SimFinMkts: A Possible Tool for Financial Markets Research

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Modern Computational Tools are Ignored in Macro

Macroeconomists oppose the use of modern computational tools

1. "We can't get computational resources"
2. "Economics does not need them"
3. "We do not have the mental abilities to use them, and neither do you"
4. "Sensitivity analysis just confuses us"
5. "Readers of economics journals do not want papers written for smart people"

Modern Computational Tools Can Be Useful in Macro

I will present facts that push back on points 1, 2, and 3. (Points 4 and 5 are just descriptions of today's reality.)

- Everyone else is using modern, powerful computational methods.
- Many complex problems need computer power orders of magnitude than what is used in economics
- The US Government spends billions of dollars each year developing computational resources
  - A gold mine of software at Argonne that would benefit economics
    - DOE was hostile to economists using their machines
    - DOE says otherwise now, but no economists with the necessary resources want to push DOE on the issue
  - The NSF is happy to have social scientists use their supercomputers and clusters
- There are many free computational resources not used by economists

Computation Matters: Tacoma Narrows, 1940

Tacoma Narrows bridge becomes unstable in the wind. Why? The engineers used linearization to analyze stability.

Almost Everyone is Using High-Power Computing

Friends at my wife's church

Two personal acquaintances use modern computational tools to model complex biological problems

- Markus Covert, Cell (2010), described in NYT:

  "The simulation, ... on a cluster of 128 computers, models the complete life span of the cell at the molecular level, charting the interactions of 28 categories of molecules — including DNA, RNA, proteins and metabolites."

- John Stephens, President and CEO of HeartFlow (2018):

  "HeartFlow creates a personalized, digital 3D model of the arteries. Powerful computer algorithms solve millions of complex equations to assess .. blockages [of] blood flow. The result is a color-coded map that [shows], vessel-by-vessel, if sufficient blood is reaching the heart."

US: National Stockpile Stewardship

- Objective: The US must have reliable nuclear weapons so that if the President decides to launch our nuclear missiles he can be sure that they will, in less than an hour, incinerate hundreds of millions of Russians, Chinese, Iranians, North Koreans,...
- Mandate: Use computational models to make sure that US nuclear weapons would work if used
- What are their computational challenges?
  - DOE: ".. nuclear weapon simulations must extrapolate far beyond available data and must predict coupled, multi–scale physical phenomena that are difficult to isolate in experiments"
  - Congress: "The Administrator for Nuclear Security shall develop and carry out a plan to develop exascale computing."
- They take their mandate seriously, and use ...

Sky Bridge (predecessor of Skynet?)

..

