Economics of Energy Demand

Lecture 8

Image of sea-level rise of Bangladesh removed due to copyright restrictions.

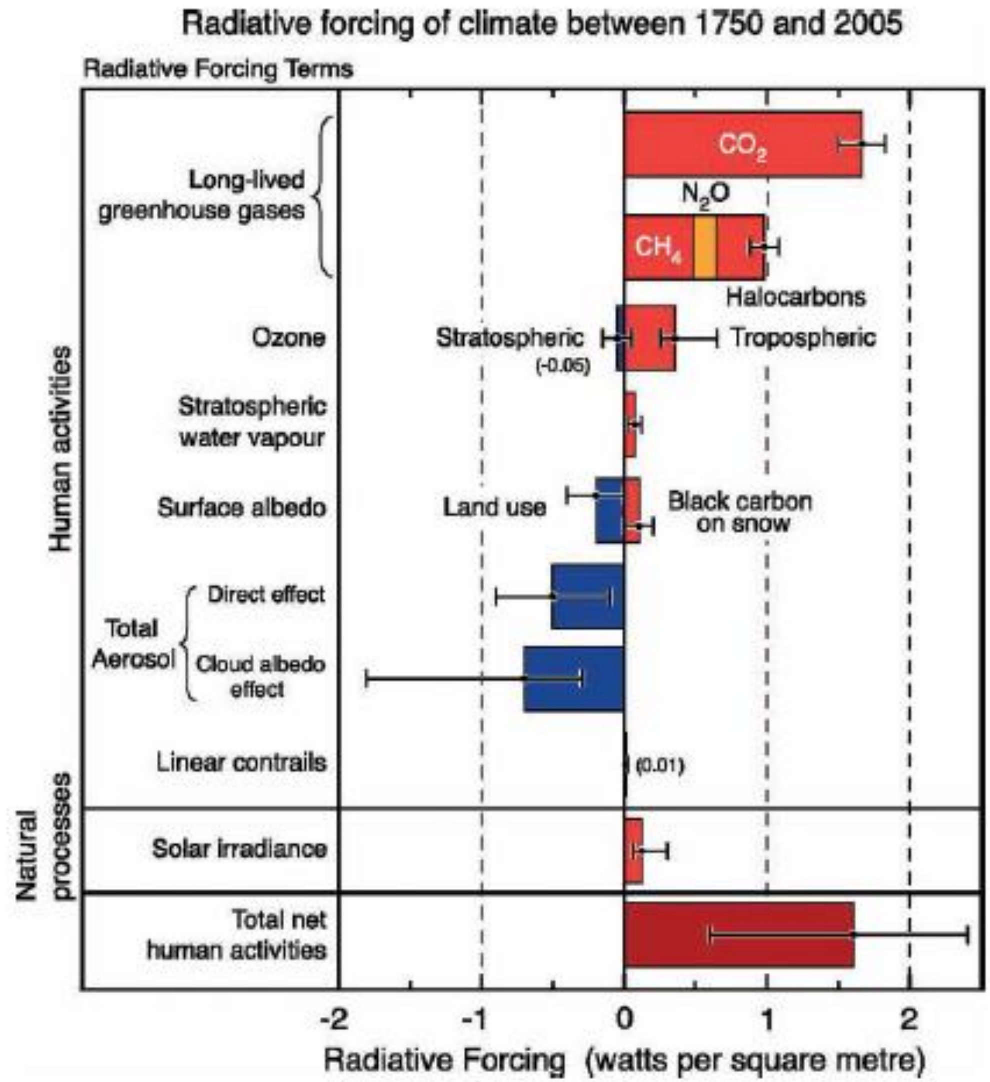


FIGURE 2.4 Climate forcing due to both human activities and natural processes, expressed in Watts per square meter (energy per unit area). Positive forcing corresponds to a warming effect. See Chapter 6 for further details. SOURCE: Forster et al. (2007).

Source: Climate Change 2007: The Physical Science Basis. Working Group I Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, FAQ 2.1, Figure 2. Cambridge University Press. This figure is in the public domain.

Today's Topics

- Energy demand as a *derived demand*
- Short-run v. long-run demand functions
- Estimating demand functions: problems & results
- Demand function instability
- Two puzzles: the McKinsey curve and the Prius

Derived Demand

- Gasoline is nasty – why do you buy it?
- The demand for energy (gasoline) is ***derived*** from the demand for energy services (transportation), e.g.
  - Food preparation, heating, lighting, cooling, loud music…
- The technology of producing any particular energy service can be summarized in a production function:

$$Q = F(K, L, E, M)$$

  - Capital is important in the production of most energy services
  - Some studies find that capital and (particularly electric) energy are *complements*: increasing the price of one decreases demand for both (coffee & cream)
- Historically there has been enormous progress in technologies for energy services

Examples: Lighting (Nordhaus), Cars

Figure 1.3 removed due to copyright restrictions. Source: Nordhaus, William D. "Do Real-Output and Real-Wage Measures Capture Reality? The History of Lighting Suggests Not." Published in January 1996 by University of Chicago Press.

