When Will the Fed Join the Third Millennium?

Kenneth L. Judd

October 5, 2020

Computation Matters: Tacoma Narrows, 1940

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

Computation Matters: Designing the Bomb

- Germany: August 6, 1945, dinner at Farm Hall in England:
  - The use of an atomic bomb was announced to the "guests"
  - Heisenberg: "I don't believe a word of it"
  - Hahn: "I didn't think it would be possible for another twenty years"
  - Their computations (~1940) argued that tons of U-235 was needed for one bomb.
- Japan (1940): Dr. Yoshio Nishina
  - Chaired Cmte. on Research in the Application of Nuclear Physics.
  - Concluded "it would probably be difficult even for the United States to realize the application of atomic power during the war."
- USA-UK
  - Einstein-Szilard letter (August 2,1939) to FDR warned of the possibility of atomic bombs. (Hoover colleague Ed Teller helped write the letter and drove Szilard to Einstein's summer home)
  - University of Birmingham, UK (1940): Frisch-Peierls memorandum argued that 10 kg of U-235 would make a bomb, light enough for it to be dropped from a bomber.
  - Manhattan Project

Computation Matters: GPS and Desert Storm

- Assertion: John Cochrane says that the equations of General Relativity are "impenetrable"
- Fact: GR is a critical part of the math behind GPS
- Fact: GPS was a critical part of Desert Storm in 1991, saving thousands of coalition casualities
- My observation: Someone who calls the equations of GR "impenetrable" is saying nothing about GR, but says a lot about himself.

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: NOAA

- They are responsible for
  - Weather prediction
  - Modeling hurricanes
- They take this mandate seriously; spend $>$ \$25M per year on computers

US: National Stockpile Stewardship

- Mandate: Use computational models to make sure that US nuclear weapons would work if used
  - Same activity in Russia and China
  - Agreement in early 1990's that this was better than nuclear tests
- 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

..

