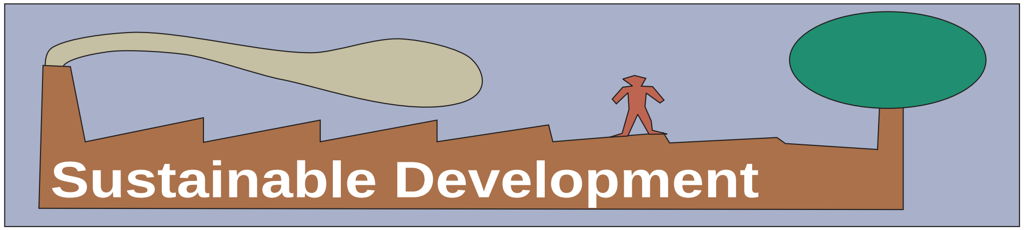
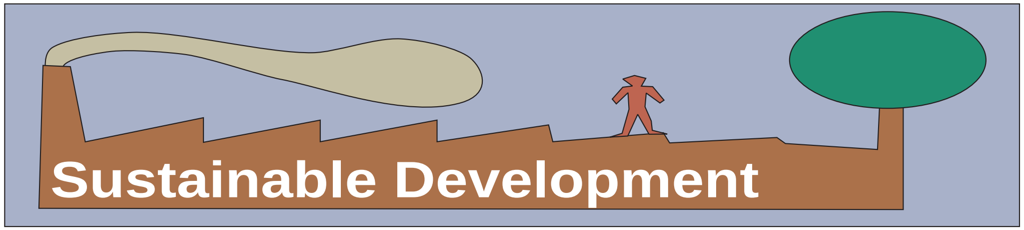




Chapter 6

Structural change

Background

- Background
- Substitution effects
- Income effects
- Reality?

Background

- Growth and structural change.
- Why we need structural change to explain energy data.
- Driving forces of structural change.
- Why it matters.

Substitution effects

- Background
- Substitution effects
- Income effects
- Reality?

Substitution effects

- Background
- Substitution effects
- Income effects
- Reality?

Two products, Y_1 and Y_2. Perfect markets.

$$Y_1 = \gamma_L A_L L;$$
$$Y_2 = \gamma_R A_R R.$$

Thus labour is the only input to Y_1, and energy is the only input to Y_2.

Aggregate production:

$$Y = (\alpha Y_1^\epsilon + (1-\alpha) Y_2^\epsilon)^{1/\epsilon}. \tag{1}$$

Thus when ϵ is negative the two aggregate products are complements in the sense that if a product becomes increasingly scarce then its factor share rises.

Substitution effects

Let labour L and the ratio of the input prices, w_R/w_L, evolve exogenously, and derive total energy use R from the model.

The solution is straightforward. Briefly, derive two different expressions for the ratio of the prices of the aggregate goods: firstly by comparing their marginal contribution to Y, and secondly by comparing their unit production costs. Use these two expressions to eliminate the price ratio, and rearrange to show that

$$\frac{R}{L} = \left[\frac{1-\alpha}{\alpha} \left(\frac{\gamma_R A_R}{\gamma_L A_L} \right)^{\epsilon} \left(\frac{w_R}{w_L} \right)^{-1} \right]^{1/(1-\epsilon)} .$$

Hence the aggregate elasticity of substitution between energy and labour is $1/(1-\epsilon)$.

- Background
- Substitution effects
- Income effects
- Reality?

Substitution effects

$$\frac{R}{L} = \left[\frac{1-\alpha}{\alpha}\left(\frac{\gamma_R A_R}{\gamma_L A_L}\right)^{\epsilon}\left(\frac{w_R}{w_L}\right)^{-1}\right]^{1/(1-\epsilon)}.$$

Now set $\epsilon = 0$. This implies that equation 1 is Cobb–Douglas, and the aggregate elasticity of substitution between energy and labour is 1. Thus we have the constant-share result and 100 percent rebound (energy demand is not affected by the direction of technological change)! The result is intuitive: we have two products, one made entirely using labour, the other using only energy. When the products are combined in a Cobb–Douglas function on the consumption side the products take constant shares, and therefore labour and energy must also take constant shares.