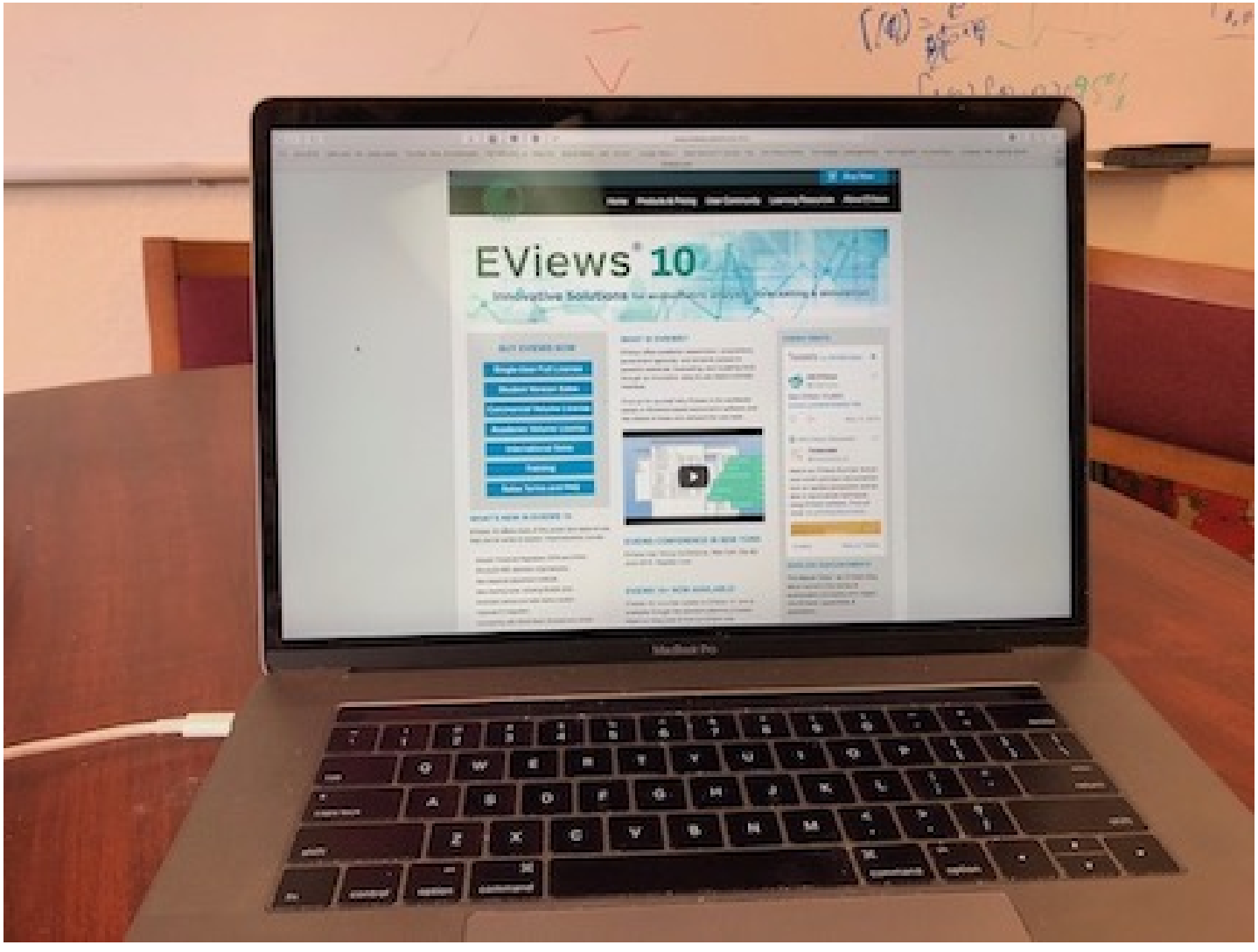
..

Sierra

..

US Federal Reserve

- Mandate:
  - Price stability
  - Full employment
- Other responsibilities include
  - Lender of last resort
  - Regulation of financial institutions; regulate systemic risk
- My view is similar to that of DOE and Congress regarding nuclear weapons
  - ".. economic policy simulations must extrapolate far beyond available data and must predict coupled, multi–scale social and economic phenomena that are difficult to isolate in experiments"
  - The complexity of economic problems make them appropriate for exascale computing."
- What computational tools does the Fed use?


EViews 10

Mismatch of Fed's ambitions and abilities

- The Federal Reserve wants to set the rules in the financial world.
- However, the Fed knows nothing about studying complex systems
  - Heartport speaks of solving millions of equations; the Fed calls a problem hard if it has hundreds of equations
  - Covert speaks of interactions among 28 different systems of a cell, many at different time scales; the Fed's models assume fewer interacting systems, acting at quarterly time steps
  - The Fed's models are done on laptops ... using EVIEWs
- Federal Reserve track record is not good
  - Before Great Recession, it deemed some derivatives as "safe"
  - Did not understand complexity
  - They were not safe

Typical Macro View: V. V. Chari

- Testified at a 2010 Congressional hearing on DSGE models
- *"Abstracting from irrelevant detail is essential given scarce computational resources,.."*
- *"...not to mention the limits of the human mind in absorbing detail!"*

Consensus on why Macro avoids computational tools

- Macroeconomists can't handle the math.
- People who can aren't welcomed in macro.

