Bounding the Rebound Effect: Key Conceptual Issues and a Framework for Estimation

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Outline

- Key Conceptual Issues
- A Framework for Estimating the Rebound
- Some Implications for Policy

Conceptual Issues: Basic Economic Theory

- Neoclassical economics:
  - Increased efficiency lowers price of energy services
  - Leads to substitution and income effects (Slutsky equation), increasing energy service consumption
  - Absent unpriced externalities, rebound is welfare enhancing. We should be happy if there is rebound
- With market failures and non-optimizing behavior:
  - Principal-agent, imperfect information, transaction costs, unobserved or imperfectly observed prices, externalities
  - Rebound may or may not be welfare enhancing
  - Intervention need not lead to rebound

Conceptual Issues: Two Types of Rebound

- **Technological Change and Neoclassical Production Functions:**
  - **If energy efficiency increases, price of an energy service decreases. Slutsky equation basis for analysis of rebound**
    - **Lower price implies substitution**
    - **Lower price implies income effects**
      - **Income effect bounded by expenditure shares multiplied by income elasticity**

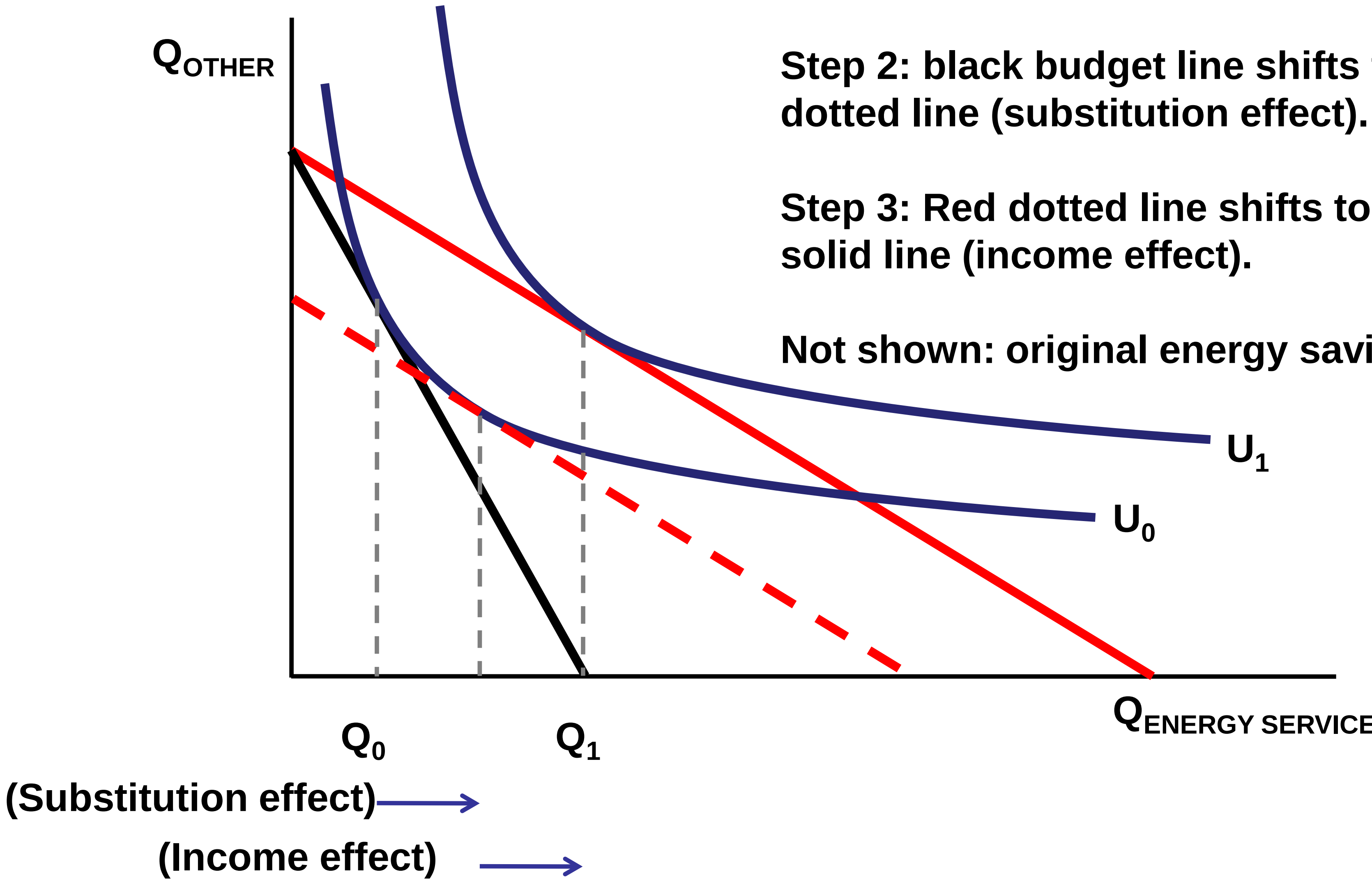
Slutsky equation: neoclassical change

Step 1: increased energy efficiency lowers the price of an energy service.

Step 2: black budget line shifts to red dotted line (substitution effect).

Step 3: Red dotted line shifts to red solid line (income effect).

Not shown: original energy savings.