Substitution effects

- Background
- Substitution effects
- Income effects
- Reality?

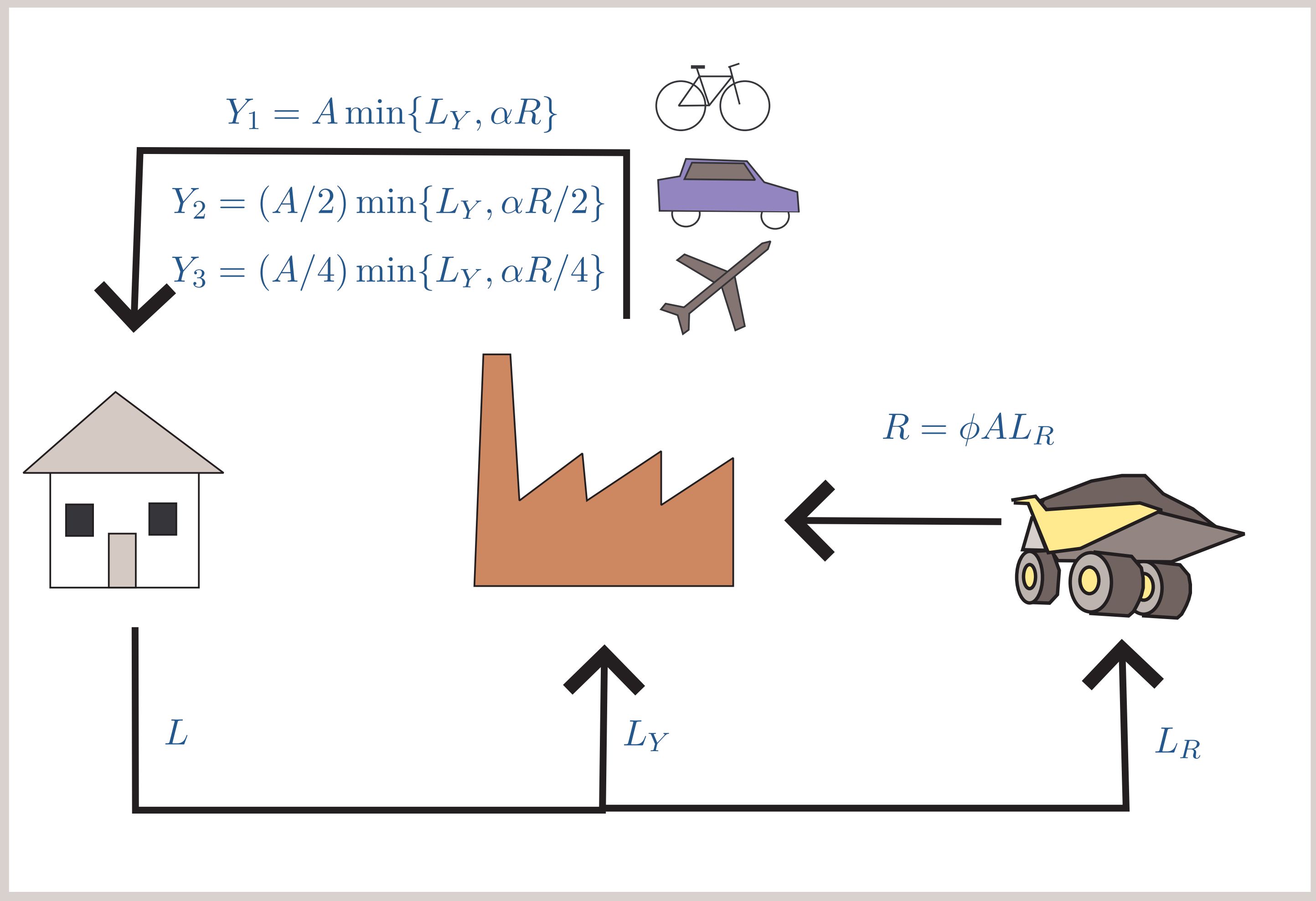
So in this economy, boosting A_R doesn't help to reduce energy demand. But what happens if we tax energy use?

