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Department of Economics
Trinity College
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06106 USA

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Did CNBC contribute to the Great Moderation or the Great Recession?

Shyam Gouri Suresh* and Mark Setterfield**

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Abstract

We construct a multi-agent system (MAS) model of cyclical growth in which aggregate fluctuations result from variations in activity at firm level. The latter, in turn, result from changes in the state of long run expectations (SOLE) or “animal spirits” and their effect on firms’ investment behaviour. We focus on the impact of a common source of information – analogous to the mass media – on the amplitude of aggregate fluctuations. Our results suggest that the amplitude of growth cycles is reduced by extremes of attention or inattention to aggregate economic performance, but that this relationship is subject to complicated (and possibly complex) phase transitions.

J.E.L. Codes: C63, E12, E32, E37, O41

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* Department of Economics, Davidson College, Davidson, NC 28036, USA;
shgourisuresh@ davidson.edu.

** Department of Economics, Trinity College, Hartford, CT 06106, USA;
mark.setterfield@trincoll.edu.

1. Introduction

According to a diverse literature in macroeconomics, confidence and sentiment play an important role in generating aggregate fluctuations (see, for example, Carroll et al, 1994; Taylor and McNabb, 2007; Stockhammer and Grafl, 2010; Starr, 2012; Christiansen and Eriksen, 2012). This theme even has a place in real business cycle and DSGE models (on which see Farmer and Guo, 1994; Basu and Bundick, 2012; Benhabib et al, 2012). It finds particular expression, however, in those branches of Keynesian macrodynamics in which fundamental uncertainty is thought to shape the economy's trajectory. Under conditions of fundamental uncertainty, economic outcomes are affected by changes in the state of long run expectations (SOLE) or "animal spirits" – psychological features of any future-oriented decision making process that affect behaviour independently of the best forecast that decision makers can fashion on the basis of their incomplete information sets (Gerrard, 1995; Dequech, 1999). In this tradition, the SOLE is thought to be influenced not only by the individual decision maker's private ruminations, but also by his/her observation of the decisions and behaviour of others (Keynes, 1936, chpt. 12).

Building on this last insight, the purpose of this paper is to develop a multi-agent system (MAS) model of cyclical growth that permits study of the sensitivity of the SOLE – and by extension, aggregate fluctuations – to the weight firms attach to general economic conditions as opposed to their own particular performance. The paper builds on the MAS model of aggregate fluctuations due to Setterfield and Budd (2011), in which heterogeneous firms pay attention to – and their SOLE is influenced by – a single, common source of information about the general state of the economy, analogous to the mass media (hence our titular reference to CNBC).¹ The model therefore resembles a *blackboard system*, in which individual firms' behaviour is affected

¹ On the specific role of the media in shaping the social psychology of economic decision makers and contributing to aggregate fluctuations, see Blanchard (1993), Doms and Morin (2004) and Starr (2012).

by both their own proprietary knowledge (of their own economic circumstances), and shared information (about macroeconomic outcomes) derived from the “blackboard” (see, for example, Wooldridge, 2002, pp.301-309). In this model, aggregate fluctuations arise – if at all – strictly as a result of fluctuations in the activity of individual firms, brought about by variations in the SOLE that are more or less influenced by information from the blackboard. The key question we address is: what is the susceptibility of the economy to the blackboard? Does the blackboard amplify or dampen volatility caused by variations in the SOLE or, in other words, is aggregate volatility increased or decreased by having heterogeneous decision makers pay attention to a common source of information about general economic conditions, rather than focusing exclusively on their own performance? Despite the simplicity of the model (in which agent interaction is deliberately limited to inter-firm transmission of the SOLE via the blackboard), we are able to show that aggregate fluctuations can emerge from idiosyncratic variations in activity at firm level, and that these aggregate fluctuations are influenced in a complex fashion by the amount of attention paid to the blackboard.

The remainder of the paper is organized as follows. Section 2 describes the model on which our analysis is based. Section 3 reports simulation results, and Section 4 concludes.

2. A MAS Model of Cyclical Growth

i) Theoretical model

Drawing on Setterfield and Budd (2011), we begin by using the following structural model of growth to represent the behaviour of the j th firm:

$$g_{jt}^i = \alpha_{jt} + g_r r_{jt}^e + g_u u_{jt}^e \quad [1]$$

$$g_{jt}^s = s_\pi r_{jt} \quad [2]$$

$$r_{jt} = \frac{\pi u_{jt}}{v} \quad [3]$$

$$g_{jt}^s = g_{jt}^i \quad [4]$$

$$r_{jt}^e = r_{jt-1} \quad [5]$$

$$u_{jt}^e = u_{jt-1} \quad [6]$$

$$\Delta \alpha_{jt} = \alpha(\Delta u_{jt-1}, \Delta u_{t-1}) \quad [7]$$

where g^i is the rate of accumulation and g^s is the rate of growth of savings, α denotes the SOLE, r^e and r are the expected and actual rate of profits, respectively, u^e and u are the expected and actual rates of capacity utilization, respectively, π is the profit share, and v is the (fixed) full capacity capital-output ratio.

