Complexity and Economics

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Why we should look elsewhere: Mankiw

• « The fact that modern macroeconomic research is not widely used in practical policymaking is prima facie evidence that it is of little use for this purpose. The research may have been successful as a matter of science, but it has not contributed significantly to macroeconomic engineering. »

Where does the difficulty come from?

• The economy is made up of individuals who interact directly.
• Such systems do not have aggregate behaviour which can be characterised as the average behaviour of the individuals
• The Gap between micro and macro is real!
“The ability to reduce everything to simple fundamental laws does not imply the ability to start from those laws and reconstruct the universe.

• In fact the more the elementary particle physicists tell us about the nature of the fundamental laws, the less relevance they seem to have to the very real problems of the rest of science much less to those of society...

• Instead, at each level of complexity entirely new properties appear and the understanding of the new behaviours requires research which I think is as fundamental in its nature as any other.”

• Phil Anderson “More is Different”, Science 1972
Frank Hahn (1925-2013)

• “In this respect, the signs are that the subject will return to its Marshallian affinities to biology. Evolutionary theories are beginning to flourish, and they are not the sort of theories we have had hitherto. In particular, biologists have always known that, say, the giraffe was not inevitable. There are many routes evolution could have taken even in stationary environments. But wildly complex systems need simulating. Interestingly enough, ideas from evolution are being applied to the learning (and behaviour) of the individual agent. There has been much interest in evolutionary algorithms which are designed for the computer. There are convergence theorems and there no doubt will be more and better ones. But while there will be work for the computer scientist, I very much doubt that economists will be able to establish general propositions in any but very special examples. Again, I do not judge - simulation, especially when based on good data, is a perfectly respectable and probably fruitful activity.”

• Frank Hahn The Next Hundred Years (1991)
So in summary your majesty, the failure to foresee the timing, extent and severity of the crisis ...was principally the failure of the collective imagination of many bright people to understand the risks to the systems as a whole. *Reply to the queen by the British Academy*
Equilibria in Financial Markets with Heterogeneous Agents

![Graph of DAX 30 index changes](image-url)
Equilibria in Financial Markets with Heterogeneous Agents

DAX 30

+321% 9000

+274% 8000

+228% 7000

+181% 6000

+134% 5000

+87% 4000

+40% 3000

-6% 2000

-53% 1000

05.94 11.96 05.99 11.01 05.04

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Systemic Threats

The systemic threats modern societies face are too complex to be eliminated, or even mitigated, using traditional approaches of economic modeling and risk assessment - these methods focus primarily upon making the current system more resilient to a specific and predictable threat, and are less capable of addressing the outcomes or uncertainties stemming from financial and economic interconnectivity.
As the complexity of modern societies and economies increases, systemic risk, vulnerabilities and uncertainty are equally on the rise. Policymakers will be increasingly challenged to understand complexity and to manage rising levels of risk under conditions of uncertainty in an interconnected, non-linear, systemic world.

Economic systems should be modeled and managed as complex adaptive systems using complex systems tools, such as agent-based modeling, system dynamics, or network science.
Deux approches

**L’approche standard**
- Nos modèles doivent avoir des fondements micro solides
- Lucas, dit que nous devons nous limiter à des hypothèses sur les individus
- Les individus satisfont des axiomes de rationalité des économistes
- Ils sont isolés et optimisent
- Ils comprennent le fonctionnement de l’économie dans laquelle ils se trouvent
- Le comportement agrégé correspond au comportement d’un individu « représentatif » rationnel

**L’économie comme système complexe**
- Les individus suivent des règles simples
- Ils s’adaptent à leur environnement.
- Ils ne sont pas irrationnels et n’agissent pas contre leurs propres intérêts
- Ils ont de l’information limitée et en grande partie locale
- Le comportement agrégé ne correspond pas a celui d’un individu
- C’est la coordination et non pas l’efficacité qui est le problème central de l’économie
The standard approach

• The economy converges automatically to an equilibrium or steady state and is only knocked off that path by exogenous shocks.

• Crises are rare events due to such shocks.
• La société s’auto organise vers un état socialement satisfaisant si les individus sont laissés libres de choisir ce qui est dans leur propre intérêt.

