# Intermediation, Money Creation, and Keynesian Macrodynamics in Multi-agent Systems

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**Abstract**

This paper offers a simple computational model of monetary creation that is derived from individual agent behavior, providing additional support for the well-known and more or less universally accepted idea that money creation is inevitable in demand-driven Keynesian economies. The endogeneity of money is linked to the process of asynchronous production, in which investment is set autonomously by a combination of animal spirits and capacity utilization, while savings adjusts to bring about macroeconomic equilibrium. It is seen that once these Keynesian motifs are translated into the agent-based framework, endogenous money arises as a natural consequence of the model.

*JEL codes*: D58, E12, C00. *Keywords*: multi-agent system, intermediation, endogenous money, Keynesian macroeconomics

## 1 Introduction

The notion that investment-led growth is accompanied by endogenous money creation is central to Post-Keynesian macroeconomics and has been discussed in great detail in the literature. This paper shows that when Keynesian mechanisms are introduced into an agent-based model, money is almost always endogenous. The mechanism comes to light in the process of extending a standard structuralist model first to two sectors and then to a multi-agent system (MAS) model. The exercise shows that in a one-sector model, the equality of savings and investment assumes a smooth and efficient transfer from savers to investors that must go on in the background. A two-sector model highlights potential problems that might arise when one firm wishes to invest more than it has saved and must therefore borrow from the other. The multi-agent extension reveals that it is highly unlikely that a "smooth and efficient transfer" could ever take place without endogenous money creation. Endogenous money emerges as a rigorous, well-defined and irreducible concept. Barring a statistical fluke, the more realistic multi-agent systems model will always generate endogenous money, irrespective of the desire on the part of the monetary authority to limit credit creation. At the same time, not all credit-worthy demand for bank loans results in money creation at the microeconomic level, and this has important implications for the theory of crisis. It is to be emphasized that none of the findings of this paper are, in any global sense, new. The goal of this paper is only to place some extremely well established results in the context of the agent-based methodology.

This model builds on an existing MAS model due to Setterfield and Budd (2011) as modified by Gibson and Setterfield (2013), which has roots in the structuralist tradition (Pasinetti, 1981; Taylor, 1983, 1991). Most multi-agent systems model the financial system in isolation from the real-side economy, as stand-alone

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models. Here a very simple model of real-financial interactions is employed in which multiple, heterogeneous firms and financial agents, or banks, are interconnected in a two-layer network. Financial nodes are connected by edges that represent borrowing on one level of the network while firms on a second level of the network are connected by edges that represent sales and purchases of goods and services. The demand side is not explicitly modeled in detail, other than that households either save or consume. The model focuses instead on the behavior of firms and their decision to invest, either by way of retained earnings or by borrowing from other firms through financial intermediaries. The financial subnetwork is sparsely connected to the real subnetwork as described in detail below.[1]

The motivation of this paper is not to represent realistically a financial system of an actual economy. There is for example no central bank and the interaction of financial agents is limited. The contribution is more theoretical and is offered as a stepping stone to more elaborate models that do capture the complexity of real-financial interactions.[2]

The core of this paper's argument is that money creation is inevitable if savings and investment decisions are made in the asynchronous ecology of agent-based models. Even if time intervals are short, the non-contemporaneous nature of savings and investment decisions leads to endogenous money creation. At some point in the evolution of the system, conflicting claims on deposits arise that are most easily resolved by way of money creation. The results of the agent-based model studied here thus support the broadly accepted notion that animal spirits and endogenous money are thus two sides of the same analytical coin.

This paper is organized as follows. The next section discusses the hidden role of endogenous money creation in Keynesian macroeconomics. This section presents a small two-firm prototype analytical model, that when stripped down to its essentials conveys the basic mechanisms on which the larger multi-agent model is built. Section three outlines the generalization of the analytical model to a full multi-layered, multi-agent system, and identifies asynchronicity as essential to an agent-based conception of endogenous money. Section four concludes.

# 2 Money and production in one- and two-sector models

In Keynesian macroeconomics, endogenous money creation within the private sector is well understood to accompany the income-generating process. Indeed, it has been known for decades that when economic activity is demand-led, endogenous money creation is logically necessary for real expansion to be feasible (Chick, 1983). As will become clear, the argument here centers on the financing of fixed capital formation and the fact that economic activity takes time, specifically that adjustment to equilibrium is not instantaneous.[3] This is self-evident to most Keynesians and goes back at least to Robertson's discussion of the multiplier concept (Robertson, 1940).[4]

## 2.1 A one-sector model

In one-sector Keynesian models, savings depends on income while investment spending does not. Unlike some neoclassical models, Solow among them, saving cannot *initiate* a change in income. In Keynesian models, an autonomous increase in investment increases income and a concomitant rise in savings follows in the wake of this change. As is commonplace, macroeconomic equilibrium is established when income rises to the point that total savings balances investment.

