

**Prepared Statement**

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**House Committee on Science and Technology  
Subcommittee on Investigations and Oversight**

**“Building a Science of Economics for the Real World”**

**July 20, 2010**

I thank you for this opportunity to address the committee.

My name is Scott E Page. I am the Leonid Hurwicz Collegiate Professor of complex systems, political science, and economics at the University of Michigan-Ann Arbor and an external faculty member of the Santa Fe Institute. I study diversity in complex social systems.

Complex systems may be unfamiliar territory to many, so I begin with a definition. Complex systems consist of diverse, connected, interdependent, and adaptive actors who collectively produce patterns that are difficult to explain or predict.<sup>1</sup> Complex systems are neither ordered nor chaotic. They lie in between.

Complex systems interest scientists because they are capable of producing emergent phenomena in which the whole differs in kind from the parts that comprise it. A brain differs in

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<sup>1</sup> Miller, J. and S. Page (2008) *Complex Adaptive Systems: An Introduction to Computational Models of Social Life*, Princeton University Press.

kind from a neuron. A society differs in kind from a person.

Given this definition, the economy, traffic on the Beltway, and the goings on “inside the Beltway” are all complex. Trying to make sense of and harness the complexity of the social world is what motivates my research efforts.

In my comments today, I first describe how, when we’re confronted with complexity, we benefit by relying on a variety of models. I then show how complex systems models, by including the diversity and interconnectedness of the economy, have a special ability to generate insights into phenomena of central interest to this committee, including the pace of innovation and market crashes.

My points both relate diversity to complexity. First, I’m saying that the economy is complex, not in some loose metaphorical way, but according to formal scientific definitions of complexity. As a result, we’re never going to predict its future with much accuracy. Our best approach will be to encourage the creation of diverse models.

Second, I’m saying that we need to develop richer complex systems models of the economy because they embrace the diversity and interconnectedness that drive fluctuations, and because they may enable us to gain deeper insights into the causes of innovation. I’ll argue that these models are much more flexible than standard neoclassical models.

I begin with a simple question: Why model? A standard response would be that models enable us to explain and predict empirical data -- to make sense of the world. Models vary in their accuracy depending upon the domain. For example, in predicting physical phenomena – the rate at which objects fall, the patterns in which the planets orbit the sun, and so on – they’re almost absurdly accurate.

Yet, as we all know, models have proven less adept at predicting the economy. That's because the economy is a complex system. The solar system may be complicated, i.e., have lots of connected parts. But the parts aren't that diverse, and they don't adapt. Hence, planetary orbits are predictable.

Prediction is only one of many reasons to encourage model building and interpretation. Models help us design policies and mechanisms. For example, the FCC spectral auction provides an excellent example of how models were used to anticipate shortcomings of traditional auction mechanisms.

Models also inform data collection, produce bounds on outcomes, explore counterfactuals, and explain whether a system will equilibrate, cycle, produce chaos, or generate complexity.

And perhaps most importantly, models help us identify the important parts and work through the logic of systems, especially complex, unpredictable systems like the economy or political systems.<sup>2</sup>

The complexity of the economy provides almost endless grist for our cognitive mills. An inquisitive person's head cannot help but develop theories and construct analogies about the economy. Many of these contain a grain of truth. Unfortunately, most also include logical inconsistencies.

The advantage of models is that they identify truths and reveal inconsistencies by forcing us to characterize the relevant parts of a system and to understand how those parts relate to one another.

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<sup>2</sup> See Bednar (2009) *The Robust Federation*, Cambridge University Press.

However, when applied to a complex system, a single model can only cast light on some dimensions. Hence, we need multiple models. The advantage of combining diverse models was recognized by Aristotle, who asserted, “a multitude is a better judge than any individual.”<sup>3</sup>

That’s not just an intuition. With the help of a little mathematics, the claim can be made formal: My research has shown that if I have a crowd of models and take the average, then it follows that

$$\text{Crowd of Models' Accuracy} = \text{Average Model Accuracy} + \text{Model Diversity.}$$

The mathematical identity that I’ve framed verbally here shows the benefits of combining models.<sup>4</sup> I want to reiterate that by no single model or even a group of models will accurately forecast the economy. It’s too complex.

We can widen our lens a bit, though. And we can use a crowd of models to predict bounds on the likely fluctuations in the economy and to anticipate unintended consequences of policy decisions, such as allowing the expansion of sophisticated financial instruments.

I now turn to my second point: the particular value of complex systems models to help understand and guide the economy.

The U.S. economy consists of over three hundred million people, nearly thirty million organizations -- about ninety percent of which seek profits -- and tens of thousands of government agencies. These actors possess diverse beliefs and goals. They adapt as circumstances change, though not in lock step. Some spend and some save. Some innovate.

