Concepts of Equilibrium and Their Role in Economic Simulation Models

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Introduction

• Types of economic simulation models
• Equilibrium concepts in economic simulation models
• Equilibrium and simulation
  • an example from thermodynamics: Boyles’ Law
  • Partial and general market equilibrium models: PE and CGE
  • Agent based (microsimulation) models
  • DSGE models
• Macro/CGE models
Typology of Economic Simulation Models: Domain

• Domain of Applicability

• Analytic—Stylized Numerical—Applied
  • Stylized: “putting numbers to theory,” narrow domain of applicability
  • Applied: more institutional detail, larger, broader domain of applicability
  • Principle of Occam’s Razor: Simplest model adequate to the task
  • Einstein: Everything should be made as simple as possible, but not simpler

• “Descriptive” models: “realistic”, principle of “similarity” to reality
  • Validation: specification, parameters, empirical results, econometrics
  • Valid/descriptive for a particular domain of application
Typology of Economic Models: Structure

• Deep structural—shallow structural—reduced form

• “Deep structural” models in economics
  • Specify agents, markets, institutions, signals, motivation, and behavior

• “Shallow structural” or “reduced form” models
  • Vague theoretical specification of relationships among variables
  • Unidentified/unidentifiable underlying structural model
  • E.g., supply/demand curves instead of specifying producer/consumer behavior explicitly: partial equilibrium (PE) versus CGE models
  • E.g., reduced form econometric models
Typology of Economic Models: Aggregation

- Global, national, regional, household simulation models
- “Representative” (aggregate) agents versus microsim/agent-based
- “Markets” specified and/or simulated in the model
  - Commodity markets and factor markets
  - National and/or international markets
    - More disaggregated: e.g., within-household “prices”
  - Market “equilibrium”: descriptive quantities and prices?
    - “market” prices and/or “shadow” prices
- Partial equilibrium (PE) versus general equilibrium (CGE): scope
Notions of Equilibrium

• Flow equilibria
  • Many product and factor markets
  • Macro flows: G-T, S-I, M-E

• Asset markets: equilibrium stock holding, financial markets
  • Not common in CGE models

• Intertemporal equilibrium: expectations
  • Dynamic recursive models ("adaptive" expectations)
  • Forward-looking agents (neoclassical growth models)
  • Rational expectations
Equilibria: Market Simulation

• Equilibrium conditions: agents and markets
  • Profit maximizing producers: supply side
  • Utility maximizing consumers: demand side
  • Commodity markets “clear”: supply = demand
  • Factor markets “clear”: various “closures”

• These equilibria are “descriptive” in that they provide empirically “reasonable” or verifiable results
  • Can validate for model’s domain of applicability
  • Reflect basic supply/demand behavior
Descriptive Equilibria

• Use of equilibrium concepts greatly simplifies model specification and, often, solution
  • Enhances model clarity and transparency: model behavior consistent with economic theory
  • Facilitates validation: “predictable” empirical results from “shocks”

• Compare with “System Dynamics” models that specify “rules of motion” but no equilibrium—very hard to tell what is going on or to validate the model
  • Models written as difference equations, but no validation of behavior
Descriptive Equilibria

• Equilibrium concept: very powerful in a model
  • Describes the results of a process that need not be specified in the model
    • Need not describe or specify disequilibrium behavior. Need only solve for equilibrium.
    • Need not discuss how individual agents interact to achieve equilibrium
  • “Descriptive” if it can be validated empirically for the domain of applicability of the model
    • Behavioral, theoretical, and statistical validation

• Compare to thermodynamics: Boyle’s Law on temperature and pressure of a gas
Boyles’ Law and Combined Gas Law

• Boyle: $PV = k$ where $P$ is pressure, $V$ is volume, and $k$ is a constant that depends on temperature and the amount and nature of the gas
  • Experimental result
• Combined: $PV/T = k$ where $T$ is the temperature (in Kelvins). The constant has units of energy divided by temperature.
• Thermodynamics and steam engines
Equilibrium: Combined Gas Law

- $P = kT/V$ is an equilibrium condition describing the amount of “work” (pressure) resulting from the application of heat (temperature) to a gas in a cylinder ($V$).
  - A “descriptive” empirical equilibrium condition—validated empirically
- If you are interested in building a steam engine or air conditioner, this equilibrium relationship is very useful.
- No need to understand “how” the equilibrium is reached, or how the system behaves “out of equilibrium”, e.g., what happens as you add heat.
- No need to understand what is going on between the gas molecules in the cylinder. Indeed, no need for any description of “molecules” or a molecular theory of gases.
Micro Behavior: Molecular Theory of Gases

• Bernoulli derived Boyle’s Law in 1737-1738 using Newton's laws of motion with application on a molecular level for an “ideal” gas.
  • “Molecules” behave like tiny billiard balls, with no loss of energy when they collide.
  • Ignored at the time because there was no observation of “molecules”. No interest in the kinetic theory of gases, which was controversial until the mid-19th century.