The model above is a MAS version of what Lavoie (1992, chpt.6) describes as the canonical Kaleckian growth model (equations [1]—[6]) augmented by a SOLE reaction function (equation [7]). The latter draws on the work of Kahneman et al (1986, pp.729-31) on the psychology of “reference points” – salient features of objective reality, including recent past events and outcomes experienced by others, on which subjective constructs (in this case, the SOLE) are founded.² As such, equation [7] describes the j th firm as revising its SOLE in response to changes in both its own recent rates of capacity utilization (and hence, via equation [3], profitability) and changes in economy-wide capacity utilization (profitability). The intuition for this specification is as follows. It is clear from the expectational structure of the model in equation [6] that:

$$\Delta u_{jt-1} = u_{jt-1} - u_{jt-2} = u_{jt-1} - u_{jt-1}^e$$

² Kahneman et al (1986) actually refer to “reference transactions”; “reference points” generalizes this terminology to allow for the fact that not all significant economic events take the form of transactions. See also Ball and Moffitt (2001) for an example of an application of this concept to economic decision making.

In other words, Δu_{jt-1} is a measure of expectational “disappointment” – the extent to which realized outcomes in the previous period differed from what was expected. According to Kregel (1976), it is precisely this expectational disappointment that motivates changes in the SOLE. If we assume that firms’ expectations of *aggregate* capacity utilization are formed in the same manner as their expectations of their own capacity utilization rates (so that $\Delta u_{t-1} = u_{t-1} - u_{t-1}^e$), this explains the salience of Δu_{jt-1} and Δu_{t-1} as reference points for revision of the SOLE in equation [7].³

Note that according to equation [4], each individual firm generates from its profit income sufficient saving to exactly fund the investment that it (independently of saving behaviour) chooses to undertake. Firms are therefore akin to city states that either engage in strictly balanced trade with one another, or else practice autarky. The condition in [4] can be relaxed and replaced with the weaker condition that $g_t^i = g_t^s$ in the aggregate (on which see Gibson and Setterfield, 2012). It is retained here, however, to maintain a narrow focus on the interaction of agents via the psychology of the SOLE.

Combining equations [1]—[6] to produce reduced-form expressions for g^i and u and combining these expressions with equation [7], we arrive at the system of equations:

$$\Delta \alpha_{jt} = \alpha(\Delta u_{jt-1}, \Delta u_{t-1}) \quad [7]$$

$$g_{jt}^i = \alpha_{jt} + \left(g_u + \frac{g_r \pi}{v} \right) u_{jt-1} \quad [8]$$

³ Equation [7] also codifies the nature of agent interaction in our model. MAS models often feature networks in which one agent must be linked to another in order for the two agents to interact. Our model, however, does not involve network connections. Instead, firms pay attention to a “blackboard” from which they derive information about the performance of the aggregate economy. It is reference to the blackboard that (assuming $\kappa_j \neq 1$ in Table 1 discussed below) that is the basis of firms’ interaction. Put differently, instead of the “direct” interaction between individual agents that characterizes networks, our model exhibits “indirect” agent interaction, resulting from the sensitivity of individual firm behaviour to aggregate economic outcomes that are a product of the actions of *all* firms.

$$u_{jt} = \frac{v}{s_{\pi}\pi} g_{jt}^i \quad [9]$$

The implicit function in [7] is then rendered explicit in the manner described in Table 1. In Table 1, ε is a constant reflecting the normal revision of the SOLE in response to encouraging or discouraging economic news, and the convention c is modelled as $c = \beta\sigma_u$, where $0 < \beta \leq 1$ and σ_u is the standard deviation of the aggregate capacity utilization rate. The idea in Table 1 is that firms revise their SOLE in response to comparison of actual changes in capacity utilization with a conventionally determined “normal” rate of change of this variable, c , subject to a sustainability criterion.⁴ The latter takes the form of a heuristic in which firms check the feasibility of maintaining their recent rate of expansion (Δu_{jt-1}) over the coming φ periods by comparing this expansion to available capacity ($1 - u_{jt-1}$). If this condition is *not* satisfied, firms are discouraged and the SOLE is automatically revised downwards. Otherwise, firms check to see if changes in capacity utilization in period $t - 1$ were better (worse) than the benchmark value c ($-c$); if so, the SOLE is revised upwards (downwards). If not, firms extend their horizons and ask: are things not as good (bad) as they previously seemed to be? Having first ascertained whether or not changes in capacity utilization in period $t - 2$ were better (worse) than c ($-c$), firms address this question by checking to see if changes in capacity utilization in period $t - 1$ were worse (better) than c ($-c$). If so, they conclude that the best (worst) is now over, and revise their SOLE downwards (upwards). The value of the parameter $\kappa \in [0, 1]$ – which measures the “degree of isolation” of individual firms – distinguishes between situations in which, in the