One Success: DSICE

Dynamic Stochastic Integration of Climate and Economy (DSICE)

- Includes uncertainty in both the future climate and economy
- Nine dimensions
  - Nordhaus' climate system, LRR productivity shocks, Tipping points
  - 600-year horizon
  - Time period: one year, results were the same down to two weeks.

Computational features

- Massive parallelism: 80,000 cores for six hours were used to solve one example
- 10% efficiency (which is good) and scalable up to 80,000 cores
- Verification – first time done in economics
- Uncertainty quantification (serious parameter sensitivity)

Solves difference equations in Banach spaces

- Describes most models is economics.
- Uses best available numerical methods for approximation, quadrature and optimization
- Easy to incorporate new methods

Recent paper of mine

- Cai, Judd-not-listed-as-author, and Lontzek (JPE, December, 2019)
- All software written in 2013

Our computer

Other Software Projects

- DPSOL, a general solver for DP problems
- Implement alternative assumptions on preferences
  - Risk-sensitive preferences
  - Robust decision making
  - Ambiguity
- Solve dynamic games
  - Supergame algorithm by Yeltekin-Cai-Judd
    - Find all Nash equilibria in games with states
    - Scalable up to 160,000 cores
    - Obvious candidate for asynchronous parallelization, and for exaflop machines
  - Compute all MPE in dynamic games

Other Software Projects

- DSGE models
  - Judd-Maliar-Maliar GSSA and EDS
    - Has been used on simple models with ~200 dimensions on a desktop
    - Clearly parallelizable
    - Obviously applicable to asymmetric information models, hidden state problems
  - Perturbation methods
  - NLCEQ method
    - Dominates log-linearization since it is a global method
    - Parallelizable
- Solving polynomials
  - Homotopy methods for polynomials
  - Groebner bases for polynomial equations
- Applications
  - Dynamic tax policy (with Yeltekin, Mueller)
    - Barro's random walk theory is wrong
    - Sargent's 2002 JPE paper is a computational atrocity
  - Optimal life cycle tax policy with borrowing costs and constraints (with Rangel, Mueller)
  - Computing likelihood level sets (with Reich)
  - Solving for time consistent solutions

Radical Idea: Do what Astrophysicists Do

Flash

- Economics and Astrophysics are similar
  - Experiments are very difficult
  - Must use observations to build models
  - Must use computational tools to validate the models
- Flash
  - Developed at UChicago and Argonne
  - Can simulate many kinds of stars, particularly ones that blow up
  - Open to all researchers

My Proposal: SimFinMkts

- Use the algorithms we have and computer power we could have to solve for equilibria of realistic financial markets
  - Specify a combination of multiple sectors, agent types, heterogenous beliefs, bounded rationality, etc.
  - Specify parameters and use DPSOL, GSSA, EDS, NLCEQ, FEniCS, PETSc, COMSOL, LS-DYNA, Trilinos, APPSPACK, POUNDERS, BORG, etc to solve the model
- Applications
  - Generate synthetic data
  - Apply your simple models and empirical methods to the synthetic data
  - Determine if your simplifications (models, approximations, empirical methods) can produce correct insights about the true, complex model.

My Proposal: SimFinMkts

- Purpose – "Dimension Reduction"
  - It would be infeasible for each researcher to solve a large model and incorporate it into their theoretical or empirical analysis.
  - However, researchers should limit themselves to methods that we know can reliably analyze models that are far more complex and realistic.
  - Parsimony may be a virtue for standard economic research papers but only reliable parsimonious models.
  - Which parsimonious models should be used can be determined by testing them against data generated by a range of complex models that are far more realistic
  - This is done in climate work, including in Nordhaus' first papers.

