DRAFT "Think Piece" for CEDM Workshop, June 27 and 28, 2011

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This "think piece" outlines recent rebound research (which will be summarized in a presentation), and offers thoughts on future directions for research and current gaps in the field.

Historical Rebound in US Productive Sectors

The great majority of energy use occurs in the productive sectors of countries' economies. Most of the energy we consume is "hidden" from us.

Globally, some two-thirds of energy consumption occurs in the productive part of the energy economy. Only about one-third is consumed directly by end-use consumers. The large majority of energy we all consume is embedded in the goods and services we all consume. While it is much easier to "see" (and relate our personal energy efficiency experiences to) the energy we consume directly in our households and for personal transportation, the future of global energy consumption, and the impact of efficiency gains, will be instead largely driven by what happens in this preponderant sector of the global energy economy.

In the US, this picture is only somewhat less dramatic. In 1987, about 58% of energy consumed was embedded energy. However, by 2002 this had climbed to 60%. It also grew in absolute terms: from something less than 50 Quads to just slightly under 60 Quads over this time period.[1]

Importantly, rebound dynamics are undoubtedly very different in these two parts of the energy economy, and are determined by very different drivers. Economically, on the end-use side of the economy, energy use is driven by dynamics relating to consumer welfare maximization; in the productive part of the economy, it is instead driven by profit maximization. These different decision dynamics by economic agents call for different analytic methods.

Accordingly, it becomes important to look explicitly at the productive side of the energy economy when examining rebound effects. This is a fairly challenging task. Significantly, these analytic challenges in fact apply to all energy use forecasting models, and it is troublesome to note that rebound effects are conspicuously absent in the vast bulk of the models used to support the work of the IPCC, the IEA, and the Stern Report analyses. The upshot of this is that, by failing to consider rebound (or, in the very few models that purport to consider it, by improperly considering rebound), these forecasts may be seriously misleading. That is, to the extent rebound is significant, we have less time than these forecasts tell us we have to devise solutions for climate change. The stakes are high when it comes to correctly accounting for rebound.

In a recent look at historical rebound in the US productive economy,[2] some of the key challenges were addressed. The results show rebound cumulated across 30 sectors to have been

[1] Results from an Input-Output analysis; these results will be shown in the presentation.
[2] Saunders H. Historical evidence for energy consumption rebound in 30 US sectors, and a toolkit for rebound analysts. (under review, submitted November 2010).

approximately 50%, considering so-called *direct* rebound effects only. But for purposes of this "think piece," the more important aspect of the study has to do with the nature of the analytic challenges, which apply more generally to rebound and energy use modeling.

To correctly forecast energy use, and rebound, in this decidedly preponderant part of the energy economy, an ideal analysis at minimum needs to do the following:

1. Explicitly account for factor substitution dynamics. It has been known since 1992 that factor substitution is a major determinant of rebound magnitudes.[3]
2. Assure that substitution elasticities (own- and cross-) are accounted for among *all* factors of production (i.e., not just between energy and "everything else").
3. Use *measured* elasticities. Assuming values for substitution elasticities is tantamount to assuming the answer.
4. Use *flexible* production/cost functions. Assuming a non-flexible form (CES is commonly assumed) is tantamount to assuming the answer.[4] Further, the parameters of these flexible forms need to be econometrically measured, not assumed.
5. Explicitly deal with capital turnover dynamics. The rate and nature of capital turnover is a significant driver of energy use, and rebound.
6. If "tiered" or "embedded" production/cost functions are used, provide justification for where energy "enters" such functions. It is known that choices about this make a big difference in energy forecasts.[5]
7. Account for technical efficiency gains for *all* factors of production, not just energy efficiency. It has been known since 1992 that technology gains for other factors are a major determinant of energy use.[6]
8. Use *measured* technology gains for all factors, or at least be explicit about their magnitudes, so analysts can accurately critique and compare forecasts.
9. Account for resulting changes in output prices and their effect on consumer demand for the energy embedded in the corresponding goods and services.
10. If discerning rebound is the goal, make sure the model can reliably depict zero rebound and 100% rebound cases as control cases.
11. Account for inter-sectoral movements of goods and services, to correctly account for the embedded energy. (This is related to so-called "indirect" or "economy-wide" effects.)
12. Adhere to general equilibrium principles.

The analysis cited above has numerous limitations, but does attempt to honor #s 1-10 in one way or another (and 12 in a somewhat hokey fashion). But more importantly for this CEDM discussion, that paper contains a long list of limitations intended to point the way to future

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[3] Saunders H., The Khazzoom-Brookes hypothesis and neoclassical growth. The Energy Journal 1992 13(4); 131-148.
[4] Saunders H. Fuel using (and conserving) production functions. . Energy Economics 2008; 30; 2184-2235.
[5] Karen Turner and her colleagues have done an elegant job of demonstrating this. Lecca P, Swales K, Turner K. An investigation of issues relating to where energy should enter the production function. Stirling Economics Discussion Papers, 2010-18. Available through: http://www.economics.stir.ac.uk/. "
[6] Saunders H. 1992, op.cit.

research aimed at overcoming these limitations. This list is recommended to the reader interested in advancing the field.

