Comments on Structural and Physical Representation of Major Technologies in the CGE Framework

Don Hanson
Argonne National Laboratory

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How Do We Envision Future Low-Carbon Technology? What Will Be the Key Technologies?

- Integration of electric grid and liquid fuels for LDVs
- Better integration of traditional and intermittent electric generation
- Polygeneration for efficient production of electricity, steam, hydrogen, and chemical feedstocks
- Improvements in batteries and other storage devices
- More and better thermal solar, PV, wind, biomass, and geothermal energy technology
- Real-time marginal cost pricing to signal consumers when energy is dear and when it is abundant
- Continued advances in lighting and other end use technologies
- Advances in cross-cutting and energy efficient technologies: materials, hot gas clean up, high temperature membranes, automatic controls

Supply, Demand and Pricing for Physical Flows

- Supply equals demand for electricity in continuous time
- Prices for electricity differ, implying that economic index numbers for electric supply and electric demand may not equate
- In addition to market transactions, Supply=Demand for internal facility flows and services (with internal shadow pricing) is important
- Example: Steam by temperature and pressure needs
- Example: Refinery hydrogen demand needed to upgrade heavier, high-sulfur crude oils
- “Physical" often means counting things, not just value: number of vehicles, power capacity: Raises interface issues with CGE model
The Electricity Sector is a Whole Range of Different Services and Prices

- Illustration from IEA data by country, energy type, and market segment

Variation in Petroleum Product Prices, IEA

Variation in Electricity and Gas Prices

Interface Flows Within our CGE / Energy Technology Model: AMIGA

CGE Model with Household Demand Disaggregation and Energy Related Service Representations

Energy Resource Supply Functions

Energy Conversion Models
- Electric Generation
- Petroleum Refining
- Hydrogen Production

Vehicles and other End-Use Capital Stocks

Input Prices

Energy Demand

Energy Product Prices

End Use Investment and Other Purchases

Energy Investment and MAC Spending

Resource Prices

Resource Demands
Hierarchical Representation of Commercial/Industrial Production Allows Capital Disaggregation and Differing Elasticities of Substitution

\[ Z = f(K, L, E) \]

Capturing Multiple Investment Opportunities for Improved, Efficient Space Conditioning

The interaction of building shell, ventilation, AC, and space heating to provide space comfort services.
The Hierarchy of CES Production Functions Implies Isoquants Reflecting Specific Factor Substitution Opportunities. These Functions may Shift due to Technological Change

A tangent point at the factor price ratio implies explicit, closed-form solutions to factor demand intensity equations


Vehicle Size & Type Choice Hierarchy: Prices are Calculated up the Hierarchy and Quantities Down
According to the National Academy's Report, There Are Opportunities to Improve Both/Either Vehicle Efficiency and Performance (with strong price and income effects)

Mathematically the functions and optimal choice are described as follows:

\[
\text{Perform}_{\text{veh}} = f^*_x(\text{Vehprice}_{\text{veh}}, 1/\text{MPG}_{\text{veh}})
\]

\[
\left( \frac{\partial f_x}{\partial P_x} \right) = \left( \frac{\partial f_x}{\partial VMP_x} \right) \left( \frac{\text{VMP}_{\text{veh}}}{\text{MPG}_{\text{veh}}} \right)
\]

\[
f_x = \left[ \left( \frac{\text{Vehprice}_{\text{veh}}}{\theta x} \right)^\zeta + \Phi \left( \frac{1}{\text{MPG}_{\text{veh}}} \right)^\eta \right]^{1/\zeta}
\]

\[
\frac{\partial f_x}{\partial r_x} = \left( \frac{\Phi}{\theta x} \right) \left( \frac{1}{\text{MPG}_{\text{veh}}} \right)^\eta
\]

Conclusions

- Household production allows a distinction between services demanded and derived demands for factor inputs, with potential for technological change improving efficiency.
- Factor separability is not necessary; useful factor disaggregation can be maintained throughout the model with interaction among specific components.
- For a number of reasons, we need to understand specific technology, not just statistical productivity trends.
- Walrasian equilibrium is not inconsistent with including specific factors and technology important to the current and future energy-economy system.