⁴ It is possible that in any period t and for any firm j , *none* of the conditions in the first column of Table 1 will be satisfied. In such cases, the SOLE will remain constant and firms so-affected will begin to converge to a steady state rate of capacity utilization consistent with the value of α established up to that point. Note that as long as $\kappa \neq 1$, however, the traverse towards this steady state may never be completed. This is because any sufficiently large subsequent fluctuation in aggregate capacity utilization will cause firm j ’s SOLE to vary once again.

process of making the comparisons described above, firms are more (low κ_j) or less (high κ_j) sensitive to aggregate economic outcomes.

[TABLE 1 HERE]

It is clear from the structure of the model as described thus far that it involves little by way of agent heterogeneity. All firms follow the same basic investment strategy (equation [1]) and adopt the same heuristic for revising their SOLE (equation [7]). The parameters found in equations [7]–[9] and in Table 1, meanwhile, are common to all firms. It follows that u_j , g_j and α_j can differ between firms only by virtue of heterogeneous initial conditions (which are described in detail below). Despite the fact that agent heterogeneity is one of the *leitmotifs* of MAS modelling, our parsimonious approach to heterogeneity is, following Dibble (2006, p.1538), quite deliberate. First, as a practical matter, it means that our model is easier to programme (and that it is therefore easier to check, thus ensuring that simulation output is meaningful rather than a product of code error). Second, by reducing the parameter space, the parsimony of our model reduces the possibilities for over fitting – i.e., manipulating parameter values to obtain the desired or “more interesting” simulation output. Finally, the parsimony of our model facilitates the systematic exploration of interactions among parameters and variables, and thereby enhances our understanding of the workings of the model and our interpretation of its simulated output. In short, whereas “thorough exploration of model behavior quickly becomes prohibitive for highly complicated simulation models ... [which] suffer exponentially from the effects of combinatorial explosion among their parameters,” (Dibble, 2006, p.1538), with a parsimonious model, we have a much better chance of being able to “tell what’s going on”.

While equations [7] – [9] (augmented by Table 1) describe the core workings of our model, they do not completely describe its workings. Note, for example, that the recursive

interaction of equations [7]—[9] is constrained by $u \in [0, 1]$.⁵ It follows from equation [9] that there exist upper and lower bounds to g_j^i , given by:

$$g_{\max}^i = \frac{s_{\pi}\pi}{v}$$

for $u_j = 1$, and:

$$g_{\min}^i = 0$$

for $u_j = 0$. In order to make sense, our model must operate within these bounds.

In fact, it is only possible for our model to test the *upper* bound identified above. This is because we set $\alpha \geq 0$ in all periods in our simulation model (see Table 2 below).⁶ Note that if $g_{jt-1}^i \geq 0$ and hence (from equation [9]) $u_{jt} \geq 0$, it follows from equation [8] that with $\alpha \geq 0$, $g_{jt}^i \geq 0 \forall t$. Recall, moreover, that our model involves a sustainability condition that causes revision of the SOLE as the utilization rate of the j th firm approaches (or reaches) one. In and of itself, however, this condition is insufficient to *prevent* the growth rate exceeding the upper bound identified earlier. Hence we ensure that our model remains consistent with $u \in [0, 1]$ by adding the equation:

$$g_{jt}^a = \min\left(g_{jt}^i, \frac{s_{\pi}\pi}{v}\right) \quad [10]$$

where g_{jt}^a denotes the rate of growth that is actually used in the calculation of u_{jt} , and replacing [9] with:

⁵ This is true as a matter of logic, but does not enter into the formulation of the aggregate (one-sector) structural model from which the MAS model in [7] – [9] is derived – hence the amendment to the model discussed in what follows.

⁶ The requirement that α be non-negative follows from the canonical configuration of the Kaleckian growth model on which our MAS model is based, in which $\alpha \geq 0$ is part of a parameter configuration that ensures the existence of positive and stable steady-state rates of growth and profit in all periods.

$$u_{jt} = \frac{v}{s_\pi \pi} g_{jt}^a \quad [11]$$

Finally, whenever the solution to equation [10] is $g_{jt}^a = \frac{s_\pi \pi}{v}$, α_{jt} is revised to α'_{jt} , where

$$g_{jt}^i = \alpha'_{jt} + \left(g_u + \frac{g_r \pi}{v} \right) u_{jt-1} = \frac{s_\pi \pi}{v} = g_{jt}^a \text{ (see Table 2). In other words, the firm's SOLE is made to}$$

comply with the maximum feasible rate of expansion that the firm can achieve or, to put it differently, no firm is allowed to persist with plans to expand that are known to be infeasible.

