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Microeconomic shocks and macroeconomic fluctuations in a dynamic network economy

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ABSTRACT

The distribution of firm-sizes in the U.S. – or at least its upper tail – appears to be well-described by a Pareto distribution with infinite variance. This fact forms the basis of the *granular hypothesis* proposed by Gabaix in his paper “The Granular Origins of Aggregate Fluctuations” (*Econometrica*, (2011)). The granular hypothesis provides a mechanism whereby independent firm-level shocks are capable of generating macroeconomic fluctuations. This paper considers the granular hypothesis in a new framework. It develops a DSGE model by superimposing a stochastic overlapping generations framework on a network. Idiosyncratic output shocks to individual firms are transmitted across the economy through income–expenditure channels. Specifically, firms represent vertices of the network, and a firm x is linked to another firm y if x employs one or more workers who purchase commodities produced by y. The paper’s findings agree closely with results first discovered by Gabaix: if firm-sizes in an economy are described by a Pareto distribution, then independent firm-level shocks can generate macroeconomic fluctuations in accordance with the granular hypothesis. Furthermore, the model is capable of generating aggregate volatility of the same order of magnitude as occurs in reality. Thus the paper describes a new general equilibrium framework where macroeconomic fluctuations can arise as the consequence of independent firm-level shocks.

1. Introduction

Is it possible for macroeconomics fluctuations to arise as the consequence of numerous independent shocks at the level of individual firms? An argument against this possibility is based on the law of large numbers: the sum of many small independent shocks will involve a great deal of “averaging out,” with positive shocks cancelling negative shocks, and so if the number of shocks is large, then there aggregate effect will be negligible relative to the size of the economy.[1] Therefore, according to this view, if all randomness in an economy is due to independent shocks at the level of individual firms, then even though the individual firms themselves may manifest significant volatility, fluctuations at the level of the macroeconomy – business cycles – will be absent. In order for this argument to have a name, I will refer to it as the *diversification hypothesis*.

An argument in favor of the possibility is provided by the *granular hypothesis*, introduced by Gabaix (2011). This hypothesis proposes a mechanism whereby independent firm-level shocks can generate macroeconomic fluctuations. The hypothesis is constructed from two ingredients. The first is the empirical fact that firm-sizes in the U.S. are distributed according to a Pareto

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[1] A version of this argument is made by Lucas (1977). However, in his discussion, Lucas indicates that it may also be possible for macroeconomic events to be driven by a mechanism such as the one underlying the granular hypothesis.

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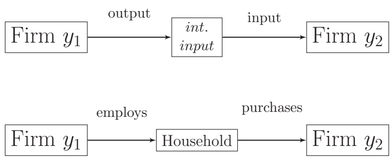

Fig. A. The top figure shows an input–ouput linkage. In this case a firm y_1 is connected to a firm y_2 if the good produced by y_1 is used as an intermediate input into the production process of y_2. The bottom figure shows an income–expenditure linkage: A firm y_1 is connected to a firm y_2 if y_1 employs one or more workers who purchase consumption goods produced by y_2.

distribution with infinite variance. The salient feature of such a distribution is that it possesses a “heavy right tail,” which means that it places a lot of probability mass, comparatively speaking, on elements that that are very large. Consequently, a random sample dawn from such a distribution will generally contain a small number of very large observations. The second ingredient is that firms in an economy are connected by a network of economic linkages.

Following is an intuitive explanation of the granular hypothesis. The hypothesis starts with the first basic ingredient, namely that the distribution of firm-sizes adheres to a Pareto distribution with infinite variance. As mentioned, a random sample drawn from such a distribution will typically include a small number of very large units. Therefore, if the size of idiosyncratic shocks to any given firm are in proportion to the size of the firm, then a Pareto distribution of firm-sizes should produce a Pareto distribution of shocks, and consequently, this distribution will generally contain a small number of very large shocks – in particular, it will contain shocks that are *not* necessarily small relative to the size of the economy. But because these large shocks are small in number, they will not cancel or aggregate in accordance with the law of large numbers. In other words, – to summarize the argument to this point – a Pareto distribution of firm-sizes will generally produce a small number of very large shocks that do not “average out” relative to the size of the economy. But since firms in an economy are connected by a network of economic linkages, the effects of these shocks will be propagated across the economy by the network, and thus converted into macroeconomic fluctuations.

Gabaix develops the granular hypothesis in a one-period general equilibrium framework where firms are connected by input–output linkages. That is, a firm y_1 is linked to a firm y_2 if the output produced by y_1 is used as an intermediate input in the production process of y_2. Another important contribution to this literature is Acemoglu et al. (2012). These authors also build a one-period network economy, and use it to address the question of whether microeconomic shocks can generate aggregate fluctuations, although their focus is on sectors rather than firms. As with Gabaix (2011), sectors in their model are connected by input–ouput linkages.

This paper addresses the same basic questions as the papers of Gabaix (2011) and Acemoglu et al. (2012), but it does so in a new framework. Specifically, this paper builds a network economy that differs from those of either Gabaix (2011) or Acemoglu et al. (2012) in two fundamental respects. First, the model in this paper is dynamic. To be precise, it superimposes a dynamic stochastic general equilibrium model with overlapping generations on a weighted (or directed) graph. This innovation permits the introduction of shocks that have a dynamic character. In particular, all shocks in the model are output shocks to individual firms that follow independent *AR(1)* processes. Consequently, any exogenous random event experienced by an individual firm sets in motion a dynamic response that spreads through the network. The second of the model’s innovations is that firm-level output shocks are transmitted through income–expenditure linkages rather than input–output linkages. Specifically, an individual firm is linked to the households it employs, and an individual household is linked to firms from which it purchases consumption goods. Therefore a firm y_1 is linked to a firm y_2 if y_1 employs one or more workers who then purchase consumption goods produced by y_2. Thus the economy can be configured as a graph where a weighted edge leads from firm y_1 to firm y_2 if cash flows from y_1 to y_2 through the income and expenditure of at least one household. By construction, all firms produce consumption goods – that is, there are no intermediate inputs in the model. Fig. A provides a schematic comparison of input–output linkages with income–expenditure linkages.

The primitive ingredients in the model that generate output-volatility are the same as those that drive volatility in a benchmark real-business cycle model (as described in say, Prescott, 1986): Firm-level productivity shocks affect labor-supply and consumption through households’ inter-temporal substitution between labor in the current period and consumption in the next period. Thus the income and expenditure of an individual household provides a connection through which the shock experienced by one firm can be transmitted to another firm. For example, an output shock experienced by firm y_2 will alter the price of the good that it sells, which then affects the labor-supply decisions of households who purchase this good. But these labor-supply decisions will then affect the level of output produced by a firm y_1 that employs one or more of these households. Thus a productivity shock at y_2 travels “backwards” along the income–expenditure channel that connects y_1 to y_2, affecting output and employment at y_1. But this is just the first step; the effects of the shock then radiate outwards from firm y_1 in the same fashion, affecting first the labor-supply decisions of households that purchase its product, and next, the employers of these households, and so on.

I believe that the model in this paper can be seen as complimentary to the models of Gabaix (2011) and Acemoglu et al. (2012). The model in this paper is dynamic; shocks are transmitted by the intertemporal decisions made by individual households. In contrast, the models of Gabaix (2011) and Acemoglu et al. (2012) are static. Therefore, the mechanism for transmitting shocks in this paper is absent from those other two papers. On the other hand, in both Gabaix (2011) and Acemoglu et al. (2012), shocks are