[1]The precise structure of the financial network is seen to be crucial to the propensity of the model to experience a financial crash. See Gibson and Setterfield (2013).

[2]There is here a clear link between the disaggregated version of the standard structuralist model of this paper and the rich history of multi-sectoral analysis in Keynesian macroeconomics (Pasinetti, 1981). For the methodological claim that MAS modeling is consistent with the pre-analytic vision of Keynesian theory see Bucciarelli and Silvestri (2013). For numerical simulations of the model discussed in this paper, see Gibson and Setterfield (2013).

[3] See Arestis (1987, pp.10-11) for similar arguments regarding the importance of endogenous money creation for the expansion of *working* capital by firms, when production takes time so that the costs of production must be incurred before revenues accrue from the sale of output.

[4]See Chick (1983, pp.257-63) for a discussion and reconfiguration of Robertson's model.

In a one-sector, one-period model the purchasing power to back up the desire to invest must come from somewhere. Traditionally, it is assumed to come from the savings that agents–some of whom who are hired as a result of the new investment–will generate. In the storied equilibrium of the Keynesian model, this all comes out "in the wash". It was clear to the early Keynesian theorists, however, that something more complex and potentially problematic was going on in the unexamined background. In particular, it became self-evident that investment spending can *increase* above its current level of savings in the previous period, if and only if additional credit is created.[5] As Chick (1983) writes

> ...[i]f the investment is not financed it will not take place...one needs to back demand with purchasing power. The solution to the problem lies in the capacity of banks to create credit in excess of current saving, and so finance investment in excess of current saving. Chick (1983, p.189)

Chick (1983) notes that there is an historical as well as logical dimension to this process: the independence of investment from prior savings requires that commercial banks have the capacity to create credit in excess of saving. Banks act as more than mere conduits or intermediaries for existing saving and hence effectively relax the constraint that would otherwise be imposed by prior savings on investment spending. Once disequilibrium adjustment is complete so that savings is once again equal to investment, current savings is sufficient to fully fund current investment spending. The bank credit originally created is now either "destroyed" by repayment of the loans as firms refinance by issuing bonds or held by households in the form of higher transactions, precautionary, and/or speculative balances.[6] For Keynesians this is received wisdom, based on a one-sector, aggregate analysis, an analysis not always accompanied by an explicit account of the timing of flows of deposits and withdrawals from individual banks.

A sufficient condition for real expansion in Keynesian systems is provided by the *horizontalists* (Moore, 1988; Lavoie, 2007; Docherty, 2005), but the necessary condition for endogenous money is only that the elasticity of the supply of credit be non-zero (Pollin, 1991; Dow, 2007). Under these conditions, the monetary authority cannot prevent banks from responding to the incentive of higher interest rates by creating more credit. The result is an upward-sloping credit supply curve in quantity of credit-interest rate space. Whether banks require an incentive in the form of some increment in the interest rate is not central to the argument. From this perspective an upward-sloping credit supply curve is just a variation on the theme of horizontalism.[7] Endogenous money is the normal state of the macroeconomic system, whatever the slope of the credit schedule.

*Verticalists*, by contrast, describe a world in which this endogenous creation of money goes to zero. In this case, the supply of money is infinitely inelastic. Here again, however, the onus of the argument is on the behavior of banks in a homogeneous banking system. A vertical credit supply function is simply a limiting case as the responsiveness of banks to the incentive of higher interest rates diminishes. It is the limit as the desire to create endogenous money goes to zero. Only at this limiting case in which the elasticity of the credit supply curve goes to zero, do central banks wrest control of the money supply from the banks. In any other state, money is endogenous.

To fix ideas, consider a standard but highly stylized Keynes-Kalecki model in which $x$ is the level of output in the economy and $K$ is the given aggregate capital stock in a particular year. Define the current level of capacity utilization, $u$ as

$$u = x/K \tag{1}$$

[5]Note that there is no parallel constraint on saving-constrained investment falling *below* its current level.

[6]See, for example, Graziani (1989). For a balance sheet presentation of how these adjustments take place, see Chick (1983, pp. 261-2).

