Rebound Effects in Transportation

David L. Greene
Oak Ridge National Laboratory
June 21, 2011

I will confine my ruminations on the rebound effect to the transportation sector because I know it best. In the past twenty years there have been a number of solid econometric analyses of the direct rebound effect for light-duty vehicles. These strongly support a relatively small direct rebound effect. Studies published before 2000 generally found an elasticity of vehicle travel with respect to the fuel cost per mile of travel (Price/MPG) in the vicinity of -0.2. More recent studies indicate a decreasing direct rebound effect, closer to -0.1.

How sure are we? I find it comforting that these estimates are very consistent with energy's share of the monetary cost of owning and operating an automobile. To a first approximation, the elasticity of vehicle travel with respect to the cost of energy (in the long run – and I will return to this point) is equal to the product of the elasticity of travel with respect to its total monetary cost and energy's share of the total cost of travel. There is reasonable evidence that the elasticity of travel with respect to the monetary cost of travel is very approximately -1. This is certainly a rough and ready way to estimate the rebound effect but it should not be neglected. Econometric studies can sometimes produce conflicting results and it is useful to have a simple, concrete means of testing their plausibility.

And then there is the data. Those who are well acquainted with state, national and survey-based vehicle travel data will empathize with the following quotation.

> "The government are very keen on amassing statistics. They collect them, add them, raise them to the n^{th} power, take the cube root and prepare wonderful diagrams. But you must never forget that every one of these figures comes in the first instance from the *chowky dar* (village watchman in India), who puts down what he damn pleases."
>
> Josiah Stamp (1880-1941), president of the Royal Statistical Society 1930-32.

At all levels, there are serious problems with the data on vehicle travel in the United States. I don't believe these problems are so severe that we would miss the main effect. I don't see how the rebound estimates cited above could possibly be off by as much as a factor of two. I don't see how thousands of traffic counters across the country counting millions of vehicles each could mistake a 10% drop in vehicle travel for a 5% decrease. More likely, the quality of the data limits the number and precision of the relationships between VMT and other variables that can be estimated.

Is the rebound effect constant? Ideally, the direct rebound effect is due to the partial derivative of vehicle travel with respect to energy efficiency, all other things constant. But are other things constant? In particular, is the capital cost of the vehicle constant? This depends on whether the increase in energy efficiency is due to pure technological improvement (which occurs on a regular basis) or due to a change that forces a trade-off between energy efficiency and capital cost. If the latter, then the long-run cost of vehicle travel must increase due to the increased cost of the vehicle. Straightforward application of rational economic behavior would imply that short-run travel decisions depend on the variable cost of travel (where fuel and time costs predominate) and that long-run travel decisions depend on the capital cost and other fixed costs, as well. Is this, in fact, how consumers behave? There are reasons to believe it may not be, in particular because some of the capital depreciation of vehicles is a function of time rather than usage.

This potentially very important (and rather obvious) point is too frequently overlooked: energy efficiency improvements are not, in general, free. The point is especially salient when the stimulus to improve energy efficiency comes from regulatory standards or increased energy prices.[1] In those cases, as opposed to the case of pure technological advancement, there will be an increase in vehicle cost that offsets the energy savings substantially but probably not entirely, mitigating but likely not eliminating the salesmix effect.[2] My guess would be that this effect reduces the long-run rebound effect by as much as half. Whether or not this effect is reflected by estimates of the long-run rebound effect is not clear.

Finally, there are sound theoretical reasons to believe that the rebound effect is not constant but changes with the cost share of energy in travel costs and with the value of time spent traveling. Both issues were highlighted in the recent, seminal paper by Small and Van Dender (2007) which concluded that the rebound effect had declined over time. Most cost/benefit assessments (and most models, I think) assume a constant rebound effect, which is almost certainly incorrect and perhaps importantly so.

