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Rebuilding macroeconomic theory from Keynes' original ideas – a minimal model of the economy with confidence and debt causing business cycles

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Abstract

We present a minimal ('toy') model of an economy as a simple set of equations modelling confidence, consumption, price, investment and debt. Behaviour in the model is grounded in simple heuristics that use available recent information and 'animal spirits' instead of complex intertemporal optimization. It is shown that such a model can endogenously generate business cycles where booms are driven by high spirits and credit, while recessions are driven by saving to reduce accumulated debt.
We discuss the potential of this minimal model as the basis of a more elaborate core economic model exhibiting cycles and non equilibrium dynamic behaviour.

Introduction

Macroeconomic theory has a problem with economic cycles. Currently the nearest to a generally accepted macroeconomic model is the DGSE model (Smets and Wouters 2003) which essentially disregards cycles as perturbations in economic growth (due to 'shocks') from which the economy will naturally revert to an underlying development path. It does not explain why busts occur (shocks are deemed exogenous, ie outside the theory); it does not allow for long term effects of busts, and since the theory is unable to generate severe recessions it correspondingly is unable to offer prescriptions to deal with boom and bust cycles.

An alternative strain of macroeconomics, the Agent Based Modelling (ABM) school (Hamill and Gilbert, 2015) does provide models in which cycles occur; but it does so at the expense of model complexity, a number of competing ABM models, and involves large numbers of model elements, behaviours and parameters. As a result it is difficult to evaluate such large computer based models or to understand the mechanisms which cause their results.

Keynes provided crucial insights on both the role of 'animal spirits' and the spend vs save decision in his view of credit cycles, which have been generally ignored in both the dynamic stochastic general equilibrium (DGSE) models and ABM approaches. We develop a simple (minimal) model grounded in simple heuristic behaviour rules that use spirits as a main driver of credit and spending, counterbalanced by a desire to keep debt levels down. We show that business cycles and economic growth emerge as a natural corollary of these behaviours and that economic cycles are a stable phenomenon under a range of behavioural parameters.

The minimal model presented in this paper is a toy model in the sense of Blanchard (2018), intentionally simplified from a more realistic ABM type simulation model in order to demonstrate the essential economic features that cause growth and business cycles. Its simplicity allows

a) replicability and testing – the model equations provided can be easily constructed into a spreadsheet model to allow examination of its behaviour
b) insight - the causal story leading to business cycles to be clearly understood (rather than hidden in a large forest of elements and behaviours)
c) scaleability – the minimal model can be expanded by the incorporation of additional entities and their behaviours to produce a more realistic economic model while preserving the fundamental causes of economic cycles

Economic cycles

The most important challenge facing any macro-model is to provide insights into the deep downturns that have occurred repeatedly and what should be done in response. (Stiglitz 2018).

(Beaudry et al 2020) indicate there are two types of explanation: it could be that observed booms and busts are mainly due to outside disturbances; or it could be that the economy's internal forces may endogenously favour cyclical outcomes, where booms tend to cause busts, and vice versa.

The former explanation (the RBC model), which remains the standard economic thinking and is embedded in DGSE models, attributes cycles to factors (eg technology shocks) outside the model, and is thus a deus ex machina explanation, merely replacing one unexplained variable (cycles) with another (shocks).

Not only do unexplained shocks in DGSE models provide no basis for understanding cycles, they are unable to explain major downturns, including the source of the perturbation in the economy which gives rise to them (Stiglitz). And they fail to explain why shocks, which the system (in these models) should have been able to absorb, get amplified with such serious consequences; and why they persist (Stiglitz 2018).

Romer (2016) explains the current situation as: macroeconomists got comfortable with the idea that fluctuations in macroeconomic aggregates are caused by imaginary shocks, instead of actions that people take, after Kydland and Prescott (1982) launched the real business cycle (RBC) model. Their models attribute fluctuations in aggregate variables to imaginary causal forces that are not influenced by the action that any person takes (Romer 2016).

The problem is that DSGE models an economy that operates at some unique and stationary equilibrium state, and which has dynamics around that equilibrium which are regular and oscillatory. This removes their ability to model non equilibrium booms and busts even if they add nominal frictions (as in Christiano, Eichenbaum, and Evans 2005) or make other small changes to the equilibrium core assumptions (Farmer 2012).

The business cycles of enhanced DSGE models with financial frictions are still triggered by exogenous shocks, even if these are not necessarily technological but still artificially imposed such as patient vs. impatient players, or random probability to become a "banker" (Gertler and Karadi 2011). Summing this up, Fagiolo and Roventini (2016) state: 'we think that the new developments in DSGE camp are certainly welcome, but they are just patches added to a torn cloth'.

The alternative explanation, that macroeconomic fluctuations may predominantly reflect strong internal propagation mechanisms, has been advocated by many in the past. Beaudry et al (2020) cite a number of proposals from Kalecki (1937) to Day and Shafer (1987).

More recently work addressing how cycles are endogenously generated has been concentrated in the ABM school. Multiple ABM models have been developed, each including different elements, different rules of behaviour and each providing different

output results. Dawid and Gatti (2018) give a survey. Some contain random variables (shocks) within their structures in the fashion of RBC/DGSE models. All of them provide some irregular trends in gdp which are interpreted as stylized business cycles. However this stream of research, with a range of different factors claimed to be instrumental in the endogenous formation of business cycles, has not clarified the main question: what is the fundamental driver of business cycles?
In agent-based macroeconomic models different types of heterogeneous agents endowed with behavioral and expectational rules interact through explicitly represented market behaviour. Macroeconomic variables are determined by aggregation of the output in this population of agents. These models are mainly validated by comparing the characteristics of their aggregate level output with empirical data. (Dawid and Gatti, 2018).