[7]As Palley (2013, pp. 414-22) has recently argued, the process of credit creation is not adequately captured by horizontalism, even when adjusted to allow for an upward-sloping credit supply schedule. It fails to take into account capital and reserve requirements, access to finance through the Federal Funds and discount windows as well as the public's liquidity preference. This critique rejects the perfectly elastic supply of finance of the horizontalists. Palley's version of the structuralist model adds welcome detail to the evidently oversimplified horizontalist account. On the other hand, Lavoie (1996, p. 277) holds that any upward sloping aggregate supply of credit will eventually lead to the "neoclassical world of scarcity, with crowding out effects and the like".

Assuming for convenience that household savings is only out of profits at rate $0 < s \leq 1$, the savings-investment balance, normalized by the capital stock, can be expressed as

$$I/K = s\pi u \tag{2}$$

where $\pi$ is profit (retained earnings) per unit of output, $x$. Investment in this variety of models is usually written as a function of capacity utilization in the previous period, $I/K = g(u_{t-1})$, where the shape of the function $g$ depends on exogenous animal spirits and is independent of savings in the economy. Equilibrium output can be expressed in terms of $u$ by combining equations 1 and 2 to write

$$u = \frac{g}{s\pi}$$

and it is seen that aggregate savings, $s\pi K$, is determined by $g$, which is turn given by expectations of ability of the firm to meet demand as a function of last-period's capacity utilization, buoyed by animal spirits. This period's savings is equal to investment but plays no role in its determination. Indeed, if last period's saving *rate* were higher, last period's capacity utilization would be lower and thus investment this period would be *lower*, for the same level of animal spirits. Last period's savings is not even available to finance current investment, since its material form is nothing but a claim on the capital stock of firms that is now enlarged by last period's investment.

The one-sector, one-period Keynesian model holds that savings will adjust to investment without bothering to explain how consumers make their savings available to firms for investment. One way to finesse this point is to say that consumers own the firms and use them as a vehicle to store their accumulated savings in the form of the capital stock and retained earnings. No banking system is then necessary since the aggregate firm controls all the savings in the system on behalf of the households. The firm simply directs investment in the way it sees fit and in the process of expanding output and employment, generates the savings.[8]

## 2.2 A two-sector model

Now let there be two sectors. Unless each firm invests precisely as much as the savings it generates, there is an unavoidable problem: how is the surplus savings of firms that do not invest as much as they save, transferred to firms who have a deficit of savings to finance their investment? It is evidently done by middlemen, the banks, based on the collateral and credit worthiness of the borrower as assessed by the financial agents of the system.

Again assume that some fraction of households owns, but does not control the retained earnings of firms. One need only consider then the borrowing of the deficit firm and the availability of loanable funds from the surplus firm.[9] Deficit firms cannot retain sufficient earnings for their investment plans, but must borrow from surplus firms that have more than enough retained earnings relative to their own investment plans. In effect, the households that own shares in the surplus firm now diversify, owning shares of the deficit firm as well.

Consider the equilibrium solution to a demand-determined real-side model in which the number of firms is $n = 2$. There is only one good, the price of which is fixed at unity. Output, $x_i$ for $i = 1, 2$, is a share, $\theta$ (for firm 1) and $1 - \theta$ (for firm 2) of aggregate demand, which is the sum of consumption and investment. Workers consume all their income while consumption of capitalists is income less savings. Equilibrium is defined by the balance of supply and demand for each of the two firms

$$\begin{aligned} x_1 &= \theta\left[(1 - s_1\pi_1)x_1 + (1 - s_2\pi_2)x_2 + g_1K_1 + g_2K_2\right] \\ x_2 &= (1 - \theta)\left[(1 - s_1\pi_1)x_1 + (1 - s_2\pi_2)x_2 + g_1K_1 + g_2K_2\right] \end{aligned}$$

Here capitalists save a fraction $s_i$ of their profits $\pi_i x_i$, where again $\pi_i$ is the profit share of output. Investment is given by $\sum_{i=1} 2g_iK_i$, where $g_i$ is the accumulation function that depends on *last period's* capacity

[8]At this level of abstraction, there is no distinction drawn between money and credit.
[9]This account ignores the rate of interest in order to simplify matters.

utilization rate. Normalizing by $K_1$, the capital stock of firm 1, so that $k = K_2/K_1$, the model can be expressed as

$$u_1 = \theta \left\{ (1 - s_1\pi_1)u_1 + g_1 + \left[ (1 - s_2\pi_2)u_2 + g_2 \right] k \right\} \tag{3a}$$
$$s_1\pi_1 u_1 + s_2\pi_2 u_2 k = g_1 + g_2 k \tag{3b}$$

where the rate of capacity utilization of the $i$th firm is given by equation 1 above for each sector. Equation 3b is simply the savings-investment balance for the economy as a whole. The firm's financial surplus $f_i$ per unit of capital in each firm is given by

$$f_i = s_i\pi_i u_i - g_i.$$

The macroeconomic equilibrium condition is

$$\sum_i f_i = 0 \tag{4}$$

that is, the sum of the financial surpluses is equal to zero.