High-Tech Finance

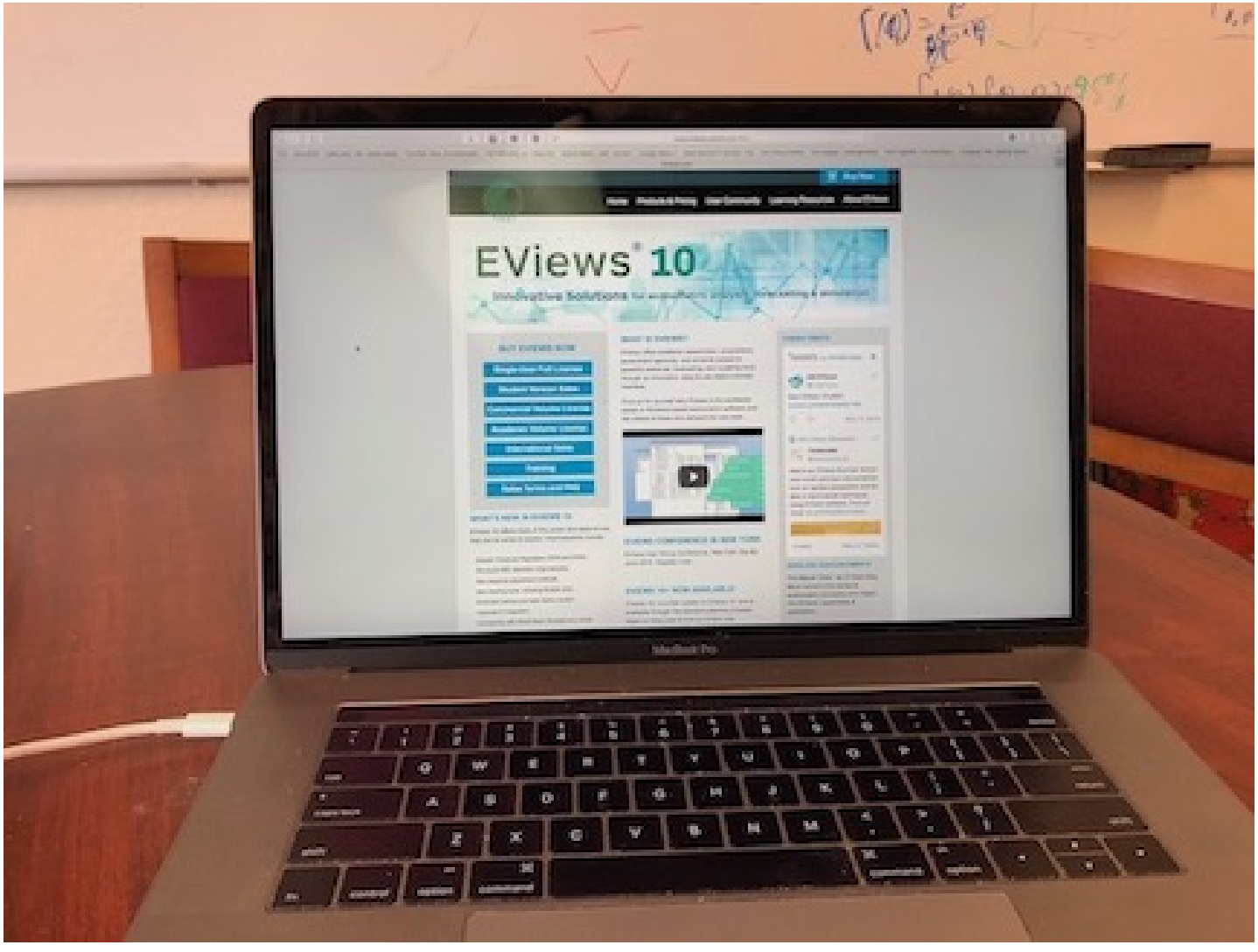
- Financial businesses are using modern computational methods and hardware
  - Option pricing
  - Financial product design
  - Data mining to learn credit-worthiness of borrowers
  - Generate information demanded by regulators
- Financial system complexity
  - Financial systems are complex, interconnected dynamical systems
  - Those interactions may lead to unstable financial markets even if all parties obey the rules
- Everybody wants a stable financial system
  - Borrowers want reliable access to credit markets
  - Lenders want to reduce risk exposure
  - Some may have benefited from a past financial collapse, but nobody wants a system where collapses will be common.

What is the Role of Government?

- Governments make financial markets possible
  - Contract law defines property rights
  - Courts enforce contract law
- Government regulators set the rules
  - Set capital requirements
  - Decides which assets they consider safe
- Government regulators rely on economic analyses
  - Rely somewhat on academic research
  - Regulators also do their own analyses
- Question: How do we analyze the economic impact of possible regulations of the hi-tech financial sector?
- Answer: "Mechanism Design", that is, choose the rules of the game so that the outcomes are good.

