A strategy switching approach to Minskyan business cycles

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WORK IN PROGRESS - PLEASE DO NOT CITE

May 23, 2017

Abstract

This paper presents a simple model of Minsky's business cycle theory. The model is based on a flexible accelerator framework where firms play strategies defined by a target debt to income ratio. Via a strategy switching mechanism, fluctuations with low perceived volatility lead to firms reducing their margins of safety by moving towards higher debt to income ratios. This increases volatility, the economy is destabilised, and firms increase their margins of safety by moving towards lower debt to income ratios. This cycle repeats itself, capturing Minsky's "stability is destabilising" insight. We demonstrate the existence of a Hopf bifurcation and a corridor of stability analytically, and the existence of homoclinic and heteroclinic bifurcations numerically. We also demonstrate the existence of chaotic dynamics characterised by sustained periods of stagnation punctuated by periods of pronounced volatility.

Keywords:

JEL Codes:

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1 Introduction

Hyman Minsky proposed his "financial instability hypothesis" in Minsky (1975, 1986), building on the debt deflation theory of Fisher (1933), the theories of credit and banking of Schumpeter (1934), and the macroeconomic theory of Keynes (1936). Since then, a large number of authors have attempted to formalise Minsky's theory, with Taylor and O'Connell (1985) being an early example. Useful summaries of the literature are presented in Chiarella and Di Guilmi (2013) and Nikolaidi and Stockhammer (2017).

One of the key mechanisms that underlies Minsky's theory of capitalist fluctuations is the endogenous evolution from financially robust corporate balance sheets, in which profits cover debt service and new investment, to financially fragile corporate balance sheets, in which profits do not cover debt service and new investment, and new debt has to be issued. This movement takes place during a period of macroeconomic tranquillity, when firms adaptively predict that tranquillity will continue and reduce their margins of safety. The upswing phase of this process is described succinctly in Minsky (1977):

> "The natural starting place for analyzing the relation between debt and income is to take an economy with a cyclical past that is now doing well. The inherited debt reflects the history of the economy, which includes a period in the not too distant past in which the economy did not do well. Acceptable liability structures are based upon some margin of safety so that expected cash flows, even in periods when the economy is not doing well, will cover contractual debt payments. As the period over which the economy does well lengthens, two things become evident in board rooms. Existing debts are easily validated and units that were heavily in debt prospered; it paid to lever. After the event, it becomes apparent that the margins of safety built into debt structures were great. As a result, over a period in which the economy does well, views about acceptable debt structure change . . . As this continues the economy is transformed into a boom economy." (Minsky 1977: 24).

Similarly, in Minsky (2008 [1986]), we are told that,

> "The required margins of safety affect the acceptable financing plans of investing units. The ratio of external financing that is acceptable changes over time to reflect the experience of economic units and the economy with debt-financing. If recent experience is that outstanding debts are easily serviced, then there will be a tendency to stretch debt ratios; if recent experience includes episodes in which debt-servicing has been a burden and representative units have not fulfilled debt contracts, then acceptable debt ratios will decrease." (Minsky 2008 [1986]: 209).

A period of tranquillity therefore leads to firms increasing their debt to income ratios. However, the resulting movement towards fragile corporate balance sheets and increased investment is enough to destabilise the economy, and macroeconomic volatility sets in. If this increase in volatility encourages firms to return to financially robust balance sheets, then the economy can experience recurrent bouts of instability, and, "stability - even of an expansion - is destabilising" (Minsky 1975: 127).

The present paper presents a simple dynamic model which captures this insight. The model is not explicitly based on optimising behaviour, and is best understood as an approximate reduced form model based on plausible behavioural functions. The reason for this approach is to gain analytical tractability in the face of pronounced theoretical complexity. In particular, models that attempt to capture the Minskyan insight using explicit optimisation tend to require simplified temporal structure. For example, the models presented in Geanakoplos (2010) are limited to two and three time periods, and the multi-period model presented in Bhattacharya et al (2015) is illustrated using a three time period calibration. In contrast, our model results in a simple set of differential equations which is straightforward to study both analytically and numerically. It is our opinion, shared by a number of orthodox and heterodox economists, that this approach to economic dynamics is a useful complement to models based on explicit optimisation.