Recent estimate: auto technology advanced 2.6%/year, 1980-2006 $\Rightarrow$

If weight, horsepower, & torque at 1980 levels, mileage $\uparrow$ 50% by 2006

Short Run Energy Demand: capital fixed

- Begin with two fundamental functions:
  - Demand function for some energy service:

    ES = D(EScost, Ps, income I Ks, "tastes")

    EScost = per-unit cost of the service (e.g., lighting)
    Ks = capital stocks & tastes are fixed in the short run

  - Production function for that energy service:

    ES = F(E, Ms, Ls I Ks, technology)

    Ms = materials of various sorts

- Given all prices, including P_E, solve for E demand by
  - Finding least-cost inputs to produce ES: E*(ES, Ps,…), EScost* (ES, P's,…)
  - Then substituting into ES demand function, get E*(Ps, …)

Consider Electricity for Lighting

- Start with the two basic functions:
  - *Demand* for lighting (lumen-hours): $L = a(Lcost)^{-b}$, a and b positive constants, Lcost is cost per lumen-hour
  - $b = -(dL/dLcost)(Lcost/L)$ = price <u>elasticity</u> of demand for lighting, the limiting ratio of percentage changes
  - In the SR bulbs in the house are fixed, so *production function* is just $L = eE$, e is a positive constant, E is electricity

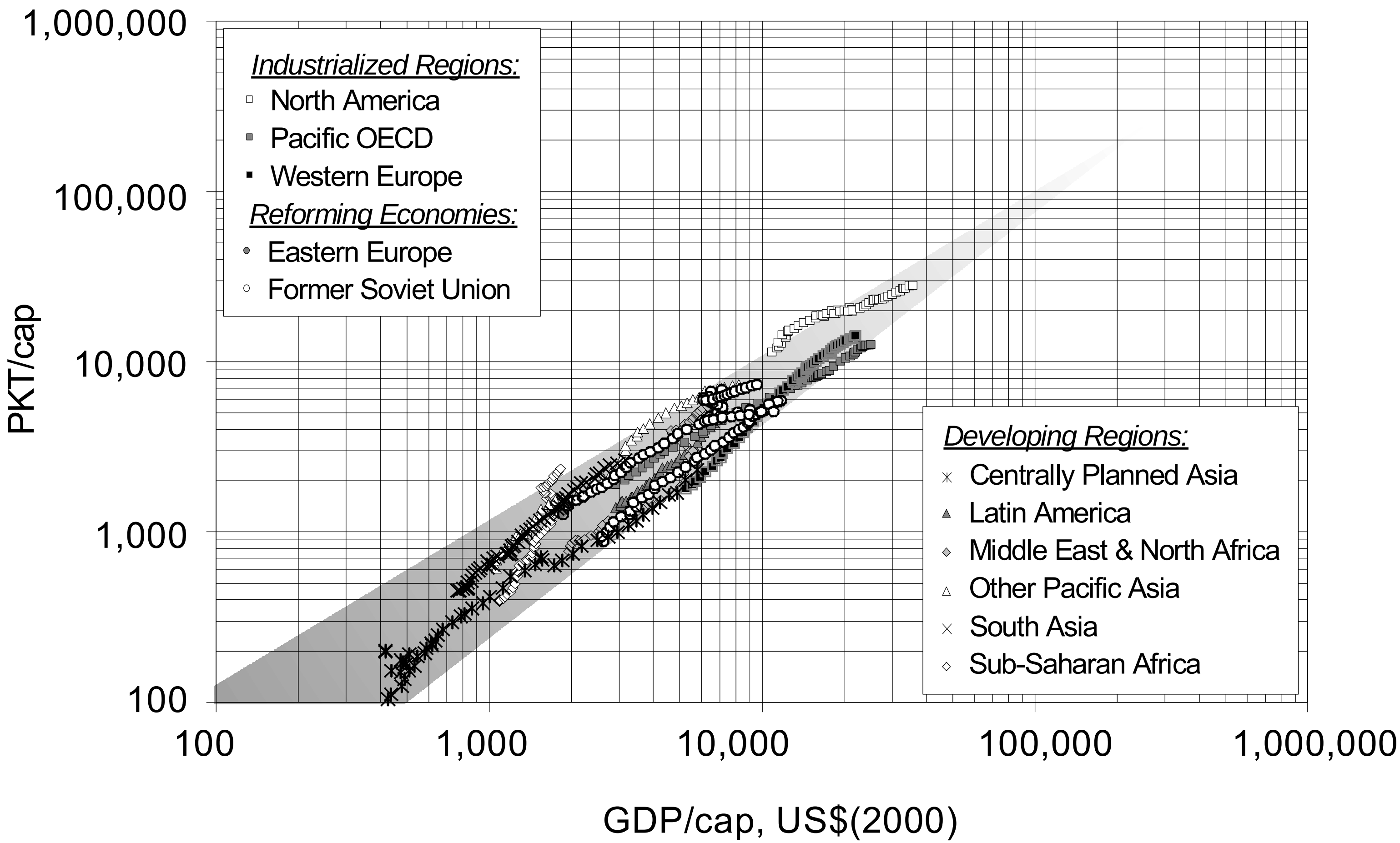
- Given price of electricity, P_E(\$/kwh), solve for \$/lumen, then substitute in demand function (check units!)
  - L(lumens)=e(lumens/kwh)E(kwh)
  - Lcost*(\$/lumen) = P_E(\$/kwh)/e(lumen/kwh)
  - Substitute & solve: $L = eE = a(P_E/e)^{-b}$; $E = a(P_E)^{-b}(e)^{b-1}$

