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A critique of Saunders' 'historical evidence for energy efficiency rebound in 30 us sectors'

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ABSTRACT

A recent article in *Technological Forecasting & Social Change* presents a calculation of historical rebound effects in thirty sectors of the United States economy over the period 1960–2005 (Saunders 2013). Here, we show that the empirical data set used to generate those findings—a prominent input–output data set developed by Jorgenson (2007)—is not appropriate for the use to which Saunders puts it. Saunders' model requires annual data on the price and quantity of energy consumed by each sector; however, the Jorgenson data are inferred from national prices, not prices observed at the sector level and disaggregated by geographic region. Furthermore, Jorgenson reports average prices, rather than marginal prices; yet the rebound effect is caused by changes in marginal price of energy services. We compare the differences between national prices and sector-specific prices across geographic regions in the United States, demonstrating that Saunders' use of national average energy prices is inappropriate for investigating the rebound effect.

1. Introduction

A recent article from Dr. Harry Saunders in *Technological Forecasting & Social Change* presents a calculation of historical direct rebound effects in thirty industrial sectors in the United States over the period 1960–2005 (Saunders, 2013). Here, we show that the empirical basis for those findings is suspect.

High-quality energy price data are essential to any study in this area because changes in the marginal price of energy services are the fundamental driver of rebound (Borenstein, 2015). Yet Saunders relies on price data that are inferred by calculation from national averages—not disaggregated by sector or geography—without acknowledging any shortcomings related to data quality. This approach raises two key conceptual issues. First, using national average prices introduces significant error into Saunders' results because actual energy prices vary widely by economic sector and geographic location. Second, average prices are not the same thing as marginal prices and cannot be used to calculate direct rebound effects. Either of these features would be sufficiently grave to undermine the basis of Saunders' findings; together, they provide ample reason to reject his conclusions.

While the broader concerns we raise about data quality are not specific to any particular research question in energy economics, this article focuses on a longstanding debate about the rebound effect and its implications for energy and climate policy. Briefly defined, the rebound effect refers to the countervailing behavioral response to an improvement in the energy efficiency of an energy-consuming system or device. In other words, the rebound effect refers to the induced increase in energy use, usually expressed as a percentage of the expected savings that "rebound" or are "taken back" from the savings calculated without accounting for behavioral responses to the efficiency improvement.

Different names for rebound effects describe specific causal mechanisms (Turner, 2013; Gillingham et al., 2014), though in many cases papers in the field do not employ consistent definitions. Borenstein (2015: Eq. 1) provides the most explicit treatment to date using a formal microeconomic framework; Azevedo (2014: Figures 2 and 3) expands on these definitions to include macroeconomic and other economy-wide impacts. For simplicity, we summarize each mechanism here, using the example of a residential consumer adopting a more energy-efficient lighting system.

The *direct rebound effect* refers to the increase in consumption of lighting due to two causal factors:

- First, there is the *direct substitution effect*. Because the new lighting system is more efficient, the marginal cost of consuming the corresponding energy service (lighting) falls. As a result, the consumer may choose to leave her lights on more often, buy brighter lights, or

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buy additional lights. This increases her energy consumption.
- Second, there is the *direct income effect*. Because lighting is now cheaper, the consumer need not spend as much money to satisfy her original demand for lighting. As a result, her purchasing power has increased, and therefore she can spend some of the money she saves on additional lighting services. Again, this increases the consumer's energy consumption.

The *indirect rebound effect* refers to changes in the consumption of other (non-lighting) goods and services. These changes arise from the same two causal factors:

- First, there is the *indirect income effect*. In addition to consuming more lighting services with her increased purchasing power as described above (the direct income effect), the consumer might also purchase more of other goods and services (the indirect income effect). This increases energy consumption, although the magnitude of the indirect income effect is highly dependent on consumer preferences. If the consumer favors energy intensive (or non-energy intensive) goods in her re-spending, these preferences will tilt the results towards more (or less) indirect rebound, respectively.
- Second, the direct substitution effect has a corresponding effect, the *indirect substitution effect* (which Borenstein calls the *compensated cross-price elasticity effect*). When energy efficiency lowers the marginal price of illumination, the consumer will consume more lighting services, as described above by the direct substitution effect. Holding the consumer's utility at the level it was before the energy efficiency improvement occurred—in microeconomic terms, accounting separately for changes in consumption due to her increased purchasing power, which are captured by the direct and indirect income effects—she must consume fewer non-lighting goods and services in order to consume more lighting. The indirect substitution effect captures this shift away from non-lighting goods and services. Note that unlike the other three mechanisms, this effect reduces energy consumption.

