"MACROECONOMIC RISK"

SCOR-PSE CHAIR NEWSLETTER N°7

Following its first three years, **the "Macroeconomic Risk" SCOR-PSE Chair has been renewed until 2023.** Through its activities, the Chair aims to strengthen high level research and the dissemination of knowledge to generate **a better understanding of contemporary macroeconomics.**

The second annual lecture of the Chair was held online on April 28, 2020, with **Jesús Fernandez-Villaverde** (University of Pennsylvania) as special guest speaker. Following this lecture, we had the opportunity to interview him about his research. This newsletter also presents two **research papers**, on collateralization and asset price bubbles and on sovereign default.

CHAIR

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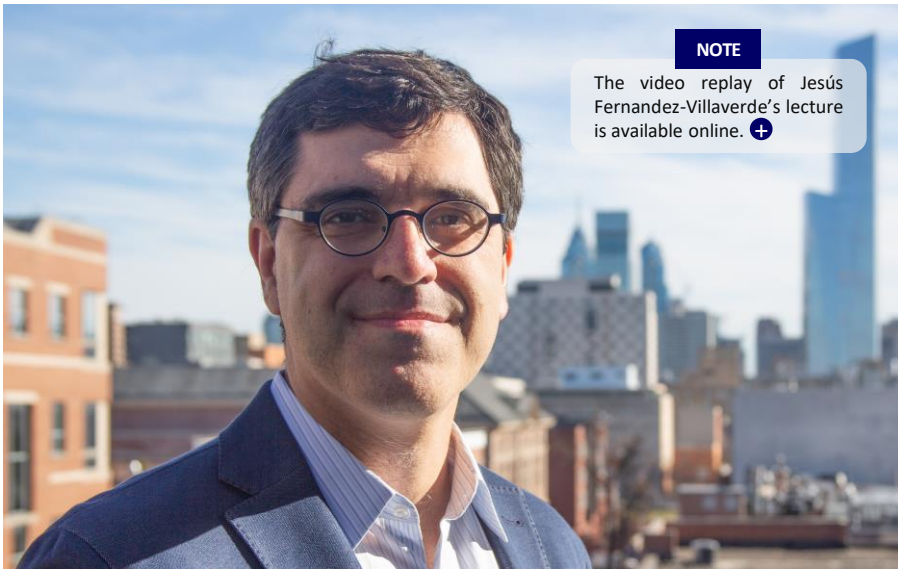
Macroeconomic Risk

Simple Rules for a Complex World with Artificial Intelligence

AN INTERVIEW WITH JESÚS FERNÁNDEZ-VILLAVERDE



NOTE

The video replay of Jesús Fernandez-Villaverde's lecture is available online.

AN INTRODUCTION TO ARTIFICAL INTELLIGENCE AND MACHINE LEARNING

Q: You began your talk by stressing that artificial intelligence (AI) has recently generated a lot of hopes and fears. Do you think these reactions are exaggerated?

Jesus: Some of it, yes. Indeed, AI will change many of the ways we organize our economies and our policies. Still, we are quite far from having an AI system that can perform simple tasks that are not well structured or require a high degree of flexibility to adapt to new circumstances. Furthermore, the current machine learning (ML) algorithms require massive amounts of data and, for many applications, that data is either not available or it is too expensive to gather.

My position, thus, is nuanced. Yes, AI is a big deal. No, AI is not the "ultimate" transformative force as some of the most exaggerated claims state.

Q: Let's take a step back. What is AI and machine learning (ML)? How would you distinguish between the two? As a practitioner, can you give a brief insight into how it works? What can and can't it do?

Jesus: AI is a general class of **algorithms that try to replicate the reasoning capabilities of humans.** ML is a subset of AI that focuses on algorithms that try to replicate the reasoning capabilities of humans by **learning automatically from patterns in the data.**

Let me give you an example. Imagine that we want to code a computer program that can play chess.