[TABLE 2 GOES HERE]

Our final model of cyclical growth is therefore based on the recursive interaction of equations [7], [8], [10], and [11] (subject to the criteria outlined in Tables 1 and 2). But since our interest is ultimately in the aggregate values g_t^a and u_t , we proceed to calculate these aggregates as follows.⁷ First, we assume that firms begin with identical capital endowments, normalized to $K_j = 1 \forall j$. Then in any subsequent period t :

$$K_t = \sum_{j=1}^n (1 + g_{jt}^a) K_{jt-1} \quad [12]$$

Where n is the total number of firms, and:

$$g_t^a = \frac{K_t - K_{t-1}}{K_{t-1}} \quad [13]$$

Given that the values of v , s_π , and π are common to all firms, u_t can then be calculated as:

⁷ Note, in fact, that we need to know the value of u_t to make the calculations described in Table 1 and so to update our simulations between periods.

$$u_t = \frac{v}{s_\pi \pi} g_t^a \quad [14]$$

ii) Parameter values and initial conditions

We begin by setting values for the parameters in equations [8], [10] and [11]. Following Setterfield and Budd (2011), we set $g_r = 0.49$, $g_u = 0.025$, $\pi = 0.33$, $v = 3.0$, and $s_\pi = 0.8$. Now note that if we replace equation [7] with:

$$\alpha = \bar{\alpha} \quad [7b]$$

equations [7b], [8], [10], and [11] can be solved for the steady-state rate of capacity utilization:

$$u^* = \frac{v\bar{\alpha}}{\pi(s_\pi - g_r) - g_u v} \quad [12]$$

Skott and Ryoo (2008) set $\bar{\alpha} = 0.0075$. Using this parameter value, together with those noted earlier, we can numerically evaluate equation [12] as:

$$u^* = 0.8242$$

The assumed value of $\bar{\alpha}$ and the computed value of u^* reported above are then used as reference points for setting the values of other parameters that we require for our simulation exercise, as will become clear below. Figure 1 illustrates that when a single firm with the parameter configuration described thus far is given an initial (negative) shock to capacity utilization, the firm's capacity utilization drops immediately (due to the exogenous shock imposed) and then gradually recovers to its steady state value ($u^* = 0.8242$) within about forty periods.

[FIGURE 1 GOES HERE]

Next, we set the parameters in Table 1 so as to operationalize equation [7] as follows. First, and consistent with what Setterfield and Budd (2011) identify as “aggressive adaptation,” the

Harrodian reaction period implicit in Table 1 is short:⁸ firms' psychology is affected (encouraged or discouraged) by changes in outcomes that transpire between just two periods. We then set $\varphi = 2$ and $\varepsilon = 0.1\bar{\alpha} = 0.00075$. Monthly data on total industry capacity utilization in the US 1986—2009, taken from the Board of Governors of the Federal Reserve System, were used to compute $\sigma_u = 0.03976$. Meanwhile, unreported simulation experiments involving identical firms subject to identical initial conditions revealed that with $\beta > 0.11$, firms cease to revise their SOLE (and begin converging toward a steady state rate of capacity utilization) within 30 periods. With $\beta \leq 0.11$, however, no convergence towards the steady state occurs and aggregate fluctuations prevail. These findings are illustrated in Figure 2 for a single firm that is allowed to revise its SOLE based on the rules in Table 1.⁹ Figure 2 shows the results of two representative runs involving a negative initial shock with either $\beta > 0.11$ or $\beta < 0.11$. Choosing $\beta < 0.11$ means that the firm's threshold for updating its SOLE is sufficiently low to generate cycles in capacity utilization. When $\beta > 0.11$, however, the firm does not update its SOLE as readily with the result that the process of SOLE revision quickly ceases and convergence to a path-dependent steady state ensues.¹⁰ Based on these observations, we set $\beta = 0.09$ and hence $c = \beta\sigma_u = 0.0035784$, consistent with self-perpetuating cycles in the experimental baseline case described above.

[FIGURE 2 HERE]

Finally, and in keeping with the focus of the paper, the degree of isolation $\kappa \in [0, 1]$ is varied to study the impact of blackboard information – news about the performance of the aggregate economy – on the amplitude of the cycle. Consistent with Table 1, $\kappa = 0$ denotes exclusive focus

⁸ On the concept of the reaction period, see Asimakopulos (1991, chpt.7).

⁹ Note that, because there is only one firm, the degree of isolation (κ) is irrelevant in this exercise.

¹⁰ The precise value of this path-dependent steady state will depend on the terminal numerical value of α that enters into the calculation of u^* in equation [12].

on the performance of the aggregate economy while $\kappa = 1$ denotes exclusive focus on local conditions (the individual firm's own performance).

