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## **Abstract**

Standard micro-founded macroeconomics starts with optimization exercises to derive the precise behavior of the representative agent and regards the macroeconomy as a homothetic enlargement of a micro agent. This paper takes a different approach and presents a new micro-foundation for Keynesian economics. The key concept is stochastic macro-equilibrium, which is a natural extension of the labor search theory.

**Keywords:** Micro-foundation, Keynesian economics.

**JEL classification:** E12, E60

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## 1. Introduction

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. By construction, it broadly underlines the efficiency of market 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 turmoil — 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. 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 lead us to neoclassical macroeconomics. The real business cycle (RBC) theory (e.g., Kydland and Prescott 1982) praised so highly by Lucas (1987) is the foremost example. The “Great Recession” and the world financial crisis during 2008–2011 have naturally shaken the confidence of mainstream macroeconomics. Some economists indeed turned to criticize the current state of macroeconomics. Paul Krugmann, for example, in his Lionel Robbins lectures at the London School of Economics and Political Science on June 10, 2009 feared that “most macroeconomics of the past 30 years was spectacularly useless at best, and positively harmful at worst” (*Economist* [July 18-24, 2009, 58]).”

To date, there is not a consensus on a new paradigm for macroeconomics. In this paper, I explain that proper micro-foundations for macroeconomics must be based on the method of *statistical physics*. 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 modern *micro-founded* macroeconomics. The latter analyzes the precise behavior of the representative micro agent, and regards the macroeconomy as a homothetic enlargement of such a micro unit. I will explain shortly that there is no fundamental reason why the method so successful in natural sciences cannot be applied to economics. Contrary to Lucas’s assertion, to study the macroeconomy, we *do* need “some other, different kind of economic theory.”

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 on 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 systems 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 not warranted. It is not essential for studying a macro system whether micro units comprising the macro system under investigation are human beings with brains or inorganic particles. The point is that because the number of micro units is large, it is impossible and meaningless to pursue precise behavior of each micro unit. Every economist knows that the economic agent who does intertemporal optimization maximizes the Hamiltonian. Likewise, every physicist knows that the inorganic particle in Newtonian motion also minimizes the Hamiltonian. Thus, in this respect, sophisticated human beings pursuing intertemporal optimization and inorganic particles are on an equal footing. To repeat, the issue is not whether a micro unit is human utility/profit maximizer or not. It is simply incorrect to analyze a macro-system by the method based on the representative micro unit. That is what natural sciences have demonstrated time and again.

In the second section, I explain that the method based on statistical physics provides a proper micro-foundation for Keynes's principle of effective demand. The theoretical model is briefly explained. Stochastic macro-equilibrium is a natural extension of the standard labor search theory. I present a simple numerical simulation to show how the model works. The third section concludes the paper.

## **2. Micro-foundation for Keynesian Economics**

In this section, I explain a new micro-foundation for Keynesian economics.<sup>1</sup> This micro-foundation is meant to make a plausible story of optimization by firms and workers that is consistent with Keynesian macroeconomics. The representative works are collected under the "New Keynesian economics" heading (Mankiw and Romer 1991). They focus on inflexibility of prices and wages. Inflexibility is defined relative to "perfect flexibility" of prices supporting the Walrasian equilibrium.

The Walrasian equilibrium is well established in economics, but it cannot be more different from the real economy. Labor and capital are assumed to swiftly move to the sector with the highest productivity, and consequently in equilibrium, their marginal products are equal

in all the sectors and firms. Demand does not matter in the determination of the aggregate output; it affects only the composition of outputs.

### **Limitations of Search Theory**

Equilibrium search theory has contributed to filling the gap between theoretical analysis and the actual economy (Diamond 2011; Mortensen 2011; Pissarides 2000, 2011). It starts with the presence of various frictions and accompanying matching costs in market transactions. In search equilibrium, potentially similar workers and firms experience different economic outcomes. For example, some workers are employed while others are unemployed. In this way, search theory well recognizes heterogeneity of workers and firms. Despite this recognition, when it comes to model optimizing behavior of an economic agent such as a worker, it, in effect, presumes the representative agent. For example, it is explicitly stated in a classical paper by Diamond (1982) that “all individuals are assumed to be alike.” Thus, in the Diamond–Mortensen–Pissarides search model of unemployment, the reservation wage is the same for all the workers.

