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A monetary Minsky model of the Great Moderation and the Great Recession

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ABSTRACT

Steve Keen's model of Minsky's Financial Instability Hypothesis (Keen, 1995) displayed qualitative characteristics that matched the real macroeconomic and income-distributional outcomes of the preceding and subsequent fifteen years: a period of economic volatility followed by a period of moderation, leading to a rise of instability once more and a serious economic crisis. This paper extends that model to build a strictly monetary macroeconomic model which can generate the monetary as well as the real phenomena manifested by both The Great Recession and The Great Moderation.

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1. Introduction

The financial and economic crisis that began in 2007 brought to an abrupt end a period of economic tranquility that many macroeconomists had celebrated as "The Great Moderation" (Benati and Surico, 2009; Bernanke, 2004; Davis and Kahn, 2008; Gali and Gambetti, 2009). The trend for recessions to become less frequent and milder abruptly gave way to a sharp decline in output, a doubling of unemployment, and a temporary fall into deflation (see Fig. 1). Q3

The causes of this economic calamity will be debated for decades, but there should be little debate with the proposition that it was not predicted by any variant of mainstream economic analysis available at the time. It was however a prediction of the non-mainstream "Financial Instability Hypothesis" (*FIH*) developed by Hyman Minsky.

Steve Keen's 1995 model of this hypothesis generated qualitative characteristics that matched the real macroeconomic and income-distributional outcomes of the preceding and subsequent fifteen years: a period of economic volatility followed by a period of moderation, leading to a rise of instability once more and a serious economic crisis; and the wage share of income declining while non-financial business incomes stabilised and financial sector earnings rose (Keen, 1995, 2000, p. 93). This model is acknowledged as the reason why Keen was one of the handful of economists to anticipate and warn of the approaching economic and financial crisis well before it actually occurred (Keen, 2007; Bezemer, 2009, 2010; Fullbrook, 2010).

This paper extends that model to build a strictly monetary macroeconomic model of the *FIH*, which can generate the monetary as well as the real qualitative characteristics of both "The Great Recession" and "The Great Moderation" that

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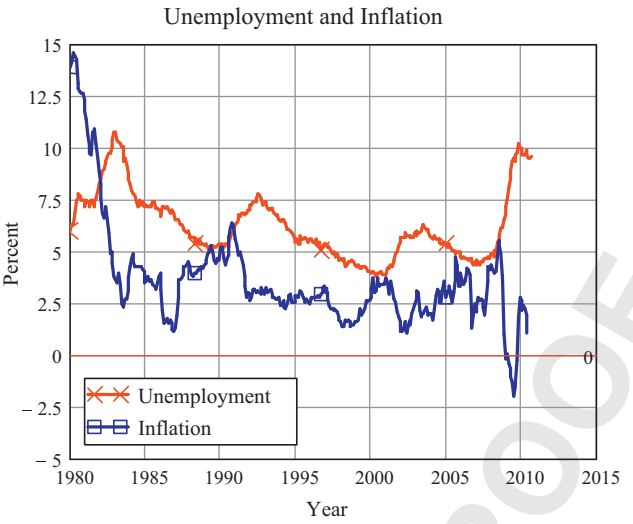

Fig. 1. The Great Moderation gives way to the Great Recession.

preceded it. I begin with an overview of Minsky's Financial Instability Hypothesis, since many economists are unfamiliar with this non-neoclassical integrated theory of macroeconomics and finance.[1]

The language and concepts in Minsky's theory were also developed completely outside the mainstream economic debate of the past 30 years,[2] and will therefore appear very foreign to most macroeconomists today. I hope that readers can look past this unfamiliarity to apply the spirit of Friedman's methodological dictum, that what matters is not the assumptions of a theory, but its capacity to give accurate predictions (Friedman, 1953).

2. The financial instability hypothesis—genesis

Minsky's motivation for developing the Financial Instability Hypothesis was that, since the Great Depression had occurred, a valid economic theory had to be able to generate such an outcome as one of its possible states:

> Can "It"—a Great Depression—happen again? And if "It" can happen, why didn't "It" occur in the years since World War II? These are questions that naturally follow from both the historical record and the comparative success of the past thirty-five years. To answer these questions it is necessary to have an economic theory which makes great depressions one of the possible states in which our type of capitalist economy can find itself. (Minsky, 1982a, p. 5)

For this reason, Minsky explicitly rejected neoclassical economics:

> The abstract model of the neoclassical synthesis cannot generate instability. When the neoclassical synthesis is constructed, capital assets, financing arrangements that center around banks and money creation, constraints imposed by liabilities, and the problems associated with knowledge about uncertain futures are all assumed away. For economists and policy-makers to do better we have to abandon the neoclassical synthesis. (Minsky, 1982a, p. 5)