Establishing initial conditions completes the set-up of our simulation model. We set the initial value of $\alpha = \bar{\alpha} = 0.0075$. The initial shock to which firms are subjected, Δu_{j0} , varies between simulations. In all cases, however, there is no aggregate shock to the economy, so that

$\sum_j \Delta u_{j0} = 0$. This means that aggregate fluctuations can only emerge from local responses to

shocks at a lower level of aggregation. In the two-firm case we set $|\Delta u_{j0}| = \gamma \sigma_u$ where $\gamma \in [0, 1]$

measures the “degree of asymmetry” built into the initial shocks, which is varied discretely

within the zero—one interval. In the n -firm case (where $n = 500$), we set γ on the basis of a

random draw, so that $\Delta u_{j0} \sim N(0, \sigma_u^2)$. Note that some but not all of the initial shocks with which

we experiment are sufficient to ensure that $|\Delta u_{j0}| \geq c \ \forall j$.

iii) Summary and discussion

Our simulations proceed as follows. Given the initial conditions and parameter values outlined above, we calculate $\Delta \alpha_{jt}$ in equation [7] in accordance with the criteria in Tables 1 and 2, using α_{jt-1} and (for $i = 1, 2$) Δu_{jt-i} and Δu_{t-i} .¹¹ Next, we numerically evaluate equations [8], [10] and [11] to produce growth and utilization rates for each of our individual firms. Finally, we numerically evaluate equations [12], [13] and [14] to produce the growth and capacity utilization

¹¹ The criteria in Table 1 involving Δu_{jt-2} play no role in determining $\Delta \alpha_{jt}$ in the first period of our simulations. This is because of the steady state pre-history with which we endow our model in its initial set up, as a result of which the criteria involving Δu_{jt-2} are always false in the first instance following the initial shocks to firms' capacity utilization rates.

rates for the aggregate economy. The simulation then moves forward one period and the process described above starts again. All of our simulations have a standard run length of 100 periods.

The outcomes of our simulations are then used to address two key questions. Can aggregate fluctuations arise from local variations in activity even when there is no aggregate shock to the economy? And if so, what is the susceptibility of the economy to the blackboard – the single, common source of information about the economy analogous to the mass media? Does the blackboard amplify or dampen volatility caused by variations in business sentiment or, in other words, is aggregate volatility increased or decreased by having heterogeneous decision makers pay attention to a common source of information about general economic performance, rather than just their own economic conditions? To restate the question in terms of the model outlined above: what is the impact of variation in the degree of isolation, κ , on the amplitude of aggregate fluctuations in a MAS system subject to local shocks of varying size and asymmetry?

It is worth reflecting on what, *a priori*, the answers to these questions might be. If the blackboard contains a single piece of information, then lowering the value of κ may prove to be volatility increasing. This is because in this scenario, all firms are responding to the same aggregate information, and this threatens to create *orderliness* in their responses to change, i.e., everyone behaving in the same way, or in other words, the formation of a *herd* (see Chamley, 2004). This can be disturbance-amplifying, thus increasing volatility.¹² On the other hand, since

¹² A good example of this is what happened at the opening of the Millennium Bridge in London. As recalled by Shin (2005), shortly after the opening of the Millennium Bridge over the Thames in London in June 2000, the bridge began shaking so violently that it was subsequently closed for more than 18 months. Engineers discovered that the event was triggered by a lateral disturbance at 1 hertz - which could result from a normal human footfall, or a gust of wind. And as Shin notes, once the initial disturbance occurred, *because people react to their environment*, they adjusted to the disturbance in a similar fashion at the same time (in an effort to steady themselves on a moving bridge). This synchronous behavior fed back to the bridge, causing it to move in a more exaggerated fashion, which caused further synchronous adjustments by the people on the bridge, and so on - resulting in the violent shaking recorded by BBC cameras covering the opening of the bridge. In short, the initial shock was amplified by adjustments within the system. These adjustments were likely to recur in the event of any subsequent small shock,

there is no aggregate shock to the economy by construction, sufficient attention paid to the blackboard could decrease volatility if it means that firms are responding to a largely quiescent aggregate environment rather than to their own (potentially large) idiosyncratic shocks. In the context of our model, then, orderliness in behaviour need not always be disturbance amplifying.

A higher value of κ , meanwhile – i.e., less attention paid to the blackboard – may succeed in creating more *disorderliness* in behaviour owing to the asymmetry of initial firm-specific shocks. It might be expected that this will result in lower aggregate volatility as firms respond to their own idiosyncratic circumstances in ways that are potentially offsetting in the aggregate. Ultimately, it is the purpose of the simulations discussed below to reveal the precise impact of variation in κ on the amplitude of aggregate fluctuations.