SR Demand: Some Remarks

- Here the elasticity of demand for electricity to produce lighting equals the elasticity of demand for lighting; this is *not* a general property of derived demand
  - Derived demand for an input (electricity) can be more or less elastic than the demand for the output (lighting) from which it is derived
- Note that if b > 0, making lighting more efficient (raising e) would raise the demand for lighting – by lowering the cost
  - Making cars more efficient makes driving cheaper, all else equal, and should increase driving – the "rebound effect" of CAFE
- If b > 1, so demand for lighting is price-elastic, making lighting more efficient raises the demand for *electricity*
  - Might be plausible in this case…?
  - Some have argued that CAFE standards increase the demand for gasoline this way, but it seems b < 1 in fact; small rebound

Income Also Affects Demand:

Passenger Kilometers Traveled/ Capita



Derived Demand: Longer Run

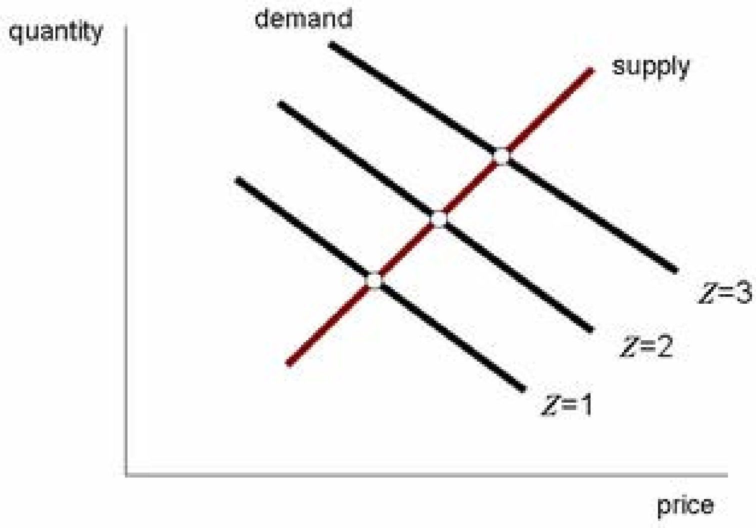
- Consider my demand for gasoline
  - In the SR, with my car given, I can only respond to price or income changes by changing driving: *the output effect*
  - In the LR, if changes persiste, I can change my car, changing the relation between gasoline demand and driving: *the substitution effect*
- Basic principle (Samuelson): Expect higher LR price or income elasticity than SR since more flexibility $\Rightarrow$ greater ability to respond $\Rightarrow$ greater response
- Most energy-transforming and energy-using capital is <u>very</u> long-lived: houses, cars, etc.
  - Past investment decisions shape future costs & options
  - Cost of rapid cuts in CO_2: either drastically cut energy services or scrap & replace existing assets prematurely

Demand Estimation: Identification

- Early demand studies for agricultural products found demand curves sloped up

  How could this happen?