ABMs often follow standard economic thinking in their construction, eg including technology shocks, so despite exhibiting dynamic non-equilibrium outcomes no additional causal insight into the causes of cycles is provided. For example the model of Naumann-Woleske et al (2006) assumes random flips from optimism to pessimism. Dosi et al (2022) requires stochastic innovations which are conceptually similar to technology shocks. He states that the model produces growth patterns with persistent fluctuations, but does not comment on the causal chain within the model responsible for these fluctuations. Gaffeoa et al (2008) include stochastic 'idiosyncratic shocks' to the productivity, firm net worth, pricing and quantity produced elements of the CATS model. Both of these models include considerable complexity of their working parts, making it difficult to discern which elements are responsible for which observed outputs. As Naumann-Woleske et al (2022) say: While agent-based models successfully capture many complex phenomena, they are generally analytically intractable, making the analysis of the precise mechanics linking volatility and growth difficult.

In summary neither the RBC school with its reliance on shocks, nor the ABM school which incorporates ad hoc mechanisms to switch behaviour from optimistic to pessimistic, and which suffers from an inability to directly link cyclic outcomes to causal factors, have provided satisfactory explanations of business cycles.

Back to Keynes: confidence and the business cycle
In Keynes' Treatise (1930), he indicates that booms and busts are the consequence of the opposition of savings and investments, and suggested that recession is the result of saving overtaking investment.
He describes business cycles as a series of phases and identifies two key phases: the primary (boom) phase and the collapse (bust) phase.

While considering that 'the possible varieties of the paths which a credit cycle can follow are so numerous that it is impossible to describe all of them', he analyses three representative paths in all of which the primary phase involves the use of additional capital ('increased investment … i.e. where there is a growth of working capital') and states that (unless this capital for investment is simply obtained by reducing the production of consumption goods) 'expansions of this type cannot come about without a substantial change in the monetary situation, since they involve an increase in earnings as well as in profits. Thus it requires the acquiescence of the banking authorities.' In other words the primary phase involves new capital, ie credit, being employed and invested.

In the collapse phase Keynes writes that '*a point will come when the effort to expand or to maintain the volume of the industrial circulation will drive the effective bank rate to a level which is deterrent to new investment relatively to saving. At this point the slump sets in*'. In other words, high interest rate and high debt tips the balance from credit to saving.

In summary Keynes' basic view of the credit cycle is of a primary (boom) phase, where credit is taken and investment increased , followed by a collapse (bust) phase where high interest rates and debt change behaviour from spend to save. Keynes' analysis is in line with more recent analyses of economic cycles, such as Borio (2014).
Borio identifies two essential features for models of cycles: '*The first feature is that the financial boom should not just precede the bust but cause it.The second feature is the presence of debt. During the financial boom, credit plays a facilitating role, as the weakening of financing constraints allows expenditures to take place and assets to be purchased. This in turn leads to misallocation of resources, notably capital but also labour, typically masked by the veneer of a seemingly robust economy. However, as the boom turns to bust, and asset prices and cash flows fall, debt becomes a forcing variable, as economic agents cut their expenditures in order to repair their balance sheets*'.

Some work in this direction by the ABM school has been done by Gross (2022) who proposes a model considering credit, debt and interest as the major determinants of economic cycles. However this model remains in the external shocks tradition by depending on the accumulation of very high debt levels followed by random perturbations in demand to seed output downturns (and also requires wage rigidities).

We follow the reasoning of Keynes and subsequent authors who have pinpointed credit fuelled upswings and debt fuelled downturns as the underlying drivers of business cycles, and supplement this with the further well known observation of Keynes that animal spirits are in turn the driver of credit and investment:
'*Most, probably, of our decisions to do something positive, the full consequences of which will be drawn out over many days to come, can only be taken as a result of animal spirits – of a spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities*' (Keynes, 1936).

Keynes however failed to formally treat spirits as part of his general theory, and while some limited attempts to introduce animal spirits mathematically within the current standard economic theory have been made, they are the exception, not the rule.

Franke and Weterhoff (2018) survey two ways in which a notion of animal spirits has been used in the literature in fundamentally DGSE based economic models: these they label the discrete choice approach and the transition probability approach. Both of these involve probabilistic (shock induced) changes in 'spirits' resulting a flip from one state to another; while these can give rise to alternating outputs they still require 'shocks' and hardly capture the essence of animal spirits as described by Keynes. Overall it is evident that mainstream macroeconomic models have little use 'or confidence' (Angeletos et al, 2015).

Perhaps unexpectedly, given the freedom that ABM models have to model realistic behaviour, this school has also largely avoided implementing animal spirits as a component of their models. The few that have attempted to model spirits include

Naumann-Woleske et al (2022) whose model assumes random flips from optimism to pessimism. However their results require timescales in the hundreds or thousands of years to exhibit cyclical behaviour.
Perhaps more promising is the WHL approach (Weidlich and Haag, 1983; Lux 1995) as described by Flaschel et al (2018), where the switch between different heuristics or attitudes, such as optimism or pessimism, is determined by an aggregate sentiment index composed of macroeconomic variables describing the state of the economy in the business cycle.
Our model will follow in the footsteps of WHL by basing spirits on an index summarizing the current performance of the economy. It will differ in allowing for the 'irrationality' of spirits. Spirits can grow (or shrink) depending on whether the economic performance in the previous period was good or bad; over time spirits may therefore become detached from the underlying economy (eg continued good performance will lead to inexorably increasing spirits).
The minimal model presented in this paper places spirits at the centre of economic activity and does not require shocks, excessive debt levels or random effects to trigger downturns.