Minsky instead combined insights from Schumpeter, Fisher and Keynes to develop a theory of financially driven business cycles which can lead to an eventual debt-deflationary crisis.[3]

3. The financial instability hypothesis—a précis

Minsky's analysis of a financial cycle begins at a time when the economy is doing well (the rate of economic growth equals or exceeds that needed to reduce unemployment), but firms are conservative in their portfolio management (debt to equity ratios are low and profit to interest cover is high), and this conservatism is shared by banks, who are only willing to fund cash-flow shortfalls or low-risk investments. The cause of this high and universally practised risk aversion is the

[1] In addition to being based on unfamiliar theoretical and philosophical foundations, Minsky's work has mainly been published in non-mainstream journals such as the *Journal of Post Keynesian Economics* and the *Journal of Economic Issues*, and minor journals such as the *Nebraska Journal of Economics and Business*. Minsky has appeared only twice in the *AER*: Minsky (1957, 1971).

[2] The evolution of Minsky's hypothesis is discussed in detail in Keen (1995, 2001). Minsky (1982b) provides his most important papers (the introduction and chapters 1–5 are sufficient). I also recommend Minsky (1975). His final book *Stabilizing an Unstable Economy* Minsky (1986), is a far less useful guide to his theories than these earlier works.

[3] This summary of Minsky is reproduced from Keen (1995) with the kind permission of the *Journal of Post Keynesian Economics*.

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memory of a not too distant system-wide financial failure, when many investment projects foundered, many firms could not finance their borrowings, and many banks had to write off bad debts. Because of this recent experience, both sides of the borrowing relationship prefer extremely conservative estimates of prospective cash flows: their risk premiums are very high.

However, the combination of a growing economy and conservatively financed investment means that most projects succeed. Two things gradually become evident to managers and bankers: "Existing debts are easily validated and units that were heavily in debt prospered: it pays to lever" (Minsky, 1982a, p. 6). As a result, both managers and bankers come to regard the previously accepted risk premium as excessive. Investment projects are evaluated using less conservative estimates of prospective cash flows, so that with these rising expectations go rising investment and asset prices. The general decline in risk aversion thus sets off both growth in investment and exponential growth in the price level of assets, which is the foundation both of the boom and its eventual collapse.

More external finance is needed to fund the increased level of investment and the speculative purchase of assets, and these external funds are forthcoming because the banking sector shares the increased optimism of investors (Minsky, 1982b, p. 65). The accepted debt to equity ratio rises, liquidity decreases, and the growth of credit accelerates.

This marks the beginning of what Minsky calls "the euphoric economy" (Minsky, 1982b, p. 121), where both lenders and borrowers believe that the future is assured, and therefore that most investments will succeed. Asset prices are revalued upward as previous valuations are perceived to be based on mistakenly conservative grounds. Highly liquid, low-yielding financial instruments are devalued, leading to a rise in the interest rates offered by them as their purveyors fight to retain market share.

Financial institutions now accept liability structures both for themselves and their customers "that, in a more sober expectational climate, they would have rejected" (Minsky, 1982b, pp. 120–125). The liquidity of firms is simultaneously reduced by the rise in debt to equity ratios, making firms more susceptible to increased interest rates. The general decrease in liquidity and the rise in interest paid on highly liquid instruments triggers a market-based increase in the interest rate, even without any attempt by monetary authorities to control the boom. However the increased cost of credit does little to temper the boom, since anticipated yields from speculative investments normally far exceed prevailing interest rates, leading to a decline in the elasticity of demand for credit with respect to interest rates.

The condition of euphoria also permits the development of an important actor in Minsky's drama, the Ponzi financier (Minsky, 1982b, p. 123; Galbraith, 1955, pp. 4–5). These capitalists profit by trading assets on a rising market, and incur significant debt in the process. The servicing costs for Ponzi debtors exceed the cash flows of the businesses they own, but the capital appreciation they anticipate far exceeds the interest bill. They therefore play an important role in pushing up the market interest rate, and an equally important role in increasing the fragility of the system to a reversal in the growth of asset values.

Rising interest rates and increasing debt to equity ratios eventually affect the viability of many business activities, reducing the interest rate cover, turning projects which were originally conservatively funded into speculative ones, and making ones which were speculative "Ponzi". Such businesses will find themselves having to sell assets to finance their debt servicing—and this entry of new sellers into the market for assets pricks the exponential growth of asset prices. With the price boom checked, Ponzi financiers now find themselves with assets which can no longer be traded at a profit, and levels of debt which cannot be serviced from the cash flows of the businesses they now control. Banks which financed these asset purchases now find that their leading customers can no longer pay their debts—and this realisation leads initially to a further bank-driven increase in interest rates. Liquidity is suddenly much more highly prized, holders of illiquid assets attempt to sell them in return for liquidity. The asset market becomes flooded and the euphoria becomes a panic, the boom becomes a slump.