• “Ce n’est pas de la bienveillance du boucher, du brasseur ou du boulanger que nous attendons notre dîner, mais plutôt du soin qu’ils apportent à la recherche de leur propre intérêt. Nous ne nous en remettons pas à leur humanité, mais à leur égoïsme.”
La Main Invisible
Confidence in our theory

The “central problem of depression-prevention has been solved,” Robert Lucas 2003 presidential address to the American Economic Association.

Ben Bernanke on the « Great Moderation »

Our models functioned well during this period but would not any model have done so?

We need models to help us understand and deal with crises.
Crisis as Rare Events

• “With notably rare exceptions (2008, for example), the global “invisible hand” has created relatively stable exchange rates, interest rates, prices and wage rates.”

• Alan Greenspan, Former Chairman of the Federal Reserve Bank
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• “With notably rare exceptions, Alan Greenspan has been right about everything.”

• Comments on the blog Crooked Timber
Exogenous Macro Shocks?

• As Wilhem Buiter a former member of the Bank of England’s Monetary Policy Committee and now chief economist of Citigroup, says,

• « Those of us who worry about endogenous uncertainty arising from the interactions of boundedly rational market participants cannot but scratch our heads at the insistence of the mainline models that all uncertainty is exogenous and additive » Buiter (2009).

• Don’t worry about exogenous shocks we do not need them.

• All you need is Positive Feedback.
The trouble is not so much that macroeconomists say things which are inconsistent with the facts. The real trouble is that other economists do not care that the macroeconomists do not care that the macroeconomists do not care about the facts. An indifferent tolerance of obvious error is even more corrosive to science than committed advocacy of error.

Paul Romer (2016) *The Trouble with Macroeconomics*
The Economic Theory Ship is Unsinkable
But the band played on
An Important Example: Financial Market Models

• Models of financial markets share the same basic building blocks.
• Agents have a way of forecasting the future prices.
• This determines how much the agents’ wish to buy and this in turn determines the price of the assets.
• The prices will influence the forecasts.
• But does this process lead to equilibrium prices which reflect the “true value” of the assets?
The Efficient Markets Hypothesis

• This is very simple
• All relevant information is contained in prices therefore there is no need to look anywhere else: paradox
• This basic argument comes from the work of Bachelier but the referee for his thesis said...
A Warning

• « When people interact with each other they do not do so by acting independently on their own information they tend to watch each other and to behave like sheep. »

Henri Poincaré (Referee of Bachelier’s thesis) Science et Méthode 1904 p.49
Mencken cited by Krugman

• H. L. Mencken: “There is always an easy solution to every human problem — neat, plausible and wrong.”
No Panic!
Where does the efficient markets hypothesis go wrong?

• Remember Poincaré’s warning
• Individuals do not only look at their own information they also observe the actions of others and infer information from those actions.
Looking into the sky quickly gets passers-by to follow.
What is the problem with the Efficient Markets Hypothesis empirically?

- What we have to explain is sudden large movements without the arrival of an exogenous shock or piece of news.
Where do sudden switches in macroeconomic variables come from?

- Put them down to an exogenous shock, but then you must be able to identify the shock

- Find a simple model of interacting agents which generates this sort of shift
The Role of Banks
Before the Great Depression

• "The goose that lays golden eggs has been considered a most valuable possession. But even more profitable is the privilege of taking the golden eggs laid by somebody else's goose. The investment bankers and their associates now enjoy that privilege. They control the people through the people's own money.” Brandeis: Other People's Money and How the Bankers Use It, 1914
• What worried Brandeis was the concentration of so much corporate wealth in the hands of so few bankers.

• Industry and commerce was controlled by a few important business men aided and abetted by investment banks.

• The network of ownership at the time was very dense

• His book was reissued in 1933
• The derivatives genie is now well out of the bottle, and these instruments will almost certainly multiply in variety and number until some event makes their toxicity clear. Central banks and governments have so far found no effective way to control, or even monitor, the risks posed by these contracts. In my view, derivatives are financial weapons of mass destruction, carrying dangers that, while now latent, are potentially lethal.

• Warren Buffet 2002
“Hysteria seems especially out of place when people proclaim that the large losses triggered by derivatives could threaten the stability of the banking system. While enormous leverage and extraordinary potential losses from derivatives will continue to receive banner headlines, a number of international study groups have concluded that a spreading worldwide financial crisis caused by derivatives is highly unlikely. Speculators who take large risks will continue to risk ruin, and some financial institutions – even large ones – will continue to fail. But a systematic undermining of world financial stability caused by derivatives trading does not deserve to be on the top of anyone’s worry list.”

