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A Growing Concern

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Energy rebound due to re-spending: a growing concern

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Abstract

Energy conservation is widely accepted as an important strategy to combat climate change. It can, nevertheless, stimulate new energy uses that partly offset the original savings. This is known as rebound. One particular rebound mechanism is re-spending of money savings associated with energy savings on energy intensive goods or services. We calculate the average magnitude of this "re-spending rebound" for different fuels and countries. We find that emerging economies, neglected in past studies, typically have substantially larger rebounds than OECD countries. The effect is generally stronger for gasoline than for natural gas and electricity. Paradoxically, strengthening financial incentives to conserve energy tends to increase rebound. This is expected to gain importance with climate regulation and peak oil. We discuss the policy implications of our findings.

JEL: Code: D12, D14, Q41, Q43, Q48

Keywords: rebound effect, re-spending, emerging economies

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1. Introduction

Energy conservation is crucial for reducing our dependence on fossil fuels and combating climate change. How much of initial energy savings are lost through various rebound effects has been debated for decades (Sorrel, 2009; van den Bergh, 2011). In the case of low- or no-cost energy conservation, rebound due to re-spending is particularly important: money saved along with energy is spent on goods and services or put in a bank account allowing for expenditures through loans to others. Either way, energy consumption is stimulated. We propose a simple model to derive the average value of re-spending rebound at a country level.

2. A macro-level model of re-spending rebound

Imagine costless energy conservation like driving fewer kilometers by car, turning down the thermostat and switching off lights. Retail energy prices (P_E) determine how much money is saved when conserving energy (E_{cons}). The average energy intensity of goods and services on which money is re-spent is approximated by the energy intensity of the economy (i_{econ}), defined as primary energy use per unit GDP. Hence, the average re-spending rebound (RR), expressed as a proportion of the original energy saving, equals $RR = (P_E \cdot E_{cons}) \cdot i_{econ} / E_{cons} = P_E \cdot i_{econ}$. Note that P_E [$/Joule] is the inverse of the energy intensity of energy purchases (i_{ener} [Joule/$]), so $RR = i_{econ}/i_{ener}$. Using this model (data and methods in the Appendix), Fig. 1 shows average rebounds due to re-spending money saved on gasoline, gas bills and electricity bills in selected countries for 2009.