3. Results

i) Cyclical growth with blackboard effects: the two-firm case

We begin by studying the simplest of heterogeneous agent environments, in which there are just two firms. The interaction of these two firms – and hence the nature of aggregate fluctuations – may vary based on the magnitude of the initial shock each receives, the degree of asymmetry of these shocks, and the degree of isolation determining how firms update their SOLE.¹³

Figure 3 illustrates the behaviour of aggregate capacity utilization in the two-firm case in three representative runs, each involving different assumptions about the degree of isolation (the

resulting in repeated violent shaking of the bridge in the normal course of its use – a fact that resulted in its closure until shock absorbers were installed.

¹³ It may appear strange to refer to “aggregate fluctuations” when there are only two firms. Note, however, that our two-firm model is analytically equivalent to a two-sector model (the like of which is abundant in the macrodynamics literature) and that most macrodynamic analysis, drawing on representative agent methodology, features only one firm. Our analysis in this sub-section, moreover, is but a precursor to analysis of the n -firm case in the following sub-section.

size of κ). The degree of asymmetry, γ , is set to 0.5, so that individual firms receive asymmetric initial shocks to their capacity utilization rates of $\pm 0.5\sigma_u = \pm 0.0199$. The results in Figure 3 suggest that the extent of isolation matters a great deal. When decision making by the two firms' is fully integrated (that is, when $\kappa = 0$ so that each firm only pays attention to information on the blackboard when revising its SOLE), the asymmetry of the firm-specific shocks cancels out leaving aggregate capacity utilization unaffected. Each firm focuses only on the aggregate shock and since (by design) the aggregate shock is $\sum_{j=1}^2 \Delta u_{j0} = 0$, the individual firms converge rapidly to steady state behaviour (as shown in Figure 4(a), which shows disaggregated (firm-specific) outcomes in the $\kappa = 0$ case illustrated in Figure 3). When the two firms are completely isolated in their decision making ($\kappa = 1$), each firm focuses only on its own idiosyncratic outcomes when revising its SOLE. In this case aggregate fluctuations do result. Figure 4(c) shows the firm-specific fluctuations in capacity utilization that result in the aggregate fluctuations depicted in Figure 3 with $\kappa = 1$. As shown in Figure 4(c), the firm-specific shocks, although of equal magnitude and opposite signs, produce variations in individual firm activity that are not entirely out of phase. The resulting aggregate fluctuations are nevertheless dampened to an extent by the differing experiences of the individual firms at any point in time. When the two firms are partly isolated ($\kappa = 0.5$, so that firms attach weight to both their own idiosyncratic experiences *and* the state of the aggregate economy when revising their SOLE), aggregate fluctuations again result and are more pronounced than in the previous case. This seemingly counterintuitive result is easily explained by reference to the variations in individual firms' activity that result in the aggregate fluctuations in Figure 3, which is illustrated in Figure 4(b). Figure 4(b) shows that when $\kappa = 0.5$, the fluctuations in individual firms' activity is only ever modestly out of phase,

and by period 50 is completely in phase. This amplifies aggregate fluctuations, as Illustrated in Figure 3.

[FIGURES 3 AND 4 HERE]

The results in Figures 3, 4(b) and 4(c) show that as κ falls from 1 to 0.5, greater orderliness emerges in individual firm behaviour which amplifies aggregate fluctuations. As κ falls further from 0.5 to 0, however, this orderliness disappears altogether so that no aggregate fluctuations are observed.¹⁴ Together, then, Figures 3 and 4(a)—(c) provide *prima facie* evidence of an inverted u-shape relationship between the degree of isolation of individual firms (the size of κ) and the amplitude of aggregate fluctuations.

In order to explore this relationship further, Figure 5 shows the standard deviation of aggregate capacity utilization in three different simulation experiments that differ according to the assumed degree of asymmetry ($\gamma = 0, 0.5, 1$). Each simulation comprises 100 runs that vary only according to the degree of isolation.. Figure 5 shows that in general (for $\gamma \neq 0$), when the degree of isolation is very low (an environment in which the blackboard is very influential on firm decision making) aggregate fluctuations are extremely damped (aggregate capacity utilization has a very low standard deviation). Intermediate levels of isolation (an environment where not just the blackboard but also a firm's own performance influences revision of the SOLE) cause aggregate fluctuations of very high amplitude (aggregate capacity utilization has a high standard deviation). Finally, very high degrees of isolation (an environment where the individual firm's own performance dominates revision of the SOLE) lead to somewhat

¹⁴ The reference to an absence of orderliness when $\kappa = 0$ is based on observed firm behaviour outside the steady state. When both firms achieve the steady state then behaviour does, of course, become perfectly orderly. But since steady states are, by definition, associated with an absence of change, this is not an orderliness in behaviour that will produce fluctuations at any level of aggregation.

dampened aggregate fluctuations relative to the case with intermediate degrees of isolation.