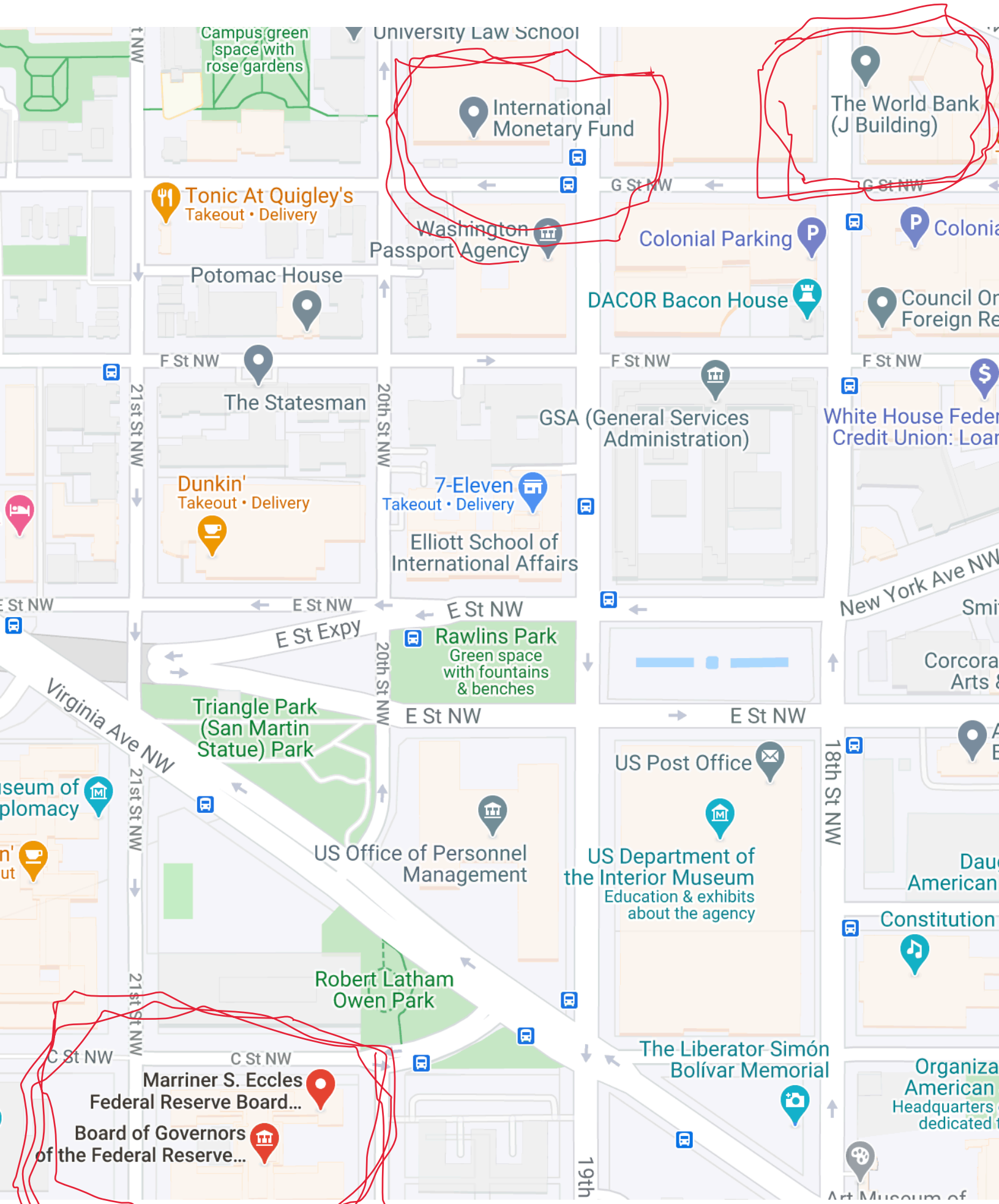
US Federal Reserve

- 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

FRB/US uses Fed's code

- FRB/US created in 1996.
- Wrote nonlinear equation solver and coded it in EViews
  - Why EViews? Because you could solve the problem and plot diagrams with the same software
  - What algorithm? 20-year old method
  - Who wrote code? A Fed guy (in-house)
- What do others use
  - World Bank: GAMS came out of World Bank general equilibrium modeling in the 1970's. It always has the state-of-the-art solvers
  - IMF uses TROLL and other multi-sector, multi-country models
- Why write your own code when far better code is available, and used by many economists?


Campus green space with rose gardens
University Law School
International Monetary Fund
The World Bank (J Building)
Tonic At Quigley's
Takeout • Delivery
G St NW
Washington Passport Agency
Colonial Parking
Potomac House
DACOR Bacon House
F St NW
The Statesman
21st St NW
20th St NW
GSA (General Services Administration)
White House Federal Credit Union: Loan
Dunkin'
Takeout • Delivery
7-Eleven
Takeout • Delivery
Elliott School of International Affairs
E St NW
New York Ave NW
E St Expy
Rawlins Park
Green space with fountains & benches
Virginia Ave NW
Triangle Park (San Martin Statue) Park
US Post Office
18th St NW
US Office of Personnel Management
US Department of the Interior Museum
Education & exhibits about the agency
Constitution
Robert Latham Owen Park
C St NW
Marriner S. Eccles Federal Reserve Board...
Board of Governors of the Federal Reserve...
The Liberator Simón Bolívar Memorial
19th