Furthermore, as Azevedo (2014) notes, there can also be nuanced effects related to accounting for the *embodied energy* any good or service. As a general matter, the energy it takes to manufacture energy-consuming equipment, such as an LED light fixture, should be included in rebound effect calculations (Borenstein, 2015). In order to calculate the net energy savings from a more efficient device, the embodied energy is often assumed to be amortized over its full working life. But if a consumer decides to abandon an inefficient lighting system in favor of a new technology, for example, and does so before the end of the inefficient lighting system's useful life, there may be complexities in accounting for the embodied energy of the old device.

Finally, some refer to an *economy-wide rebound effect*. In certain instances, this term is used to refer to the sum of the direct and indirect effects (Sorrell, 2007). In other applications the term is used to refer to additional types of rebound effects, as discussed by Azevedo (2014). This latter use is more common, but suffers from the lack of both a precise definition and a consistent causal mechanism for producing any additional rebound effects. As an example of one suggested mechanism, some have argued that energy efficiency improvements could induce broader technological change or alter the overall structure of the economy, as might an exogenous improvement in labor or capital factor productivity (Jenkins et al., 2011). Most studies that consider this possibility use theoretical production functions or computable generalized equilibrium (CGE) models, however, and not empirical analysis (Sorrell, 2007). As a result, these types of estimates are usually contingent on detailed assumptions embedded in model structures that may not accurately characterize real world market imperfections, let alone the complexities of individual and organizational behavior. In general, papers in this area have not yet identified the precise causal mechanisms involved in producing an economy-wide rebound effect, in contrast to the well-defined microeconomic effects described in Borenstein (2015) and Azevedo (2014).

The debate over the rebound effect can be traced to William Stanley Jevons' 1865 book, *The Coal Question*, but our focus here is on the contemporary debate about energy efficiency policy. Over the past few years, the rebound effect has enjoyed a noticeable increase in popular attention due to increasingly efficient promotion from groups such as the Breakthrough Institute (Jenkins et al., 2011; Nordhaus and Shellenberger, 2014), with which Saunders is affiliated, and at least one prominent journalist, David Owen, whose work appeared in *The New Yorker* and *The Wall Street Journal* (Owen, 2010, 2012). Owen has championed the notion of the "Prius Fallacy"—as he sees it, the misguided belief that switching to a more benign form of consumption is good for the environment. In Owen's view, this belief is misguided because the Prius owner drives more and also becomes richer due to the gasoline savings. As a result, Owen claims, she uses more energy than she did before buying an efficient car (Owen, 2013).

Scratch the surface of the Prius example, however, and one finds a less compelling story. Shakeb Afsah and Kendyl Salcito of CO_2 Scorecard analyzed the data on Prius drivers' behavior in California and found an average increase in vehicle miles traveled of 0.5%, resulting in much smaller impacts relative to the efficiency gains of the Prius over comparable non-hybrid vehicles. Similarly, when considering how a Prius owner might re-spend her fuel savings on other more energy intensive goods and services, Afsah and Salcito find that on average, just under 7% of the re-spending is allocated to new consumption of fossil fuels (comparable to total energy expenditures as a percentage of GDP in the U.S.). At least for this example, then, the evidence suggests the rebound effect is relatively small, counter to what Owen claims (Afsah and Salcito, 2012, based on Gillingham, 2011).

Direct rebound effects, which arise from the lower effective prices for energy services that result from energy efficiency improvements, are generally estimated to be less than 30% for end uses in the residential and transportation sectors in advanced economies; often, the estimates are much lower, though in isolated cases they can also be higher (Sorrell, 2007; Gillingham et al., 2013). In a recent report on energy efficiency, the IEA found that estimates of the direct rebound effects in developed economies range from a minimum of 0% to a high of 65%, with most estimates converging in the area of 10% to 30% (IEA, 2014: 39). No one estimate holds across all applications, however—the context is critically important. For example, direct rebound effects are likely to be zero where energy consumption is subject to the principal–agent problem[1] (Borenstein, 2015; IEA, 2007) or other market imperfections (Azevedo, 2014), although the indirect rebound effects remain relevant in these instances because the consumer will have more money to spend.

In general, indirect rebound effects due to re-spending the savings from lower energy bills likely reflect the average share of energy-related expenditures in the broader economy—for the U.S., between 6 and 8% (Gillingham et al., 2013). Including the pessimistic possibility that consumers preferentially re-spend their new income on energy-intensive goods and services, an input–output analysis found that the range expands to between 5 and 15% for efficiency improvements that benefit households in the U.S. (Thomas and Azevedo, 2013a,b).

As these findings suggest, there is general agreement among experts that the household and transportation sectors are unlikely to experience large rebound effects—at least not in wealthy countries. Nevertheless, some find reason for concern. Theoretical studies conducted using economic forecasting models show the potential for significant

[1] The principal-agent problem refers to the case when one party makes decisions on behalf of another, or when the decision-making authority is split between two parties with different interests. For example, in many situations a tenant will be responsible for operating appliances and paying utility bills, but the landlord chooses the type (and therefore the energy efficiency) of major household appliances.