The model is most similar to the early formalisations of Minsky's theory presented in Delli Gatti et al (1993) and Delli Gatti et al (1994), and the later approaches presented in Chiarella and Di Guilmi (2011, 2012), and Carvalho and Di Guilmi (2015). All of these models base their analysis on firm heterogeneity, over firm age in the first group of papers, and realised balance sheet fragility in the second group of papers. Of these, only Carvalho and Di Guilmi (2015) incorporates behavioural heterogeneity within the firm sector, but this paper does not incorporate explicit strategy switching. Our contribution is to incorporate explicit strategy switching along the lines of Brock and Hommes (1997) and Hommes et al (2005). Based on the quotes given above, we believe that strategy switching is central to Minsky's story, and its omission from existing models is a serious problem that we attempt to rectify in the present paper.

The model builds on a relatively straightforward flexible accelerator framework where firms play strategies defined by a target debt to income ratio. We introduce strategy switching by firms, and derive an analytically tractable reduced form by the use of a "large firm" approximate aggregation assumption. The simplicity of this set-up allows us to demonstrate the existence of a Hopf bifurcation and corridor of stability analytically, and homoclinic and heteroclinic bifurcations numerically. In addition, we demonstrate the existence of chaotic dynamics characterised by sustained periods of stagnation punctuated by periods of pronounced volatility. Section 2 presents a two dimensional version of the model, and presents results on the various bifurcations and a discussion of the dynamics. Section 3 presents a three dimensional version of the model, and presents results on chaotic dynamics. Section 4 concludes.

2 A 2D model of Minskyan dynamics

2.1 A simple linear model

This section presents a two dimensional model of Minsky's business cycle theory. The linear part of the model is inspired by the Phillips (1954) continuous time multiplier accelerator model,

$$\dot{Y} = \alpha(C + I - Y),$$

$$\dot{K} = \gamma(vY - K),$$

where Y denotes income, C denotes consumption, I denotes investment, and K denotes the capital stock. This traditional Keynesian model is considered in detail in Gabisch and Lorenz (1987), and combines fixed prices, disequilibrium adjustment in the output market, and a flexible accelerator function in the capital stock. In Minsky's business cycle theory, physical capital is largely left to the background. Instead, target debt-income ratios are the key decision driving investment. This suggests replacing the flexible accelerator function in the capital stock in the Phillips (1954) model with a flexible accelerator function in the stock of firm debt. In this case, the model becomes,

$$\dot{Y} = \alpha(C + I - Y), \tag{1}$$

$$\dot{D} = \gamma(vY - D), \tag{2}$$

where D denotes firm debt. In (1), as in the original Phillips model, firms increase output as inventory stocks decline, and decrease output as inventory stocks increase (where the change in inventories is given by $Y - C - I$). In (2), firms adjust their debt level towards a target debt to income ratio v, which for the moment is assumed to be fixed.

As well as the traditional Keynesian features of (1) and (2), which includes fixed prices, the model is characterised by radically incomplete markets. In particular, there is no functioning market for firm equity - in fact, there are no financial markets other than the market for firm debt. Given this, the model produces oscillatory dynamics in output and the debt stock whenever the eigenvalues of its Jacobian are complex conjugate. If we denote by ς a fixed share of profits in total income, then total profits are equal to ςY, and the equation of motion for firm debt is,

$$\dot{D} = I + rD - \varsigma Y. \tag{3}$$

Combining (3) with (2) yields the investment function,

$$I = (\gamma v + \varsigma)Y - (\gamma + r)D, \tag{4}$$

where r is the interest rate, which we assume to be fixed as with the other prices in the model. Finally, let $C = cY$, and without loss of generality assume $c = 1 - \varsigma$, so total consumption is equal to total wage income. We thus arrive at the reduced form model,

$$\dot{Y} = \alpha\gamma vY - \alpha(\gamma + r)D, \tag{5}$$

$$\dot{D} = \gamma vY - \gamma D. \tag{6}$$

which has a unique equilibrium at the origin in the general case or a continuum of equilibria under restrictive parameterisations. The Jacobian for the model is,

$$J = \begin{bmatrix} \alpha\gamma v & -\alpha(\gamma + r) \\ \gamma v & -\gamma \end{bmatrix},$$

and our model produces oscillatory dynamics whenever $\tau^2 - 4\Delta < 0$, where the trace $\tau = \alpha\gamma v - \gamma$, and the determinant $\Delta = \alpha\gamma vr$.

