heutel (2011) represents a good start, but those papers highlight that nuance will be required in designing optimal policy responses. Grafting nuanced theoretical results onto the actual policy landscape will require more effort from the research community.

Firm-side market failures

The existing research in the car market has focused heavily on bias located in the consumer side of the market. Economic reasoning suggests that, if consumers demand fuel economy in privately efficient quantities, then the car market, where many firms are competing, will provide it. But, might there not be a market failure on the producer side? It is possible that consumers have long valued fuel economy more than firms believed was true, and that firms have, as a result, provided too little of it to the market. The automobile market is characterized by strong brand loyalty (Train and Winston 2007), which has been shown to even extend across generations of consumers (Anderson, Kellogg, Langer and Sallee 2011b). In such a market, firms can make mistakes and continue to survive for a long period.

It fits with standard narratives to suggest that the Big Three believed that consumers did not care about fuel economy, in particular during the 1990s. They may have been incorrect, and when gasoline prices rose they were not prepared to offer consumers what they wanted, suffering declines in market share as a result. If firms are making systemic mistakes, then a test of the energy paradox on the consumer side could show no evidence of consumer bias, even if a paradox exists. In this view, consumers make rational choices based on the products that arrive at market, but firms are offering the wrong products.

Another producer-side inefficiency could arise if firms are unable to appropriate all of the benefits from innovation. Intellectual property laws allow firms to patent new technologies and patents, but an important market barrier for a new technology might be consumer uncertainty. Suppose, for example, that consumers are unwilling to purchase a vehicle with a novel power train, like a hybrid, until a sufficient number of other consumers have purchased them and verified their quality. In such a setting, a manufacturer that pioneers a new technology will provide spillover benefits to its competitors by opening up the hybrid market. If such spillovers are large, firms may do too little innovation from a social point of view. Heutel and Muehlegger (2010) provide some initial empirical estimates that suggest such network effects do exist and do influence the diffusion of hybrids, but more work is needed.

If firms are making mistakes or if some aspects of innovation are not appropriable, the optimal policy response may be quite different from the one that best addressed consumer myopia or cognitive barriers. Understanding these potential causes of a paradox and their implications for policy is a key research need.

Endogenous preference formation

Microeconomic reasoning is fundamentally premised on the notion that consumers have pre-determined preferences. This extends to the automobile market, where the welfare analysis of various policy options assumes that consumer preferences for fuel economy, vehicle size, horsepower and other attributes are fixed and immutable. If preferences are malleable, then policy options may be radically different.

One version of malleability, for example, is that consumers can "get used" to different types of vehicles. If regulation forced the vehicle fleet to become more fuel efficient, at the expense of size and performance, then consumers might not like this today. But, they would get used to and learn to enjoy cars of a different configuration. If it is possible to lead people to get used to vehicles that produce fewer externalities, then it may be possible in the long-run to have a more efficient fleet without any sacrifice in individual welfare.

Anderson et al. (2011b) present evidence that the brand choices of parents influences the choices that their children subsequently make when they reach adulthood. Their work is suggestive of a long-run evolution in brand preferences across the generations. Might not the same be true of vehicle attributes, like size or horsepower or fuel economy? If so, it suggests that preferences are malleable. In such a context, research is needed to contemplate policies that are designed to not just influence the vehicle choice of consumers but also to *shape their preferences*. Policy design in such a world could be very different from what past research has analyzed.

Downsizing and footprint-based standards

The notion of endogenous preferences links with an aspect of the new fuel economy regulation that deserves special mention. Prior to recent reforms, the CAFE standard treated all cars and all trucks equally, regardless of their attributes. Going forward, vehicles will be treated differently depending on their footprint – the size of the vehicle's wheelbase. Larger vehicles will be subject to a less stringent standard. This gives automakers an incentive to expand the size of a vehicle in order to relax the standard, an incentive which they are likely to respond to, given their fine-tuned response to discontinuous tax incentives for fuel economy (Sallee and Slemrod 2010). The incentive to expand vehicle size is an important unintended consequence of the policy, but it is not directly related to the energy paradox.

The link between the energy paradox and footprint-based standards comes from the fact that footprint-based standards dramatically decrease the automaker's incentive to downsize a vehicle – make it smaller – in order to improve fuel economy. A vehicle engine of a certain efficiency is able to convert a gallon of gasoline into a specific amount of energy for moving a car. The heavier is the car, or the more powerful it is, the lower will be the fuel economy of the vehicle, for a given level of engine efficiency. Automakers therefore face an option of trading off vehicle size and performance against fuel economy, something which is shown eloquently in Knittel (2011). Making a vehicle lighter or less powerful is therefore a straightforward way to improve its fuel economy. The European car fleet is dramatically more fuel economic than the US fleet not because it utilizes better technologies, but because the vehicles are smaller and less powerful. Footprint-based standards, however, eliminate that avenue for improvement. Is this a good idea?

If consumers have endogenously formed preferences over vehicle attributes, it might be very detrimental to lock in the vehicle fleet at its current size composition. Footprint-based standards sharply limit the likelihood that automakers will respond to stringent standards by radically shifting the size of the fleet, which conceivably could have pushed consumers into a new equilibrium of appreciating smaller vehicles.

The rationale for preventing downsizing is that downsizing poses a safety risk. Smaller vehicles are not as safe to be in during a collision. (The *political* rationale for footprint-based standards is likely that it favors the domestic automakers, relative to a uniform standard that would put less pressure on Asian automakers who specialize in smaller vehicles.) The safety analysis used in the regulatory analysis, however, seems to ignore the fact that such a safety benefit is a private benefit that consumers enjoy and will be willing to pay for, but their increased size poses a negative, unpriced *externality* to others. New empirical work in Jacobsen (2011) and Anderson and Auffhammer (2011) suggest that the welfare impacts of these safety factors are considerable. How these safety concerns would interact with multiple equilibria from endogenous preferences would be an important area for exploration.

4 Conclusion

The current administration has proposed very aggressive new fuel economy standards that would double fuel economy from present levels by 2025. The regulators themselves suggest that this will generate a very large net benefit to society. The lion's share of these benefits, however, come in the form of private fuel savings to consumers. In the absence of an energy paradox, consumers would be willing to pay for such improvements even in the absence of policy, which would imply that they cannot reasonably be counted as assets on the regulation's ledger. The existence of a paradox is, therefore, pivotal to evaluating policies that are on the table.

Recent research has made great strides in testing for the existence of an energy paradox in fuel economy. Research has also begun to explore in much more detail how the exact nature and size of a paradox determines the optimal policy response. Despite this progress, many key questions remain unanswered. A great deal more research is needed to establish the nature and size of an energy paradox in fuel economy, to understand how the paradox impacts the design of policy, and to evaluate the policies that we have. Research in the directions discussed in this paper could therefore be very beneficial to policy-makers as they evaluate and modify these critical regulations in the future.

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