A theoretical framework to study the economic importance of energy

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An empirical regularity

Costanza & Herendeen (1984)

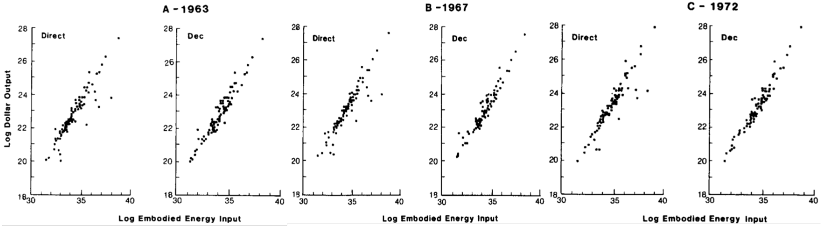

Fig. 2. Log–log plots of embodied energy inputs vs. dollar output for the 87 sector data, for three years and two alternative direct energy input vectors.

An empirical regularity

Liu et al. (2008)

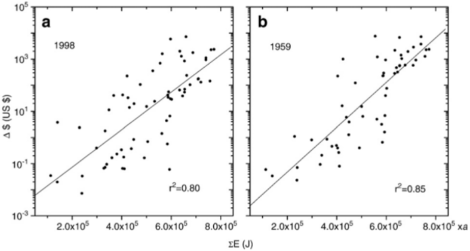

Fig. 4 – Correlation between total energy cost for refinement and the market value of each mole of the elements total energy cost for refinement ∑E closely correlate to the market value of the elements (correlation coefficient > 0.80)When *a*/*b* = 13 in Eq. (1). The correlation is held through the investigated 40-year period. Prices are in 1992 constant US dollar.

An empirical regularity

Gutowski et al. (2013)

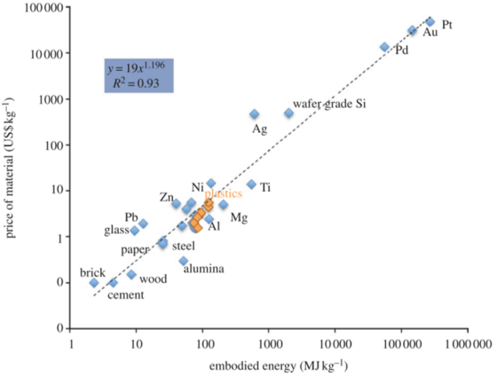

Figure 6. Price of various materials plotted against the embodied energy of the materials. The data for embodied energy comes from Ashby [10], for material prices for metals from the *Mineral yearbooks* [17], plastics from IDES [28] and brick, wood and glass from Ashby [10]. Plastic prices are for year 2011, and all others are for 2009.

Why are prices proportional to embodied energy?

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  (Csereklyei et al., 2016; Ayres et al., 2013; Lindenberger & Kummel, 2011)
- An energy theory of value creates more problems than it solves
  (Huettner, 1982; Alessio, 1981; Webb & Pearce, 1975)

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- Only when they further human purpose

Intertemporal utility maximization

The agent's main objective is

$$\begin{aligned} \max_{\boldsymbol{Q}_{FT}} \quad & U(\boldsymbol{Q}_{F1}, \boldsymbol{Q}_{F2}, ..., \boldsymbol{Q}_{FT}) \\ \text{s.t.} \quad & \boldsymbol{\tau}^{A'}_{Ft} \boldsymbol{Q}_{Ft} \quad \leq \quad E_t \quad \forall\, t \in T \end{aligned}$$

with

- Q_{ft}: Final good f during period t
- τ^{A}_{ft}: Good f's average energy cost during t
- E_t: Energy surplus during t

Intertemporal utility maximization

The FOC to chose optimal quantity of Q_{ft} is

$$\frac{U_{ft}}{\lambda_t} = \tau_{ft} \quad \forall f \in F, t \tag{1}$$

with

- λ_t: Marginal utility of energy surplus during t
- τ_{ft}: Good f's *marginal* energy cost during t

Minimization of direct energy transfers

Given the energy budget constraint, a secondary objective is to minimize direct energy transfers subject to productive and prime mover constraints. The FOC of this problem is

$$\tau_{kt} = \psi_{kt} + \theta_{kt} \quad \forall\, k, t$$

with

- $\psi_{kt} = \frac{1}{L} \sum \epsilon_l g'_{-lkt}$: Average direct energy transfers at the margin
- $\theta_{kt} = \frac{1}{L} \sum \phi_{lt} g'_{-lkt}$: Average indirect energy transfers at the margin

Other secondary objectives

Energy surplus maximization

$$\tau_{et} = \beta_{t1}\delta_e \quad \forall\, e, t$$

Prime mover accumulation

$$\tau_{lt} = \sum_{i=1}^{T} \beta_{ti}\phi_{li+1}d_l^{i-1} \quad \forall\, l, t$$

Energy surplus assignment

$$\tau_{ft} = (1-\rho_t)\Lambda_{ft} \quad \forall\, f, t$$

Gains from trade

- Following conventional ricardian logic, if ‘agent 1’ exchanges q_B units of good B for q_C units of good C with ‘agent 2’, and both consume the same as under autarky, gains from trade are

$$GT = \int (\tau_B^2 - \tau_B^1) dq_B + \int (\tau_C^1 - \tau_C^2) dq_C - TC$$

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- Under broad conditions $GT > 0$

The commodity price

- Maximizing GT choosing q_B and q_C yields

$$\tau_i^I = \tau_i^E + MTC_i \quad (2)$$

with

- τ_i^I: Marginal energy cost of good $i = B, C$ of the importing agent
- MTC: Marginal transaction cost of good $i = B, C$

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- Under (3) and no transaction costs, optimal exchange involves the commodity price

$$\frac{q_B}{q_C} = p^c = \frac{\tau_C}{\tau_B} \tag{3}$$

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- Define a representation of real money as n. The commodity price between both yields n's purchasing power

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Market prices and average embodied energies

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$$\tau_k = \gamma_k + (\theta_k - \vartheta_k)$$

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- Considering the relation between marginal and average values, nominal prices are

$$P_k = \frac{\gamma_k^A(1 + \mu_k) + (\theta_k - \vartheta_k)}{\tau_s}$$

Highlights of the model

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Further implications

- New layer to microeconomic analysis - Price formation, Nonmarket valuation

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- New micro-foundation for macroeconomics - Growth, interest rates, inflation, inequality

Thank you