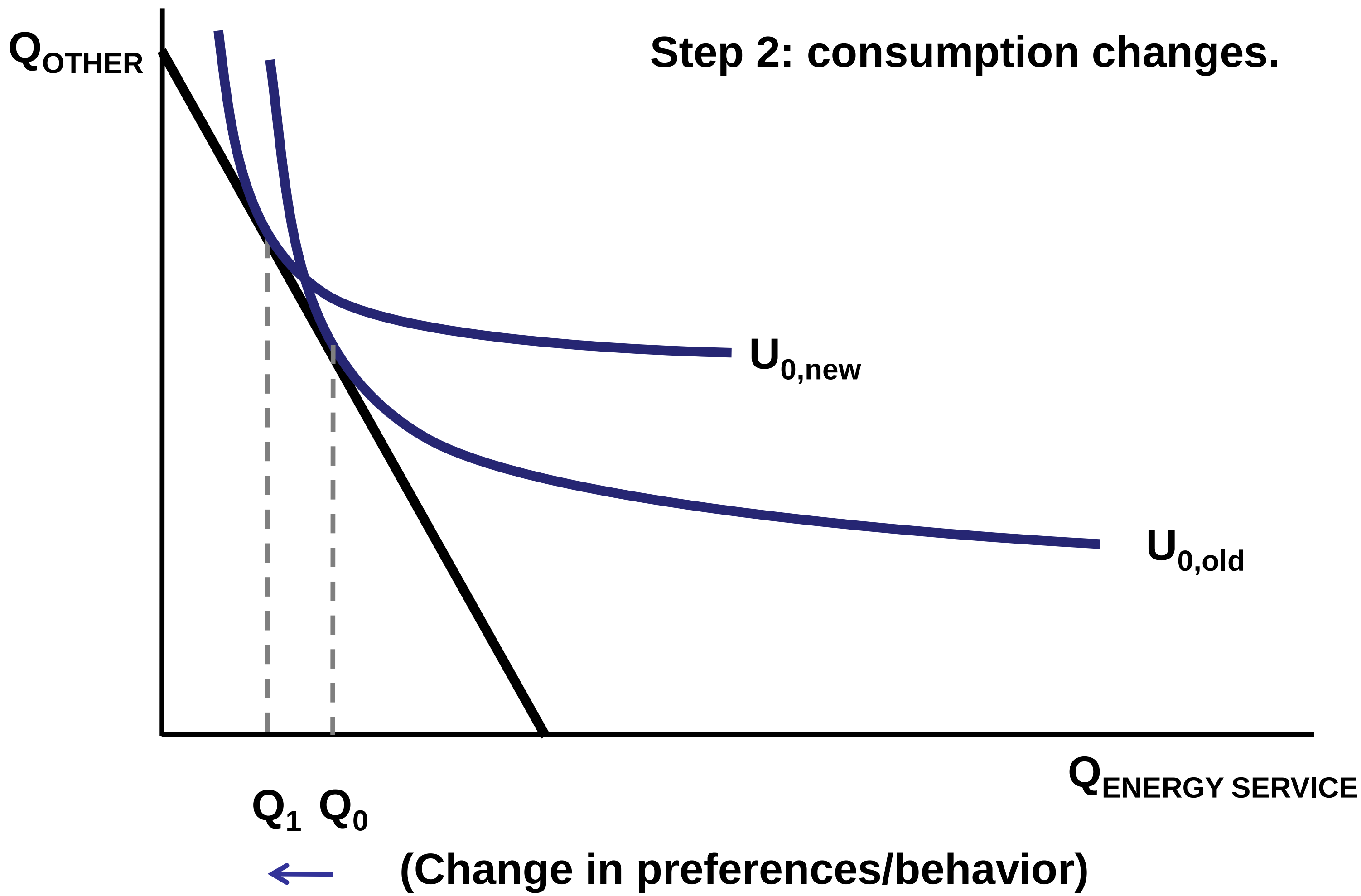
Conceptual Issues: Two Types of Rebound

- Market Failures and Successful Interventions
  - Market failures lead to inefficient use of energy.
    - Information, principal-agent problems, transaction costs, externalities
  - Some ways of increasing energy efficiency:
    - Create behavioral change:
      - Consumer preferences or social norms change
    - Or policy intervention:
      - Provide information, impose standards, tax consumption, etc.
- Perhaps no direct rebound effects
- Re-spending effect depends on whether change reduces overall costs or increases costs.

Behavioral Change

Step 1: raise awareness about energy use; consumers prefer to reduce consumption. Utility function shifts.

Step 2: consumption changes.



(Change in preferences/behavior)

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Conceptual Issues: The Counterfactual Scenario

- **Goal is to demonstrate a causal link between efficiency improvements and greater than otherwise energy use.**
  - **Must allow for potentially larger growth/income effects, new technologies**
  - **Don't attribute all change to energy efficiency**
- **One must calculate rebound with respect to a scenario in which efficiency doesn't change.**
  - **Right question:**
    - **How does energy consumption and level of energy service change relative to scenario in which efficiency doesn't change?**
  - **Wrong question:**
    - **How does energy consumption change after efficiency improves, relative to before improvement?**
  - **Difficult to establish credible counterfactual scenarios with macroeconomic or long-term analyses.**