The oscillations produced by this simple linear model arise due to a straightforward multiplier accelerator mechanism. In an upswing, when the debt stock is below its target level vY, firms take on more debt to hit their target. However, under certain parameterisations, this accelerator behaviour will result in the debt stock overshooting its target, leading to a recession in which firms attempt to scale back their debt levels. This repeated overshooting leads to oscillatory dynamics, which are both locally and globally stable whenever $\tau < 0$ and $\Delta > 0$ (Pemberton and Rau 2007: 540). As the determinant $\Delta = \alpha\gamma vr$ is positive in the empirically relevant part of the parameter space, the binding condition for stability is $\tau < 0$, which implies the necessary and sufficient condition,

$$v < \frac{1}{\alpha}. \tag{7}$$

The oscillations - business cycles - in the simple linear model are therefore stable if the target debt-income ratio is not too high.

2.2 A model with strategy switching

To capture the "stability is destabilising" insight of Minsky, we now allow firms' target debt to income ratios to vary. Borrowing from the strategy choice literature, we suppose that firms can play a hedge strategy defined by v^h, or a speculative strategy defined by v^s, with $v^h < v^s$. If the probability of firms playing the hedge strategy is given by n, and there exists a continuum of firms, then at each point in time a proportion n of firms play strategy v^h and we have,

$$v = nv^h + (1 - n)v^s. \tag{8}$$

To capture the Minskyan intuition, we assume that firms switch to the hedge strategy (low debt to income target) when the economy is perceived to be volatile, and to switch to the speculative strategy (high debt to income target) when the economy is perceived to be tranquil.

To determine n, we follow the standard discrete choice framework introduced to the economics literature in Brock and Hommes (1997). Denoting perceived tranquillity by Z (discussed further below), the probability of a firm playing the hedge strategy at any moment in time is given by,

$$n = \frac{e^Z}{e^Z + e^{-Z}}. \tag{9}$$

The probability of a firm playing the speculative strategy is then $1 - n$, or,

$$1 - n = \frac{e^{-Z}}{e^{Z} + e^{-Z}}. \tag{10}$$

From (8), (9), and (10) we have the result that $n \to 1$ and $v \to v^h$ as $Z \to \infty$, and $n \to 0$ and $v \to v^s$ as $Z \to -\infty$. Thus firms increasingly opt for the hedge strategy rather than the speculative strategy as perceived volatility increases, and opt for the speculative strategy rather than the hedge strategy as perceived volatility decreases.

At first glance, it would appear that equations (8) - (10) can easily be incorporated into the simple linear model described in section 2.1 above. However, firms' strategy histories are now heterogeneous given the strategy switching mechanism in (9) and (10), and therefore their debt accumulation history will be heterogeneous. As a result, aggregate debt accumulation will not necessarily be given by (6). To avoid this issue, and avoid numerical integration, we borrow the "large firm" concept from the heterogeneous agent real business cycle literature, following Merz (1995), Andolfatto (1996), and more recent papers such as Faccini and Ortigueira (2010) and Chugh and Ghironi (2011). Specifically, we assume that large holding companies exist, each of which owns a large number of firms. While firms switch stochastically between hedge and speculative strategies in target debt ratios, actual debt accumulation and investment decisions are undertaken by holding companies according to the average target debt ratios of their constituent firms.

In a sense, the "large firm" assumption is equivalent to assuming the existence of an average firm, and tracking the debt accumulation of the average firm as an approximate aggregation approach. This is not dissimilar to the stochastic approximation approach used by Chiarella and Di Guilmi (2015) in a formalisation of Minskyan dynamics. In addition, it is similar to the "large household" assumption commonly used in the DSGE literature and search theory literatures. Although it is a dissatisfying assumption from a purely theoretical perspective, we consider it justifiable as it yields a tractable reduced form model.