Heuristics
The DSGE model comprises a set of optimising households and firms who are assumed to know everything about the operation of the economy and thereby plan their actions to maximize their utility over their lifetime. This unlikely scenario is termed rational expectations (Sheffrin 1996). The ABM school generally replaces the rational expectations assumption of the DGSE school with heuristics (Sheffrin, 1996). Again we revert to Keynes as a precursor of this view that heuristics are the natural form of behaviour:

"*(1) We assume that the present is a much more serviceable guide to the future than a candid examination of past experience would show it to have been hitherto. In other words we largely ignore the prospect of future changes about the actual character of which we know nothing.*
"(2) We assume that the existing state of opinion as expressed in prices and the character of existing output is based on a correct summing up of future prospects, so that we can accept it as such unless and until something new and relevant comes into the picture. (Keynes 1937)

Keynes implies that decisions are made on the basis of current facts, not on expectations that differ from the current situation. More recent work has reinforced this belief that simple rules of thumb are what guide decisions in real economies. Economic agents often rely on heuristics - simple decision rules (Gigerenzer 2011). Haldane (2016) notes that use of such rules is sometimes thought to be arbitrary, sub-optimal or irrational, when in fact heuristics may be the most robust means of making decisions in a world of uncertainty. Allen and Carroll (2001) provide evidence that, many consumers appear to follow simple rules of thumb when deciding their spending rather than solving a complex inter-temporal optimisation; and monetary policy in practice seems to follow simple rules of thumb (Taylor and Williams 2010).

In many ABM models Dawid and Gatti (2018) note that the design of the behavioural rules build on the extensive psychological and empirical literature showing the prevalence of relatively simple heuristics or rules of thumb for making decisions. Further, in these models adaptive agents typically do not have detailed internal models of their environment (Axtell

and Farmer). Rather, they are myopic and are commonly referred to as *reactive* agents in the computer science literature (Weiss, 2000).

Our model will therefore follow Keynes' description and include decisions made on the basis of the current (and recent past) state of the economy, rather than expectations. The heuristic rules employed will be myopic and chosen to be the simplest available.

The need for a Minimal model

How should a complex economic model be evaluated? This is a recurring issue because of the difficulty of analysing the behaviour of a large model with many elements, relationships and parameters. First it is necessary for replicability and transparency that models should be presented in mathematical form. If they are presented as large software implementations it is difficult to determine how much of a given result is due to specific implementation features and parameter values or whether a given element or relationship contributes significantly to the result. All this means it is difficult to provide a causal story of how in general the result occurs, which could be tested in other models. Often little understanding is generated simply from presentation of a complex model's results.

These evaluation problems are particularly prominent in the ABM school, and have been well noted. Grazzini and Richiardi (2015) state that models are often poorly documented and hardly replicable, and Richiard (2017) complains that models often exhibit too many degree of freedoms, and are therefore non-falsifiable.

The additional difficulty of knowing which elements of an ABM contribute to the result is discussed by Fagiolo, Andrea Roventini (2016): they consider that if an ABM contains many free parameters and it is able to reproduce a given set of stylized facts, it is difficult to be sure that it represents the key mechanisms that are fundamentally capable of reproducing this set of stylized facts. And the need for causal understanding is stressed by Dawid and Gatti who state that 'the appeal of a policy recommendation certainly increases if it is backed up by a clear intuition for the causal mechanisms driving the policy effects. Given the rich structure many of the agent-based models have, developing such a narrative is typically difficult, even more so if the intention is to demonstrate that the mechanisms highlighted in that narrative can actually be identified in the simulation data'.

These issues are summed up in the comments of Kling (2011): 'My concern with ABM is getting a result and not really knowing why you got it. Alternatively, if you really understand how the ABM is getting its result, you should be able to show how to get that results in a simple model, perhaps with a numerical example'.

However criticisms of evaluation are not limited to the ABM school. DGSE models have also been criticised by Blanchard (Do DSGE models have a future?) both for the numbers of parameters and how their values are estimated (Blanchard 2017a) and for over complexity : 'DSGE modelers should accept the fact that theoretical models cannot, and thus should not, fit reality closely. The models should capture what we believe are the macro-essential characteristics of the behavior of firms and people, and not try to capture all relevant dynamics. Only then can they serve their purpose, remain simple enough, and provide a platform for theoretical discussions'. (Blanchard, 2017b).

Furthermore, Gaffeoa et al (2008) critically note that advocates of the DSGE model have assumed that the central question to be answered by theories of business cycles is not why aggregate activity periodically falls and rises, but is in fact co-movements of aggregate variables over time. Hartley et al (1997) agree that this co-movement form of

model evaluation does not address the primary question of what causes cycles, but deflects attention to a secondary question of correlations among variables in the model, which may or may not have much bearing on the primary question.

Because of the failings described above in current models, both in the DGSE and ABM schools, there is no standard core macroeconomic model which can be applied to most economic issues; economic work is fragmented using special purpose models for different applications. In contrast to sciences such as physics (Oerter 2006).
Blanchard (2018) in discussing the need for core models in macroeconomics, lists 5 types of economic model: foundational, toy, core, policy, and forecasting.
Foundation models set out micro-foundations of economic behaviour. Building on these foundations toy models present a simplified view of how some elements of an economy interact as a system. And in turn building on these a core model provides an integrated and reasonably realistic model of the economy. According to Blanchard a core model should provide ‘a generally accepted theoretical framework for the profession’ but as Vines and Wills (2021) say, ‘we don’t think that any core models actually exist at all’.

Following Blanchard’s categorization, it follows that if we want a core model that can explain cycles, the first necessary step is the construction of a toy model that can itself explain economic cycles. This toy model will necessarily include the foundational behaviour assumptions. We prefer the term minimal model to toy model, since the latter term is susceptible to a pejorative interpretation when in fact this level of model is the most fundamental and is a necessary underpinning for any core model.
Given the criticisms outlined above about both DGSE and ABM models, it is important that a minimal model, as well as being simple, should allow for a causal explanation of its output. A model that gives apparently convincing results such as economic cycles, but for which no clear causal explanation can be derived from the model, is not insightful and may be producing its results from luck (parameter settings) rather than from a fundamental causal mechanism.

We refer to the model we construct as the Spirits Heuristics and Debt or SHD model, these being the primary characteristics trhat both differentiate it from current macroeconomic models, and form the basis of its capability to produce credit fuelled booms and debt fuelled busts. The minimal version of this model that we present in this paper is correspondingly labelled the minimal SHD model (MSHD).

