

Economic Modeling: Purpose, Practice, and Potential

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Is Economics a Science?

- ▶ Economics examines quantitative measurements of economic phenomena: prices, quantities, decisions
- ▶ Nearly universal paradigm: Economic actors make that choice which is “best” for “them” given what they “can do”
 - ▶ “them”: actor could be an individual, family, social group, etc.
 - ▶ “best”: some measure of actor preferences
 - ▶ “can do”: decisions are constrained by wealth, resources, information, ability, social custom, law, etc.

- ▶ Economics examines quantitative measurements of economic phenomena: prices, quantities, decisions
- ▶ Economists believe that there are empirical regularities that are explained by the “rational actor” paradigm
- ▶ Economists use many models, but know that “All models are false. Some are useful.”

Our Objectives Today

I will

- ▶ Describe the key elements of economics that distinguishes it from physics (broadly defined)
- ▶ Describe the kinds of mathematical problems that economics models lead to
- ▶ Give an overview of how economists deal with VVUQ
- ▶ Entertain with war stories
- ▶ Argue that economics is ripe for transformational change focused on the introduction of applied math methods, computational science tools, HPC and HTC, and is a fertile ground to apply VVUQ ideas

Todd: Give more mathematical detail about the mathematical structure of economics problems

Alan will cover some validation issues

Ben will discuss in greater detail

Key Fact: People are not Particles

People are not particles

- ▶ Economic agents are self-aware
- ▶ Economic agents make decisions today that use information and/or beliefs about the future.

Testable implication: Efficient Market Hypothesis

- ▶ Statement: No investor can consistently achieve returns in excess of average risk-adjusted market returns given the information available at the time the investment is made.
 - ▶ This is a statistical assertion only; “efficiency” means “statistical efficiency”, not economic efficiency
 - ▶ The “news” narrative is not necessary
- ▶ Statistical tests support EMH

Computable General Equilibrium

Equilibrium

- ▶ A set of prices, across goods and time, such that supply = demand
- ▶ Does not mean a rest state, nor thermal equilibrium

Mathematical nature

- ▶ Variational inequalities (more from Todd)
- ▶ Solution methods: Newton's method, SQP, Interior Point, Path (Todd will talk more about this)

Dynamic Stochastic General Equilibrium

Stochastic elements

- ▶ Recurring shocks to productivity: rainfall, earthquakes, climate
- ▶ Random events: inventions, wars

Dynamic problems:

- ▶ Physics: initial value problems
- ▶ Economics: two-point boundary value problems - maximize dynamic criterion (e.g., PV of profits) subject to initial asset level and terminal requirement to be solvent.
- ▶ Economics challenges:
 - ▶ Problems are high dimensional
 - ▶ Solutions are often smooth: usual are solutions to parabolic systems (such as Black-Scholes)
 - ▶ Presents different combinations of numerical needs

Mathematical nature

- ▶ The unknown: a function, $h(x)$, mapping current state of the world, x , to prices and decisions
- ▶ Formulation of equilibrium law: $F(h)=0$, where F is a mapping between function spaces

Solution methods:

- ▶ Find h to minimize norm of $F(h)$
- ▶ Collocation: approximate h in some space of orthogonal functions, choose collocation points, solve for coefficients of representation
- ▶ Galerkin: use enough projections to fix coefficients

Common forms

- ▶ $V = TV$, where T is a contraction map in L-infinity
- ▶ $G(x, h(x), h(h(x))) = 0$
- ▶ $G(x, h(x), h(h(x)), \epsilon h'(h(x)), \epsilon) = 0$

Example: portfolio management

- ▶ Let $V(x)$ be the expected utility of optimal management if current portfolio is x
- ▶ Use Bellman formulation of dynamic programming in discrete time
- ▶ $V(x)$ can be solved exploiting contraction map properties

Uses of Models

Policy analysis example:

- ▶ In 1984, CEA Chairman Feldstein predicted that high deficits would raise interest rates and reduce investment.
 - ▶ Based on a 1980 paper (Feldstein and Horioka), using a statistical non-economic model
 - ▶ Concluded that foreigners would not finance the deficits.
- ▶ Dynamic stochastic general equilibrium models: foreign capital inflows would finance the deficits.
- ▶ DSGE was correct.
 - ▶ FH relied on correlations between savings and investment in trivial models
 - ▶ FH extrapolated from history to an unusual event.
 - ▶ DSGE was an economics model; IF you have the structure correctly modeled you can predict outside of historical events.