Figure 1 shows the solution to the two-sector model when the savings rates are given. Start with last period's capacity utilization of firm 1, measured in the negative direction on the ordinate. Given $u_{1t-1}$, the level of investment undertaken by firm 1 is determined by the dotted line in the third quadrant, labeled $g_1$. To get total investment, shown by the solid line in the same quadrant, add $g_2k$, which also depends on a given level of lagged capacity utilization for firm 2. The sum is total investment normalized by $K_1$, the right-hand side of equation 3b. The 45-degree line in quadrant 2 reflects this quantity onto the positive ordinate, and in turn determines total (normalized) savings in the current period, shown by the solid line in the first quadrant.

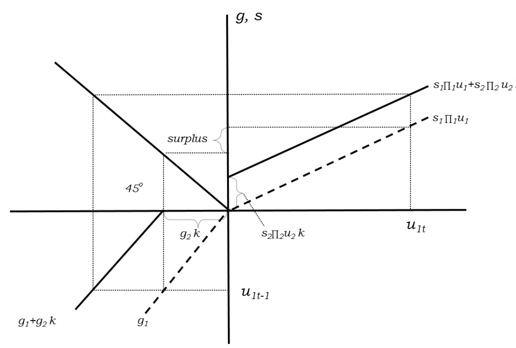


Figure 1: Saving and investment of the surplus firm

Given $u_2$ in the current period, there is only one level of $u_1$ consistent with total savings equaling total investment and that level is shown in figure 1 as $u_{1t}$ on the positive abscissa. The dotted line in the first quadrant, labeled $s_1\pi_1u_1$, shows the savings of the first firm on the positive ordinate as a function of its current capacity utilization. The reflection of the first firm's investment onto the positive ordinate confirms a financial surplus for firm 1.

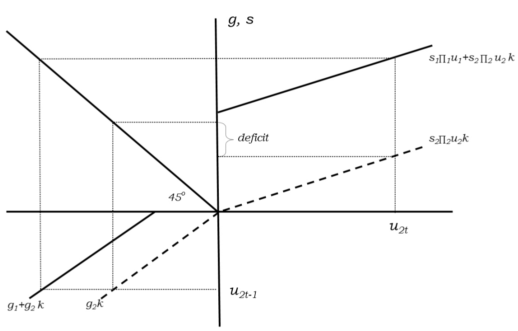


Figure 2: Saving and investment of the deficit firm

Figure 2 employs parallel logic for the second firm, which is in financial deficit. Total investment, determined by the solid line in the third quadrant and reflected onto the positive ordinate by the 45-degree line in quadrant 2, is once again equal to total savings. This is shown as a solid line in the first quadrant. Firm 2 is in financial deficit since at $u_{2t}$, its savings, $s_2\pi_2u_2k$, determined by the dotted line in the first quadrant, is less than its investment $g_2k$, determined by the dotted line in the third quadrant and reflected from the negative ordinate through to the second quadrant.

As noted, in the two-firm example of figures 1 and 2 there must be an implicit financial sector channeling funds between the two real-side firms. Could this flow of funds be disrupted? Clearly yes if the deficit firm in figure 2 cannot borrow. Only if loans are available and meet or exceed the firm's deficit can the latter invest at its desired level. A second problem lies in the intermediation itself. Despite the existence of a surplus of loanable funds *and* a potential intermediary, there is no guarantee that a financial agent might not block the flow of funds, effectively preventing financing from finding its way to the deficit firm. Since banks' profits depend on facilitating the flow, it may seem natural to assume that they will find an efficient way to channel resources from lender to borrower. If, however, the firm is not deemed to be creditworthy or the financial agent perceives some threat to the ability of the firm to repay the loan, the agent may well defer.

Observe that were a financial agent to block the flow of funds from firm 1 to firm 2, the level of activity at which savings comes into balance with investment depends only on the level of investment by the first firm and what can be financed by the second firm so that its financial surplus is zero. The new equilibrium condition replaces equation 4 with

$$f_i = 0, \qquad \forall\, i$$

To the extent that intermediation fails, part of the *ex ante* surplus of the lending firms simply evaporates. Investment becomes financially constrained, and the system cycles down to an equilibrium in which aggregate savings is equal to aggregate investment at a *lower* overall level of economic activity. All this is brought about by the unwillingness of the bank to serve as a conduit of loanable funds. On the other hand, if credit is widely available, there is no limit to the rate at which the economy can expand. For horizontalists and their associates, the current period is untethered to the past.