In order to complete the model we require a definition of Z. In the quotes considered in the introduction, Minsky suggests that both realised losses as well as instability *per se* are important in firms' strategy decisions. Thus on the one hand we are told that, "if recent experience includes episodes in which debt-servicing has been a burden and representative units have not fulfilled debt contracts, then acceptable debt ratios will decrease" (Minsky 2008 [1986]: 209), while on the other we are told that, "stability - even of an expansion - is destabilising" (Minsky 1975: 127). To capture both of these insights, we assume that Z is given by a weighted average of realised losses and a bounded rational estimate of output variance,

$$Z = \theta(rD - \varsigma Y) + (1 - \theta)Y^2. \tag{11}$$

Realised losses, $rD - \varsigma Y$, reflect the extent to which existing debt contracts cannot be serviced. As the average level of output will turn out *ex post* to be close to zero, Y^2 is a plausible bounded rational estimate of output variance[1].

[1]Earlier incarnations of the model experimented with more sophisticated estimates of output variance, including the incorporation of an additional state equation of the form $\frac{d}{dt}\left[\hat{E}[Y^2]\right] = \varphi(Y^2 - \hat{E}[Y^2])$. However, varying φ in this equation did not appear to alter the dynamics in an interesting manner, so we have not included it in the final model.

Incorporating (8) - (11) into the reduced form linear model described by (5) and (6), we arrive at the two dimensional model of Minskyan dynamics,

$$\dot{Y} = \alpha\gamma \left[v^s + \left(\frac{e^Z}{e^Z + e^{-Z}} \right) (v^h - v^s) \right] Y - \alpha(\gamma + r)D, \tag{12}$$

$$\dot{D} = \gamma \left[v^s + \left(\frac{e^Z}{e^Z + e^{-Z}} \right) (v^h - v^s) \right] Y - \gamma D, \tag{13}$$

with,

$$Z = \theta(rD - \varsigma Y) + (1 - \theta)Y^2. \tag{14}$$

The model is therefore structurally identical to the simple linear model presented above, with the sole exception of an endogenous target debt-output ratio v driven by a strategy choice mechanism based on perceived volatility.

2.3 Equilibria in the 2D model

Before discussing the dynamic behaviour of the model described by (12) - (14), we state the following propositions:

Proposition 1: In the model made up of (12) - (14), there is always an equilibrium where $Y = D = 0$. In this case, the proportion of firms playing the hedge strategy $n = 0.5$.

Proof: See section A1 in appendix A.

Proposition 2: In the model made up of (12) - (14), there can exist two further equilibria where $D = 0$ and output is given by,

$$Y = \frac{\sigma\theta \pm \sqrt{\sigma^2\theta^2 - 2(1 - \theta)\ln(-v^h/v^s)}}{2(1 - \theta)}.$$

These equilibria exist for parameterisations satisfying the inequality constraint,

$$-v^s \exp\left[\frac{\sigma^2\theta^2}{2(1 - \theta)} \right] < v^h < 0.$$

If this constraint is satisfied, such that the two further equilibria exist, the proportion of firms playing the hedge strategy is given by,

$$n = \frac{-v^s}{v^h - v^s}.$$

Proof: See section A2 in appendix A.