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<sup>3</sup> Aristotle, *Politics* (trans. Benjamin Jowett), Book Three, Part XV, available at <http://classics.mit.edu/Aristotle/politics.3.three.html>

<sup>4</sup> See Page, S (2007) *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies*, Princeton University Press.

Some seek the comfort of routine.

The aggregated interdependent actions of these millions of actors – people, organizations, and governments – produce the macroeconomic patterns that economists seek to explain and predict.

How then, do we model this? The neoclassical approach assumes that individuals and firms make optimal choices subject to constraints on budgets, technology, and time. Both sets of actors accurately anticipate future effects of their actions and the government. In its simplest form this model produces a stable equilibrium with balanced growth.

Modern variants of this model include technological shocks that reverberate through the economy. These variants also include frictions, such as wages that are slow to fall. This stickiness exacerbates the depth and length of the echoes caused by the shocks.

The neoclassical model is stark. It assumes no sectors of the economy, no physical geography, no networks of connections, no learning (agents always optimize), and little or no heterogeneity of income, wealth, or behaviors.<sup>5</sup>

Oh yeah, and the only unemployment it includes is voluntary.

Further, almost all of the responses by the actors in the neoclassical model tend to equilibrate the system. An increase in demand for housing increases the price of housing, thereby causing a reduction in future demand for housing. This is an example of a “negative

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<sup>5</sup> Narayana Kocherlakota, the President of the Minneapolis Fed, has written that *“as far as I am aware, no central bank is using a model in which heterogeneity among agents or firms plays a prominent role.”* Kocherlakota (2010) *“Modern Macroeconomic Models as Tools for Economic Policy,”* Federal Reserve Bank of Minneapolis.

feedback.” Negative feedbacks stabilize systems and lie at the core of neoclassical economic models.

The complexity approach assumes individual agents with diverse incomes and abilities who are situated in place and time. Their actions influence those in their social and economic networks. These actors don’t optimize some hypothesized objective functions, be it a single period’s profits or lifetime’s income. Instead, they follow rules that have survived or are succeeding in the marketplace.

In a complex systems model, if financial firms with greater leverage are making higher profits, other firms may follow their lead even if the aggregate effect of all that leveraging is not sustainable.

This sort of effect – in which more leverage leads to even greater leverage – is called a “positive feedback.” Positive feedbacks produce correlation in observed behavior. Hence, systems that contain them can exhibit both clustered volatility and large events, for instance, stock market bubbles and home mortgage crises. These could be avoided if the agents in the model were capable of predicting the future consequences of their actions, but they are not. Neither are economists.

I do not mean to imply that complex systems models can predict crashes. They cannot. What they can do is provide an alternative lens to enable us to design rules, laws, incentives, and institutions – as well as encourage the development of productive social norms – that might reduce the likelihood and severity of financial collapses.

Adopting complex systems models requires a change in tools as well as a change in paradigm. Complex systems models are often analyzed using computational or what are called

“agent based” techniques. These techniques are capable of including sector level details – financial markets, real estate markets, and service markets.<sup>6</sup>

The ability of complex systems models to include realistic detail has other advantages as well. It creates the potential for new insights into causes and rates of innovation. The innovative potential of an economy depends on its building blocks – ideas, technologies, and basic science. Innovation comes about by combining and recombining those building blocks.

Lest I make agent based models seem a panacea, I should add a word of warning. A model that contains too much detail can be as perplexing as the reality it was built to explain. Models should include only as much detail as necessary and no more.

In 1922, Georgia O’Keefe wrote that “details are confusing. It is only by selection, by elimination, by emphasis that we get to the real meaning of things.” She was right. That’s why standard macro models, which leave out so much information, can still be of great value. However, I would argue that to get at the real meaning of things in the economy, the necessary details should include the financial sector, unemployment, and heterogeneous consumers.

To sum up, our goal is to understand an economy that’s increasing in complexity. The neoclassical approach emphasizes optimization in the face of constraints and responses to shocks, and sees macro level patterns as the re-equilibration of those shocks. The complex systems paradigm emphasizes diversity, networks, interdependencies (positive as well as negative feedbacks), and adaptation. Neither is right. Neither is wrong. They’re both models. And both can be useful.

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<sup>6</sup> Farmer, D and D. Foley (2009) “The Economy Needs Agent Based Modelling” *Nature* 460: 685 686/

I'll conclude by reiterating my first point. For noncomplex systems, we can use single models. We can, for example, just multiply an object's mass by its acceleration to get a really good approximation of force. But for a complex system, like an economy, no one model will be accurate. We need a crowd, a crowd of diverse models.

I thank you for the opportunity to speak to the committee.