# 3 A multi-layered network model

The model with just two firms initiates the transition to a full multi-agent system that depends on the microeconomic details of inter-agent communication and negotiation (Gibson and Setterfield, 2013). Multi-agent systems do not just allow for a more careful examination of agent interaction but actually require it, since the rules agents follow are together responsible for the macroeconomic properties of the system. Such an examination uncovers some important properties that are concealed in models lacking detail about the activities of individual agents.

Consider an economy consisting of two breeds of agents: firms and financial entities, or banks. The model structure is summarized by a multi-level network, as shown in figure 3. The top plane represents the financial sector, and is populated by nodes that are linked by borrowing relationships that are non-directional in the sense that funds can flow in either direction between financial entities. Observe that these agents are not randomly connected, but are preferentially attached in that the probability that any new node would connect to an existing node is proportional to its degree or number of existing links to other entities (Gibson and Setterfield, 2013).

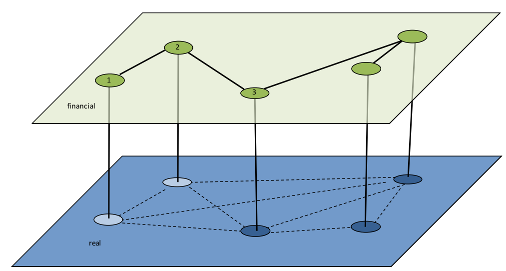


Figure 3: Multi-level network structure with firms on the lower level and financial agents on the upper level. Light disks are *deficit firms* that wish to invest more than they save, while dark disks are *surplus firms* that save more than they invest.

The lower level represents the real sector in which firms are linked by flows of intermediate and final aggregate demand, purchases and sales of commodities, that in principle change with technology and demand preferences.[10]

Were there just one unconnected financial agent per firm, the agent could only accumulate loanable funds when its associated firm was in surplus. These funds would

[10] In the two-sector example above, a change in demand is captured by a change in $\theta$. For simplicity, there are no intermediates in that example.

then be available to the same firm to use in the following period. In effect the network would then break up into a set of separate autonomous economies as in the one-good model above.

Figure 3 shows financial agents connected to each other, with just one agent per firm. Note that the lightly shaded deficit firm on the far left cannot fulfill its investment plans since its financial agent, shown as number 1, is only connected to another deficit firm through financial agent 2. To arrange for funding, the firm would have to persuade financial agent 2 to ask financial agent 3 to for funds from its associated firm, which is indeed in surplus.

Despite its simplicity, figure 3 affords some insight into the necessary structure of financial networks. Observe that if the upper network is *connected*–there are no isolated communities of financial agents–any firm would have access to the surpluses of the *entire grid*, were there no blocking financial agents. The agent-based framework would then add nothing of value to the two-sector model studied in section 2.2. In reality, firms have limited access to the financial surpluses of other firms and for the model to reflect this more realistically, a 1-ply assumption is invoked: financial agents can borrow from their linked neighbors only 1-ply deep.[11] In figure 3, the assumption prevents financial agent 1 from borrowing, using financial agent 2 as an intermediary to 3. As a result, only the second deficit firm (in the NW corner associated with financial agent 2) can borrow from the surplus firm served by financial agent 3.

The 1-ply assumption enhances the realism of the model, but it also implies that any given firm will only be able to borrow from firms served by associates of its own financial agent. This assumption is restrictive. It causes the network of firms to experience large deficits of aggregate demand since so many deficit firms are unable to find financing for their projects. A less restrictive assumption is simply that the number of financial agents, $m$, is greater than then number of firms, $n$. This assumption produces more robust growth and prevents subsets of firms from experiencing very low levels of effective demand and capacity utilization when the rest of the grid is booming. The two critical assumptions of the model are then 1-ply and $m > n$ and it should now be clear how the model would behave if either of these assumptions were relaxed.