Two Practical Algorithms for Solving Rational Expectations Models

Flint Brayton

2011-44

Flint Brayton
Federal Reserve Board
October 11, 2011

Abstract

This paper describes the E-Newton and E-QNewton algorithms for solving rational expectations (RE) models. Both algorithms treat a model's RE terms as exogenous variables whose values are iteratively updated until they (hopefully) satisfy the RE requirement. In E-Newton, the updates are based on Newton's method; E-QNewton uses an efficient form of Broyden's quasi-Newton method. The paper shows that the algorithms are reliable, fast enough for practical use on a mid-range PC, and simple enough that their implementation does not require highly specialized software. The evaluation of the algorithms is based on experiments with three well-known macro models—the Smets-Wouters (SW) model, EDO, and FRB/US—using code written in EViews, a general-purpose, easy-to-use software package. The models are either linear (SW and EDO) or mildly nonlinear (FRB/US). A test of the robustness of the algorithms in the presence of substantial nonlinearity is based on modified versions of each model that include a smoothed form of the constraint that the short-term interest rate cannot fall below zero. In two single-simulation experiments with the standard and modified versions of the models, E-QNewton is found to be faster than E-Newton, except for solutions of small-to-medium sized linear models. In a multi-simulation experiment using the standard versions of the models, E-Newton dominates E-QNewton.

Some in the Fed System Recognize Problems

Have We Underestimated the Likelihood and Severity of Zero Lower Bound Events?

Hess Chung
Federal Reserve Board of Governors

Jean-Philippe Laforte
Federal Reserve Board of Governors

David Reifschneider
Federal Reserve Board of Governors

John C. Williams
Federal Reserve Bank of San Francisco

January 2011

Working Paper 2011-01
http://www.frbsf.org/publications/economics/papers/2011/wp11-01bk.pdf

Abstract

Before the recent recession, the consensus among researchers was that the zero lower bound (ZLB) probably would not pose a significant problem for monetary policy as long as a central bank aimed for an inflation rate of about 2 percent; some have even argued that an appreciably lower target inflation rate would pose no problems. This paper reexamines this consensus in the wake of the financial crisis, which has seen policy rates at their effective lower bound for more than two years in the United States and Japan and near zero in many other countries. We conduct our analysis using a set of structural and time series statistical models. We find that the decline in economic activity and interest rates in the United States has generally been well outside forecast confidence bands of many empirical macroeconomic models. In contrast, the decline in inflation has been less surprising. We identify a number of factors that help to account for the degree to which models were surprised by recent events. First, uncertainty about model parameters and latent variables, which were typically ignored in past research, significantly increases the probability of hitting the ZLB. Second, models that are based primarily on the Great Moderation period severely understate the incidence and severity of ZLB events. Third, the propagation mechanisms and shocks embedded in standard DSGE models appear to be insufficient to generate sustained periods of policy being stuck at the ZLB, such as we now observe. We conclude that past estimates of the incidence and effects of the ZLB were too low and suggest a need for a general reexamination of the empirical adequacy of standard models. In addition to this statistical analysis, we show that the ZLB probably had a first-order impact on macroeconomic outcomes in the United States. Finally, we analyze the use of asset purchases as an alternative monetary policy tool when short-term interest rates are constrained by the ZLB, and find that the Federal Reserve's asset purchases have been effective at mitigating the economic costs of the ZLB. In particular, model simulations indicate that the past and projected expansion of the Federal Reserve's securities holdings since late 2008 will lower the unemployment rate, relative to what it would have been absent the purchases, by 1½ percentage points by 2012. In addition, we find that the asset purchases have probably prevented the U.S. economy from falling into deflation.

Policy Implication: Keep it Simple!