The Minimal SHD model
The MSHD consists of a time-stepped closed economy producing just one good, with a population that at each step receives income from the previous step, so total income equals total spend from the previous period. It can then decide in the current step either to spend exactly its received income, or to obtain credit from a bank so as to spend more than its received income, or to save some money into its bank account so as to spend less than its received income.
The decision on how much to borrow or to save depends on both the received income and the average confidence level (spirits) of the population. Spending is divided between consumption and investment.
Borrowing means paying an interest rate back to the bank, which is variable depending on inflation and the ratio of debt to income in the economy. Saving is constrained to a maximum of 20% of received income so as to avoid unrealistic falls inconsumption and investment.

Note the minimality of this model: major features of an economy such as the distinction between firms and labour, unemployment, government, tax, heterogeneous goods, and bankruptcy which have been found unnecessary for an explanation of output cycles have been eliminated from the MSHD model. Such missing features can be rebuilt into a fuller SHD model on the foundations of the minimal model.
Further, in all the equations for the MSHD model extremely simple forms have been used. For example in modelling confidence (spirits) we would expect that a number of indicators of the state of the economy would be involved, including gdp, inflation, interest rate, debt levels and recent trends. But for minimality we use only the current GDP level: this provides the smallest number of variables and a myopic decision. This simplicity principle has been applied to all equations in the model. These equations can be expanded and made more complex in a larger more realistic model of the economy, but the focus of the minimal model is on simplicity so that clear causal mechanisms underlying economic trajectories can be identified. The equations below specify the model.

Confidence (spirits) in the MSHD is simply based on the current performance of the economy (GDP). This adjusts the previous confidence level up if GDP is increasing and down if GDP is decreasing, while constraining it to a 0 – 100 scale where 50 represents neutral confidence having no impact on economic decisions.

$confidence_t = confidence_{t-1} + (gdp_{t-1}/gdp_{t-2} - 1).\ confidence_{t-1}$ if $confidence_{t-1} > 50$ and $(gdp_{t-1}/gdp_{t-2} - 1) < 0$, or if $confidence_{t-1} < 50$ and $(gdp_{t-1}/gdp_{t-2} - 1) > 0$

$confidence_t = confidence_{t-1} + (gdp_{t-1}/gdp_{t-2} - 1).\ \min(confidence_{t-1}\ ,\ 100 - confidence_{t-1})$ if $confidence_{t-1} > 50$ and $(gdp_{t-1}/gdp_{t-2} - 1) > 0$, or if $confidence_{t-1} < 50$ and $(gdp_{t-1}/gdp_{t-2} - 1) < 0$

The borrow or save decision is a tussle between two opposing tendencies as noted in Keynes description of cycles above; a desire to borrow based on high confidence and a desire to save to reduce high debt levels. The amount which it is desired to borrow in MSHD depends on income, which is previous period spend, the confidence level and a parameter s which reflects the impact of confidence on the desire to borrow

$desired\ borrow_t = \max(0,\ s.(confidence_{t-1}/50 - 1).spend_{t-1})$

Desired save, the amount that is desired to be saved in order to keep debt down, is a proportion of debt which increases with the debt to income ratio,

$desired\ save_t = \min(\max(debt_{t-1},0).\max(debt_{t-1},0)/spend_{t-1},\ spend_{t-1})$

The borrow or save decision is then determined depending on which of these two opposing desired amounts is greater:

$Borrow\ or\ save_t = desired\ borrow_t - desired\ save_t$

The actual amount borrowed is then

$Borrow_t = desired\ borrow_t$ if $Borrow\ or\ save_t > 0$, 0 otherwise

The actual amount saved is capped at 20% of income in any period (since living standards are not allowed to drop precipitately in any one period)

$Save_t$ = min(desired $save_t$, 0.2$spend_{t-1}$) if Borrow or $save_t$ < 0, 0 otherwise

This period's amount which can be spent (but which may not all be spent depending on the goods available) is then

$Spend_t = spend_{t-1} + borrow_t – save_t$

The demand/supply ratio (sv) will affect both the amount of investment and the price. It is the previous period's $ demand (ie the potential spend), divided by the value of goods actually available (produced). The value of goods produced is the production of the economy multiplied by the price per unit. The production is simply a multiple c of the capacity of the economy. Hence

$sv_t = spend_{t-1}/(c.capacity_{t-1}.price_{t-1})$

The price of goods changes mainly according to whether supply exceeds or is less than demand; if in the previous period demand was higher than supply then the price is pushed up, and vice-versa. Price is also slightly affected by the level of confidence. Price may be highly sensitive to changes in demand and supply or to confidence levels, or it may be sticky; the parameter k shows how much influence confidence has on price, while the parameter a determines how much the price changes in response to changes in the demand/supply ratio and confidence.

$Price_t = price_{t-1} + a.price_{t-1}.(k.sv_{t-1} + (1-k).confidence_{t-1}/50)-1)$

Spending is divided into investment spend and consumption spend. We assume an average level of investment spending as the proportion b of total spend (0<b<1). This proportion varies with the demand/supply ratio, increasing with the ratio.

$Investment_t = b.sv_{t-1}.spend_t$

The productive capacity of the economy will fall from depreciation which is set at a constant 1-r if there is no new investment, and it will rise in line with the real (inflation adjusted) value of the amount of investment

$Capacity_t = r*capacity_{t-1} + investment_{t-1} /price_{t-1}$ where r= 1- depreciation

If any borrowing is repaid at the end of a period, then at the end of each period the balance in the economy's ledger is the previous balance minus interest accrued plus any saving

$balance_t = balance_{t-1} – interest_{t-1} + save_{t-1}$

However since interest is charged on debt, and debt at any time except the end of a period includes any credit taken out for that period, the in-period debt level on which interest is charged is

$debt_t = max(0, -balance_t) + borrow_t$

The interest rate for credit is set at an amount above inflation (inflation = $price_{t-1}/price_{t-2} – 1$) and for realism it is constrained to a maximum of 30% an a minimum of 1%. The amount above the inflation rate is the risk premium, a function of lending risk which is here the debt

to spend ratio. This has a parameter t determining how much impact debt levels have on the interest rate. If there is extremely low demand for credit (borrow/spend < 0.01) then the desire of the bank to lend means that the risk premium disappears

