Special issue on Reconstructing Macroeconomics

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Macroeconomics has gone astray. In the past 30 years, macroeconomics has become less relevant. Events in the world economic crisis since fall 2008 have unmistakably demonstrated this fact.

The mainstream macroeconomics today begins with optimization of the representative consumer. The optimum growth theory once meant to be normative is now being taught as a descriptive theory. It is the neoclassical equilibrium theory. By construction, it broadly underlines the efficiency of markets albeit with mild admission of the so-called "market failures". In reality, far from being efficient, most of the time, the economy must move on a bumpy road. It is simply misleading and wrong to analyze such problems as business cycles, unemployment, deflation, and financial turmoils—the subject matters of macroeconomics—with the neoclassical equilibrium theory.

Nevertheless, many economists still believe that the first principle of economics is the optimization of economic agents such as household and firm. This principle and the notion of equilibrium, namely equality of supply and demand, constitute the core of the neoclassical theory. To some, this is the only respectable economic theory on earth. For example, Lucas (1987: 107–108) concluded his Yrjo Jahnsson Lectures as follows:

> The most interesting recent developments in macroeconomic theory seem to me describable as the reincorporation of aggregative problems such as inflation and the business cycle within the general framework of 'microeconomic' theory. If these developments succeed, the term 'macroeconomic' will simply disappear from use and the modifier 'micro' will become superfluous. We will simply speak, as did Smith, Ricardo, Marshall and Warlras, of *economic* theory. If we are honest, we will have to face the fact that at any given time there will be phenomena that are well-understood from the point of view of the economic theory we have, and other phenomena that are not. We will be tempted, I am sure, to relieve the discomfort induced by discrepancies between theory and facts by saying that the ill-understood facts are the province of some other, different kind of economic theory. Keynesian 'macroeconomics' was, I think, a surrender (under great duress) to this temptation. It led to the abandonment, for a class of problems of great importance, of the use of the only 'engine for the discovery of truth' that we have in economics. Now we are once again putting this engine of Marshall's to work on the problems of aggregate dynamics.

Thus, over the last thirty years, economics has attempted, in one way or another, to build maximizing microeconomic agents into macroeconomic models. To incorporate these agents into the models, the assumption of the representative agent is usually made. By and large, these exercises have lead one to the neoclassical macroeconomics. The real business cycle (RBC) theory (e.g. Kydland and Prescott, 1982) praised so highly by Lucas (1987) is the foremost example.

We maintain that the standard approach represented by RBC is misguided, and that a fundamentally different approach is necessary to analyze *the macroeconomy*. Such an approach is based on the method of *statistical physics,* which is commonly used in physics, biology and other natural sciences when one studies a system consisting of a large number of entities.

The basic idea of statistical physics is explained in every textbook. Here is an example:

> Many systems in nature are far too complex to analyze directly. Solving for the behavior of all the atoms in a block of ice, or boulders in an earthquake fault, or the nodes on the Internet, is simply infeasible. Despite this, such systems often show simple, striking behavior. Statistical mechanics explains the simple behavior of complex system. (Sethna, 2006: p. 1)

Thus, statistical physics begins by giving up the pursuit of the precise behavior of individual units, and grasps the system as a whole by statistical methods. This approach, which is nothing but common sense in natural sciences, is indeed in stark contrast to the method underlying the modern *micro-founded* macroeconomics! We will shortly argue that there is no fundamental reason why the method so successful in natural sciences cannot be applied to economics. Contrary to Lucas' assertion, to study the macroeconomy, we *do* need "some other, different kind of economic theory".

A new approach to macroeconomics based on statistical physics has gradually emerged. Meanwhile, a closely related research area has come to be broadly dubbed *econophysics*. It is fair to say that econophysics has established itself in finance. See, for example, Mantegna and Stanley (2000), McCauley (2004), and Stanley *et al.* (2006). However, the research in the areas of economics is still in its infancy. So far, the major achievements are important empirical findings made by physicists. They have found that just as financial variables such as stock returns, many other real economic variables such as personal incomes and the size of firms also obey the Pareto distribution or the *power-laws*. The size distribution of firms and cities has, in fact, a long research history in economics (Ijiri and Simon, 1979). Personal incomes have also been studied by many researchers (Champernowne, 1953).

Despite their importance, so far the impact of these empirical studies on economics has been rather limited, to say the least. They were often ignored by a majority of economists. The reason is that their relation to the mainstream economic *theory* is by no means clear. A notable exception is a seminal paper by Foley (1994) who proposed the notion of "statistical equilibrium" in relation to the standard Walrasian general equilibrium theory.

We believe that time has come to integrate the new approach based on statistical physics or econophysics into macroeconomics. The organizers of this special issue presented a way to proceed (Aoki and Yoshikawa, 2007). It is our hope that the existing gap between the new approach and the mainstream macroeconomics will be narrowed by contributions in this issue, and that more economists will become aware of the significance of the new approach.