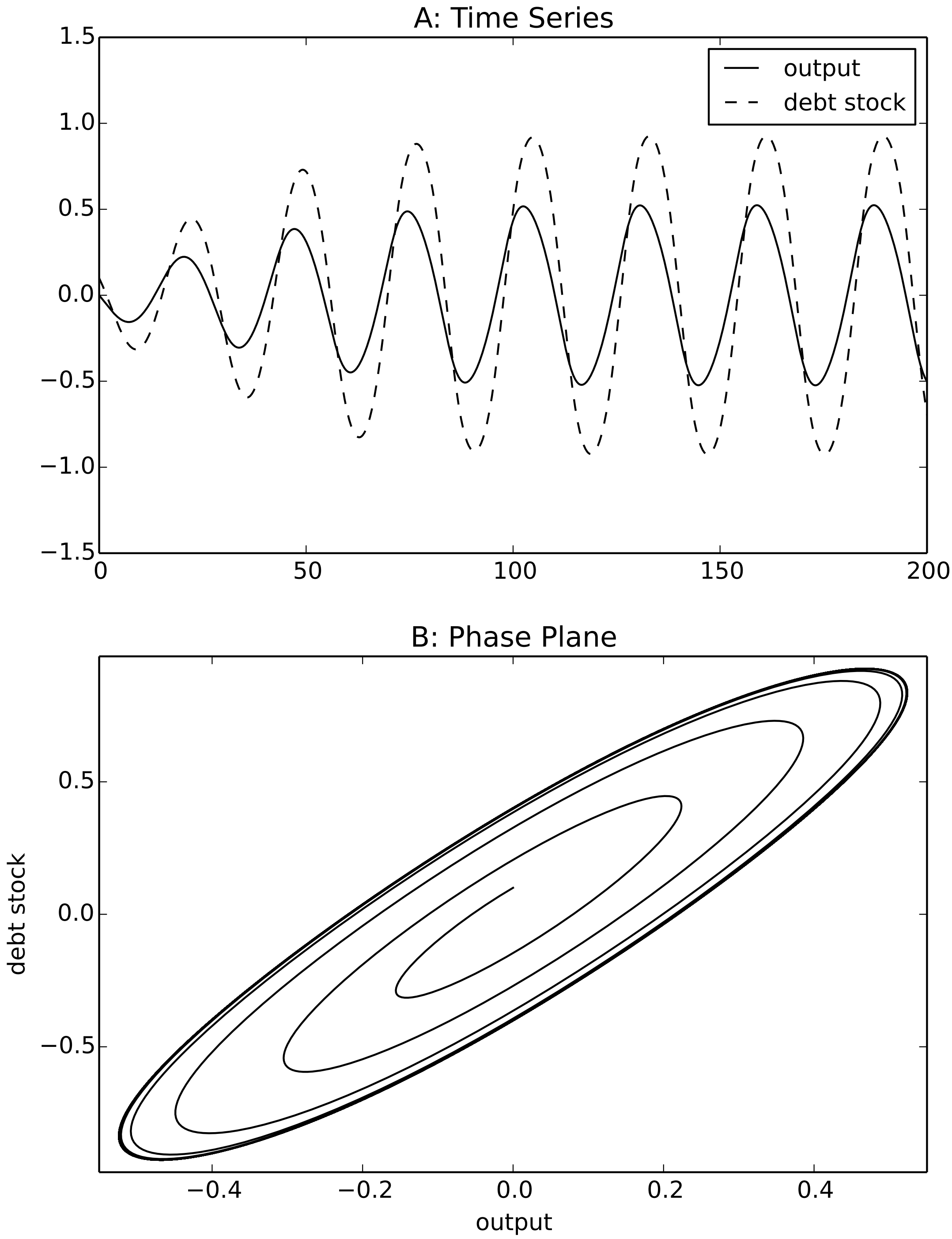

Figure 1: Phase portrait of the 2D model, $\alpha = \gamma = 0.5$, $v^h = 1$, $v^s = 3.5$, $r = 0.1$, $\varsigma = 0.4$, $\theta = 0$, showing convergence to a stable limit cycle.

2.4 Dynamics in the 2D model

We are now in a position to describe the dynamic behaviour of the 2D model. The most important result is the existence of periodic trajectories, contained in the following proposition:

Proposition 3: In the model made up of (12) - (14), a Hopf bifurcation occurs at the equilibrium where $Y = D = 0$. Noting that the proportion of firms playing the hedge strategy $n = 0.5$ at this equilibrium results in an average target debt to output ratio $v^{eq} = 0.5v^h + 0.5v^s$, the Hopf bifurcation occurs when,

$$v^{eq} = \frac{1}{\alpha}.$$

Proof: See section A2 in appendix A.

The Hopf bifurcation condition can usefully be compared to the stability condition for the linear model described in (7). There, overshooting debt dynamics lead to oscillations that are unstable whenever the (fixed) target debt to output ratio is greater than $1/\alpha$. In the model with strategy switching, the target debt to output ratio is allowed to vary. When oscillations are large (and therefore perceived volatility is large), the average target debt to output ratio reduces, and in the limit v approaches $v^h < 1/\alpha$ which stabilises the oscillations. However, as the oscillations are stabilised, perceived volatility decreases, and in the limit v approaches v^s. If v^s is sufficiently high then the balance of centrifugal and centripetal forces leads to the existence of a periodic trajectory, which the foregoing discussion suggests will be a limit cycle (i.e. the Hopf bifurcation will be super-critical). This appears to be the case from numerical simulation, e.g. the phase plot presented in figure 1. This shows the existence of a stable limit cycle in output and debt, where debt is procyclical and lagging.

