Economic Analysis of the *Rebound Effect*: A principal challenge for energy conservation policies

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Introduction

- Many countries rely on improvements in “technical” efficiency to reach their energy reduction targets.
  - Switzerland’s ambition: 43% reduction by 2035
- Understanding rebound effects is important:
  - Depending on their magnitude, the effectiveness of policies favoring efficiency may be questioned.
- In formulating these policies rebound effects have been systematically downplayed.

Why? ...

- Many technocrats and politicians are too fond of technical energy-efficiency to think twice.
  - They consider it as:
    - The “5th fuel” (or the 1st fuel: the least expensive)
    - Better than a free lunch: “a lunch you’re paid to eat”
    - “The most evenly distributed energy resource” over the globe.
    - The least controversial measure, when it comes to political and international debate about climate change.

More importantly,

- Long-run rebound effects are generally difficult to estimate.
- This has left many openings for speculation.

Empirical findings: debate continues ...

International Risk Governance Council (IRGC):

- A recent report (literature review) confirms that the rebound effect is about 30%, but it could reach levels higher than 100% (*backfire*) for developing and transition countries.

This presentation's objective

- To provide an analytical framework for the identification of rebound effects
- To present some empirical findings especially from a long-term perspective

Rebound Effect

The Coal Question **(1865):**

Jevons observed that an improvement in energy efficiency reduces the costs of energy hence, increasing (rather than reducing) its use.

Today the effect is known as ***Jevons paradox***, or ***rebound effect***.

William Stanley Jevons (1835 –1882)

A basic model: *I = PAT*

- ***P*** is quite easy to model but much more difficult to handle!
- ***T*** and ***A*** are usually represented by resource intensity and disposable income.
- Main criticism: ***A*** and ***T*** have a complex inter-relationship that is not captured.
- An extension at the individual level:

$$I = \sum_k A^{(k)} T^{(k)}$$

Overall energy use: $I = \sum_k A^{(k)} T^{(k)}$

- $A^{(k)}$ is the spending in sector *k*.
- $T^{(k)}$ is the energy intensity of sector *k*: the result of the individual's choice among available technologies.
- vary across sectors of economic activities (or consumption categories).
- An individual's impact (total energy use) depends on their income, consumption pattern and technology choice.

Energy intensity in various consumption categories

Category	Energy intensity in MJ per Euro
Air travel	55.39
Heating	33.37
Car usage	13.36
Travel by public transport	8.78
Purchase of food and beverages	5.40

Rebound

- Both choices ($A^{(k)}$ and $T^{(k)}$) are influenced by external factors (prices, standards, institutions) as well as internal drivers (preferences, values, social norms).
- Adopting a better technology $T^{(k)}$ decreases energy but also:
  - Creates more disposable income and therefore, affects how income is distributed across sectors, $A^{(k)}$.
  - In general this effect counters the original energy reduction, hence, **rebound effect**.

Example:
10% decrease in your car's fuel intensity

- Direct rebound:
  - If you have a fixed budget for gasoline you will not change your fuel consumption: you will use your car 10% more often (direct rebound: 100%)
  - If you have a fixed usage (driving km), then your fuel consumption will decrease by 10% (direct rebound: 0)
- Indirect rebound:
  - If direct rebound <100%: you will have some savings that you will spend it: additional energy.
  - If the new spending is more energy intensive, sum of direct and indirect could be higher than 100% (backfire).

Example (cont'd): 10% decrease in fuel intensity

- Now suppose your investment does not create any savings (no more disposable income).
- In this case, the indirect rebound is probably negligible. But the direct rebound is still there:
  - Your variable cost of using your car is now, 10% lower (relatively lower than the cost of public transport).
  - You probably use your car more often (and public transport less often) to amortize your investment in a new car.

Economy-wide indirect effects

- If individual rebound < 100%, then we'll have a decrease in aggregate energy demand, hence a lower price for energy.
- Lower price creates an additional demand in the economy: economy-wide rebound.

An additional long-term effect (generally neglected in the empirical literature)

- Potential indirect rebound due to:
  - Improvements in non-efficiency-related attributes
  - Better and cheaper access to specific products to previous non-users

Technological innovations …

- Have often brought about more consumption opportunities through:
  - New products (electric light, computer, internet)
  - Better comfort and flexibility of usage
  - Higher speed (energy consumption increases in proportion with s^2 in computers and s^3 in transport)
- Not much can be done in separating energy efficiency improvement from other aspects of technological progress.