We can do this in (at least) two ways. One approach is to design a computer program that "understands" the logic of chess. I can code the rules of the game and a long set of ideas such as "a bishop is stronger than a knight in an open endgame, but a knight is more powerful than a bishop in endgames with static pawn arrangements" that you find in standard chess textbooks and induce the software to "reason" through the different positions in the board. This is what we do when we teach children to play chess: we give them the basic rules, some basic strategy, and tactic considerations and hope they will start working through the inner logic of the game on their own. This was, roughly speaking (I am skipping here some details to allow the reader to follow the argument), how we tried to build AI systems in the 1960s and 1970s.

A second approach is more "brute force." I just specify a set of weights that map positions in the board into payoffs (i.e., if you are playing whites, a white pawn in e4 has a weight "+0.2" and a black rook in h8 as a weight "-0.3") and tell the code to play the move that maximizes the payoff of the board after such a move. The initial weights are not very important, although if you have initial weights that are "reasonable," the algorithm will converge more quickly. Then, I create 1,000 copies of the code and get them to play against each other multiple times. Each copy has the same weights with a small random shock (i.e., copy 345 has a weight for the white pawn in e4 "+0.201" and copy 567 "+0.199"). I keep the copies of the code that win more often than the ones than lose but, and this is the key, I introduce from time to time some additional random shocks in the winning copies (i.e., the weight for the white pawn in e4 goes from "+0.201" to "+0.2012"). After enough iterations, the final copies of the code will have "quasi-optimal weights" in the sense that those weights value "correctly" the positions on the board and trigger winning moves. Now, the code does not "understand" chess in any meaningful sense of the word. It just crunched numbers again and again until it reached a good strategy.

> "There is an intimate link between many ML algorithms and genetic and evolutionary algorithms."

If this approach reminds you of natural evolution, you are right. **There is an intimate link between many ML algorithms and genetic and evolutionary algorithms.**

So, when does this approach work in economics? In two situations. First, when, as in chess, I can simulate the model easily. For example, I can give agents in my model simple rules of behavior, and I let them update those rules again and again given some reward function until they converge to something "quasi-optimal." I have used this approach to solve models with heterogeneous agents, and it works extremely well. **Second, when we have plenty of data from the real world, and we can "estimate" the weights that agents are using in real life.** This should remind some readers of the Hotz-Miller approach to avoid numeric dynamic programming in the estimation of conditional choice problems because it builds on the same intuition.

Where does it not work? When simulating the model is expensive or when we have too little data. Also, in problems with low dimensionality and complexity (i.e., solving a simple real business cycle or a Neo Keynesian model), traditional approaches (perturbation and projection) will work better in the sense of requiring less computational time.

"SIMPLE RULES"

Q: Quoting Epstein, you stress that "simple rules" are the foundations of today's complex socio-economic systems. Furthermore, you draw an analogy between how "simple rules" were discovered and a promising technique in ML, reinforcement learning. Can you develop?

Jesus: Yes. Let me give an example. A modern economy works because we have well-defined property rights and contracts law. Contrary to the naive view of many economists, property rights and contracts law did not appear out as a Promethean burst of creativity by an enlightened legislator. **Property rights and contracts evolved, first in Rome and latter during the Middle Ages, by the constant work of jurists working through rules and agents accepting or rejecting those rules and modifying them in the process, exactly as reinforcement learning works.**

Particularly interesting is the rediscovery and adoption of Roman Law during the Middle Ages. Roman law mostly died in Western Europe after the fall of the western half of the Roman Empire in the 5th century. It was replaced with an ad hoc patchwork of Germanic law, local customs, and the scattered remains of Roman ideas.

The situation in the eastern part of the empire was different. The Byzantine Emperor Justinian (r. 527-565) commissioned a group of legal scholars from Constantinople and Beirut (and perhaps even Rome) to create a compilation of the Roman law existing at his time. This compilation was intended as a central component of Justinian's project of imperial power reconstruction. The work has been known since 1583, when Dionysius Gothofredus (1549-1622), a reputed french jurist, edited a learned version of the medieval manuscript, as the Corpus Juris Civilis, or the Body of Civil Law.