Note that the Hopf bifurcation around the equilibrium where $Y = D = 0$ takes place regardless of the existence of the remaining equilibria. The second result for the dynamic behaviour of the 2D model concerns the existence of a corridor of stability around the equilibrium at $Y = D = 0$ and, if one exists, a limit cycle around this equilibrium. This is contained in the following proposition:

Proposition 4: In the model made up of (12) - (14), if the equilibria described in proposition 2 exist, then they are saddles.

Proof: See section A3 in appendix A.

If the two outer saddles exist, then from proposition 2 it is clear that one equilibrium is characterised by negative equilibrium output and the other is characterised by positive equilibrium output. Thus we have a situation where a central equilibrium with $Y = D = 0$ - and possibly a limit cycle around this equilibrium - is surrounded by two outer saddle points. Consider the case when the limit cycle around the central equilibrium exists. As this limit cycle has a basin of attraction surrounding it, and there is no reason to suppose that a further unstable cycle exists, then each saddle must have unstable manifolds "pointing inward" towards the limit cycle. This implies that when the system is "outside" either saddle, it will eventually get drawn to unstable manifolds "pointing away" from the limit cycle, and eventually diverge to positive and/or negative infinite output and debt levels.

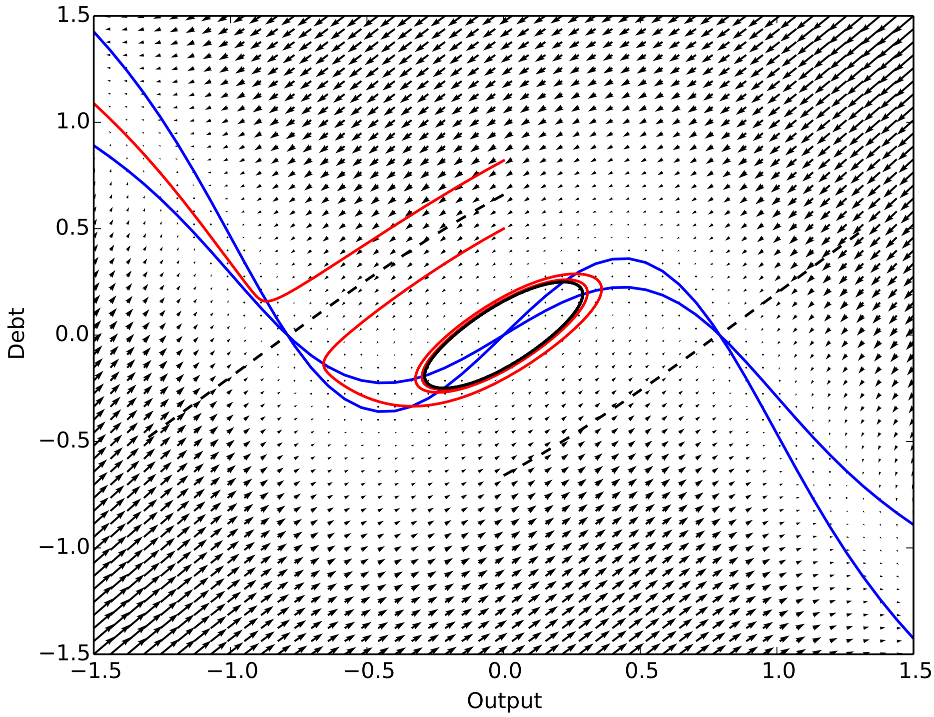

Figure 2: Phase portrait of the 2D model, $\alpha = 0.9$, $\gamma = 0.5$, $v^h = -1$, $v^s = 3.5$, $r = 0.3$, $\varsigma = 0.4$, $\theta = 0$, showing a trajectory converging to a limit cycle and a trajectory diverging.