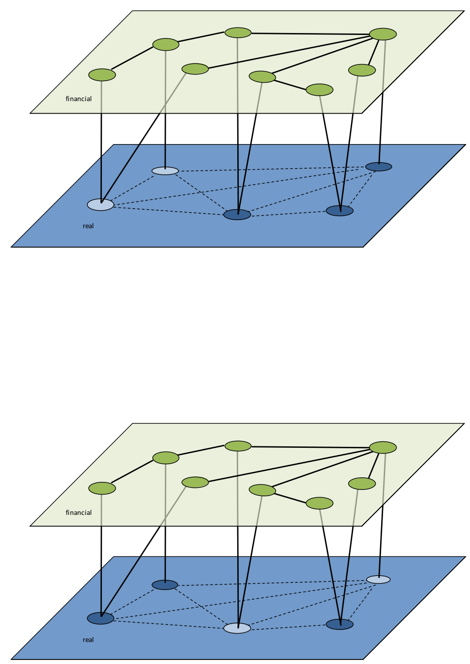


Figure 4: Multi-level network structure with more than one financial agents per firm. Notice that the pattern of surplus and deficit firms changes in the bottom frame, one period later.

## 3.1 Endogenous money in asynchronous agent-based models

If, at any point in time, the client of the $i$th financial agent is a *surplus firm*, the change in loanable funds, $\Delta\ell$, of bank $i$ is

$$\Delta\ell_i = F_i/m_i$$

where $F_i = S_i - g_iK_i$ is the current savings, $S_i$, less investment planned for the next period, $g_iK_i$. The number of financial agents directly linked to firm $i$ is $m_i$. If the banking system is unwilling to allow any credit expansion, then investment by deficit firms is limited by the availability of loanable funds. In the standard account, the central bank can prevent money creation by simply limiting loans to $\sum_{f^+} F_i$, where $f^+$ is the set of surplus firms. The crucial asymmetry here is that for surplus firms no financial constraint

[11] A 2-ply assumption, or indeed an $n$-ply assumption, would serve the same purpose of limiting borrowing access, although by much less. The 1-ply assumption is invoked for simplicity.

binds. In principle, they can always execute their investment plans up to the full extent of their savings in the previous period.[12]

Figure 4 shows the final model for $m > n$, so that some firms are served by more than one financial agent. Notice the pattern of preferentially attached network structure for financial agents, while firms are connected in a more random network. This structure is intuitively appealing and conforms to the assumptions commonly made in networked financial systems (Gibson and Setterfield, 2013). The performance of this system is prone neither to explosive growth nor collapse due to lack of effective demand. The two figures represent two periods in time for the same model; in the first, the pattern of surplus and deficit firms is the same as in figure 3 but just one sweep of the model later, the two deficit firms on the left are now in surplus.

This is stereotypical of the model's behavior and easy to interpret. If a firm cannot invest as much as it wants because it cannot find funds, it cannot increase its installed capacity. If demand continues apace in the next period, it remains a deficit firm. Any of its linked neighbors that did invest, however, and are now operating with higher capacity levels, are likely become surplus firms. The latter could then provide funds to allow their frustrated associate to proceed with its planned investment. Figure 5 summarizes the normal functioning of the model. The deficit firm in the foreground has two financing options. The first is with financial agent 1 who is linked to agent 2. The problem here is that the client of agent 2 has no surplus to lend. The deficit firm must then ask financial agent 3 to obtain funds from its linked neighbor, financial agent 4, and then channel them along to the deficit firm as shown by the arrows. This assumes that neither of the agents blocks the flow because of negative expectations. It is easy to see how a blocked flow could set off a crisis that then spreads through the grid.

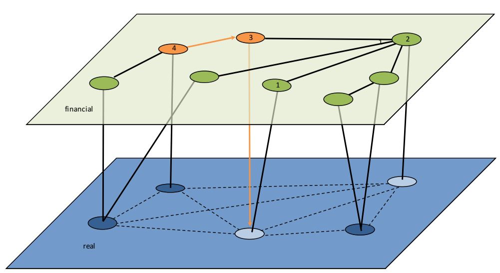


Figure 5: The deficit firm associated with financial agent 1 obtains financing from the firm associated with financial agent 4 via agent 3.

How then does endogenous money come about? Consider figure 6, which is an enlargement of an aspect of the multi-layer grid. At time period $t$ the surplus firm on the right-hand side of the diagram holds funds with financial agent 1. However, in period $t + \delta t$ those very funds are borrowed by the deficit firm, via financial agent 2, depriving the surplus firm of access to its own funds.

This raises the key question: could a financial agent block a surplus firm from accessing its deposits on the grounds that those funds had already been loaned to a deficit firm? In reality, of course, the answer is no: surplus firms are legally entitled to their deposits and so it is only under the extraordinary circumstances of a credit freeze that a surplus firm would be barred from using its deposits for investment.[13] In practice, the financial agent or bank simply creates the money to reinstate the funds of the surplus firm. In this way there is a forced increase in the money supply, whether planned or not by the monetary authority. This increase causes the money supply to become *endogenous* in the sense that the central bank is powerless to stop the credit expansion.