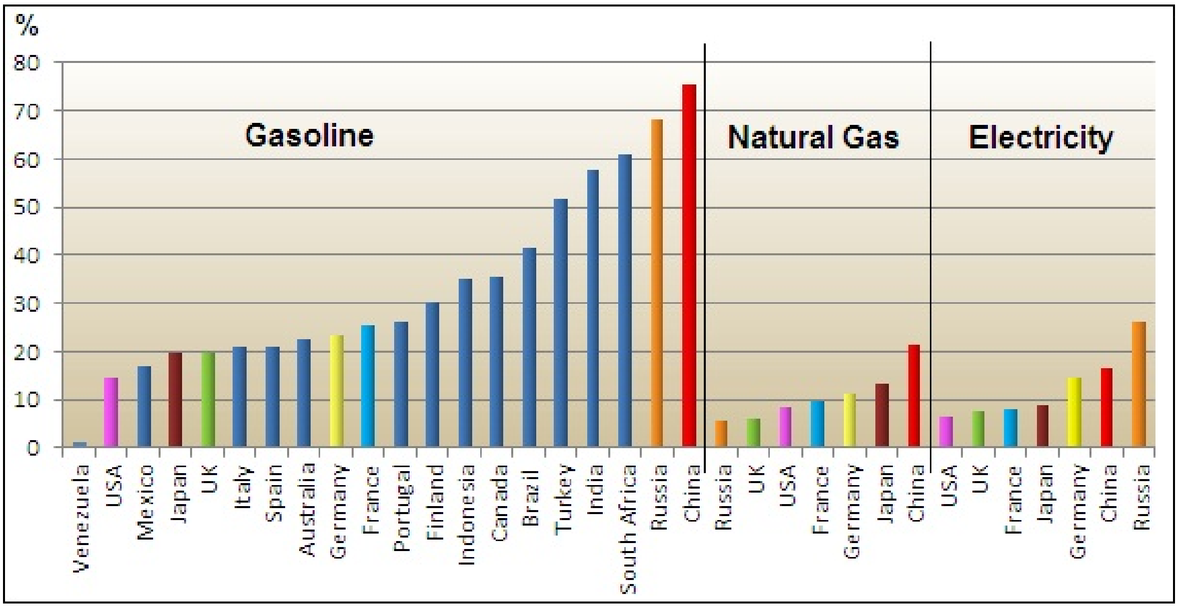

Fig. 1. Re-spending rebound for three energy carriers, national averages (2009).

Two remarks about the main assumptions are in order. First, although i_{econ} is a rough approximation of the national average energy intensity of marginal consumption, there is no straightforward approach to improve upon this. For countries with large populations it is impossible to collect sufficient information to accurately assess this marginal consumption given the heterogeneity of consumers in terms of income, awareness of energy or money savings and spending patterns. At the aggregate level, the most relevant information is probably the historical relationship between per capita GDP and per capita energy consumption. This shows that for low income levels energy consumption increases approximately linearly with income and then levels off (Fig. A1). It is tempting to conclude that this pattern is the result of a lower energy intensity of consumption at high income levels. However, it is also affected by supply-side factors, notably energy efficiency improvements following from sectoral and technological changes. The relative importance of these factors is unknown (Webster et al., 2008). Assuming a linear relationship between income and energy consumption at the individual level probably inflates values for countries where GDP is high.

Furthermore, if the energy intensity of imports is significantly higher (lower) than that of exports, the rebound will be larger (smaller). This may for some countries be a third cause of the leveling-off pattern of the curves in Fig. A1. Since countries in Fig. 1 have low import/export-to-GDP ratios (< 30%), the trade-related bias of rebound calculations is limited (Appendix).

3. Insights

Three insights follow. First, there are large differences between countries while their order is not trivial. The frequent assumption that i_{ener} is an order of magnitude larger than i_{econ}, so $RR \approx 0.1$ (Schipper and Grubb, 2000; Sorrel, 2009), is only supported for the USA and to a lesser extent for the EU. In various other countries rebound is higher, the extreme case being China with an average rebound of 75.6% for gasoline. More generally, in emerging economies the re-spending rebound will often be high as both energy intensity and energy prices are high in terms of purchasing power (Appendix). This is illustrated by BRICS countries where, due to higher fuel taxes, even nominal gasoline prices are above those in the USA. Furthermore, assuming a leveling-off pattern instead of a linear relationship between energy consumption and income would increase the estimated difference of re-spending rebound between low and high income countries. As emerging economies play an increasingly important role in the global economy, the re-spending rebound is a growing concern.

Second, this rebound is very different between gasoline on the one hand and natural gas and electricity on the other. Crude oil has an integrated world market, which makes it relatively expensive for countries with a low general price level. Less globally integrated markets for natural gas and coal allow their prices to be generally lower in poorer countries. Furthermore, natural gas and electricity are often taxed at lower rates than gasoline. Hence, associated re-spending rebounds tend to be lower. For natural gas, large subsidies amplify this difference in Russia while high taxes – and a high general price level – reduce it in Japan.

Third, a paradox can be observed: if energy prices are high, energy conservation is stimulated but rebound is high, while for low energy prices rebound is weak but so is the incentive effect. In both cases the effectiveness of conservation will be reduced. The combined impact of climate policy and peak oil on future energy prices will strengthen incentives for conservation. However, as our results show, if energy intensity is not quickly reduced, re-spending rebound is likely to rise. Tackling this issue is especially urgent in countries where energy intensity is high and energy pricing is under reform.