Conceptual Issues: Technological Change

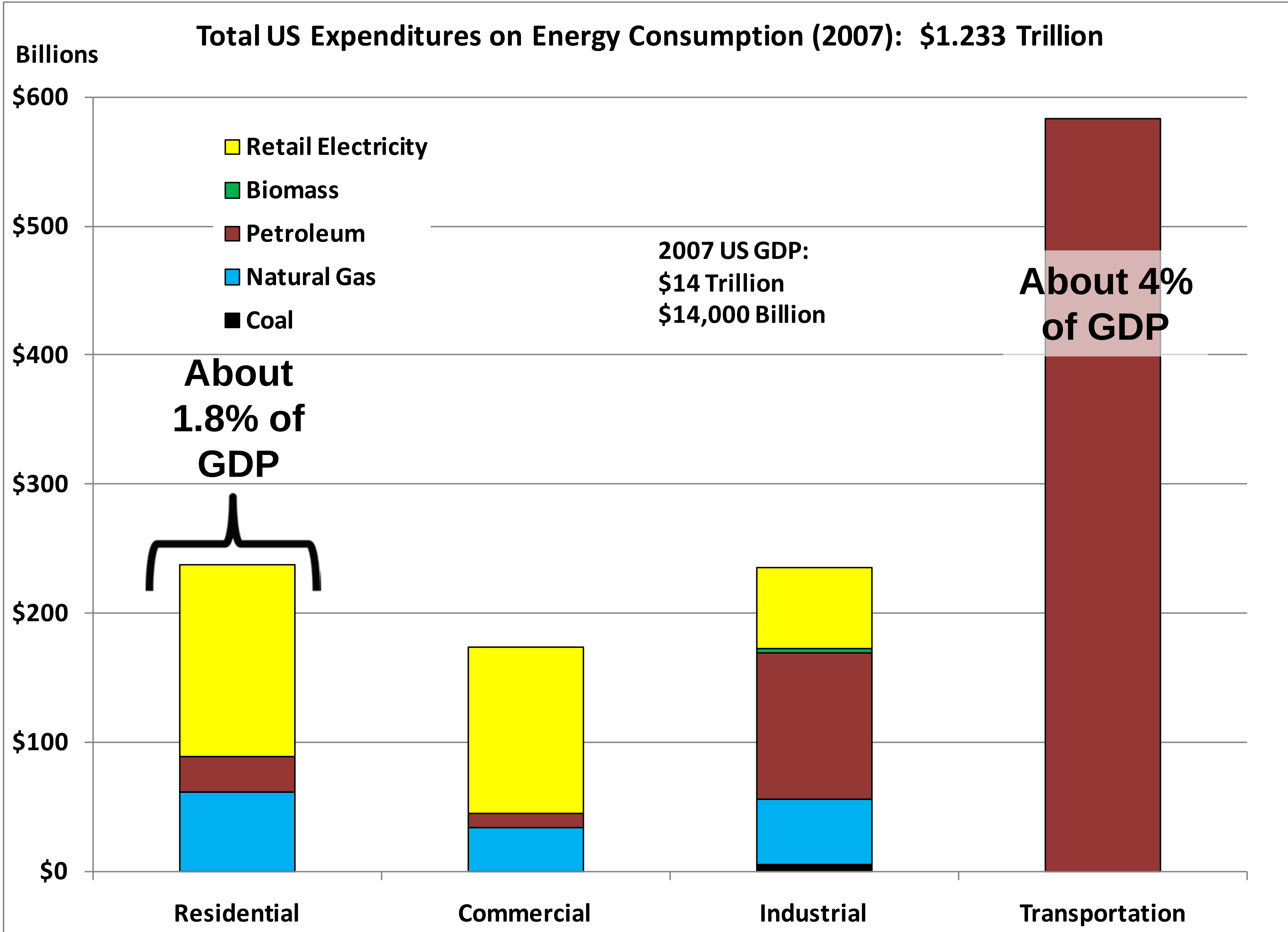
- **What happens when technology changes?**
  - **Technological change often includes, but is not limited to, energy efficiency.**
    - **Example: cars getting more powerful and still use less fuel than old.**
    - **Example: big-screen TVs yet lower kwh consumption than smaller tube TV.**
  - **Sometimes more efficient technology coincides with increased consumption.**
    - **Example: Personal computers have gotten more functional and more energy efficient**
    - **Did increased efficiency *cause* energy consumption?**
    - **Did increased wealth *cause* energy consumption?**
    - **Need more inferential power than correlation provides.**

Neoclassical re-Spending Effects: Costless Efficiency Increases

- **With costless efficiency changes, on average, re-spending should not exceed ration of energy expenditures to GDP (~9%).**
  - **If efficiency increases are costly, re-spending typically smaller.**
- **For energy efficiency changes in one sector, re-spending effect approximately proportional to 1st order energy reduction, with ratio of re-spending to 1st order reduction:**

$$-\left(\frac{\text{Sector expenditure on Energy}}{GDP}\right)\left(\frac{\text{Economy-wide Energy Quantity}}{\text{Sector Energy Quantity}}\right)$$

  - **Assumes all commodities have 1.0 income elasticity. If income elasticity of energy intensive commodities is less than 1.0, re-spending effect smaller; conversely if income elasticity greater than 1.0.**