In agent-based modeling, agents interact sequentially during each period of time and the interaction is typically random. In the first sweep, agent $i$ interacts with agent $j$ *before* $k$ interacts with $l$, but in the following sweep, this temporal sequence can change. Contrary to models of general economic equilibrium, in which all agents come into balance at one instant, synchronously, multi-agent systems are typically *asynchronous*, and randomly so. In some runs, therefore, the surplus firm will be able to invest without any additional money creation; in others the deficit will deplete the funds the surplus firm has on deposit with financial agent 1. The surplus firm still invests but this time with funds created by the monetary system. Which occurs is determined by

[12] Note that if a surplus firm elected to spend more than authorized by previous period savings, it would become a *de facto* deficit firm.

[13] To deny surplus firms the use of their own savings is to announce catastrophic financial failure. In this worst-case scenario, a system-wide run on deposits could well occur.

the order in the queue of the two firms.

The asynchronicity of the multi-agent system implies that the central bank becomes powerless to stop the endogenous creation of money. This gives rise to the possibility that investment in this period may exceed the sum of savings in the last. The root cause of the increase in the money supply is that there is a time interval $\Delta t$ in the model *between* the instant that firms make deposits and the spending down of those deposits for investment purposes. Financial agents in the model, however, are under no obligation to deny a request for a loan from a deficit firm on the grounds that some of its deposits might soon be withdrawn by surplus firms for their own planned investment. All the financial agent perceives is that it is flush with deposits at that moment. Indeed, there is no mechanism in the model to communicate to the financial agent that some of its recent inflow of deposits should be held in reserve to enable their owners to purchase capital goods as planned when their time comes in the queue. The model thus makes explicit how endogenous money might come about, since if deficit firms have already contracted to borrow in excess of what would be the available financial surplus, financial agents have no choice but to create the liquidity when surplus firms are themselves ready to invest. Although deficit firms can and do crowd out other deficit firms, they cannot legally crowd out surplus firms. The larger conclusion is that the realism imparted by the agent-based approach breaks the dependence of current investment on previous savings. In this way the model retains its Keynesian flavor, since animal spirits, in the function $g$ above, ultimately allow aggregate investment in period $t+1$ to exceed savings in period $t$.

## 3.2 Money and Keynesian macrodynamics

It may seem that relying on a computer program to determine the order and therefore sum of investment is somewhat arbitrary. After all, in a standard Walrasian account no trades would be made until the auctioneer balances offers to sell with offers to buy. Epstein and Axtell (1996) have argued, however, that computer driven bilateral trades between two discrete agents offer a more realistic account of how markets actually function. The multimarket equilibria in bilateral systems produces a *statistical equilibrium* rather than a unique price vector, provided additional necessary but reasonable assumptions hold.

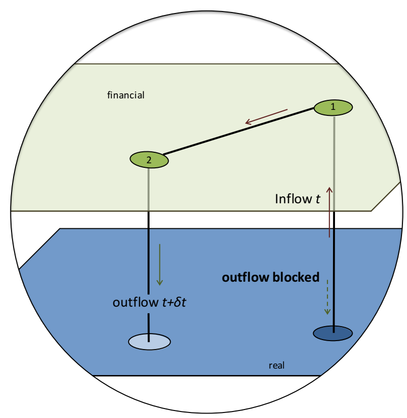


Figure 6: The deficit firm associated with financial agent 2 obtains financing from the firm associated with financial agent 1, thereby blocking the return of those funds to the surplus firm when it is ready to invest.

It follows that if all savings and investment decisions were made at the same instant in time, synchronically, the monetary authority could drive endogenous money to zero. In asynchronous models, however, this is generally not possible. Unless events happen to arrange themselves in an unlikely way, essentially by fluke, endogenous money will necessarily arise in asynchronous models.

The synchronous model is logically coherent but has some important and highly unrealistic implications that may not be immediately self-evident. One is that without endogenous money, aggregate savings in the previous period determine investment. Even if the excess savings of one firm is channeled to another, at no point can aggregate investment in period $t$, or $I_t$, exceed the savings available from the previous period. Since savings also equals investment in the previous period, it follows that investment is at best *constant over time*. This is a serious defect in the simple prior savings model and obviously rules out any important expansionary effects of animal spirits. Moreover, were this constant level of investment to exceed depreciation, capital stock would then accumulate with each round of investment. With a fixed distribution of capital-output ratios, capacity utilization, $u_t$ in equation 1, will therefore have to fall. In the standard structuralist model, investment itself depends on capacity utilization. If follows that investment will not remain constant but will instead fall below its savings-constrained value. Since savings will immediately adjust to this lower level of investment, savings available for investment in the following period will be even less. Since investment cannot escape the constraint of prior savings, the model becomes unstable, cycling down to zero output and employment. The prior savings model, evidently, cannot serve as the foundation for any coherent model of systems with both real and financial components.