Examples

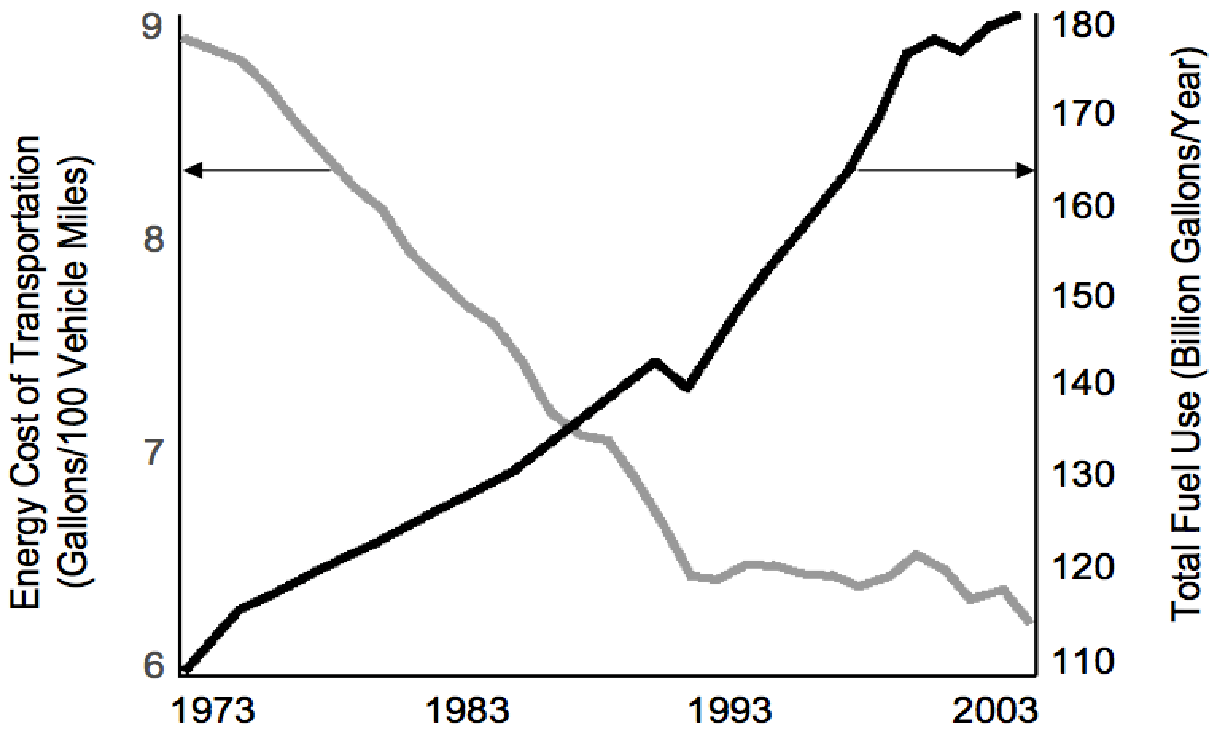
- Due to higher fuel efficiency in cars:
  - Maintaining heavy SUVs is less expensive
  - Cars are more affordable to previous non-users
  - Acceleration/speed capabilities are possible at lower cost
- Due to lower U value in windows and better efficiency of heating systems :
  - The use of large windows has become more common
  - Larger apartments and higher ceilings are relatively less expensive in terms of energy use

Estimate the overall rebound effect from 20th century's developments

- Approximately efficiency has increased from 4 to 10 times (4 for industrial use, 10 for thermal plants)
- Energy consumption in terms of useful energy services has increased about 25 times
- Income per capita has increased by a factor of 4
- This implies a rebound effect of about 60% to 150% (after adjusting for GDP per capita)

A medium-term example: Transport in the US: more efficiency, more consumption

Figure 7.1 Energy Cost of Transportation versus Total U.S. Consumption*



*All modes

Source: Department of Transportation, *National Transportation Statistics 2003*; EIA, *Annual Energy Review 2003*.

Transport (US, 1973-2003)

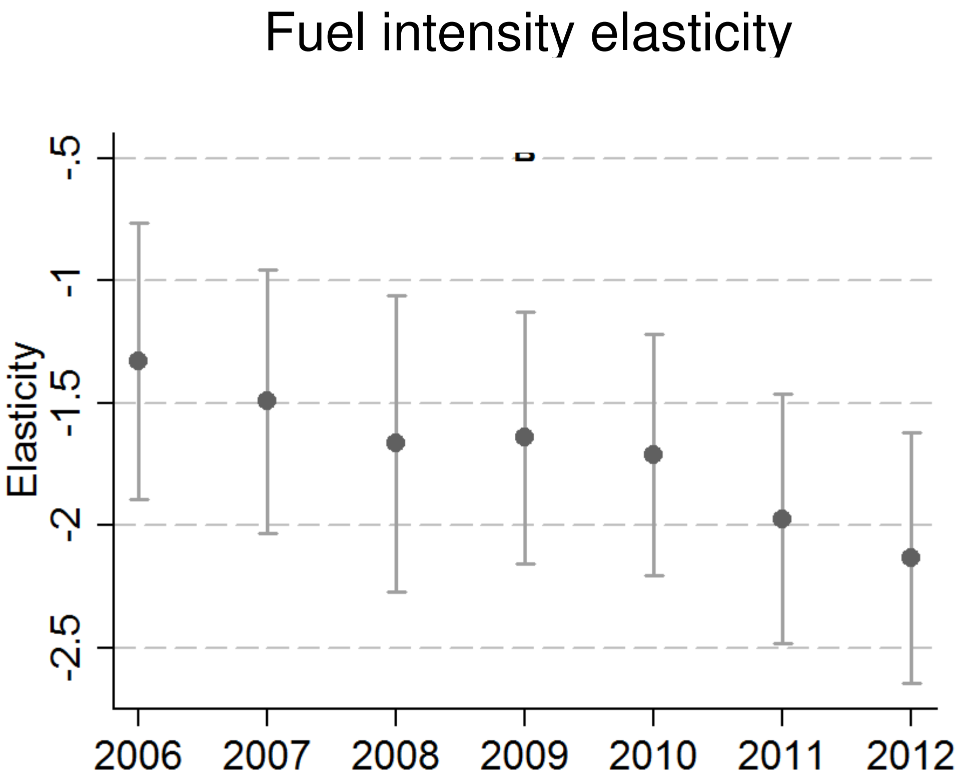
- About 50% increase in efficiency with a similar increase in total consumption.
- This corresponds approximately to a direct rebound of:
  - 100% (without adjustment): no effect of efficiency improvement
  - 73% (after adjusting for population)
  - 40% (after adjusting for GDP)