The Corpus, prepared between 529 and 534, included the Codex, a collection of imperial enactments since the time of the Emperor Hadrian (r. 117-138); the Digesta, a selection of comments by 39 of the most distinguished Roman legal experts; and the Institutiones, an introductory law textbook.

The Corpus was soon summarized into Greek (which had replaced Latin as the language of administration in the Byzantine Empire), but forgotten in Western Europe. The last reference we have of it in the former western half of the Empire is in a letter of Pope Gregory the Great in 603.

At some point, though, around 1050, Justinian's work was rediscovered in the north of Italy. While we do not quite know when or how it came about, this rediscovery was likely linked to the revival of urban life and trade in the 11th century and the reassertion of Church powers against the Holy Roman Emperor, which begat a search for legal texts and precedents by the clergy in libraries across Europe.

> "The impression the Corpus made on those who had contact with it was nothing less than breathtaking."

The impression the Corpus made on those who had contact with it was nothing less than breathtaking. Instead of the underdeveloped working of the Germanic law or the contradictions and inconsistencies of local customs, Roman law was an engrossing intellectual construction, rational, systematic, and comprehensive, a product of centuries of thought by brilliant jurists that dealt with the rich and prosperous economy of the late Roman Republic and early Principate.

Law students fell in love with Roman law and created institutions (our modern universities) to study it systematically. Soon, cohort after cohort of law students at Bologna (and later at Paris, Oxford, Salamanca, and other universities) and started applying the spirit if not the letter of the Corpus. And they found plenty of cases in which to do so because economic agents liked the use of the Corpus: it was a superior system that allowed for a better and more predictable solution of legal disputes.

Without the need of any royal decree or explicit mandate, Roman law and its derivatives extended all over Europe. In some territories the adoption of Roman law was so widespread that it even became official (among the earliest examples, we find Pisa in 1161, Catalonia in 1173, and Siena in 1176) and imposed itself over the legislative desires of territorial rulers. In fact, royal law-making was only vigorous in those lands, such as Sicily or Normandy, where the reception of the Roman law had been the weakest. This revival of Roman law created an spontaneous order: the ius commune, the general law across Europe (also known as the Civil law, as in the Body of Civil Law of Justinian), in delicate opposition with the ius propium, the specific statury and customary laws of each territorial polity. Without the ius commune, the European commercial revolution that started in the 13th century would have never been possible.

That ius commune was codified, in France, by Napoleon but we too often forget that Napoleon really did not create much ex novo, but to a very large extent he (well, the jurists he hired) simply systematized a body of civil law that had emerged over centuries.

That is why I draw parallels between ML and our simple rules of property rights and contracts. Both are based on experimentation.

ML & POLICY APPLICATIONS

Q: In your talk, you revisited a somehow old debate on the efficiency of central planning. Your point is: ML won't help fix the issues with central planning. What are your arguments?

Jesus: There is a naive view out there that somehow central planning did not work because the soviet computers were not good enough or the algorithms they used were poor. Under this view, now that we have better computers and algorithms, we can revisit central planning. I argue that yes, the soviet computers and algorithms were terrible, but this was not the key to the problem of central planning. **The soviet system did not work because it never provided incentives for the agents in the economy to disclose information** (in fact, even to create such information to begin with).

In my paper "Simple Rules for a Complex World with AI," I present a real-life example regarding how to allocate teaching at a department of economics (a problem that, as the director of graduate studies at my department, I have repeatedly encountered). The problem is never how to compute the optimal solution if I have the information available about the teaching preferences and capabilities of my colleagues: that would take me 5 minutes. The problem is always to induce the right revelation of information and to induce them to perform their teaching duties at the optimal level. I am not even sure Penn gets the optimal teaching level from me! That is why we have thousands of papers with asymmetric information.