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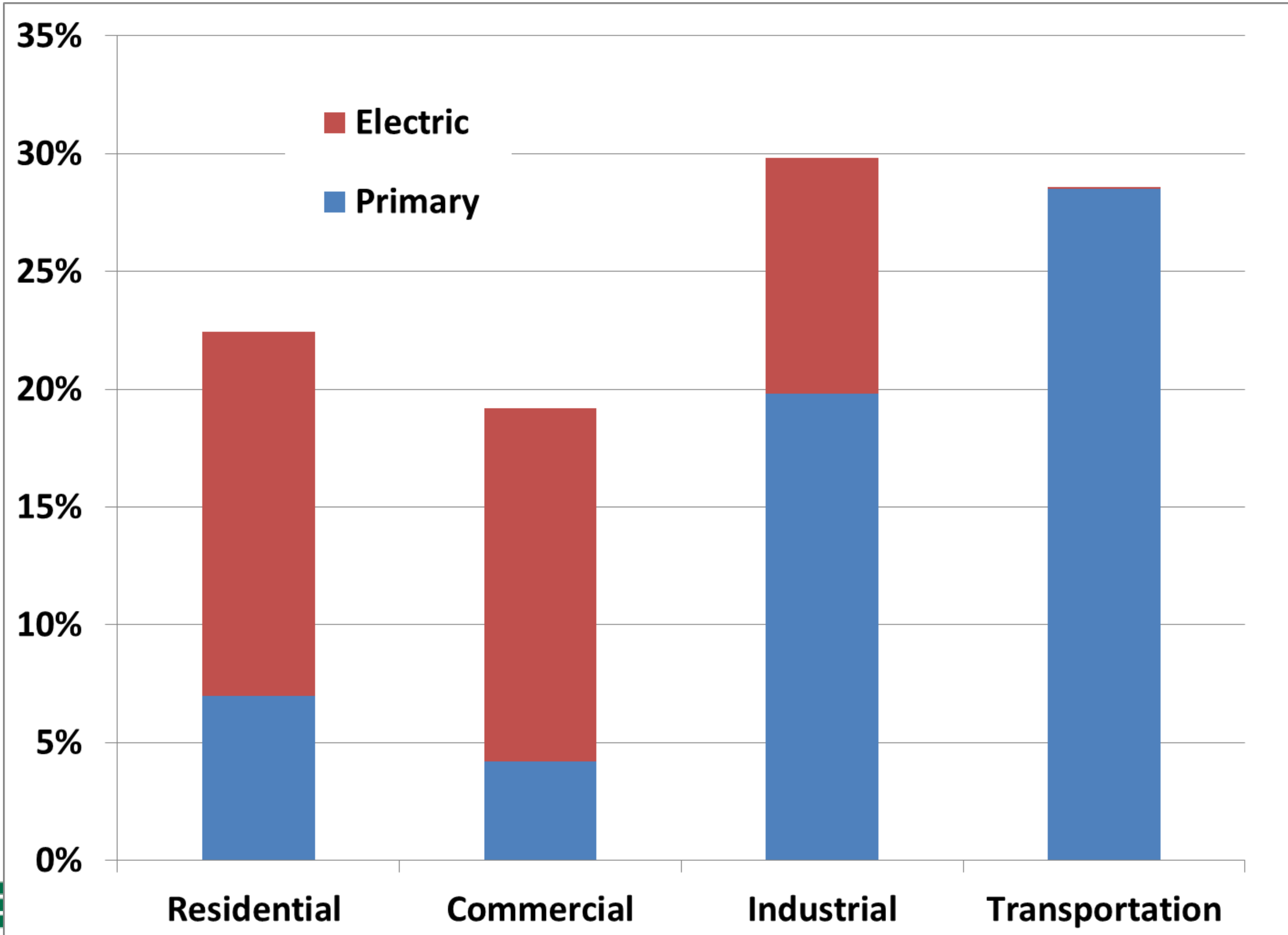
Electricity includes non-primary energy costs of electric system