Interest $rate_t$ = max(0.01, min(0.3, max(0, $price_{t-1}/price_{t-2} - 1$) + t.(1 + $debt_{t-1}/spend_{t-1}$) if $borrow_t/spend_{t-1} > 0.01$,
max(0.01, min(0.3, max(0, $price_{t-1}/price_{t-2} - 1$) if $borrow_t/spend_{t-1} < 0.01$

The interest paid on debt is
$interest_t$ = interest $rate_t.debt_t$

The number of units of goods sold is spend/price as long as the capacity of the economy is able to produce that number of units, and number of units produced if it is not able

$units_t$ = min($spend_t/price_t$, c.$capacity_{t-1}$)

And we take the number of units sold as the measure of gdp for the economy

gdp_t = $units_t$

As base case parameter settings we take s=0.25, c =0.5, a = 0.5, k = 0.9, b = 0.2, r = 0.95, t=0.05.

Initial values are set to ensure that the economy can grow from its zero base, avoiding the possibility that small downswings will crash the economy before it has had a chance to evolve.
Initial conditions are that for the first two periods income, spend and units are set to 1, and for the first 7 periods balance and debt and interest rate are set to 0, demand/supply ratio and price are set to 1, capacity is set to 2, and confidence is set to 50.

These equations can easily be put into a spreadsheet (also available on request from the author) to derive the results presented below.

Results
As is usual in ABM models (Mahajan and Ingalls 2005), a warm up period (here the first 20 time periods) is removed from the presentation of results since the model economy is growing and needs time for the various elements' values to adjust to each other from the arbitrary starting values.

We first run the MSHD with spirits set to a constant 50. At this value there is neither borrowing nor saving. The model outputs exponential growth accompanied by deflation and with no economic cycles since consistent investment grows the number of units produced but with no borrowing or saving the amount of money in the economy remains fixed, hence prices fall. The deflation could be removed by the central bank injecting money to match the growth of production, but still in the absence of debt there is no need to reduce spending and hence no dips or cycles in the economy.

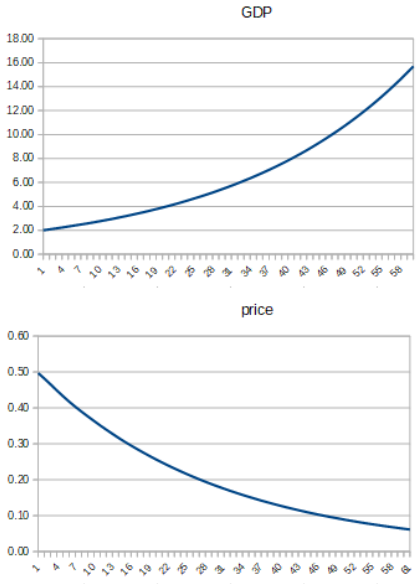

Fig 1: Spirits fixed at neutral 50

If we now allow spirits to evolve, we immediately get economic cycles (fig). Fig 2 shows that spirits rise and fall in cycles and debt to income rises during the boom phases, increasing the chance that desired saving will overwhelm desired borrowing, hence starting a bust. Debt to income then falls during the bust so that credit is again taken and a new boom period starts. The base parameters case of the MSHD gives economic cycles of around 15 periods (years) length.

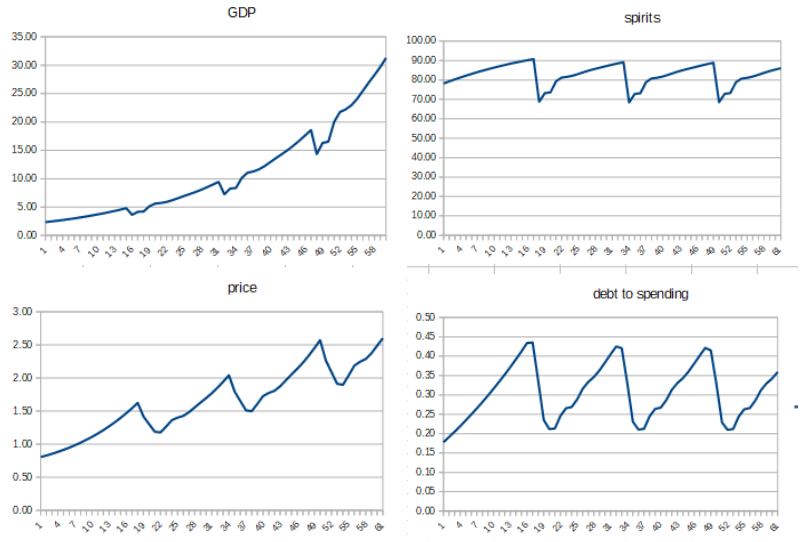

Fig 2: Base case parameters

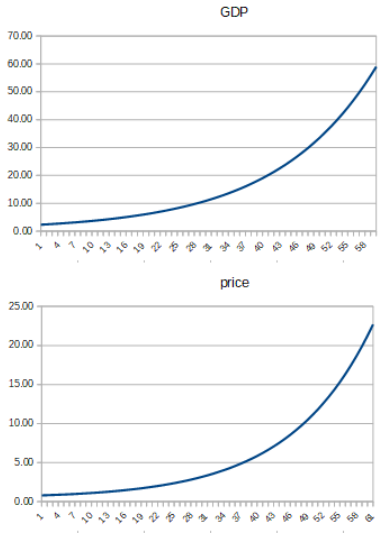

Fig 3: debt set to zero

The role of debt in causing busts is illustrated in Fig 3 by putting debt to zero in the MSHD. We then get no cycles, showing the causative role of debt.