Let me recommend you a novel: "Red Plenty", by Francis Spufford, a fascinating historical fiction re-creation of the follies of soviet planning in the 1950s and 1960s. Truly a wonderful novel to read for an economist. By the way, Francis Spufford is the son of Peter and Margaret Spufford, two outstanding Cambridge historians. Peter Spufford's book "Power and Profit: The Merchant in Medieval Europe" is one of the very best introductions to the financial revolution of the 13th century.

> "Amazon is just a more sophisticated version of your old-fashion local bookseller who knew her clients and their tastes."

Q: You said that central planning cannot work because individuals would never tell the truth about their preferences and capabilities to the planner. Yet, tech giants are able to extract a lot of information about our tastes and preferences out of their very large dataset. Does that make them superior to old-fashioned central planners?

Jesus: Note that Amazon and Netflix get information from me because they provide me with the incentives to do so in a very concrete context. I buy a book from Amazon, and I get recommendations about the next book I might like. In that sense, Amazon is just a more sophisticated version of your old-fashion local bookseller who knew her clients and their tastes.

But Amazon knows next-to-nothing about my intertemporal preferences, and that is the information that one needs to determine key issues in society, such as investment and capital accumulation. In fact, Amazon takes basic market prices (real interest rates, price of land, etc.) as given when it makes decisions such as where to open a warehouse.

At the end of the day, Amazon and Netflix gather some information, yes, but we cannot infer from it that we can scale their approach to a national economy level because they will not be able to provide the incentives required to do so. Selling a book is very different from determining the right path of intertemporal capital accumulation.

Note, in particular, that I do not deny that firms can gather and process information efficiently in their business. I am skeptical about jumping from this "partial equilibrium" statement to a "general equilibrium" statement where suddenly all prices are endogenous and not given.

Q: In which cases has ML proven useful for policy then?

Jesus: An example where ML has worked very well: detecting money laundering. We need to go over gigantic amounts of data and ML is great at detecting "odd" patterns. More in general, **ML works well in all situations where the key is to parse through large amounts of data and the feedback mechanisms from the agents is not very strong.**

ML & ECONOMIC METHODS

Q: You teach and use machine learning for your own research, how do you think those techniques can best be applied in economics?

Jesus: In two contexts:

1) As a solution method for complex models. "Solving a model" means finding the equilibrium function that maps states into actions. ML is a great way to approximate complex function, such as the equilibrium function, about which we might not know a lot.

2) As an empirical method. Now the function we want to approximate is the one mapping data into some object of interest (for example, a conditional expectation). The argument is the same as before: ML is a great way to approximate complex function about which we might not know a lot.

Q: What are the promising applications of ML to macro predictions?

Jesus: For example, aggregating data from social media, satellite photos, high-frequency observations, etc. into useful indicators of short-run economic activity and "nowcasting." Also, it might help to process natural language from policymakers. I am working on that right now.

Q: Machine learning is sometimes described as signing the death of theory - for example because human intelligence could not beat the improbable strategies imagined by the algorithms of AlphaGo. Is there a place for machine learning and economic theory to work hand in hand?

Jesus: Yes. If we come up with new strategies nobody thought of before, we can develop theories that explain them. We do that all the time in math. We bumped into strange objects (think about when Dirichlet first encountered nowhere continuous function or when Liouville discovered that second-order linear differential equations could be written as integral equations), little by little we realize that those objects are not so strange after all, and before we realized it, we have developed modern functional analysis. Theory is not a world on its own. More often than not, it is motivated by puzzles and new observations.

AI IN EUROPE VS. CHINA AND THE U.S.

Q: ML has a lot of economic applications and is increasingly turning into a strategic stake for most great powers. Are you afraid of Europe falling behind China and the US in that field?

Jesus: Yes, very much so. Think about the "Big Nine" (Amazon, Google, Facebook, Tencent, Baidu, Alibaba, Microsoft, IBM and Apple). 6 US firms and 3 Chinese. Let me ask you: "when was the last day in your life when you did not use a product of one of these Big Nine"? In my case, perhaps over a decade ago. Even when I am on vacation in Europe in a remote location I call my family (Apple product). Now, when was the last day I did not use a product of a European company while I am in the U.S.? Probably last week, and I take out the Spanish newspaper I read in the morning, probably yesterday.