Percentages of Energy Use: US 2009



Neoclassical re-Spending Effects: Costless Efficiency Increases

$$-\left(\frac{\text{End use expenditure on Energy}}{GDP}\right)\left(\frac{\text{Economy-wide Energy Quantity}}{\text{End use Energy Quantity}}\right)$$

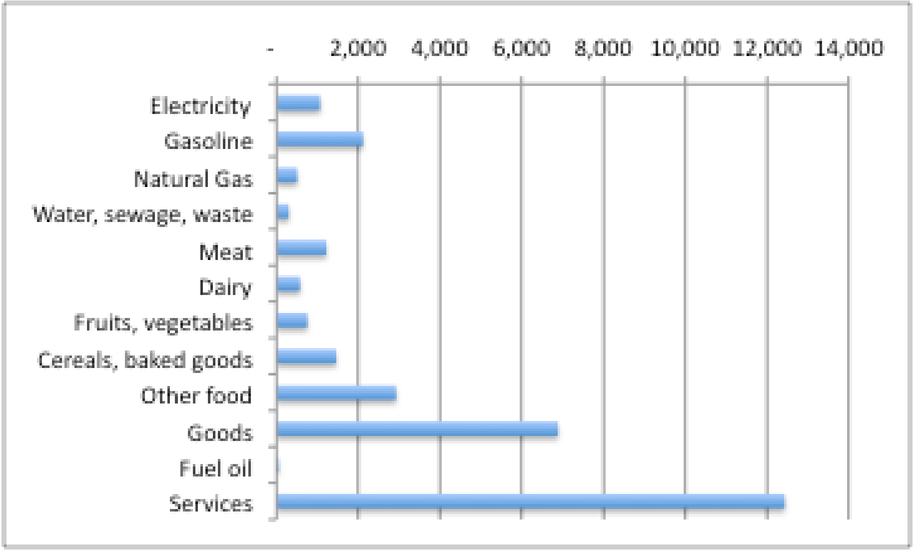
	Energy Expenditure /GDP	Economy-wide Energy/End Use Energy	Re-spending fractional effect
All Residential	1.8%	4.5 (1/22%)	7.6%
All Transport	4.2%	3.4 (1/29%)	14.6%
Personal Transport (assume 50% of All)	2.1%	6.8 (1/14.5%)	14.6%
All Commercial	1.2%	5.2 (1/19%)	6.5%
All Industrial	1.7%	3.4 (1/30%)	5.6%
All Energy	8.8%	1	8.8%

Induced Shifts in Final Goods Consumption

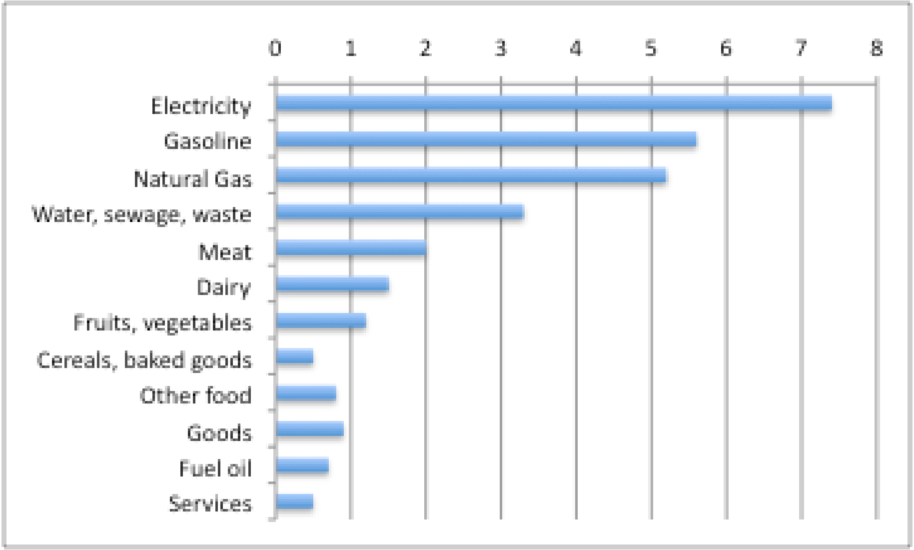
- **Policy could theoretically shift consumption from energy services into other energy-intensive activities.**
  - **But energy services (provision of heat, light, cool, washing, drying, lighting) are energy-intensive on a per dollar basis, whereas most consumer goods are much less energy-intensive per dollar spent.**
  - **Thus, energy efficiency policy is likely to shift consumption to less energy-intensive goods (for most applications).**