- 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 regulations on assets
  - Before Great Recession, it deemed some derivatives as "safe"
  - Did not understand complexity
  - They were not safe
- Policy must be as simple and robust as possible
  - Only really safe assets should be certified "safe"

Three Examples of Young Economic Policy Leaders

- Stanford students 20+ years ago; recently spoke with them
- Volker Wieland, Goethe U., one of Germany's five "Wise People"
  - Presented analysis of 2017 U.S. tax changes at 2018 conference
  - My comment: The US has multiple sectors and types of taxpayer, not just one
- John Williams, President of FRBNY (formerly FRBSF President)
  - Stated (2017 talk) that we need models combining monetary and tax policy analysis
  - My question: You are SF Fed Prez with $$$ for research. Why not build one at SF Fed?
  - Williams answer: Other things are more important.
- Bo Li, Former Director General, Monetary Policy Department, PBoC
  - Understands that tariffs on different goods have different impacts
  - Told me about serious modeling efforts at Tsingua University
- Conclusion: Short the US, bet on China

Sargent on languages.

- Sargent (#PyDataNYC): *"The kind of economics I like to do, if you can't write a #python program, you are a bulls*****r".*

- Response:
  - Aiyagari-Marcet-Sargent-Seppala (JPE 2002) used Fortran. The results were ########, but due to bad algorithm and bad math.
  - Cai and Judd use Fortran code of best available software. Math matters more than language.

Economists are far behind

- Opinion of an OR person who knows economists well: “Economists are so far behind that soon they will not be able to catch up”
- WHY?

One economist's opinion

I attended a talk of a Columbia University macroeconomist:

- He used a linearization procedure and found that the result included unit roots. He liked that.
  - I pointed out that if a linearization produces unit roots, you know nothing about the stability of the system
  - I referred him to papers by Benahbib in the late 1970's
- He started out by saying that macro models are very difficult to solve
  - I pointed out that he flew from NYC to SFO and the equations used to design his airplane were far more complex than any macro model
- I asked him what he is doing so that his students can solve models he cannot
  - He said he would tell them to talk with Benhabib (at NYU)
- I brushed this off as typical Ivy League behavior: send students to "lesser" universities to learn how to do difficult things.
- Richard Clarida is now Fed VP.

Another economist's opinion

I asked a prominent macroeconomist (affiliated with the Fed):

- ... *you assert "In practice we have to work with simplified models". In some sense, that is obviously true... Your comment applies to any quantitative analysis, even work in physics, chemistry, and engineering. However, I have the impression that you meant something far more substantive. ...you appear to excuse the infinitesimal complexity [that DSGE models] display. ... What binding resource constraint prevents you from examining less simplified models?*

His response:

- *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?
- *As you certainly know the issue is not comptuational in the sense of numerically solving the model. It's coming up with ways to figure out and communicate what's going on under the hood and deciding what is quantitatively significant.*
  - I agree, but these are reasons for more computation, not less.

- *I do think that there is a backlash among academics against people programming up really complicated DSGE models in DYNARE and hitting the solve button.*
  - I suppose you are against building a telescope and taking a look at Jupiter to see what is there, or building CERN and smashing protons to see what happens.

Typical (Official?) Macro View: V. V. Chari

- Testified at a 2010 Congressional hearing on DSGE models
- Models:
  - *".. 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 computational resources, even 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. The earlier two guys excluded me from the set of people lacking in mental abilities. Chari did not.
  - 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 better minds to become economists.

Initial Success: DSICE

Dynamic Stochastic Integration of Climate and Economy (DSICE)

- Incorporates modern decision theory
- Includes uncertainty in both the future climate and economy
- DSICE aims to be a flexible framework

Solves difference equations in Banach spaces

- Describes most models is economics
- Uses best available numerical methods; easy to incorporate new methods

Recent papers

- Cai, Judd, Lenton, Lontzek, and Narita; PNAS (2015)
- Lontzek, Cai, Judd, and Lenton; NCC (2015),
- Cai, Judd, and Lontzek; JPE (2019) (but all software done in 2013)

Our computer

Conclusions

- Supercomputing is widely used by the US and other governments
  - Important to forecast hurricanes
  - Mapping the Covid-19 is important
  - Important to be sure we can incinerate each other
- Economic policy groups use little computing power
  - Agencies, like the Fed, do not have an operational focus that directs research into important areas
  - The Fed makes no effort to educate their researchers (IMF is better)
- The main problem is the hostility towards high-power computing among academic economists.
- People at UT have a unique advantage: Stampede2. USE IT!