Income effects

- Background
- Substitution effects
- Income effects
- Reality?

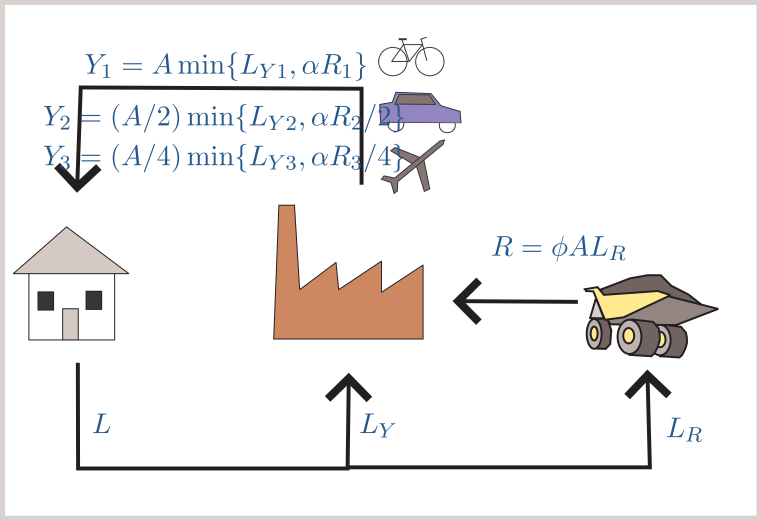
Income effects

- Background
- Substitution effects
- Income effects
- Reality?



Income effects

- Background
- Substitution effects
- Income effects
- Reality?



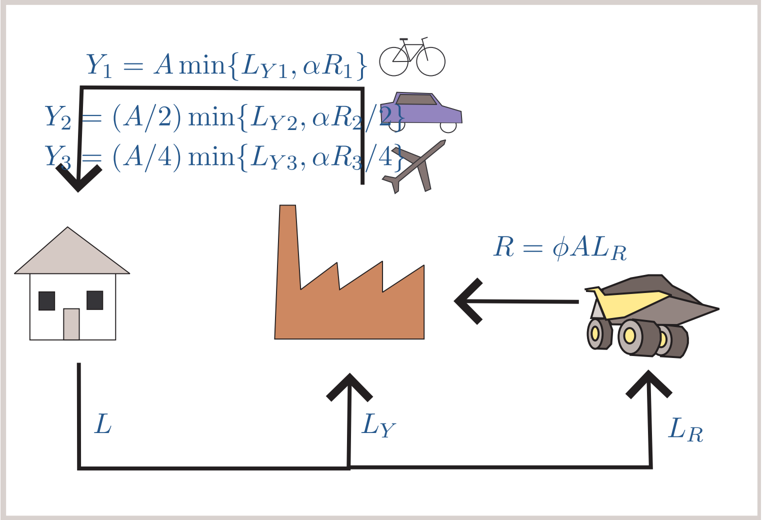
$$Y_i = (A/2^{i-1})\min\{L_{Yi}, \alpha R_i/2^{i-1}\};$$

$$L_{Yi}/L_{Ri} = \alpha\phi A/2^{i-1};$$

$$\frac{R_i}{L} = \frac{\phi A}{1+\alpha\phi A/2^{i-1}}.$$

Income effects

- Background
- Substitution effects
- Income effects
- Reality?



$w_L = A$, GDP$= A \times L$. L identical agents.

Lexicographic prefs: choose highest i available, subject to $c_i > \bar{c}$.

$\bar{A}_i$ is minimum A such that good i affordable. Then (see book)

$$\bar{A}_i = 2^{i-2}\left[1 + \left(1 + \frac{4}{\alpha\phi\bar{c}}\right)^{0.5}\right]\bar{c}.$$

Income effects

- Background
- Substitution effects
- Income effects
- Reality?

What happens in this economy if we raise α (energy efficiency)?

Rebound?