The similar problems arise for models in which the behavior of a firm is explicitly analyzed. In the first place, a firm does not usually employ workers with the same quality, but rather different kinds of workers, say white-collar and blue-collar workers or full-time and part-time workers. Their wages and separation rates differ, of course. These problems are assumed away in the standard search models. In summary, standard models are built on extremely unrealistic assumptions such as identical workers, risk neutral economic agents, and the stationary distribution of productivity.

The point is *not* that we must *explicitly* introduce all these complexities characterizing the labor market into an analytical model. It would simply make the model intractable. Rather, we must fully recognize that it is absolutely impossible to trace the microeconomic behaviors of workers and firms in detail. From this viewpoint, the merits of doing sophisticated optimization exercises based on representative agent assumptions are dim. In the labor market, microeconomic shocks are indeed *unspecifiable*. Nor we are assured that the standard central limit theorem holds true for *non-self-averaging* (see, Aoki and Yoshikawa 2012).

Thus, for the purpose of the analysis of the macroeconomy, sophisticated optimization exercises based on representative agent assumptions do not make much sense. This is actually partly recognized by search theorists themselves. The recognition has led to the introduction of the “matching function” into the analysis. The matching function relates the rate of meetings of job seekers and firms to the numbers of the unemployed and job vacancies. However, what a job seeker is looking for is not simply a good wage, but a good job offer which cannot be uniquely defined but differs across workers. It is simply *unspecifiable*. Pissarides (2011) recognizes such

“real-world features” as differences across workers and jobs. Then, at the same time, he recognizes that we need a “macro black box.” The matching function is certainly a black box not explicitly derived from micro optimization exercises. The analysis presented below is based on the motive similar to the one behind the matching function.

### Stochastic Macro-equilibrium

Our vision of the macroeconomy is basically the same as standard search theory. Workers are always interested in better job opportunities, and occasionally change their jobs. Job opportunities facing workers are stochastic. While workers search for suitable jobs, firms also search for suitable workers. A firm’s job offer is, of course, conditional on its economic performance. The present analysis focuses on the firm’s labor productivity. Because labor adjustment always takes time, labor productivity changes when demand for the firm’s output changes. Given labor hoarding, when demand suddenly falls, productivity necessarily falls. As for wages, following search theory, we regard wages as determined by bilateral bargaining between the firm and workers, and assume that the higher the firm’s labor productivity is, the higher wages ensue.

The question we ask is: what is the distribution of employed workers across firms whose productivities differ? As we argued in the previous section, because microeconomic shocks to both workers and firms are so complex and unspecifiable, optimization exercises based on representative agent assumptions do not help us much. Instead, Yoshikawa (2003) proposed the notion of stochastic macro-equilibrium based on the principle of statistical physics. The fundamental constraint in the model is aggregate demand,  $D$ . The basic idea can be explained with the help of the simplest case.

Suppose that  $n_k$  workers belong to firms whose productivity is  $c_k$  ( $c_k < c_{k'}$  where  $k < k'$ ). There are  $K$  levels of productivity in the economy. The total number of workers  $N$  is given.

$$\sum_{k=1}^K n_k = N \tag{1}$$

A vector  $n = (n_1, n_2, \dots, n_K)$  shows a particular allocation of workers across firms with different productivities. The combinatorial number of obtaining this allocation,  $n$ ,  $W_n$  is equal to that of throwing  $N$  balls to  $K$  numbered boxes. Therefore, we obtain

$$W_n = \frac{N!}{\prod_{k=1}^K n_k!} \tag{2}$$

Because the number of all the possible ways to allocate  $N$  identical balls to  $K$  different boxes is  $K^N$ , the probability that a particular allocation  $n = (n_1, n_2, \dots, n_K)$  is obtained is

$$P_n = \frac{W_n}{K^N} = \frac{1}{K^N} \frac{N!}{\prod_{k=1}^K n_k!} . \quad (3)$$

It is the fundamental postulate of statistical physics that the state or the allocation  $n = (n_1, n_2, \dots, n_K)$  which maximizes the probability  $P_n$  or (3) under macro-constraints is to be actually observed in the economy. The basic idea is similar to maximum likelihood in statistics/econometrics.

Maximizing  $P_n$  is equivalent to maximizing  $\ln P_n$ . Applying the Stirling formula for large number  $x$

$$\ln x! \cong x \ln x - x , \quad (4)$$

we find that the maximization of  $\ln P_n$  is equivalent to that of  $S$ .

$$S = -\sum_{k=1}^K p_k \ln p_k \quad (p_k = \frac{n_k}{N}) \quad (5)$$

$S$  is the Shannon entropy.