Is the Statistical Approach Applicable to Economics?

The fundamental method based on statistical physics has been extremely successful in natural sciences ranging from physics to biology. Because the macroeconomy consists of a large number of economic agents, typically of the order of 10^6 to 10^7, we can expect that this method should show the same analytical power in macroeconomics as in natural sciences.

A common argument to the contrary is, however, that natural science analyzes system comprising inorganic particles such as atoms or molecules whereas economics analyzes the economy in which agents with brains purposefully pursue their respective goals. This understandable skepticism on the applicability of the method based on statistical physics to economics is actually without foundation. The truth is the method can be fruitfully applied to the analysis of system comprising a large number of micro units regardless of the nature of micro unit.

A good example is analysis of traffic jams on turnpike. Here, the micro unit is a driver, a purposeful human being with brains! And yet, traffic jams have been beautifully analyzed by the method based on statistical physics. Furthermore, econophysics has demonstrated that certain important aspects of stock prices can be explored by the statistical method which on purpose, ignores detailed behavior of an individual trader (Stanley *et al.*, 2006). The fact that the returns on assets obey power-laws rather than the normal distribution has far reaching implications for finance. Aoki and Yoshikawa (2007: chapter 10) explores its implications for macroeconomics.

Productivity Dispersion

In economics, econophysics has done extensive empirical studies on size distributions of firm, city, and so forth. By and large, they are found to obey *power-laws*. In fact, particular types of such empirical distributions have been long known as the Gibrat's Law or the Zipf Law (Sutton, 1997). The empirical distributions of city, firm, and some odd variables are certainly interesting in themselves. However, *it is the distribution of marginal productivity that matters from the view point of economic theory.* That is why we must first and foremost focus on productivity dispersion.

In the Walrasian general equilibrium theory, the marginal products of a production factor such as labor are equal in all the sectors and firms. This is required for the Pareto efficiency, and constitutes the concept of the equilibrium. However, in the real economy, we know that labor productivity differs across firms and industries (Mortensen, 2003). In fact, following the basic principle of statistical physics, we can show that the productivity dispersion depends crucially on the level of aggregate demand. Namely, when the level of aggregate demand is high, more labor enjoys high productivity while less struck in low-productivity firms and sectors, and *vice verse*. In this sense, the aggregate demand corresponds to temperature in physics. Yoshikawa (2003) and Aoki and Yoshikawa (2007) argue that this is the proper microeconomic foundation for Keynes' principle of effective demand. This theory also provides precise definition of Tobin's (1972) "stochastic macro-equilibrium", see also Okun (1973). Scalas and Garibaldi (2009) in this issue present a stochastic process which leads us to the equilibrium distribution of labor productivity.

Meanwhile, Aoyama *et al.* (2008) demonstrates that the empirical distribution of labor productivity is actually not the Gibbs (exponential) distribution but the power distribution. The paper not only explores the empirical distribution, but also suggests a theoretical framework for understanding the obscured power-law. The framework is called *superstatistics* in which the level of aggregate demand is allowed to fluctuate rather than is simply assumed to be constant. Aoyama et al. (2009) in this issue further explores the superstatistics framework, and proposes a new concept called *the demand index* which conditions the level of aggregate demand. This approach looks very promising to give firmer foundation for Keynes' theory of effective demand.

Now, at the present stage, it is still important to pin down the exact empirical distribution of labor productivity. Souma et al. (2009) in this issue explores the distribution of labor productivity for the Japanese manufacturing and non-manufacturing industries. Basically, it endorses the previous results that the distribution of labor productivity obeys the power law. In addition, it makes a very interesting finding that the distribution of relatively low productivity is more strongly affected by changes in the growth rate of real GDP than that of relatively high productivity.

Ishikawa (2009) in this issue also very carefully analyzes the empirical distributions of such corporate data as profits and sales. He concludes that the Pareto laws hold for large firms whereas the log-normal distributions hold for medium-size firms. He first draws our attention to the theoretical result that the combination of the detailed balance condition and the Gibrat's law, namely the independence of the conditional probability density function of the growth rate from the current level, necessarily leads us to the power laws. By the same token, the combination of the detailed balance and what he calls the non-Gibrat's law leads us to the log-normal distribution. He obtains the empirical results which basically accord with these theoretical results.

Because we observe productivity dispersion, plainly, the Walrasian equilibrium theory cannot be literally applied to the real economy. Search theory allegedly fills this gap by encompassing apparent "disequilibrium" phenomena such as productivity dispersion in the neoclassical equilibrium framework. Aoki and Yoshikawa (2009) in this issue take up Lucas and Prescott (1974) as an example, and argue that the observed productivity dispersion cannot be explained within the framework of the standard equilibrium search theory. Our argument rests on the concept of non-self-averaging.