The MHSD model contains a number of parameters; we distinguish between structural and behavioural parameters. Structural parameters are unlikely to change in the short term and can be estimated from data. In the MHSD these are depreciation (r), capacity to production (c) and debt on interest rate (t).
Decision parameters are decided by the players in the economy and thus may change quickly – since they are not stable estimation from data is unreliable and we need to consider a range of possible values for the decision parameters. Decision parameters in the MSHD are the impact of confidence on desired credit (s), the amount price changes in response to demand/supply and confidence changes (a), the base investment proportion (b), and the relative impacts of demand/supply vs confidence on price (k). We focus on the effects of variation of the decision parameters.

We now vary each decision parameter and compare outputs with the base case. If we decrease the impact of confidence on desired credit (s) from 0.25 to 0.1 we get reduced gdp growth as shown in Fig 4, and if we increase it to 0.4 we get increased gdp growth as shown in Fig 5. This is consistent with the intuitive expectation that increased credit will lead to increased growth.

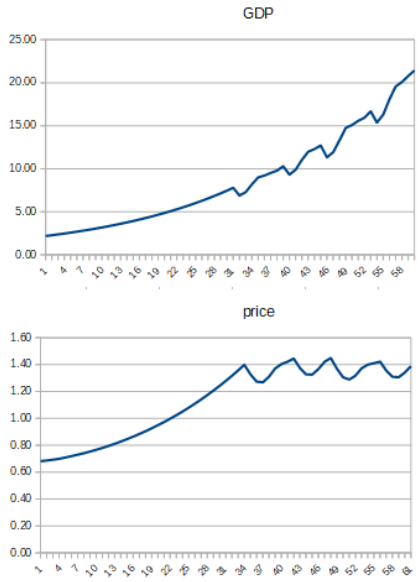

Fig 4: s=0.1

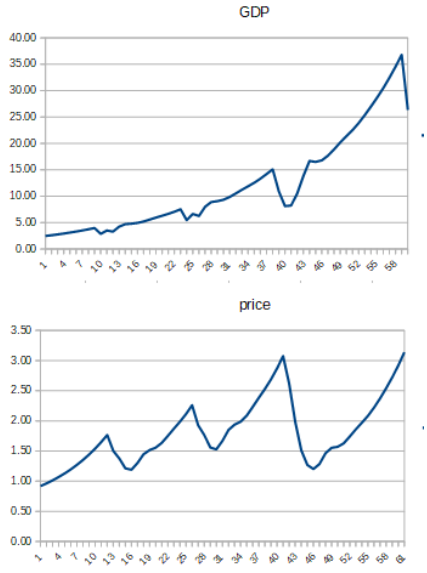

Fig 5: s=0.4

If we decrease the amount price changes in response to demand/supply and confidence changes (a) from 0.5 to 0.25 we get higher gdp growth and slower growing price as shown in Fig 6, and if we increase it to 0.75 we get lower gdp growth and price oscillating around its starting level as shown in Fig 7. Highly sensitive price adjustments result in more booms and busts while more stable prices lead to smoother growth.

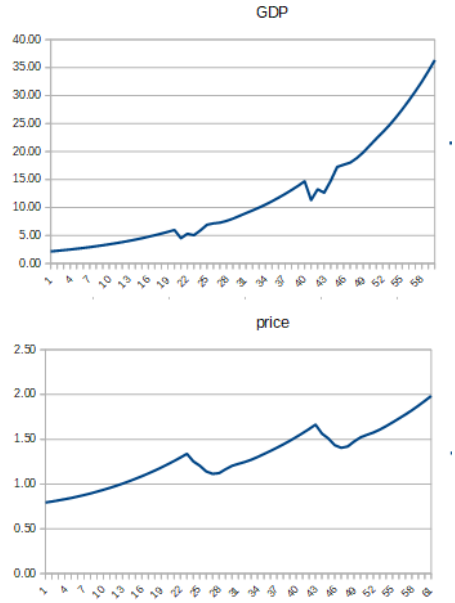

Fig 6: a=0.25

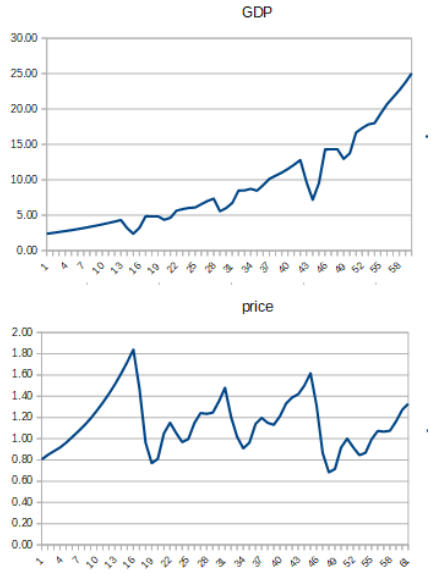

Fig 7: a=0.4

If we decrease the amount of spend devoted to investment (the investment proportion, b) from 0.2 to 0.1 we get a decreasing GDP as investment is hardly sufficient to make up for depreciation as shown in Fig 8, and if we increase it to 0.3 we get much higher GDP growth as shown in Fig 9. Higher investment leads to higher growth, but still with economic cycles.