These observations confirm the inverted u-shape relationship between the degree of isolation and the amplitude of aggregate fluctuations alluded to earlier. Figure 5 does show, however, that the effect of isolation on aggregate fluctuations is subject to extreme discontinuities, the relationship undergoing significant phase changes – i.e., sharp transitions from low (high) amplitude fluctuations to high (low) amplitude fluctuations at particular low (high) degrees of isolation. These degree of isolation thresholds have not been built into the model.

[FIGURE 5 HERE]

It is also important to note that the relationship in Figure 5 between the degree of isolation and the standard deviation of aggregate capacity utilization is sensitive to the precise degree of asymmetry. As noted above, aggregate fluctuations occur for intermediate and high degrees of isolation regardless of the size of $\gamma > 0$, but the *degree of isolation threshold* at which fluctuations begin and the *amplitude* of these fluctuations both vary with the precise degree of asymmetry. This observation is borne out by Figure 6, which reports the standard deviation of aggregate capacity utilization from three simulation experiments with different assumed degrees of isolation ($\kappa = 0, 0.5, 1$), each comprising 100 runs that vary only according to the degree of asymmetry. Figure 6 shows that in general (for $\kappa \neq 0$), aggregate fluctuations are only observed when the degree of asymmetry is sufficiently large. This result is intuitive given that revision of the SOLE only occurs if variations in capacity utilization exceed a threshold value (c), and that the magnitude of the initial shock to each firm's capacity utilization rate varies directly with the degree of asymmetry. But the results in Figure 6 otherwise confirm the interaction of γ and κ in the determination of aggregate fluctuations that is suggested in Figure 5. Specifically, if firms are completely isolated ($\kappa = 1$), aggregate fluctuations begin at a lower degree of asymmetry

threshold and the amplitude of these fluctuations is also lower. If firms have an intermediate degree of isolation, however, aggregate fluctuations begin at a higher degree of asymmetry threshold and the amplitude of these fluctuations is also higher.

[FIGURE 6 HERE]

ii) Cyclical growth with blackboard effects: the n -firm case

Our analysis of the two-firm case suggests that aggregate fluctuations are sensitive to the degree of asymmetry characteristics of the initial shocks to which firms' capacity utilization rates are subjected. To control for this in the n -firm case, we set γ on the basis of a random draw so that $\Delta u_{j0} \sim N(0, \sigma_u^2)$. Given that our model is populated by 500 firms, the sample of firm-specific shocks with which each run of our model begins is large enough to ensure that the moments of this population distribution are satisfactorily approximated. This claim is confirmed by Table 3 below, which reports the mean and dispersion of the first four moments of the actual distributions of initial shocks in all 1000 runs of the model in the n -firm case. Each run can therefore be regarded as featuring no aggregate shock while simultaneously controlling for the effect of variations in the degree of asymmetry on aggregate fluctuations. Bearing this in mind, we can now ask: are our results regarding the effects of the degree of isolation on aggregate fluctuations in the two-firm case robust to the introduction of the greater heterogeneity that arises in the n -firm case? It is possible in principle that this greater heterogeneity will "wash out" in the aggregate, creating a more tranquil aggregate environment regardless of the value of κ . Our results show that this is not, however, the case.

[TABLE 3 GOES HERE]

Figure 7 plots the standard deviation of aggregate capacity utilization against the degree of isolation for six different simulation experiments, each comprising 100 runs that vary only according to the degree of isolation. Note that the inverted u-shape relationship between these variables once again emerges, and that (once again) this relationship is clearly not smooth. Instead, as suggested earlier, we observe two discrete phase changes: one at a “high” degree of isolation ($\kappa \approx 0.85$) and the second at a “low” degree of isolation ($\kappa \leq 0.4$). Note the extreme sensitivity to initial conditions (the precise distribution of initial shocks to firms’ capacity utilization rates) of the “low” κ phase change, suggesting that the latter is subject to complexity. This seems to be an emergent property of the model.

[FIGURE 7 HERE]

The observations above are borne out by analysis of the relationship between aggregate fluctuations and the degree of isolation over a larger number of simulation experiments. Figure 8 presents summary statistics of this relationship over a total of one thousand runs. The characteristic inverted u-shape relationship is once again evident in panel (a) across the various summary statistics presented therein. Panel (a) also draws attention to the large difference between the maximum and minimum values of the standard deviation of capacity utilization at values of $\kappa \leq 0.4$. This variation around the mean and median values of the standard deviation of capacity utilization is more thoroughly explored in panel (b) of Figure 8. Panel (b) shows that when $\kappa > 0.4$, the distribution of the amplitude of aggregate fluctuations is tightly bunched around its mean. But when $\kappa \leq 0.4$, the standard deviation of this distribution is many orders of magnitude larger. Together, these observations confirm the complexity (extreme sensitivity to initial conditions) of the “low” κ phase change in the amplitude of aggregate fluctuations.