Neoclassical re-Spending Effects: Costless Efficiency Increases

U.S. Household Expenditures ($/yr)



U.S Carbon Intensities (tCO2/$)



Source: Chris Jones, UC-Berkeley Carbon Calculator

(CO2 is key reason for wanting less energy consumption)

Estimation Issues: Physical and Economic Data

- **Physical Data:**
  - Very few data sets are available with measures of physical energy efficiency and levels of energy services.
    - (i.e., how many air conditioners with what COP, ?)
  - Good data sets on household capital equipment, its efficiency and approximate utilization
  - Some data sets on energy intensity (gallons/mile, miles, and vehicle characteristics)
- **Expenditure Data:**
  - In the absence of physical data, one must infer physical efficiency from expenditure data.
  - To do this, one needs <u>marginal</u> prices by customer segment and geography:
    - Different rates (e.g., industrial vs. residential)
    - Different rate structures (e.g., peak demand charges)
    - Different markets (e.g., natural gas in CA vs. TX)
  - National and average prices will not suffice

Using General Equilibrium Models

- CGE models
  - Typically used for neoclassical analysis; less used for behavioral changes
  - Some CGE models predict backfire when significant efficiency changes are introduced.
  - CGE models usually do not include detailed physical and economic representations of consumption and efficiency.
  - CGE models are complex; results often not easily reduced to clear, causal relationships. Without an independently valid casual explanation for results, we should view them with caution.
- Challenge for all Models
  - "Efficiency" not portrayed – too disaggregated
  - Energy services also overlooked
  - Thus basic link "Efficiency -> growth" weak or missing.

Other Growth Models

- **Ecological Economics (E.g. Ayres, Kümmel)**
- **Basic idea: exergy is fundamental constraint on the size of economy, therefore more efficient use of exergy leads to economic growth. Economic growth leads to more consumption and more energy use.**
- **Historical studies develop production functions with K, L, E (but not tech change); thus, various terms pick up tech change.**
- **Theory implies marginal productivity for energy almost an order of magnitude greater than actual energy prices. Not consistent with optimizing.**
- **Approach excludes household and private transport (including “own account” trucks). Does include exergy in food. Analysis changing as we speak to include estimates of exergy conversion in human brains.**

How Large Is Rebound? My Current Judgment

- Direct rebound
  - Small to modest for HH applications where only energy required (i.e., not attention)* (~10-30%)
  - Smaller in household appliances with fixed cycles (e.g. refrigerators)
  - More important for *some* parts of industry, transportation (but not all transport, and small in personal vehicles).
- Indirect rebound
  - Re-spending effect:
    - May vary, but on average should be ~9%
  - Importance in manufacturing and services with high energy cost component (air travel, some chemicals)
- Induced growth?
    - Weak evidence; more study needed.

* Space heating and cooling, some water heating, lighting

Where Does This Matter For Policy?

- **Energy Efficiency Policies – Clearing Market Barriers**
  - **Appliance and Thermal Standards – Small Rebounds**
  - **Small rebates ($15 for a dishwasher) – trivial capital transfer may lead to behavior changes.**
  - **Retrofit Subsidies – Possibly large rebounds for low income (Scott 1980)**
- **Automobile Sector**
  - **Much debated CAFE standard impacts small (Gillingham 2011; Hymel, Small and Vandender 2010) 20% direct**
  - **Other uncertain effects with large subsidies for hybrids, EV – need to observe real use of vehicles**
- **Lessons**
  - **Policies complement, do not eliminate need for pricing**
  - **Careful monitoring needed to identify big rebounds with effects that counteract important policy goals**