4. Policy suggestions

In light of these findings, what policies can be suggested to reduce total CO_2-intensive energy use? The mentioned paradox means that a trade-off between initial energy savings and re-spending rebound is often inevitable. If energy saving is stimulated by some form of carbon pricing, which seems an inevitable part of an effective climate/energy policy package (Nordhaus, 2007; Sinn, 2008), then it should apply not only to consumers but also to producers. Only then can we avoid that energy savings by consumers generate rebound in the production sector. Currently, many energy-intensive industries are exempted from energy taxation through deductions, special tariffs and low VAT rates (van Beers and van den Bergh, 2009), which contributes to the re-spending rebound. The removal of these implicit subsidies can reduce the rebound. Any negative distributional effects of comprehensive carbon pricing on low income households can be alleviated through block pricing or tax revenue recycling (Fullerton, 2009).

In addition, efforts to stimulate low-cost energy efficiency measures can be more effective if they concentrate on energy carriers associated with lower rebounds. An important example is the building sector that offers significant opportunities to save gas and electricity. A combination of appliance standards, smart technology and behavioral incentives might avoid high re-spending rebounds in this context.

Finally, low-cost or no-cost energy saving projects might target sectors that can be expected to re-spend their savings on less energy intensive products and services. If money savings associated with energy conservation in the public sector are used for deficit or debt reduction, re-spending may even be negligible. This suggests that in the current political climate where deficit reduction is predominant, promoting low-cost energy-saving measures in the public sector can help to simultaneously alleviate environmental and economic crises, namely by avoiding a high rebound.

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Steven Sorrell and Adriaan Perrels provided useful comments. Financial support was provided by the EU through the WWWforEurope project (www.foreurope.eu).

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Appendix: Data, methods, and supporting information

Data sources

Energy intensities (2009):

Energy Information Administration, International Energy Statistics, Energy Intensity - Total Primary Energy Consumption per Dollar of GDP (Btu per Year 2005 US Dollars, Market Exchange Rates), http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=44&pid=46&aid=2&cid=groups,&syid=2005&eyid=2009&unit=BTUPUSDM

Natural gas prices:

Energy Information Administration, International Energy Statistics, Natural gas prices for households http://www.eia.gov/countries/prices/natgasprice_households.cfm (USA: 2008, Japan: 2007).

Eurostat, Half-yearly electricity and gas prices, first half of year, 2009-2011, http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Half-yearly_electricity_and_gas_prices,_first_half_of_year,_2009-2011_(EUR_per_kWh).png&filetimestamp=20120514103022 (Germany, UK, France: 2009).

J. Henderson, Domestic gas prices in Russia – Towards export netback? Oxford Institute for Energy Studies, 2011. http://www.oxfordenergy.org/wpcms/wp-content/uploads/2011/11/NG_57.pdf, p. 36. A derived average value of 2 Russian Ruble per cubic meter was used (Russia: 2009).

N. Higashi, Natural Gas in China (2009), International Energy Agency Working Paper Series, 2009. http://www.iea.org/papers/2009/nat_gas_china.pdf, p. 27. A derived average value of 9.5 $/MBtu was used (China: 2008).

Electricity prices:

Energy Information Administration: Electric Power Monthly http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_3 (USA: 2009).

Eurostat: Half-yearly electricity and gas prices, first half of year, 2009-2011, http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Half-yearly_electricity_and_gas_prices,_first_half_of_year,_2009-2011_(EUR_per_kWh).png&filetimestamp=20120514103022 (UK, Germany, France: 2009).

International Energy Agency: Key World Energy Statistics 2010, http://www.iea.org/textbase/nppdf/free/2010/key_stats_2010.pdf, p. 43. (Japan: 2009).

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Historical prices in R. Abdurafikov, Russian electricity market – Current state and perspectives, VTT Working Papers 121 (Julkaisija, Utgivare, 2009). http://www.vtt.fi/publications/index.jsp and current prices at http://www.mosenergosbyt.ru/portal/page/portal/site/personal/tarif/msk (accessed June 15, 2012). A derived average value of 0.09 $/kWh was used (Russia: 2009).