It is essential for us to understand that the present approach does *not* regard economic agents' behaviors as random. Certainly, firms and workers maximize their profits and utilities. The economic behavior is purposeful, not random. Randomness underneath this analysis comes from the fact that both the objective functions of and constraints facing a large number of economic agents are constantly subject to *unspecifiable* micro shocks. We must recall that the number of households is of order  $10^7$ , and the number of firms,  $10^6$ . Therefore, there is nothing for outside observers, namely economists analyzing the macroeconomy but to regard a particular allocation as equi-probable. Then, it is most likely that the allocation of workers which maximizes the probability  $P_n$  or (3) under macro-constraints is to be realized.

The first macro-constraint concerns the labor endowment, (1). The second macro-constraint concerns the effective demand.

$$\sum_{k=1}^K c_k n_k = D \quad (6)$$

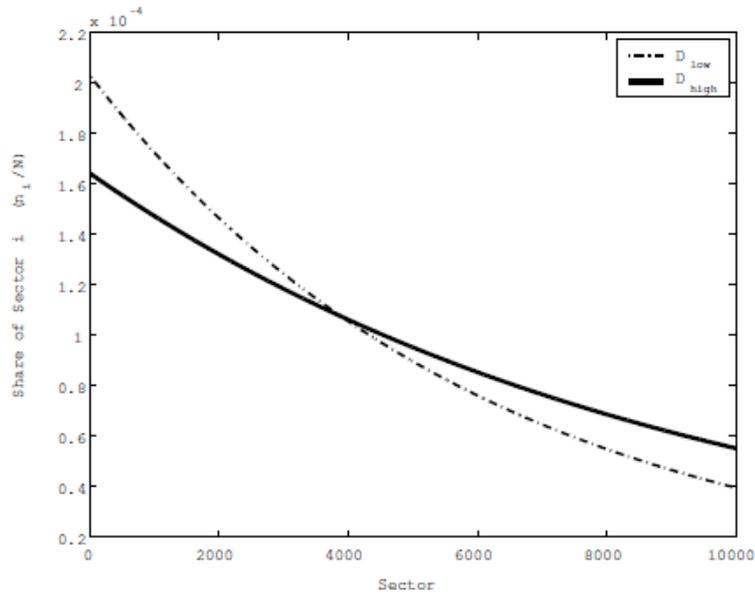
Here, aggregate demand  $D$  is assumed to be given. By maximizing  $P_n$  or  $S$  under two macro-constraints (1) and (6), we obtain the following exponential distribution (Aoki and Yoshikawa 2007, 79-81):

$$\frac{n_k}{N} = \frac{e^{-\frac{Nc_k}{D}}}{\sum_{k=1}^K e^{-\frac{Nc_k}{D}}} \quad (7)$$

This distribution depends crucially on the level of the aggregate demand  $D$ , which corresponds to temperature  $T$ , in physics. According to (7), the share of workers at firms whose

productivity is high gets larger when the aggregate demand  $D$  — to be precise, the aggregate demand relative to the endowment, namely  $D/N$  — becomes greater, and *vice versa* (Figure 1).

Figure 1: Productivity Dispersion



### A Numerical Simulation

Yoshikawa (2011) presents an extended theoretical model based on the same idea. In what follows, I present a simple simulation result to show how the model works. In the extended model,  $N$  is a variable on the assumption that it is smaller than the total number of workers,  $L(N < L)$ . The total number of workers or labor force  $L$  is exogenously given. The difference between  $L$  and  $N$  can be naturally interpreted as the number of the unemployed,  $U$ .