From: (2007) A Random Walk Down Wall Street, by Burton G. Malkiel, Professor of Finance, Princeton University
Easy Credit
Who was right?
A Very Simple Example

• What we must do is to build models which capture the role of the interaction between individuals, their local rationality and the impact of this on the aggregate evolution of the market or economy.

• The idea of our example is to show how the gradual but rational adoption of rules at the individual level may lead to radical change at the aggregate level.
HISTORICAL MOTIVATION

1. trading complex credit derivative products without really understanding what they’re worth

2. ... in the face of bad news accumulating ...

3. Crash!!!

Why so sharp?

THE MODEL: RULE EPIDEMICS

- The rule:
  buy an ABS without checking whether it is “toxic” or not

- **Strategy**: follow the rule \( z_i=1, i=1,...,N \) labels agents
  don’t, i.e. check before buying \( z_i=0 \)
  Idea: checking is costly, if majority follows the rule, then I better follow it too

- \( \text{Prob} \{\text{ABS is toxic when checked}\} = p \) (bad news: p larger than expected)

- **Agents** connected in a network (OTC market):
  i trades with j drawn at random among his neighbors

- **Payoffs**: pay a price \( p_0 \) to seller
  resell at \( p_2 < p_0 \) if buyer checks & ABS toxic
  resell at \( p_1 > p_0 \) else
  checking costs \( -\chi_i \) (drawn from pdf \( \Phi(\chi_i) \))

(reduce # params. by rescaling: \( p_1-p_2=1, c=p_0-p_2 \))

<table>
<thead>
<tr>
<th>( z_i )</th>
<th>check &amp; toxic</th>
<th>no check</th>
</tr>
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<tbody>
<tr>
<td>( z_i=0 )</td>
<td>-( \chi_i )</td>
<td>1-c -( \chi_i )</td>
</tr>
<tr>
<td>( z_i=1 )</td>
<td>-c</td>
<td>1-c</td>
</tr>
</tbody>
</table>

Presentation for NAEC Masterclass April 17th 2019
Analysis

Expected payoffs:
\[ u_i(z_i = 1) = E_j \left[-p(1 - z_j)c + [1 - p(1 - z_j)](1 - c)\right] \]
\[ = 1 - p(1 - \bar{z}_i) - c \]

\[ u_i(z_i = 0) = (1 - p)(1 - c) - \chi_i \]

\[ \bar{z}_i = \frac{1}{|N_i|} \sum_{j \in N_i} z_j \]

Best response:
\[ z^*_i = \theta \left(u_1(1) - u_i(0)\right) \]
\[ = \theta \left(p(\bar{z}_i - c) + \chi_i\right) \]

Nash equilibria?
**Mean Field Analysis**

- Regular random graph ($|N_i|=k$ for all $i$)

\[
\pi(\chi) \equiv P\{z_i^* = 1|\chi_i = \chi\}
= \sum_{\ell > (c-\chi/p)k} \binom{k}{\ell} \bar{\pi}^\ell (1 - \bar{\pi})^{k-\ell}
\]

- Taking expectation over $\chi_i \Rightarrow$ self-consistent equation

\[
\bar{\pi} = E[\chi_i > p(c - \bar{z}_i)]
= \sum_{\ell=0}^{k} \binom{k}{\ell} \bar{\pi}^\ell (1 - \bar{\pi})^{k-\ell} P\{\chi > p(c - \ell/k)\}
= F(\bar{\pi})
\]
The function $F(\pi)$

$p=0.1, 0.01, 0.005, 0.002, 0.0013, 0.001$

$\chi_i = 0.01$ for 80% of agents, 20% informed minority ($\chi_i=0$)

$k=11$ neighbors, $c=0.8$
Coexistence

$z_t = 1$ for all agents is always an equilibrium.

If $p$ is small enough it is the only equilibrium.