Gasoline prices (2010):

Deutsche Gesellschaft für Internationale Zusammenarbeit GIZ, International Fuel Prices 2010/2011, (German International Cooperation, Eschborn, 2011). http://www.gtz.de/de/dokumente/giz2011-international-fuel-prices-2010-2011-data-preview.pdf (mid-November 2010, at a crude oil price of US$ 81/barrel Brent)

Export-import ratios (2009):

World Bank statistics. http://data.worldbank.org/indicator/NE.EXP.GNFS.ZS and http://data.worldbank.org/indicator/NE.IMP.GNFS.ZS

Conversion factors

Energy content of 1 m^3 natural gas: 37 MJ.

Energy content of 1 liter gasoline: 35 MJ.

As the energy content of re-spending is calculated with primary energy intensities, primary energy factors of electricity are needed to convert energy saving. We applied commonly used factors: USA: 3.3, Europe and Russia: 2.7, Japan: 3, and China: 3.5.

Exchange rates in 2010: 1$ = 28 Russian ruble = 0.706 € = 6.36 Chinese yen (other price data available in US$).

US currency deflator: CoinNews Media Group, US Inflation Calculator http://www.usinflationcalculator.com

All monetary values converted to 2009.

A comment on trade data

Portugal, Finland and Germany have slightly higher ratios but trade mostly with similar EU member states. Trade between countries with very distinct energy intensities may narrow the distribution shown in Fig. 1.

Methods

Calculations were done using nominal energy intensity and price values. As a dollar of GDP represents more physical products or services in countries where general price levels are relatively low, these countries had relatively high energy intensities. For example, China's energy intensity was 3.4 times that of the US. Variables can also be expressed in purchasing power parities. Then the difference between general price levels is not reflected in the energy intensities but in the energy prices. For example, China's intensity is then only 1.47 times that of the US, while Chinese nominal energy prices are multiplied by a factor 2.31 ($3.4 \simeq 2.31 \cdot 1.47$). The results for RR are the same for both calculation methods.

Figure A1

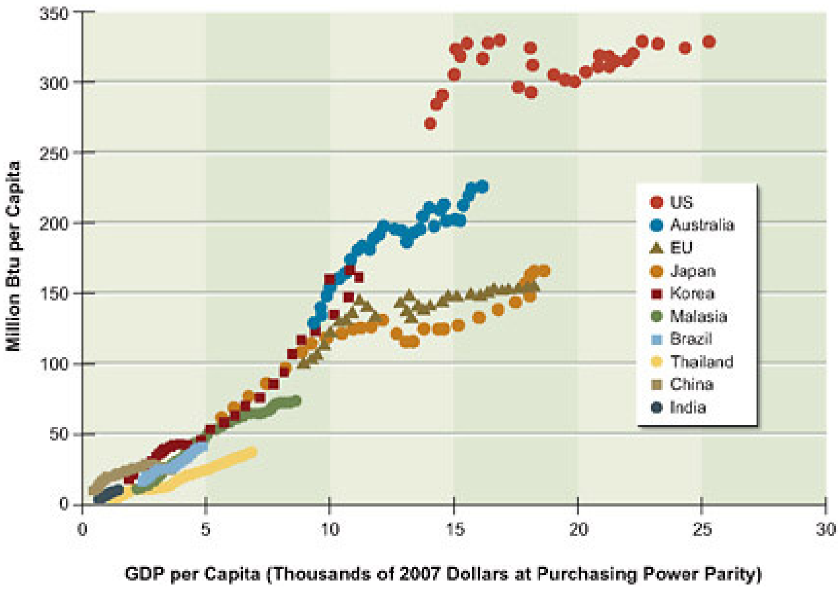

Fig. A1. The relationship between per capita GDP and per capita energy consumption for various countries (CAEF, 2009).