Figure 2 : Distribution of Productivity and Aggregate Demand

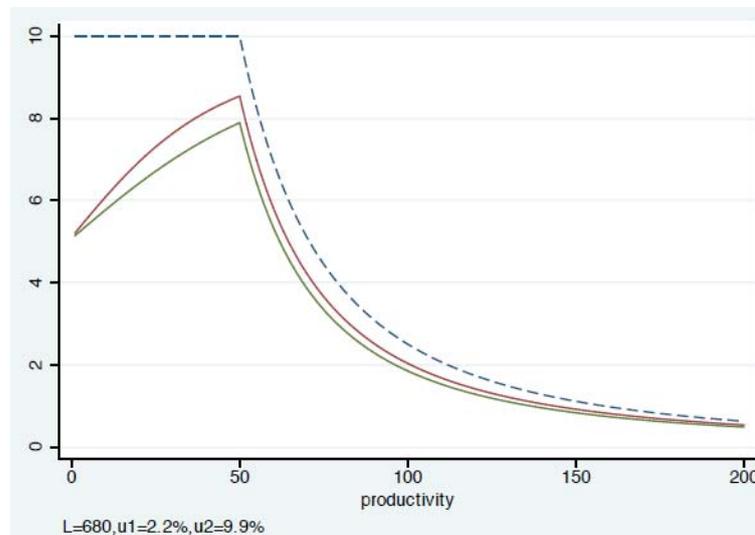


Figure 2 shows the distribution of  $n_j$  which maximizes the entropy under macro-constraints. In the figure, the level of productivity  $c_1 = 1, \dots, c_{200} = 200$  are shown horizontally. In this example, we have two cases; Case A corresponds to high aggregate demand whereas Case B corresponds to low aggregate demand.

When aggregate demand rises, the distribution of productivity as a whole goes up. To the extent that wages offered by the firm are proportional to the firm's productivity, the distribution shown in Figure 2 corresponds to the wage offer distribution function in the standard search literature. It depends crucially on the level of aggregate demand.

When  $D$  goes up, the number of employed workers  $N$  which corresponds to the area below the distribution curve, increases. Specifically,  $N$  is 665 in case (A) while it is 613 in case (B). It means that the unemployed rate  $U/L = (L - N) / L$  declines when aggregate demand  $D$  rises. In this example, the unemployment rate is 2.2% in case (A) while it is 9.9% in case (B) ( $L$  is 680 in both cases).

The mechanism that generates this result is as follows. As aggregate demand increases, more firms make better job offers than previously, and *vice versa*. When  $D$  rises, therefore, more workers in the unemployment pool find acceptable jobs. Employment  $N$  increases, and the unemployment rate declines. At the same time, more workers who are currently employed move to better jobs without experiencing any spell of unemployment.

In the standard search theory, the matching function relates the successful worker-job meetings to the number of workers unemployed and job vacancies. As a first step, it may be a useful analytical concept. However, to the extent that abstracting itself from qualities of job seekers and vacancies it depends only on the numbers, it misses an important aspect of the labor market. What really happens in the labor market is concisely described by Okun (1973) as follows.

The evidence presented above confirms that a high-pressure economy generates not only more jobs than does a slack economy, but also a different pattern of employment. It suggests that, in a weak labor market, a poor job is often the best job available, superior at least to the alternative of no job. A high-pressure economy provides people with a chance to climb ladders to better jobs.

The industry shifts are only one dimension of ladder climbing. Increased upward movements within firms and within industries, and greater geographical flows from lower-income to higher-income regions, are also likely to be significant. (Okun 1973, 234-235)

This is exactly what happens in the present model.

### 3. Conclusion

While acknowledging the achievement of search theory, we pointed out that it rests on many unrealistic assumptions. The theory is, in fact, a curious hybrid of two different assumptions of many heterogeneous agents on one hand and the representative agent on the other; It emphasizes heterogeneity of agents due to the presence of various market frictions and matching costs while at the same time it carries out optimization exercises, in effect, on the representative agent assumption. To get closer to reality, we must abandon the pursuit of the exact micro behavior of economic agent. This is the motive for the introduction of the matching function in the standard literature.

Not to pursue the behavior of micro unit for understanding macro system is nothing but the basic principle of statistical physics. Following this principle, we presented a model of stochastic macro-equilibrium (see Tobin 1972). A concept of stochastic macro-equilibrium is motivated by the presence of all kinds of unspecifiable micro shocks. The model is an alternative to, and in some respects, an extension of standard labor search theory. In particular, in contrast to the standard search theory, our model of stochastic macro-equilibrium designates the level of aggregate demand to the most important factor for determining the distribution of productivity, and accordingly, the level of unemployment. It provides a proper micro-foundation for Keynes's principle of effective demand (Keynes 1936). The level of aggregate demand  $D$  is taken as exogenous in our model. It is, of course, an important research agenda to inquire how  $D$  is determined, but it is precisely what the old macroeconomics is all about.

#### Footnote

<sup>1</sup> For Keynesian economics and the development of macroeconomics, see Yoshikawa (2009).

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