> "Theory is not a world on its own. More often than not, it is motivated by puzzles and new observations."

Q: Why did Europe fail to create tech giants of its own?

Jesus: So many reasons! As our friends in history love to say, it is an overdetermined outcome. I wrote a paper with Lee Ohanian a couple of years ago: lack of top universities (except a few great departments such as PSE, Europe lags behind in most fields), lack of good venture capital, barriers to entry everywhere, silly regulations, you name it. A few years ago, Zidane had a problem with the Spanish league because he did not have a professional degree to be a coach. Why in the world do we force professional soccer teams to have to hire coaches with a degree? Isn't the Real Madrid, which Zidane was managing at the time, a sophisticated organization that knows what it is doing? Do we need the government to tell Real Madrid who to hire and who not to hire?

I can see an argument for a coach of kids in school to have some basic certification to avoid injuries for the children but at the professional level? Paradoxically, the higher you go in the ranks, the tighter the requirements to be a coach are, which is the completely wrong strategy! The more sophisticated you are as a football team, the less protection you should be getting.

When the Zidane case came out, I spent some time looking at the requirements to be a coach in Spain. One of them was to take a class on the history of football. Come on! History of football can be fascinating, but if a team does not feel they need their coach to know much about it, who are we to tell them otherwise? The regulation is just pork for coaching academies.

Worst of all, when I wrote about this, a prominent politician replied to me that she wanted her coach to be certified. I tried to explain to her that I did not want to prevent her from hiring a certified coach. I just wanted her to let me hire a non-certified coach. Unfortunately, that nuanced was too much for her.
Now multiply this silly regulation and barriers to entry by one thousand everywhere, and next thing you know, there are not big European IT firms.

Collateralization and Asset Price Bubbles when Investors Disagree about Risk

Broer, Tobias (PSE, IIES and CEPR), Afroditi, Kero (Neapolis University Pafos),
Collateralization and asset price bubbles when investors disagree about risk, Journal of Banking & Finance, Volume 128, July 2021.

From the mid-1990s to the beginning of the Great Recession, the world economy has seen an unprecedented wave of financial innovation, partly in the form of new collateralized debt products. At the same time, prices of collateral assets, such as real estate, but also stocks, experienced an unprecedented increase. This paper links these two phenomena to a third, less documented one: disagreement among investors about economic risk. Broer and Kero provide evidence for this argument from several US surveys. They first show how the data analyzed by Amromin and Sharpe (2012) and Ben-David et al. (2013) imply strong disagreement among both retail investors and finance professionals about the dispersion of future stock returns. Second, to analyze a longer time horizon covering the Great Moderation period, they document that, since the early 1990s, near-term GDP forecasts from the Survey of Professional Forecasters show increasing disagreement among forecasters about the dispersion of GDP growth, while disagreement about mean growth has fallen. They conclude from this that disagreement about risk is substantial, and that there is some evidence that it became more important relative to disagreement about mean payoffs in the 1990s and early 2000s.

> Heterogeneous risk perceptions, when combined with financial innovation, can create asset price bubbles.

Broer and Kero show how such heterogeneous risk perceptions, when combined with financial innovation in the form of collateralized debt products, can create asset price bubbles. In the absence of collateralization, risk-neutral investors trade assets at their common fundamental value even if they disagree about payoff risk. The introduction of risky collateralized debt products increases asset prices above this common fundamental value by splitting cash flow into senior debt and junior debt or equity claims. Investors who perceive low volatility are happy to pay high prices for senior debt, which they regard as riskless. Those who think volatility is high, in contrast, value the upside potential in junior claims. Disagreement about risk thus raises the equilibrium price of collateral assets as investors self-select into buying the claims they value most highly. They show how this may have been an important driver of the boom in `Structured Finance' assets, such as collateral debt obligations (CDOs), whose senior tranches are attractive to investors who believe in diversification and thus think default rates of collateral pools are stable. Those, in contrast, who think default rates are more reflective of aggregate conditions, and thus more volatile, think senior tranches may still fail in bad times, but are happy to pay for junior and equity tranches, which they expect to pay when conditions are sufficiently good.