UQ in Economics

Seldom done

The methods discussed earlier this week are all applicable

I always advocate response surface approximation to avoid arguments over pdfs

I use methods from approximation theory, not statistics – not an important point in this presentation

Economics needs UQ-squared

People are not particles

- ▶ The economic actors know they live in an uncertain environment
- ▶ They also have UQ problems

Scientific examination of economic behavior needs to say something about how individual actors deal with uncertainty

- ▶ Bayesian model averaging: Brock
- ▶ Robust Decisionmaking: Hansen and Sargent; applies and extends Hinfinity control

Policymakers face UQ problems for their decisionmaking as well as understanding UQ methods used by actors

Validation in Economics

Validation: Statistical Methods

- ▶ Form a model with unknown coefficients/parameters; some are economics model based, some not
- ▶ Collect data: essentially all data is observational; no one gives economics money for serious experiments
- ▶ Use statistics - maximum likelihood, method of moments, linear and nonlinear regression, seminonparametric methods, Bayesian method - to estimate unknown coefficients/parameters
- ▶ More from Ben and Alan

Verification in Economics - I

Verification of code is rare and undervalued

Well-known example

- ▶ Feldstein (1974): Social Security substantially reduces total saving
- ▶ Replication efforts corrected a code error; all results disappear
- ▶ Feldstein changed definition of variables and magically.... all the old results reappeared
- ▶ Regression fishing?

Verification in Economics - II

Possible and easy to check quality of numerical solution

- ▶ Economics problems can be formulated as zeros, $F(x)=0$, of some continuous operator between Banach spaces.
 - ▶ Can always report $F(x)$ for approximate solution x .
 - ▶ Collocation check: Evaluate operator at non-collocation points.
- ▶ Method of Manufactured Solutions
 - ▶ Economists are excellent at their version of MMS
 - ▶ I can't think of an example in economics where the Oberkampf version could not be applied

Current Attitudes: Transparency

EPPA, a DOE-funded project at MIT

- ▶ To Prof. Reilly: I recently saw your paper "Indirect Emissions from Biofuels" in the December 4, 2009, issue of Science. . . . Could you send me the system of equations you solved in the CGE modeling in the paper?
- ▶ Reply: Modern CGE analysis uses software that doesn't require one to explicitly write down all equations—that is a good exercise for graduate students, but an unnecessary burden in applied work.
- ▶ Outcome:
 - ▶ After six months of email argument (no support from economists at MIT), I contacted the Chair of their External Advisory Board.
 - ▶ Two weeks later, I got the code and "Any time you are in Cambridge, please stop by and say hi."
 - ▶ The code was put online at their MIT energy project website last February.

EPA Climate Projects

- ▶ Supports IGEM (\$2.5 million for 2010-14) and ADAGE (??) but says they cannot force them to reveal models.
- ▶ IGEM was asked if it could add stochastic shocks to economic model.
- ▶ Response: “this is beyond the scientific frontier”.
- ▶ Fact, they could easily apply Fleming (1971) “small noise” analysis, as is done currently by mathematical economists.

American Economic Association

- ▶ I asked if the AEA would take a stand on transparency issues
- ▶ “The AEA executive committee is very unlikely to be willing to take a stand on policy issues, even those relating to disclosing research done at public expense, on behalf of the membership. There is some language in the AEA’s constitution that forbids it.”

Conclusion

Economic models fit into standard computational and mathematical frameworks

- ▶ Models can be defined in terms of relatively well-behaved operators on Banach spaces
- ▶ Can easily exploit modern supercomputing architectures

Current practice is abysmal

- ▶ Current economic modeling is done on laptops
- ▶ Current economists know little numerical analysis

A sustained effort, using VVUQ themes, can change the status quo.

- ▶ The young economists have some access to serious training in numerical methods
- ▶ Young economists want to do this
- ▶ There is a growing network of economists and computational scientists who want to change current practice
- ▶ Using modern software and hardware, we could do 10,000 times better than status quo