Non-Self-Averaging—A Key Concept for Macroeconomics

Consider a sequence or a group of random variables $X_n (n = 1, 2, \cdots)$. If the coefficient of variations, namely the standard deviation of X_n divided by its mean, approaches zero as n goes to infinity, then X_n is said to be self-averaging. If not, X_n is *non-self-averaging*.

The Gausian normal distribution and the Poisson process so commonly assumed in economic analysis are self-averaging. However, these cases of self-averaging cannot be actually taken as the norms. Put it differently, non-self averaging is not pathological case to be left only for mathematical curiosity, but rather quite naturally emerges and is generically present in nature (see, for example, Sornette, 2000, p. 369). For example, suppose that n random variables form K_n clusters. Clusters may be the subsets of firms or households to be distinguished from each other by their respective characteristics. Now, in a two-parameter model in which one parameter, θ, effects the way existing clusters grow while the other parameter, α, influences the way a new cluster (of initial size one) is born. This model is known as the Poisson-Dirichlet two-parameter process, PD(α, θ). In this model, the number of clusters, K_n, is self-averaging with α =0, but is non-self-averaging for α >0; See Aoki (2006). In other words, if the number of clusters is given, we obtain self-averaging, but when the number of clusters stochastically grows, we obtain non-self-averaging. Note that the standard Poisson process is nothing but a special case of α =0. Aoki and Yoshikawa (2009) in this issue demonstrate that non-self-averaging quite naturally emerges in a simple model of economic growth.

Non-self-averaging means that we cannot ignore the fluctuations around the mean even if n (typically, the number of agents in the model) becomes large. This, in turn, means that optimization exercises in the standard micro-founded macroeconomics do not make much sense because such analyses are meant to capture the dynamics of the means. Using the concept of non-self-averaging, Aoki and Yoshikawa (2009) in this issue criticizes the equilibrium search theory of Lucas and Prescott (1974).

Corporate Networks

Analysis of corporate networks is another important topic. Fujiwara et al. (2009) in this issue analyzes the structure of credit networks between banks and firms in Japan, and its changes during the period of 1980-2005. It analyzes the credit network by means of a weighted bipartite graph in which the edge corresponds to the financial relationship whereas the weight refers to the amount of loans. The effects of changes in the amounts of loans on banks on one hand and firms on the other are reciprocal. Setting up the analysis of this problem as an eigen-value problem, they successfully clarify the stability and fragility of the credit network.

Konno (2009) in this issue is another analysis of corporate networks. His analysis based on a large data of 800,000 Japanese firms, demonstrates the presence of *hierarchical structure* among the Japanese firms. In the standard micro-founded macroeconomics, it is commonly (albeit tacitly) assumed that firms are symmetric. The assumption of the representative firm for which optimization exercises are made, in effect, means that all the firms are similar. Konno's finding shows that this assumption is not tenable. We must explicitly take into account the fact that corporate networks are hierarchical. Aoki and Yoshikawa (2007: chapter 5) explain the implications of hierarchical structure for macroeconomics.

New Approach

Toward reconstructing macroeconomics, the first step is to discard the standard sophisticated micro-optimization exercises because to pursue the precise behavior of micro unit based on the representative agent assumption is meaningless for understanding the macroeconomy comprising many agents. Instead, we need a different approach based on statistical physics. It explicitly takes into account *heterogeneity* necessarily present in the macroeconomy. Various attempts are being made to demonstrate the usefulness of such approach.

Challet et al. (2009) in this issue presents a simple model in which the economy consists of two sectors, one growing and the other declining. It demonstrates that this simple two-sector framework can be usefully applied to severe downturns and recoveries which thirty countries experienced in this regime transitions.

Hawkins and Aoki (2009) in this issue show how time-dependent macroeconomic response follows from microeconomic dynamics using linear response theory and a time-correlation formalism. It explores a particular hierarchical dynamics of output and unemployment to show that Okun's Law naturally emerges.

Wright (2009) in this issue calls new approach based on statistical physics "implicit microfoundations for macroeconomics". It argues that 'a "black box" probabilistic model of individual agency does not imply that the choice mechanism is in fact random, only that, when placed in the range of situations routinely presented by a dynamic large-scale economy, it is operationally equivalent, at the aggregate level, to an ensemble of

random processes.' It presents such a model, and shows that the model is able to replicate many of the observed macroeconomic distributions.

Finally, Da Silva (2009) in this issue surveys the related literature, and argues that economics must contribute to providing foundations for preferences in neuroscience while at the same time, must make attempts to understand aggregate economic phenomena by non-equilibrium statistical physics.

The editors of this special issue hope that papers gathered here contribute to making economists open their minds to the new approach to macroeconomics based on statistical physics.

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