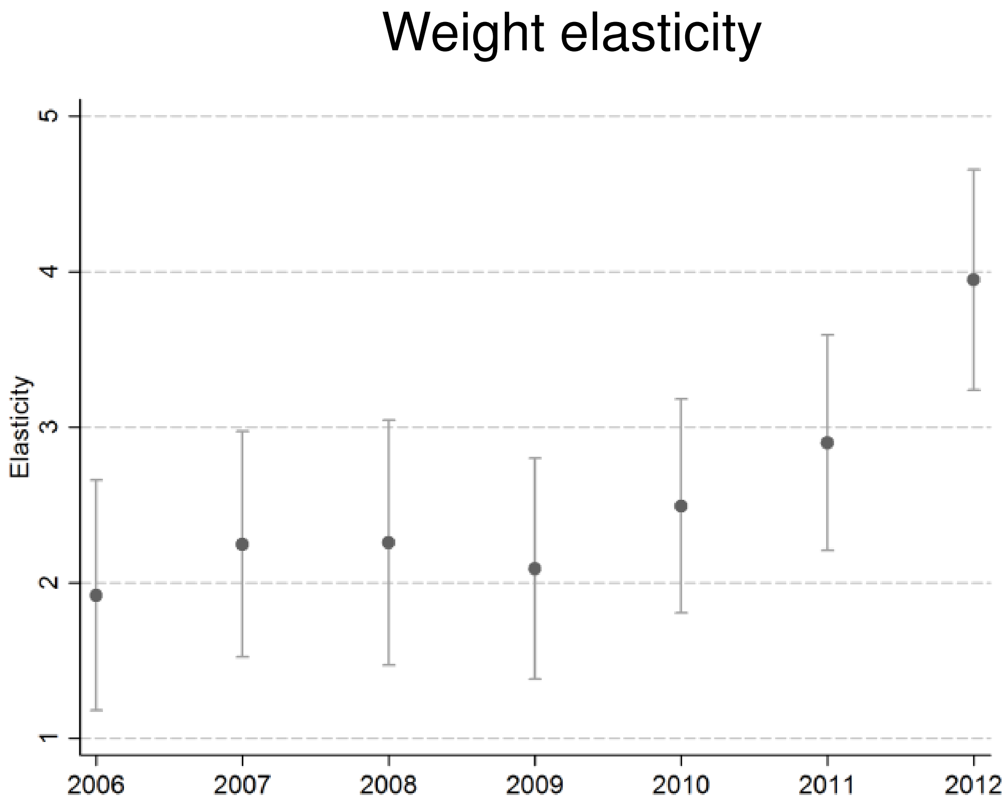
Rebound in private vehicles: an example from Switzerland

- Data: Microcensus on Mobility and Travel, 2010
- More than 30,000 respondents merged with car characteristics (fuel intensity)
- Model with simultaneous equations
- Preliminary results:
  - 66% direct rebound
  - Income elasticity of about 1 for fuel consumption (suggesting fixed budget hypothesis)

Primary results from new car market data in Switzerland (2006-2012)

- Market shares of new cars show an increasing trend in favor of fuel-efficient cars.
- At the same time, heavy cars are increasingly favored by customers.
- The magnitudes are more or less similar in terms of energy use.
- This implies approximately 100% rebound in the Swiss car market.


Fuel intensity elasticity
Elasticity
-.5
-1
-1.5
-2
-2.5
2006
2007
2008
2009
2010
2011
2012


Weight elasticity
Elasticity
5
4
3
2
1
2006
2007
2008
2009
2010
2011
2012

Conclusion

- Efficiency improvement could be plagued by various rebound effects:
  - Little is known about the long-term rebound effects in future, but relying on efficiency is not a safe bet.
- If we receive guidance from historical trends, the best intuition leads us to conclude:
  - An urgent need for change in consumption behaviors and sufficiency strategies.