• Non-equilibrium thermodynamics. Interest in the behavior of the system as it moves from one equilibrium to another (e.g., add heat)
  • Very difficult to handle mathematically, involving rates of change (“dynamics”)
  • Need to work at the molecular level. Very difficult to specify “descriptive” dynamic processes. Models are very “stylized”.
Thermodynamics: Agent Based Models

• Model the behavior of gas molecules as an agent based model system
  • Specify “rules of engagement” as ideal gas molecules are heated and collide with one another
  • Able to simulate the equilibrium results of the combined gas law, which requires specification of the “shape” of the molecules
  • Ideal gas is a robust specification—works for most actual gases for a reasonably wide domain of application. Can be weakened, if useful.

• Experiments with different numbers of “agent” molecules
  • Works well with relatively few “representative” molecules: 100.
Thermodynamic Agent Based Models: Lessons

• Validation of agent based model: it has to achieve thermodynamic equilibrium specified by the combined gas laws
  • Led to improvement of the agent based model
• Equilibrium result supports analysis of how many “representative” agents are needed for a good “descriptive” model, important for specifying and using “stylized” models
• Separate validation is needed to determine if the domain of application of the agent based model includes disequilibrium behavior of the system
Agent Based CGE Model

• Herb Gintis: “The Dynamics of General Equilibrium” (EJ, 2007)
  • Agent based CGE model to describe the “process” of achieving a market equilibrium, and applied to famous Scarf example of odd GE behavior
  • Agents have a simple “learning” procedure and also require “money” for transactions (cash-in-advance model)
  • Models successfully solves for market equilibrium

• Is his agent based model descriptive, or is it a solution algorithm?
  • Important research for agent based models: implications for model specification and validation for disequilibrium adjustment behavior
  • Behavior specification and number of representative “agents” are crucial
Equilibria: Forward-Looking Dynamic CGE Models

• Neoclassical growth models—variants of the Ramsey model
  • Households maximize discounted utility
  • Producers maximize present value of discounted profits (the “value” of the firm)
  • All agents have perfect foresight
  • Models specified to have steady-state solutions

• In terms of typology, these are very stylized numerical models
  • Specification is strongly influenced by available math methods

• Provide core theory of DSGE models
Equilibria: DSGE/ Macro Models

• DSGE: neoclassical growth models, but subject to random shocks: e.g., productivity in Real Business Cycle (RBC) models
  • Agents assumed to know long-run trend steady state solution and adjust quickly to shocks
  • Models generate cycles that have been interpreted as business cycles
• Macro models: rational expectations (Lucas, Sargent, Prescott)
  • No involuntary unemployment
• Very stylized models with limited domain of applicability
  • Well within the neoclassical paradigm
Descriptive Dynamic Equilibria

• Are Ramsey/DSGE/rational expectations model equilibria “descriptive”? Specification of agent behavior is not “realistic”.
  • Signals agents see: perfect foresight
  • Agents borrow only for intertemporal smoothing
    • No uncertainty. No “precautionary” savings motive.
  • Ability to adjust easily: no borrowing constraints
  • Unemployment only because of distortions in labor/leisure choices by agents
  • Realism of assumption of steady state growth paths

• Weak econometric support for these assumptions and models yield unrealistic macro results
DSGE Models

• Kehoe and Prescott, *Great Depressions of the Twentieth Century*.
• Blurb by Thomas Sargent: “Studying this book is an excellent way to learn about how to apply and adapt the optimal growth model to understand the most disturbing of macroeconomic events of the twentieth century, great depressions. The book bristles with intriguing stories, creative ways of expressing them in terms of dynamic equilibrium models, and ambitious attempts to compare them with data.”
• Is “compare them with data” the same as “validation”? Are they descriptive models? Very stylized models.
Macroeconomic Models: Keynes and Others

• Short to medium-run focus: widen the domain of applicability

• Want to analyze macro “shocks”:
  • Asian and other financial crises
  • Structural adjustment programs
  • Impact of IMF stabilization programs