Rebound occurs when (for instance) a 10 percent increase in energy efficiency does not give a 10 percent *decrease* in energy use. In the above economy there is almost no rebound. (Why is there any at all?) The reason is that increases in energy demand are driven entirely by *income effects*.

What happens in this economy if we tax energy use?

- Background
- Substitution effects
- Income effects
- Reality?

Reality?

- Background
- Substitution effects
- Income effects
- Reality?

Reality?

So we have two models, one based entirely on income effects with no rebound, and one based entirely on substitution effects with 100 percent rebound. Now we need some evidence!

Reality?

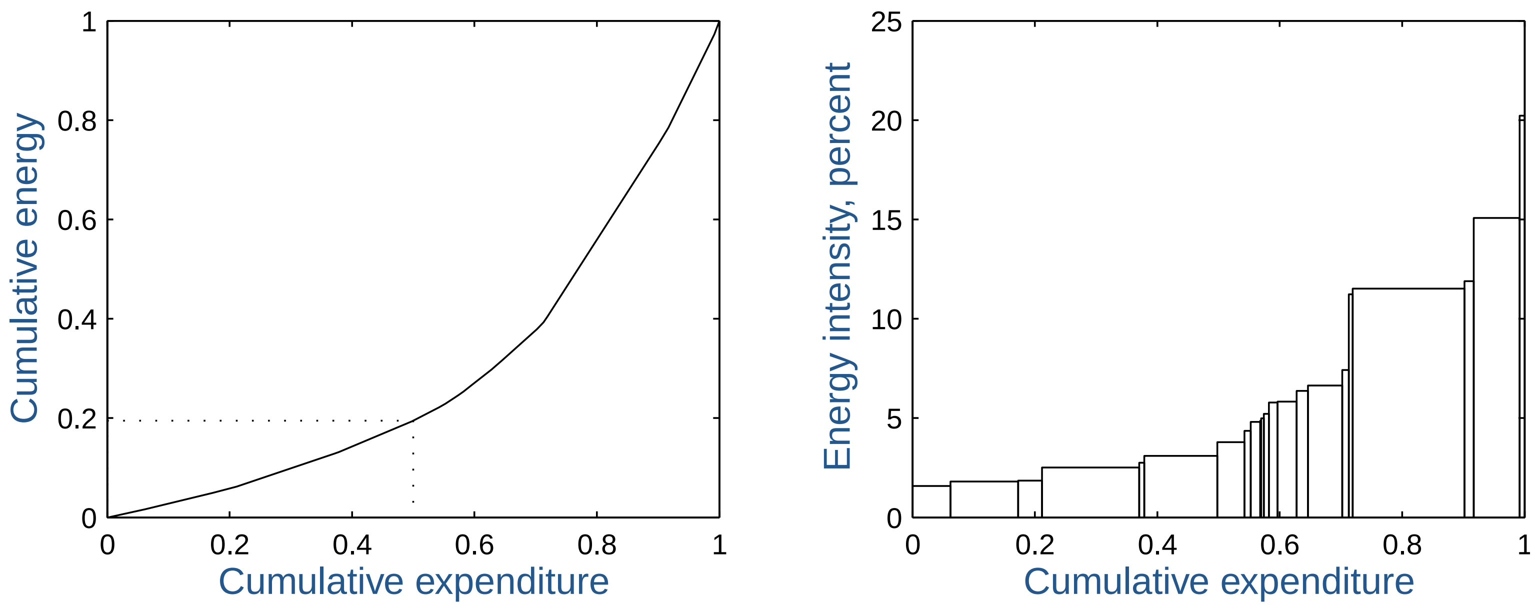


Figure 1: Cumulative energy use and energy intensity plotted against cumulative expenditure when consumption products are sorted in order of increasing energy intensity. All the axes are normalized. Regarding energy intensity, we only have data on relative intensities, and we normalize to give an average intensity of 4 percent.

Reality?

- Background
- Substitution effects
- Income effects
- Reality?