Rebound Mitigation and Policy

As will be shown in the presentation, an energy/carbon tax can be effectively used to offset rebound effects. Importantly, however, there are significant ancillary economic welfare impacts to such a policy. For instance, if such a tax had been used in the US to offset rebound in the productive sector in the period 1980-2000, analysis shows that economic output would have been about 5% lower at the end of this period than it was without the tax. Also, employment would have been about 5% lower, according to this analysis. This is a truly significant negative welfare effect. Furthermore, these numbers are weighted averages—some industries would have suffered far worse.

On seeing this analysis, Steve Sorrell pointed out to me that the UK has taken a different approach with its Climate Change Levy tax, or CCL, and that some analyses have projected positive welfare *gains* from the CCL.[7] The idea is to offset the energy/carbon tax with a reduction in employer payroll taxes. This, in principle, is "revenue neutral" to the UK government and also reduces the burden on firms.

When the above analysis is re-run with a payroll tax offset, it shows that welfare in the US productive part of the economy indeed would have shown a slightly positive gain. However, there are some serious cautions:

First, for this to have worked in the US, the payroll tax offset would have needed to be large enough (6.4%) to almost entirely offset employer payroll taxes (7.6%). Second, this scheme would not have resulted in a *decline* in energy use, but rather would have roughly stabilized it at 1980 levels. Third, it would have produced winners *and* losers among firms, which could have had problematic compounding effects inter-sectorally (inter-sectoral effects were not measured in this analysis). And while the analysis does show welfare losses could be minimized by tailoring the tax differently to different industries, it would be hellishly difficult to implement such a scheme fairly, effectively, and with minimum economic damage.

Finally, and most importantly, governments would need to be *extremely disciplined*, especially in this time of major budget shortfalls, to continue using all tax revenues to offset payroll taxes. In the case of the UK, for example, the government eventually reneged on the payroll tax offset to the CCL. Such tax revenues are far too tempting to governments…

Future Research Needs

In addition to the requirements suggested above, a broader picture of gaps in rebound research might include the following:

[7] Terry Barker, using the MDM model, according to Steve Sorrell.

1. Better understanding of rebound dynamics in developing countries.
2. Incorporation of Input-Output analysis coupled with consumer expenditure surveys in energy use forecasting to better understand economy-wide rebound effects.[8]
3. Better modeling of end-use consumer demand, both for direct end-use energy consumption and for consumption of goods and services (and their corresponding embedded energy).
4. Overcoming data limitations:
    a. Data for developing countries, which will drive the bulk of future energy growth, appear much too limited in some cases to undertake high quality analysis.
    b. Data for I-O analysis are currently limited by the fact that countries do not in general collect data on the use of imported inputs by industry category (e.g., the US). These data are key to better distinguishing embedded energy use.
    c. Ideally, I-O data disaggregated below the country level would be available for energy analysis. Currently in the US, for example, it is extremely difficult to "tear apart" regional differences in production, prices, and use of inputs.
5. Highly technical issue: Advances are needed to practically apply the most general of the flexible production/cost functions, such as the Gallant (Fourier) function. The Translog function, while so far the best candidate given its data needs and data availability, is not entirely general.
6. Account must be taken of "frontier" rebound effects, that is, the possibility that energy efficiency gains can enable, or at least partly enable, the advent of new applications, products or even whole new industries that use energy. The analysis of Tsao et al.[9] showed that new uses for lighting have almost precisely offset their energy efficiency gains for 300 years, across 6 continents and across 5 technologies.
7. A better understanding is needed of how changes in energy demand due to efficiency gains affect global energy prices. Given the presence of OPEC, which for all practical purposes sets energy prices globally, it is improper for energy models to make what would otherwise be a standard assumption of perfectly competitive energy supply, as may be appropriate for other inputs. If measuring rebound is the goal, such dynamics distort both zero rebound and 100% rebound control cases in complex ways.
8. Policy measures to offset or mitigate rebound (or, more generally, to reduce energy use) must better account for resulting economic welfare losses. To form the basis for an honest discussion and to provide policy makers, and the public, sound and reliable advice, welfare effects need to be front and center in models and forecasts. This is currently a major shortcoming in many analyses.
9. Given the climate change implications, there is urgency to this research area.

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[8] Angela Druckman and Steve Sorrell are making advances here. (See Druckman A, Chitnis M, Sorrell S, Jackson T. Missing carbon reductions? Exploring rebound and backfire effects in UK households. Energy Policy 2011; 39; 3572-3581.)

[9] Tsao J, Saunders H, Creighton J, Coltrin M, Simmons J. Solid-state lighting: an energy economics perspective. Journal of Physics D 2010; 43(35); 1-17.