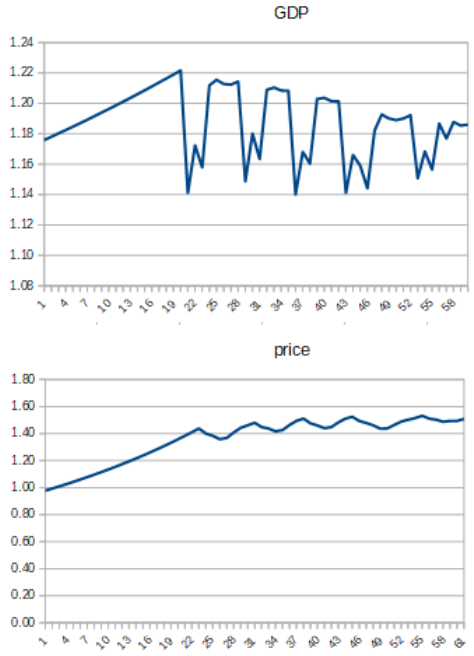

Fig 8: a=0.25

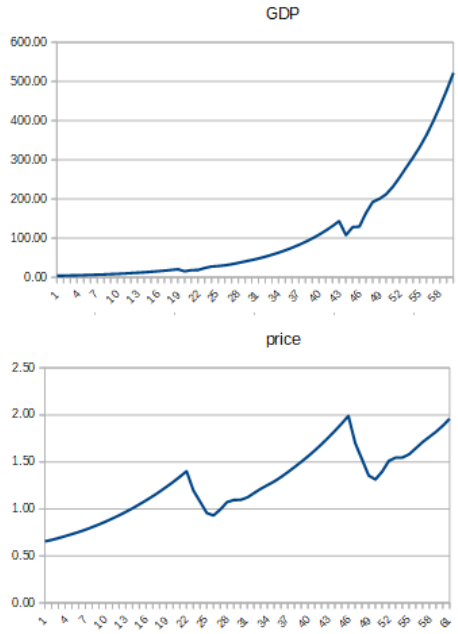

Fig 9: a=0.25

If we decrease the dependence of price on the demand/supply situation (k) and correspondingly its dependence on confidence by changing k from 0.9 to 0.8 we get lower GDP and higher inflation as shown in Fig 10, and if we increase it to 1.0 (making price

entirely dependent on demand/supply) we get higher GDP with slight deflation as shown in Fig 11. Although higher sensitivity of price to demand/supply variations helps optimize the economy at any given point, it also results in more booms and busts.

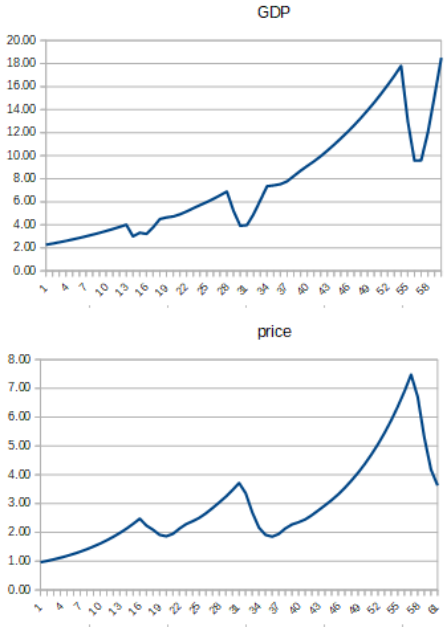

Fig 10: k= 0.8

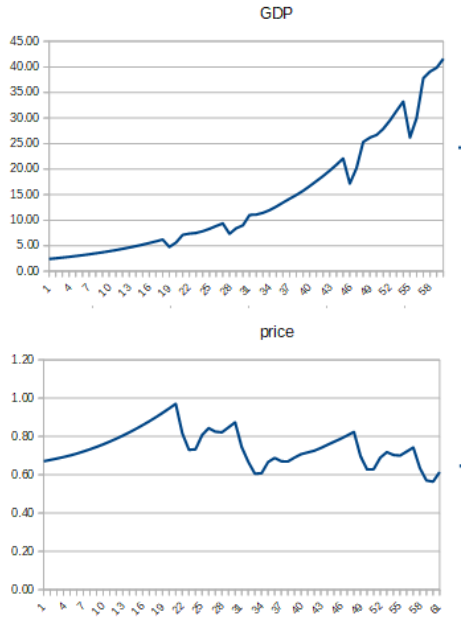

Fig 11: k = 1

We have seen (Fig 3) that GDP is much higher in the absence of debt. If we now decrease the interest rate by decreasing t from 0.05 to 0.01 we get increased GDP with high inflation as shown in Fig 12, and if we increase it to 0.09 we damage GDP growth and introduce deflation as shown in Fig 13. Lower interest rates and lower debt increase growth, while higher rates decrease growth and can cause deflation.

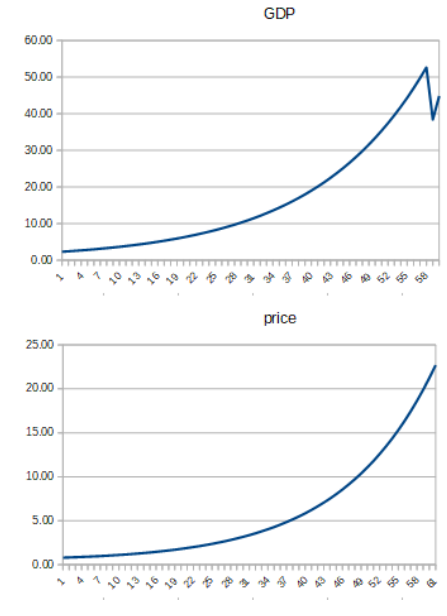

Fig 12: t = 0.01

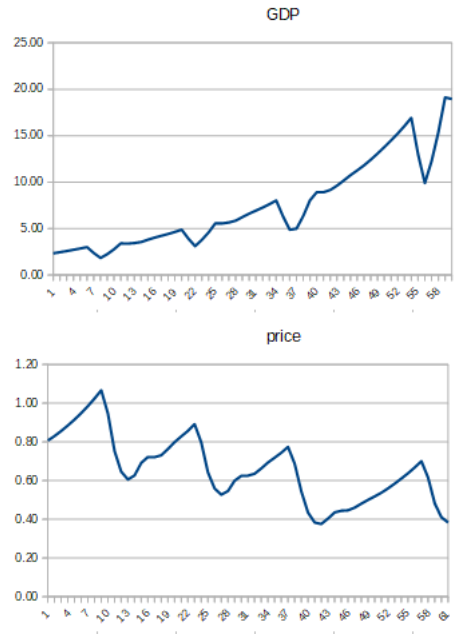

Fig 13: t = 0.09

The above results assume that credit is taken for one period and repaid at the end of the period; if credit is taken for a longer period, debt becomes higher. For the case that debt is

taken for two periods the base parameterization gives Fig 14 where the higher debt results in lower GDP growth and more frequent cycles of about 12 periods.