A corridor of stability of this sort is illustrated in figure 2. The nullclines are drawn in blue, two example trajectories are drawn in red, and the stable manifolds of the saddles are drawn in dashed black lines. These stable manifolds form the boundaries of the corridor of stability for the limit cycle. As is apparent from the Jacobian matrix of the simple linear model in section 2.1 above, the aggregate stock of firm debt is the stabilising state variable in the model. This can also be seen from the flow arrows in figure 2. If the model's initial conditions are outside the corridor of stability - e.g. to the North West of the stable manifold of the leftmost saddle in figure 2 - then it will approach the nullclines as the debt stock reduces. Eventually, as it approaches zero, the stabilising properties of the debt stock disappear, and the destabilising properties of output become dominant. At this point the model diverges, as illustrated in the upper trajectory (in red) in figure 2.

Finally, the third result for the dynamic behaviour of the 2D model concerns the existence of homoclinic and heteroclinic bifurcations. The existence of these bifurcations follows quite naturally from propositions 3 and 4, which establish the existence of a limit cycle surrounded by saddle points. In parameterisations which yield symmetric nullcines, a heteroclinic bifurcation can occur in which the limit cycle collides with the two saddle points simultaneously. In parameterisations which yield asymmetric nullclines, a homoclinic bifurcation can occur in which the limit cycle collides with one saddle point. As situation just prior to the former scenario is illustrated in figure 3, and a situation just prior to the latter scenario is illustrated in figure 4.

Unlike the Hopf bifurcation and existence of a limit cycle, and the corridor of stability, the existence of homoclinic and heteroclinic bifurcations has no obvious economic intuition. Indeed, as far as the 2D model is concerned, these bifurcations have no economic interest.

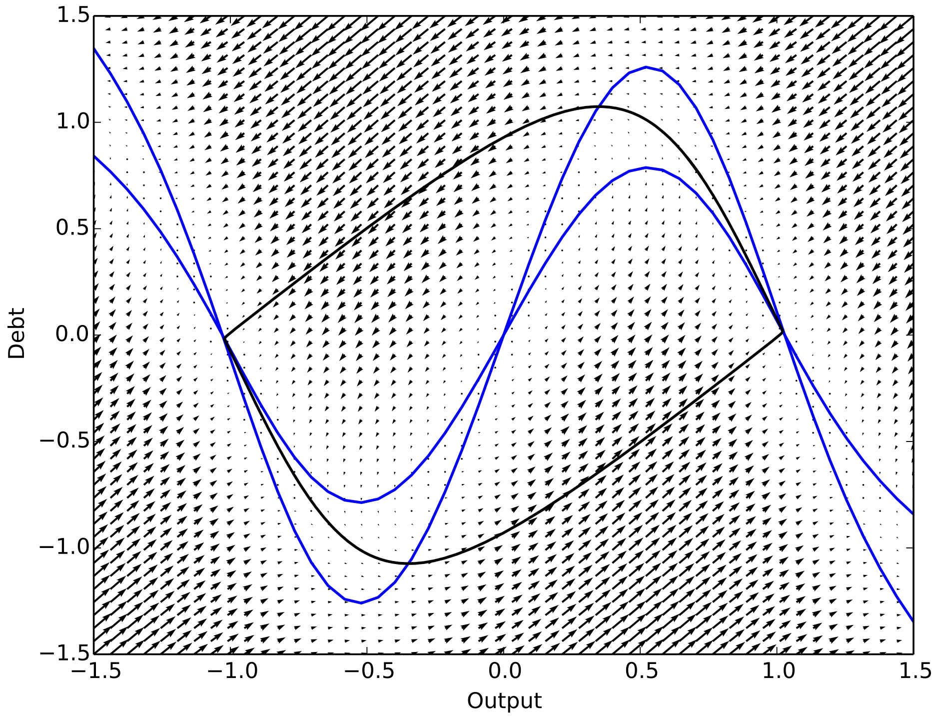

Figure 3: Phase portrait of the simplified 2D model just prior to a heteroclinic bifurcation, $\alpha = 0.9$, $\gamma = 0.5$, $v^h = -1$, $v^s = 8.3$, $r = 0.3$, $\varsigma = 0.4$, $\theta = 0$.