Sovereign Default and Imperfect Tax Enforcement

Pappadà, Francesco (Banque de France, PSE Visitor), Zylberberg, Yanos (University of Bristol, CESifo and the Alan Turing Institute),
Sovereign Default and Imperfect Tax Enforcement, "Macroeconomic Risk" Chair, SCOR-PSE Working Paper n°2021-05, July 2021.

Sovereign default risk typically decreases in response of fiscal consolidations. However, the response of sovereign default risk to fiscal policy is dampened when tax enforcement is weak. A fiscal consolidation leads to an expansion of the informal sector, thereby limiting fiscal surpluses, but also hampering future tax collection and failing to reduce default risk. For instance, during the European sovereign debt crisis of 2009-2014, several economies with relatively low tax enforcement implemented fiscal consolidations that led to significant welfare costs but limited effects on default risk.

This paper studies the dynamics of fiscal policy and default risk when tax enforcement is imperfect. The contribution is threefold. First, Pappadà and Zylberberg document stylized facts about tax compliance and its dynamics in economies with imperfect tax enforcement, most notably the relationship with fiscal policy and default risk. They then provide a model of sovereign debt with limited commitment in order to understand how the dynamics of tax compliance---disciplined by the empirical moments---affects optimal fiscal policy and default risk. Finally, they quantify the ignored, yet important, welfare cost associated with imperfect tax enforcement: a *responsive* tax compliance significantly constrains optimal fiscal policies, which, ultimately, has an impact on consumption smoothing.

Novel empirical facts are established about the dynamics of tax compliance and its impact on default risk. First, tax compliance is volatile and there is large heterogeneity in volatility across countries. Tax compliance is volatile because it strongly responds to fiscal policy and business cycle fluctuations. The heterogeneous volatilities across economies reflect large heterogeneity in such responses. In some economies with imperfect tax enforcement, a larger share of taxpayers hide their activity in downturns and in periods of austerity. In contrast with the standard behavioral response, the magnitude of fluctuations in tax compliance implies sharply decreasing returns to taxes, and some economies display an extreme form of fiscal fatigue. Second, the response of tax compliance to fiscal policy alters the relationship between fiscal policy and default risk. Fiscal consolidations are associated with a marked decrease in default risk, but only in countries where tax compliance is inelastic. Instead, when tax compliance strongly responds to taxes, this adjustment directly affects default risk and significantly limits the returns to fiscal consolidations.

> The response of tax compliance to fiscal policy alters the relationship between fiscal policy and default risk.

Pappadà and Zylberberg explore the implications of fluctuations in tax compliance on the dynamics of optimal fiscal policy in a model of sovereign debt where a benevolent government uses fiscal policy as a consumption-smoothing instrument. In their quantitative analysis, they evaluate how the *dynamic properties* of tax compliance affect optimal fiscal policy and welfare by comparing two compliance response to fiscal policy and business cycle fluctuations around the (same) steady-state level. The *baseline* economy differs from the *low-response* economy in two important dimensions. First, the *baseline* economy is ten times more likely to experience a default (with a yearly probability of 0.2%, and a yearly probability to be excluded from financial markets of 1.8%). Default is more likely, even though the baseline economy accumulates far less debt on average (10% of output versus 21%). Second, fiscal policy in the *baseline* economy is less able to smooth fluctuations in consumption: household consumption is much more volatile around the same average levels. The model is used to quantify the costs of such fluctuations, which are found to be equivalent to a 2.2% decrease in certainty equivalent consumption. These findings illustrate that fluctuations in tax compliance constrain the set of feasible fiscal policies and significantly lower welfare.

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