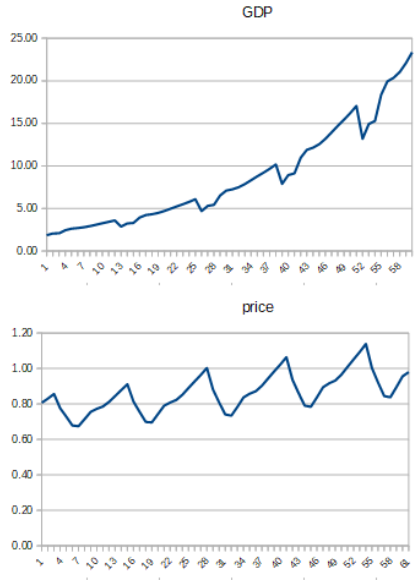

Fig 14: credit repaid after 2 periods

In summary the MSHD model
1) outputs economic cycles for a range of plausible decision parameters
2) can output both overall growth paths and overall recessionary paths
3) outputs a positive relation between increasing inputs of investment and credit with gdp, and negative relation between increasing inputs of interest rate and debt with gdp
4) shows price (and inflation) generally growing in boom periods and falling in bust periods, but the price trajectory can be changed by the degree of price sensitivity to demand/supply changes, and by the level of interest rates

We can also summarize the causal story underlying the model's outputs. When confidence is held at the neutral value of 50, or when debt=0, no economic cycles are produced; both confidence and debt are needed for cycles to endogenously emerge.
These two factors interact as follows: borrowing (credit) driven by confidence grows the economy (spend, investment, units bought and confidence)but also builds debt until it reaches a level at which entities switch from borrowing to saving in order to reduce their debt to income ratio (risk). Saving then reduces the debt to income ratio and the reduced spending in turn shrinks the economy. Once the debt ratio is sufficiently reduced by saving, a positive level of confidence enables borrowing to start again, which in turn grows the economy. This cycle then repeats. These elements are illustrated in the s=0.4 case in Fig 15.

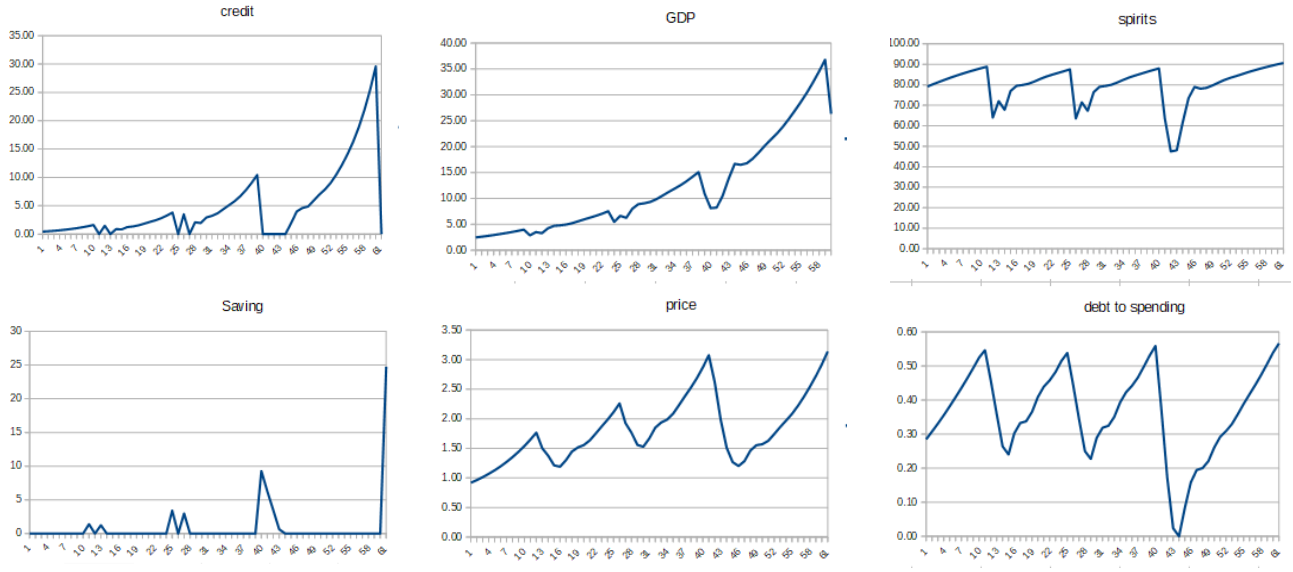

Fig 15: Cycles with booms seeded by credit and busts by debt and saving

Conclusions

We have shown that a minimal ('toy') model with extremely simple myopic heuristic decision rules gives endogenous economic (business) cycles stemming from the tension between expansionary credit and the risk of debt buildup. This MHSD model's exhibition of cycles is robust to a range of behavioural parameters.

The MHSD is sufficiently simple to be implemented as a spreadsheet model; it does not require mathematical or simulation software to be examined, and therefore allows for replicability and testing.

It may be asked whether more complex models built on the foundations of the MSHD would continue to show the emergence of economic cycles. A more advanced model (not discussed here for reasons of brevity but the subject of forthcoming papers) has been constructed on the principles of the MSHD but providing more sophisticated treatment of the elements in the MSHD and adding in many elements of an economy missing from the MSHD, including the distinction between firms and labour, unemployment, government, tax, and bankruptcy. This more complex SHD model is necessarily implemented in simulation software, and Fig 16 shows a partial output of a run of this model, showing that this SHD model continues to endogenously generate cycles.

Fig 16: example output of a more complex SHD model

The MHSD does not require any equilibrium assumptions but allows modellers to see the evolution of an economy over time. This model does away with the need for unrealistic assumptions about intertemporal optimization on the part of individuals and shows the potential for macroeconomic theory grounded in simple and realistic decision rules to be developed in a way which can explain (and therefore address) the major policy challenge of economics: how to obtain growth and avoid or manage deep downturns. Further elaboration has the potential to form the basis of a core economic model that avoids the unnatural assumptions and inability to predict business cycles of current DGSE models.

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