- The classic *identification problem:* shifts in demand traced out the supply curve



- Teaching note works out a simple example with linear supply & demand curves:
  - Not possible *in principle* to estimate demand without data on some variable that shifts the supply curve
  - Similarly, need demand shifters to estimate the supply curve
  - Generally use special techniques to get "good" estimates

Demand Estimation: Dynamics

- "Partial adjustment" models let SR response (to temporary Δ) & LR response (to permanent Δ) differ
  - $E(t) – E(t-1) = \lambda[E^*(Ps,Y, tastes,\ldots) – E(t-1)]$, $0 < \lambda < 1$

    E^* is a model of *long-run* equilibrium demand; gives demand in the limit if Ps, Y constant for a long time
  - Put $E(t-1)$ on the right, find coeffs that "best fit" data:

    $E(t) = \lambda E^*(Ps,Y, tastes,\ldots) + (1- \lambda)E(t-1)$

    Response to temporary change in Ps = λ reponse to permanent change

    Coefficient of lagged demand gives λ, can then get E^*
- Other approaches are also used
  - E.g., Huntington (see teaching note) decomposes oil P into P_{max}, $[P – P_{max}]$, finds P_{max} has larger effect
- Very durable assets (esp. structures, cities) in energy $\Rightarrow$ full response to changes in price, income, … can take a LONG time

Demand Estimation: Results

- Estimated LR price & income elasticities for energy generally <u>much</u> larger than SR elasticities (small λ)
- SR income & price elasticities generally < 0.5 – limited ability to respond with fixed capital assets
- Gasoline & electricity are the most studied; ranges for rich countries from teaching note:

		Gasoline	Electricity
Price Elasticity	Short-Run	.15 – .25	.20 – .40
	Long-Run	.50 – .70	.50 – .80
Income Elasticity	Short-Run	.30 – .50	.15 – .30
	Long-Run	.60 – 1.10	.80 – 1.10

Demand functions are NOT constants of nature!

- 1970 electricity wisdom: income e > 1, price e $\cong$ 0.1; Res. = 33%, Comm. = 25%, Ind. = 41% of end use

  Let's try to "forecast" long-term changes in demand

Period	GR GDP	GR Real P_E	GR Elect Use
1950-60	3.50	-2.40	10.61
1960-70	4.20	-3.22	7.30
1970-80	3.18	3.45	4.17
1980-90	3.24	-0.77	3.08
1990-00	3.40	-1.66	2.39
2000-07	2.40	1.62	1.27

- What happened?

And Demanders (People!) Sometimes Don't Optimize!

- McKinsey uses the so-called "engineering approach": calculate what energy technology <u>should</u> be used
- They & others (e.g., Amory Lovins) find lots of $$-saving (NPV > 0) investments in energy efficiency that aren't made
- This "$$ on the sidewalk" is the "efficiency paradox"

Source: Exhibit G in Granade, Hannah Choi, Jon Creyts, Anton Derkach, et al. "Unlocking Energy Efficiency in the U.S. Economy, Executive Summary." McKinsey & Company, July 2009.

Why is this low-hanging efficiency fruit not picked?

- Easy first answer, 1970s: “engineering” assumptions too optimistic, esp. about old structures. **Yes, but lots of clear examples of $$ on the sidewalk.**
- Second “answer”: Hausman and Joskow cite studies showing consumers act **in this setting** as if VERY high discount rates: 20-30%. **But why? What about commercial & industrial demand?**
- Imperfect information, riskiness of future savings probably play a role, but no simple story…
- But there is more…

Some folks overinvest in efficiency!

Photo by IFCAR on Wikimedia Commons.

- Consider the Toyota Prius:
  - >3 Million sold, >1 Million in the US
  - $\cong$ A Corolla + 50mpg v. 28mpg
- Did all those consumers make a good investment?
  - C = cost difference, S = annual savings, r = interest, T = breakeven time:
    r=0, T = C/S; r>0, solve $C = (S/r)(1 - e^{-rT}) \Rightarrow T = (-1/r)\ln[1-(rC/S)]$ if $rC < S$
  - Average Prius cost premium C = $7,450; assume = maintenance
  - Cars average 12k miles per year; if $3/gallon, cost/year:
    Prius: (12000/50)x3 = $720, Corolla: (12000/28)x3 = $1,286; S = $566
  - At r = 0, breakeven in 7450/566 = 13.2 years
  - At 5.0% breakeven in 21.6 years; > 7.6% $\Rightarrow$ rC>S, forever is not long enough
  - Initial subsidies, higher gas prices make Prius more attractive, but…
- Hard to reconcile this with high discount rates in other settings … unless this (economic) model is missing something important!