My Proposal: SimFinMkts

- More generally, we need computational frameworks that allow for exploration of alternative specifications in a nested manner.
- Conjecture: Its nickname will be "Death Star" because it will show that commonly-used methods in economics cannot be trusted.

My responses to the opposition

Nordhaus

Nordhaus (President of AEA, Provost of Yale)

- "*We need to recognize that most economists and environmental scientists are amateurs at software design and architecture*."
  - I agree. In DICE2010, Nordhaus assumed that CO2 emitted 10 years from now would cause warming...NOW.
- "*We should restrain the urge to develop ever larger and more complex computational models unless there is a clear case that they will improve our understanding*."
  - How can we know which models are useful without solving them?
- "*The large systems are clearly not as versatile as personal computers.*"
  - Yes, no email, facebook, instagram, iTunes .... porn .....
- *"The price of supercomputing is generally unfavorable relative to personal computers."*
  - Supercomputers and advanced software expands what is *possible!* The issue is *not* cost, but the benefits relative to the costs. Macroeconomists do not think that serious computational analysis in economics is worth the cost. They prefer spending millions of dollars on more of the same.

Responses to "weak IQ" guy

- *You ask the question: 'What binding resource constraint prevents you from examining less simplified models?' In my case it's IQ.*
  - I applaud his honesty.
- *If I don't understand the economics of a model and what makes it tick, the model is useless, at least to me. For example I'm pretty sure I would find it very hard to understand the economics of a two hundred sector model.*
  - The world is much more complex than a 200-sector model.
    - How do you propose to understand reality? with two-sector models?
    - It would be far better to build 200-sector models, explore ways that will allow you to understand them, and then use reliable methods to analyze the real world.
- *The 'we' is my sense of mainstream macro people. ...*
  - I am grateful he did not include me or my collaborators in that set! Why not expand the set of people who are allowed to do mainstream macro to include people who are not so IQ-challenged.

Response to V. V. Chari

- *[A model is an] ".. abstraction which incorporates features of the real world thought important to answer the policy question ... and leaves out details unlikely to affect the answer much."*
  - Question: How do you know, before you do the analysis, which details are not important? do you have "perfect foresight"? If so, then you knew what my response was going to be?
- Chari: *"Abstracting from irrelevant detail is essential given scarce computational resources,.."*
  - Economics was not constrained by resources in 2010
    - Cai and Judd were using high-power computing in Cai's 2008 thesis
    - A $6M NSF grant in 2010 promised to extend the Cai and Judd work to supercomputers
    - I have used millions of core hours in the past several years. How much have you used? macroeconomists in general?
    - Fact: Work by Cai, Judd, L. Maliar, S. Maliar, Brumm, Scheidegger, Kubler, Hazonhodjic, Kotlikoff, Yeltekin, Rangel, Mueller, Schmedders, Reich,... show that economics is NOT constrained by scarce computational resources.

- Chari: *"...not to mention the limits of the human mind in absorbing detail!"*
  - Oh, where do I begin?
    - In a conversation, I asked him "Which minds are you describing" He said nothing. He did not even exclude me from this set of pathetic minds.
    - Fact: Work by Cai, Judd, L. Maliar, S. Maliar, Brumm, Scheidegger, Kubler, Hazonhodjic, Kotlikoff, Yeltekin, Rangel, Mueller, Schmedders, Reich,... show that economics is NOT constrained by limits of the human mind.
    - Perhaps macro should encourage people with minds that are better at absorbing detail to become economists.

Conclusions

- The "leaders" of macroeconomics are hostile to the development and deployment of computational tools, grabbing funding you have raised for this work and using their control of top journals to squash criticism
- We could use currently available computing power and methods to dramatically alter economic analysis.
  - Evaluate the performance of empirical methods
  - Do far better analysis of the impact of economic policies
  - Incorporate heterogeneity of many kinds in economic modeling
- The problem is not brain power or computing power – it is the tyrannical power of the incumbents.
- Tools like SimFinMkts can help direct economic research in useful and reliable directions