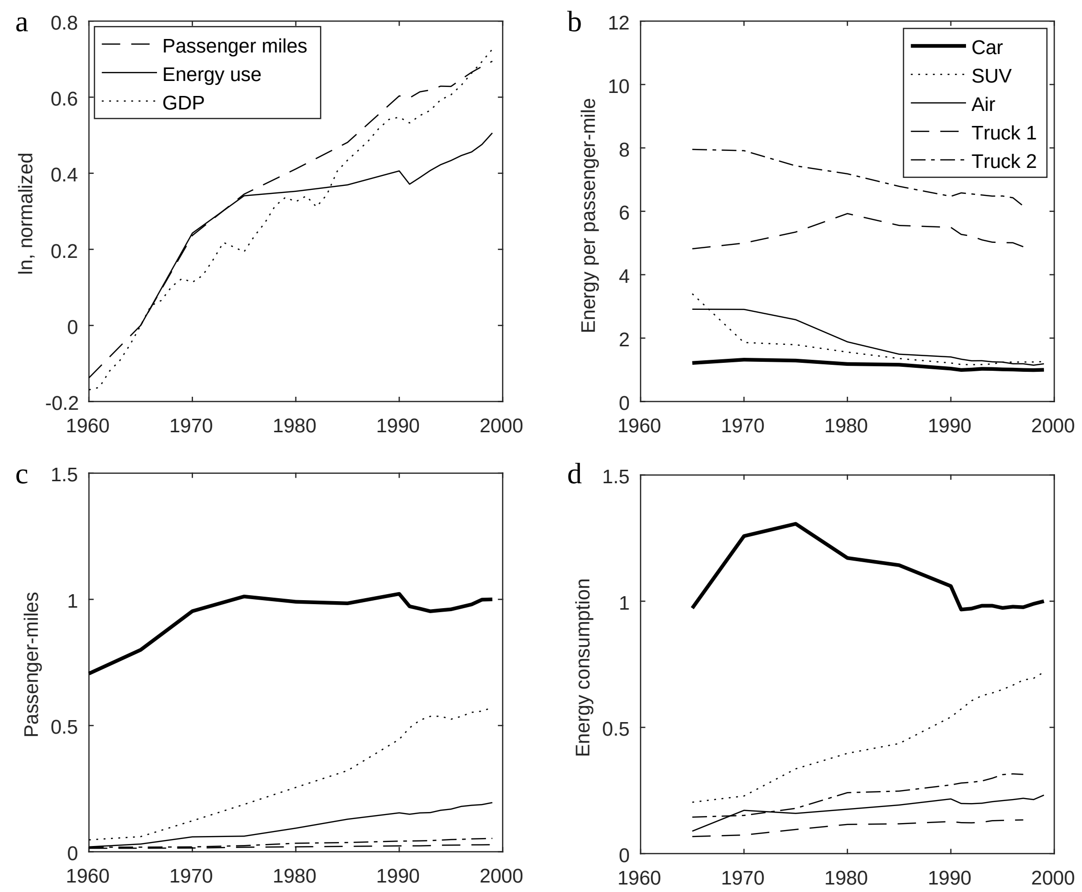


Figure 1: Aggregate data for passenger-miles and energy consumption in the U.S. for private vehicles and air travel (combined).

Reality?

- Background
- Substitution effects
- Income effects
- Reality?

Reality is messy! We have a broad range of products consumed, none of which is all that energy intensive (up to approximately 20 percent expenditure on energy). So clearly our model based on substitution effects is way off. But so is the model based only on income effects, in which we consume one product at a time.

Much more work is needed to build a picture of past developments and the future.

Air travel. Our work (Stråle 2021, Tourism Economics) suggests that the income elasticity of demand for air travel is very high—around 3—hence income effects seem to be powerful. At the same time, the real price of long-distance air travel has fallen by around 2 percent per year, so a relatively modest elasticity of substitution between air travel and other goods could also explain a lot of the shift.

Reality?

- Background
- Substitution effects
- Income effects
- Reality?

Note that the price fall of air travel is not just driven by increasing fuel efficiency, but to a greater extent by the increasing efficiency of the entire operation.

What happens when A_L rises faster for energy-intensive goods than for labour-intensive goods? ‘Rebound’?