[FIGURE 8 HERE]

4. Conclusions

Did CNBC contribute to the Great Moderation or the Great Recession? To address this question, we construct a multi-agent Keynesian macrodynamic model where aggregate fluctuations result (if at all) from individual firms revising their state of long run expectations (SOLE) in response to both idiosyncratic variations in their own capacity utilization rates, and (to a greater or lesser extent) variations in aggregate capacity utilization. Our simulation results show that the effect of the mass media (the “blackboard” that serves as the source of information about the state of the aggregate economy common to all decision makers) on aggregate fluctuations is not as simple as the either/or question posed in the title of this paper suggests. The amplitude of aggregate fluctuations does vary with the degree of isolation, κ (the weight that firms attach to variations in their own capacity utilization rates *vis-a-vis* variations in aggregate capacity utilization when revising their SOLE). But this variation is extremely non-linear. In the first instance, the relationship that emerges between the amplitude of aggregate fluctuations and the degree of isolation is best described as an inverted u-shape. This relationship is, however, far from smooth, instead involving two discrete phase changes between high and low amplitude fluctuations at “high” and “low” values of κ . The “low” κ phase change, moreover, has been shown to be complex, in the sense of displaying extreme sensitivity to initial conditions (the precise distribution of idiosyncratic shocks to which firms are initially subject). In general, it appears that extremes of attention or inattention to aggregate conditions are most conducive to reducing the amplitude of aggregate fluctuations, with an admixture of attention paid to local (idiosyncratic) and aggregate outcomes ($0.4 < \kappa < 0.85$) serving to raise the amplitude of the business cycle. To the extent that the development of the mass media has drawn decision makers

further away from a singular focus on their own conditions ($\kappa = 1$) and into this range, it must be concluded that when the business cycle is sentiment-driven, the mass media increases the amplitude of aggregate fluctuations.

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Table 1: Revising the state of long run expectations (SOLE).

Criteria	Value of $\Delta\alpha_{jt}$
$\kappa\Delta u_{jt-1} + (1-\kappa)\Delta u_{t-1} \geq c$ And $1 - u_{jt-1} \geq \varphi\Delta u_{jt-1}$	$\Delta\alpha_{jt} = \varepsilon$
$\kappa\Delta u_{jt-1} + (1-\kappa)\Delta u_{t-1} > -c$ And $\kappa\Delta u_{jt-2} + (1-\kappa)\Delta u_{t-2} \leq -c$ And $1 - u_{jt-1} \geq \varphi\Delta u_{jt-1}$	
$\kappa\Delta u_{jt-1} + (1-\kappa)\Delta u_{t-1} \leq -c$ $\kappa\Delta u_{jt-1} + (1-\kappa)\Delta u_{t-1} < c$ And $\kappa\Delta u_{jt-2} + (1-\kappa)\Delta u_{t-2} \geq c$	
$1 - u_{jt-1} < \varphi\Delta u_{jt-1}$	$\Delta\alpha_{jt} = -\varepsilon$

Table 2: Further criteria affecting the SOLE.

Criteria	Value to which α_{jt} re-set
$\alpha_{jt} < 0$	$\alpha_{jt} = 0$
$g_{jt}^a = \frac{s_\pi \pi}{v}$	$\alpha_{jt} = \alpha'_{jt} = \frac{s_\pi \pi}{v} - \left(g_u + \frac{g_r \pi}{v} \right)$

Table 3: Moments of the distribution of initial shocks to capacity utilization in the n -firm case.

	Mean of Δu_{j0}	Standard Deviation of Δu_{j0}	Skew of Δu_{j0}	Excess Kurtosis of Δu_{j0}
Mean	-0.0001	0.0396	0.0065	-0.0298
Standard Deviation	0.0017	0.0013	0.1084	0.2090

Figure 1: Return to Steady State Following a Once-Over Shock

Figure 2: The Potential for Fluctuations in the Activity of a Single Firm

Figure 3: Aggregate Fluctuations: The Two-Firm Case

Figure 4: Decomposing Aggregate Fluctuations in the Two-Firm Case

a) Capacity utilization for fully integrated firms ($\kappa = 0$)

b) Capacity utilization for partially isolated firms ($\kappa = 0.5$)

c) Capacity utilization for isolated firms ($\kappa = 1$)

Figure 5: Variation in the Degree of Integration and Aggregate Fluctuations

Figure 6: Variation in the Degree of Asymmetry and Aggregate Fluctuations

Figure 7: Aggregate Fluctuations and the Degree of Isolation in the n -Firm Case: Individual Simulations

Figure 8: Aggregate Fluctuations and the Degree of Isolation in the n -Firm Case: Summary Statistics for 1000 Runs

a) *Minimum, Median, Mean and Maximum Values of Simulated σ_u by Degree of Isolation*

b) *Standard Deviation of Simulated σ_u by Degree of Isolation*