How important are indirect effects? Indirect rebound effects in transportation have been less studied. These include the possibility that increasing the energy efficiency of vehicles might lead to a shift in sales favoring less efficient vehicles. This is certainly possible but by no means a given, and the magnitude of the effect is almost certainly small, in any case. A reasonable assumption might be that in response to a fuel price increase or regulatory standard or pure technological change, the energy efficiency of all vehicles might improve by the same percentage. The result would be a larger expected present value dollar savings for the more energy intensive vehicles. The degree to which this would change the mix of vehicles sold would depend on their prices and price elasticities. *A priori*, it is not certain which way the effect would go (for increased or decreased energy efficiency). In any case, large changes in the mix of vehicles are required for even moderate changes in average energy efficiency. For example, consider two vehicle types, one with an energy intensity of 0.05 gallons per mile and the other 0.03, each with an initial 50% market share. The average energy intensity is (0.05)0.5 + (0.03)0.5 = 0.04. If the market share of the energy intensive vehicle increases by 60% and that of the less energy intensive decreases by 60%, then the average energy intensity becomes (0.05)0.8 + (0.03)0.2 = 0.046, a 15% increase.

By lowering the energy costs of travel, increased energy efficiency might also contribute to the spatial dispersion of people and the built environment, thereby increasing the demand for travel. Again, this effect is almost certainly real, and almost certainly very small. Whether it is picked up by econometric studies that estimate a long- and short-run rebound effect is not entirely clear.

[1] This raises the question of whether the market for vehicle energy efficiency is itself efficient, in the sense of equating the marginal cost of increased energy efficiency with its marginal expected present value. I will not address this here but have elsewhere (Greene, 2010; Greene, 2011). I consider it highly unlikely.

[2] This, like many other aspects of the rebound issue, depends on how the market for fuel economy actually functions, a subject that has received far too little scientific analysis.

Finally, an increase in energy efficiency can cause a reduction in the price of energy. This is especially likely in the world oil market where the market power of nationalized oil companies frequently holds the price of oil far above what would prevail in a competitive market. Of course, in the case of policies to increase transportation energy efficiency this is the principal goal, to undermine the market power of oil producing states and bring the price of oil closer to a competitive market level. While the main effect is an economic benefit to oil consumers there will be secondary effects that are undesireable, such as an increase in petroleum consumption in other sectors, possibly resulting in an increase in GHG emissions. This raises the question of the policy context in which the rebound effect should be evaluated. For example, it would matter a great deal in evaluating such a rebound effect whether there were also in place a cap-and-trade system for carbon emissions, for example.

"Premises matter, only premises matter, now what was your question?" [3] Very often the consequences of a rebound effect that are of interest are also external costs (e.g., traffic congestion, air pollution, GHG emissions, unaccounted for costs of traffic accidents). If energy efficiency improvements increase vehicle travel and local air quality goals are not met, will emission standards be tightened or will air pollution be allowed to worsen? In general, will countermeasures be taken to offset the increased external costs due to a rebound effect or not? These countermeasures are not, in general, free either, but the costs are likely to differ from the external damages in question.

This issue also extends to the motor fuel tax, the cornerstone of highway finance. If no adjustment is made, increased energy efficiency will reduce highway revenues. But history shows that motor fuel taxes have been raised (sporadically) to recoup revenue lost to inflation and fuel economy improvement. If one assumes that future motor fuel taxes will be raised in proportion to the increase in fuel economy, the rebound effect will be partially mitigated. What should the analyst assume?

What are the key remaining questions?

- How is the rebound effect influenced by energy's share of the cost of travel and by the value of travel time, and how should these relationships be incorporated in cost/benefit analyses?
- Are the effects of energy efficiency and energy price on vehicle use symmetric (equal in magnitude) or do consumers respond differently to energy efficiency improvements?
- Do increases in the acquisition cost of vehicles affect long-run travel decisions in the same way as increases in variable costs?
- Why do estimates derived from cross-sectional data often differ greatly from estimates based on time-series and time-series cross-sectional data?
- Is there really a lagged adjustment effect such that the long-run elasticity of travel with respect to energy costs is much greater than the short-run elasticity? What are the mechanisms?
- What are the rebound effects for air travel and heavy-duty highway vehicles?
- If the world transportation system attempts to transition from petroleum to low-carbon energy sources, what will happen to the price of petroleum and how will that affect the cost and feasibility of the transition?

---

[3] I attribute this quote to the late Barry D. McNutt, Senior Policy Analyst, U.S. Department of Energy.