Observe that if there were no constraint on credit, there would be no reason to distinguish surplus and deficit firms. Firms that lacked sufficient savings from the previous period would simply borrow for investment from bankers who are freely able to create credit. Monetary policy is then entirely accommodating. While this may be one definition of endogenous money, equating endogenous money to the absence of any imposed financial constraint does not reflect the centrality of the institutions that define the monetary system (Palley, 2013, pp. 417-19). In this simple but arguably more realistic account of the financial system, time matters and time intervals in which conflicting claims on financial resources can arise imply that money must be inherently endogenous in a way that a central monetary authority cannot avoid.

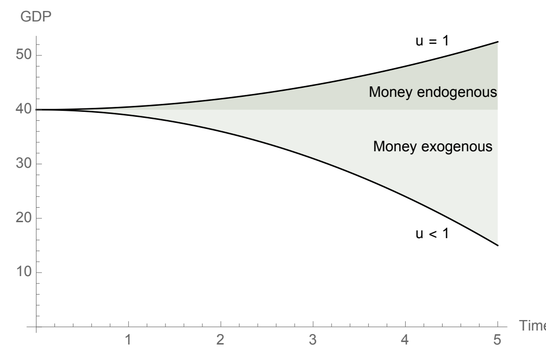


Figure 7: The upper bound of the shaded area describes the model with no financial constraint. The lower bound shows the path when investment in the period is determined by savings in the previous period.

Note that if monetary policy were fully accommodating, nothing prevents the system from expanding without limit.[14] Figure 7 shows two possible limiting cases, derived from the empirical model in Gibson and Setterfield (2013). The upper trajectory corresponds to full capacity utilization, with fully endogenous money and nothing but pure animal spirits guiding economic expansion. Along the lower trajectory the economy is limited by previous savings. This is the synchronous model, described above, and the simulation clearly shows a negative trend to GDP as expected. Any real economy would, presumably, operate inside the shaded region of the figure.

Even with endogenous money, there are other important impediments to smooth growth that are easily captured by the multi-agent model depicted in figure 3. Intermediation failures can arise, for example, in which either a deficit firm is rejected by the financial agent or the deficit firm cannot locate an agent willing and able to lend in the local region. If investment by a deficit firm is blocked for either of these reasons, then total investment falls and with it available savings for the next period. Firms that would otherwise have been in surplus are now in deficit if their investment plans are not scaled back to match their savings. With a sufficient contraction of demand, all firms can fall into deficit simultaneously and the result will be a sharp contraction in investment in the following period. None of this is possible, of course, in standard real-side models that assume accommodating monetary policy and thereby fail to model important real-financial interactions.

# 4 Conclusions

Keynesian economies are more intrinsically monetary than is often recognized. On one hand, an economy is unable to enjoy continuous net expansion without *some* money creation. In its absence, an economy is unlikely to maintain a constant level of investment. On the other hand, the view that money creation is always and everywhere fully accommodating masks the still-important role of intermediation as a cause of significant macroeconomic imbalances. It neglects the power of the financial sector to affect real performance by blocking the flow of finance from surplus to deficit firms. In the worst case, models of social learning show that learning can break down, leading to a financial crisis, when agents place time-dependent weights

[14]This is due to the underlying simplicity of the structuralist model, of course, in that the model ignores diminishing returns, technical change, endogenous growth and other features of more advanced models. The model of this paper includes a highly simplified, demand-driven, structuralist account of the real side only to keep the interaction with the financial side manageable.

on social and private signals. This is all beyond the scope of this paper, but has been thoroughly addressed elsewhere (Gibson and Setterfield, 2013).

This paper shows only that "endogenous money" need not be associated with the view that banks are passive players in an essentially horizontalist world. Financial agents in multi-tiered network structures retain significant power due essentially to the institutional framework in which they operate. Not only can they lay the groundwork for financial catastrophe and collapse but they necessarily wrest away power from the central monetary authority, power that is essentially bottom up in its nature and resistant to monetary restriction. The key element of this paper's model is asynchronicity: if time is built into a model in a careful and realistic way, the non-contemporaneous nature of real-financial interactions almost guarantees endogenous money creation.

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