Exponential distribution of $\chi_i$ with $E[\chi_i]=0.01$, $k=11$ neighbors, $c=0.9$
Noisy best response

Logit: \( P\{z_i = 1\} \propto e^{B[u_i(1) - u_i(0)]} \)

z_i=1 state unstable for large p if response too noisy (B small)
Noisy best response

Logit: $P\{z_i = 1\} \propto e^{B[u_i(1) - u_i(0)]}$

z_i=1 state unstable for large $p$ if response too noisy (B small)

Back to ABS story:

increasing $p$ ...

... sharp transition!
Some problems that are difficult to handle in the standard framework
Heterogeneity

• This is one of the oldest problems in macro economics and we still don’t deal with it satisfactorily despite the HANK models or the even more limited TANK models

• Old ideas  Grandmont Hildenbrand, Chiappori

• Billette de Villemeur, Hildenbrand and Kneip

• These have not solved the problem.
“As physicians, we are ambivalent about heterogeneity in medicine. We actively suppress it—ignore it, tune it out—because doing so is crucial for establishing the efficacy of tests, drugs, and procedures. But heterogeneity is ubiquitous in complex systems, including all of biology and human society.... we recognize that suppressing it exacts a heavy price and struggle to take it into account”

Homogeneity and the Representative Agent
Problems with Analytical Models

• Complexity leads to computational irreducibility, where analytical methods fail. The economy cannot be modelled as a system in which individuals behave according to some axioms where their behaviour generates an “equilibrium” which can be solved.

• Having many heterogeneous agents can lead the system to be over-identified, so even if the tools of standard methods could be applied, the result will not be a closed system. There is not a unique solution.

• As a result, heterogeneous agent models move from deduction to simulation Romer’s (2016) critique of macroeconomics focuses on the problems of over-identification within the real economic system.
C’est qui que nous analysons?

• Homo Sapiens  
• Homo Oeconomicus
La Psychologie: Attention Sélective
Big Data and Social Media

• The Role of Social Media in popular uprisings

• Using big data differently: Case Studies against general statistics
A Recent Reminder
Political twittosphere Aug-Dec 2016
Figure 1. A picture of the political « Twittosphere politique » from August 2016 to February 2017. Each point is a Twitter account and a link indicates frequent retweets between two accounts. This figure shows 96,000 accounts and 357,000 links.
The Network strongly constrains diffusion
Spreading Fake News

Account spreading URLs from the decodex category “doubtful” (hot colors)
Trust

• There is widespread concern about the breakdown in trust in our societies.
• Many institutions which were based on trust have lost that foundation
• They have replaced trust with contracts
• More work for lawyers but is this an improvement?
Trust: The Hull Insurance Contract on the Titanic: Lloyds
The signatures
Morality

• « First, morality matters. As Prof Zingales argues, if those who go into finance are encouraged to believe they are entitled to do whatever they can get away with, trust will break down. It is very costly to police markets riddled with conflicts of interest and asymmetric information. We do not, by and large, police doctors in this way because we trust them. We need to be able to trust financiers in much the same way ».

• *Martin Wolf Financial Times*
Rational Expectations

• In a General Equilibrium model in which there is uncertainty, individuals will take their decisions in the light of what they expect to happen in the future.

• The only way therefore to define an equilibrium in such a model is to attribute expectations about the uncertainty in the economy to the individuals.

• But unless we know those expectations the exercise of showing the existence of an equilibrium is futile.

• The way out is to assume that firstly individuals have the same expectations and secondly that they are “correct” in the sense that they coincide with the “real” process generating the stochasticity in the economy.

• There are many criticisms of this notion and a lot of experimental evidence has been provided by Cars Hommes and his team.
A more modest view

• Ben Bernanke,

« I just think it is not realistic to think that human beings can fully anticipate all possible interactions and complex developments. The best approach for dealing with this uncertainty is to make sure that the system is fundamentally resilient and that we have as many fail-safes and back-up arrangements as possible »

Interview with the IHT May 17th 2010
Overall Conclusions

• Contrary to what is said in standard macroeconomic models aggregate behaviour is not like individual behaviour
• The organisation of interacting individuals generates aggregate structure
• We should distinguish between collective and individual rationality. Neither implies the other.
• How things come to be coordinated is what we need to explain
• We should shift to models in which collective behaviour emerges from the interaction rather than making an implausible jump from the individual to the aggregate.
A Related Book

Let a Thousand Flowers Bloom!