However, their existence points towards the potential for chaotic dynamics in a higher dimensional version of the model, as heteroclinic and homoclinic orbits are often associated with chaotic dynamics in higher dimensional systems of differential equations.

3 Concluding remarks

This paper presents a simple model of Minsky's business cycle theory. The model is based on a flexible accelerator framework where firms play strategies defined by a target debt to income ratio. Via a strategy switching mechanism, fluctuations with low perceived volatility lead to firms reducing their margins of safety by moving towards higher debt to income ratios. This increases volatility, the economy is destabilised, and firms increase their margins of safety by moving towards lower debt to income ratios. This cycle repeats itself, capturing Minsky's "stability is destabilising" insight.

The linear part of the model is inspired by the Phillips (1954) model, which is a traditional Keynesian model in the sense that it incorporates fixed prices and radically incomplete markets. At the same time, the behavioural equations are not based upon explicit optimisation problems, and as a result the model is best thought of as a an approximate reduced form. This analytical simplification yields greatly increased tractability, and the model can be expressed as a simple system of differential equations. Given this, one line of future research might be to incorporate explicit microfoundations, perhaps along the lines of Geanakoplos (2010) or Bhattacharya et al (2015).

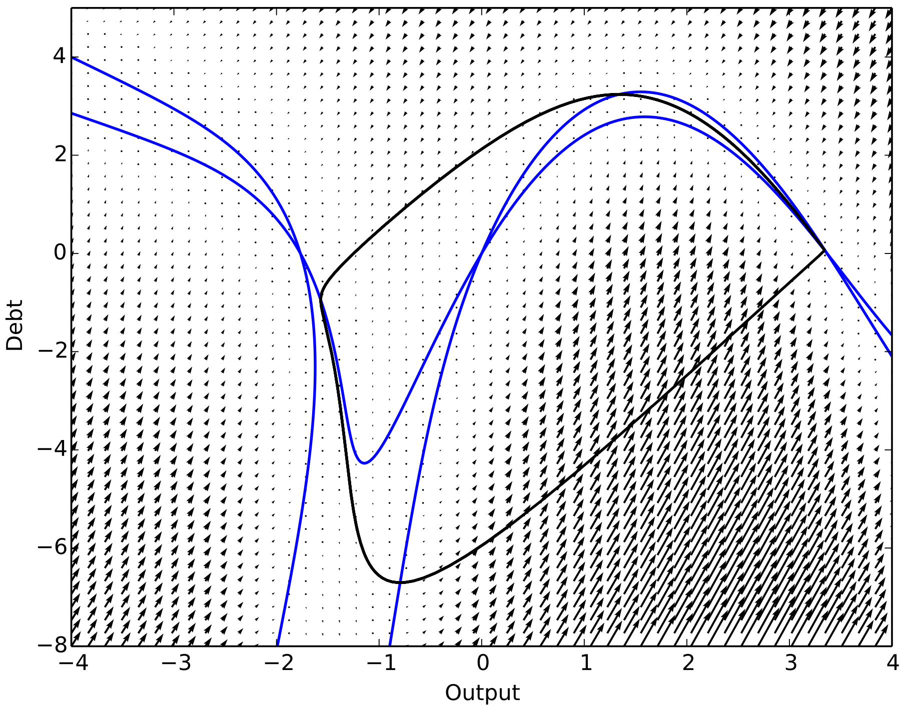

Figure 4: Phase portrait of the simplified 2D model just prior to a homoclinic bifurcation, $\alpha = \gamma = 0.5$, $v^h = -1$, $v^s = 10.8$, $r = 0.2$, $\varsigma = 0.4$, $\theta = 0.8$.

The major contribution of the paper is to incorporate explicit strategy switching along the lines of Brock and Hommes (1997) and Hommes et al (2005). Based on the quotes from Minsky given in the introduction, we believe that strategy switching is central to Minsky's story, and its omission from existing models is a serious problem that we have attempted to rectify in the present paper. Given this contribution, a final line of future research might be to enrich the strategy set in the model. This would require more intensive numerical techniques, and would allow us to consider the robustness of our results to more extensive strategy choice by firms.

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