• Factors can be unemployed: various markets do not “clear”, especially factor markets
  • DSGE specification: distortions in labor-leisure choice of workers—no “involuntary” unemployment
  • Involuntary unemployment is at the core of any Keynesian model
“Financial” CGE Models

• Links between financial and real sides of the economy.
  • Non-neutrality of money: nominal rigidities.
  • Inflation matters

• Serious stretching of the Walrasian paradigm
  • No money, no assets in neoclassical GE or CGE models
  • Keynes versus neoclassical general equilibrium theory
  • Difficult to introduce in DSGE models, but there are attempts
“Financial” CGE Models

• CGE model as the core “supply side” in a broader financial macro model

• Need to have many sectors in order to analyze issues of structural adjustment and trade shocks
  • Exchange rate and trade balance shocks
  • International price shocks (e.g., Oil)

• Different modeling philosophies in the same neoclassical theoretical framework
  • Implicit in DSGE models, which neglect the financial side
Orthodox School

• “There is only one Model, and its prophet is Walras”
• The Walrasian model is truth and should not be corrupted to analyze macro issues
  • Stick to relative prices, resource allocation, and full employment in the long run
• Yale: Srinivasan, Kehoe, Whalley
• Schizophrenia with DSGE models: neoclassical growth model with a few features to incorporate macro concerns
Eclectic School

• Integrate financial variables and asset markets into neoclassical Walrasian CGE model. Draw from all schools

• State of the art in CGE models:
  • Bourguignon, Branson, and de Melo
  • McKibbin-Sachs and McKibbin-Wilcoxen
  • Agénor (World Bank, Manchester)
  • All incorporate a standard CGE model (e.g., the 1-2-3 model) to specify the supply side of a macro model
Ecumenical School: A Modular Approach

• “Render unto Walras the things which are Walras’, and unto Keynes the things which are Keynes’.”

• Separate real and financial models, CGE and macro models
  • Specify each model in its own theoretical framework

• The issue is to link the models
  • Variables exogenous in one model are endogenous in the other
  • Need to have the CGE model incorporate the results of the macro model
Ecumenical School: A Modular Approach

• Build two models: A modular approach
  • CGE supply-side model
  • Macroeconomic model

• Formally link the models:
  • Robinson/Tyson.
  • Dixon et al.

• Clean division between the models
  • Links to force consistency between macro and CGE models
Ecumenical School

• Problems.
  • Same agents in both models doing very different things:
    • E.g., savings as flow equilibrium versus asset allocation equilibrium
  • Some variables jointly determined, with potential conflicts (e.g., exchange rate)
• Schizophrenia shared by literature on micro foundations of macro.
  • Still no fundamental reconciliation
Macro Closure Approach: Implement Modularity

• Tell the macro story outside the CGE model.
  • Explicit macro-econometric model
  • Macro “story”: informal specification of a macro model
• Impose the results on the CGE model.
  • No money, assets, or financial variables in the CGE model.
• Define “macro closure” rules to ensure macro flow equilibrium in the CGE model
Macro Closure: Modular Approach

• Closure to achieve:
  • S-I balance
  • G-T balance
  • E-M balance

• Major link between external macro model and a CGE model: loanable funds market
  • Convert financial markets (assets, money) in the macro model into a “shock” on the flow equilibrium in the loanable funds market in the CGE model
Macro Closure

• Heated debates in the 1970s
  • Structuralist
  • Neoclassical
  • Johansen
  • Keynesian
  • Kaldorian
  • Orani
Full Employment Closures

• “Compositional” macro.
• Closure rule affects macro aggregates (C, I, G, E, and M), but not aggregate GDP.
• Factor markets clear, ensuring full employment and essentially fixed GDP
• Minimal strain on the neoclassical paradigm, but inadequate for any Keynesian model
Unemployment Closures

• Links between demand aggregates and real supply (GDP)
• Must assume non-neoclassical factor markets
  • Must stretch the neoclassical paradigm for a Keynesian model
• Factor markets do not clear. Two common variants:
  • Firms on demand curve for labor
  • Firms not on demand curve for labor
• Introduce a “wage curve” into the CGE model
  • Reduced form, but strong empirical support
  • Unemployment equilibrium imposed: consistent with Keynesian view
Conclusion

• Concepts of equilibrium are crucial in economic simulation models
  • Issues of domain of applicability of different models

• Much work to be done
  • Validation of descriptive equilibrium specifications
  • Links between models at different levels of aggregation
    • Multisector CGE models and macro models: Keynes, CGE, DSGE
  • Agent based models should be consistent with market equilibrium models: discipline for agent based models
  • Specification and validation of agent based disequilibrium adjustment models