As the boom collapses, the fundamental problem facing the economy is one of excessive divergence between the debts incurred to purchase assets, and the cash flows generated by them—with those cash flows depending both upon the level of investment and the rate of inflation. The level of investment has collapsed in the aftermath of the boom, leaving only two forces which can bring asset prices and cash flows back into harmony: asset price deflation, or current price inflation. This dilemma is the foundation of Minsky's iconoclastic perception of the role of inflation, and his explanation for the stagflation of the 70s and early 80s.

Minsky argues that if the rate of inflation is high at the time of the crisis, then though the collapse of the boom causes investment to slump and economic growth to falter, rising cash flows rapidly enable the repayment of debt incurred during the boom. The economy can thus emerge from the crisis with diminished growth and high inflation, but few bankruptcies and a sustained decrease in liquidity. Thus though this course involves the twin "bads" of inflation and initially low growth, it is a self-correcting mechanism in that a prolonged slump is avoided. However the conditions are soon re-established for the cycle to repeat itself, and the avoidance of a true calamity is likely to lead to a secular decrease in liquidity preference.

If the rate of inflation is low at the time of the crisis, then cash flows will remain inadequate relative to the debt structures in place. Firms whose interest bills exceed their cash flows will be forced to undertake extreme measures: they will have to sell assets, attempt to increase their cash flows (at the expense of their competitors) by cutting their margins, or go bankrupt. In contrast to the inflationary course, all three classes of action tend to further depress the current price level, thus at least partially exacerbating the original imbalance. The asset price deflation route is, therefore, not self-correcting but rather self-reinforcing, and is Minsky's explanation of a depression.

The above sketch describes Minsky's perception of an economy in the absence of a government sector. With big government, the picture changes in two ways, because of fiscal deficits and Reserve Bank interventions. With a developed social

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security system, the collapse in cash flows which occurs when a boom becomes a panic will be at least partly ameliorated by a rise in government spending—the classic "automatic stabilisers", though this time seen in a more monetary light. The collapse in credit can also be tempered or even reversed by rapid action by the Reserve Bank to increase liquidity.

4. Modeling Minsky I: the Goodwin model

Minsky's own attempts to devise a mathematical model of his hypothesis were unsuccessful,[4] arguably because the foundation he used—the multiplier-accelerator model—was itself flawed (Keen, 2000, pp. 84–89). Keen (1995) instead used Goodwin's growth cycle model (Goodwin, 1967), which generates a trade cycle with growth out of a simple deterministic structural model of the economy.

Goodwin's model can be expressed as two differential equations in the rate of employment and the wages share of output. I outline it here in terms of absolute values, since this is the form in which the final monetary Minsky model in this paper is expressed. The basic deterministic causal cycle of the model is:

1. The level of capital stock K determines the level of output per annum Y via the accelerator v: $Y = \frac{K}{v}$.
2. The level of output determines the level of employment L via labor productivity a: $L = \frac{Y}{a}$.
3. The level of employment determines the employment rate λ (the ratio of L to population N): $\lambda = \frac{L}{N}$.
4. The employment rate determines the rate of change of real wages w via a Phillips curve: $\frac{1}{w}\frac{dw}{dt} = (-c + d \cdot \lambda)$.
5. Subtracting the wage rate w times labor L from output Y determines the level of profit Π; $\Pi = Y - w \cdot L$.
6. Profit determines investment I (in the simple Goodwin model, all profits are invested): $I = \Pi$.
7. Investment minus depreciation γ determines the rate of change of capital stock K, closing the model: $\frac{dK}{dt} = I - \gamma \cdot K$.

With population growth of β percent per annum, labor productivity growth of α percent, and a linear Phillips curve relation of the form $P_h(\lambda) = (-c + d \cdot \lambda)$ (where a and b are constants), the model consists of the following 4 differential equations in the level of employment, the real wage, labor productivity and population growth:

$$\begin{aligned} \frac{d}{dt}L &= L \cdot \left(\frac{1 - \frac{w}{a}}{v} - \gamma - \alpha \right) \\ \frac{d}{dt}w &= (-c + d \cdot \lambda) \cdot w \\ \frac{d}{dt}a &= \alpha \cdot a \\ \frac{d}{dt}N &= \beta \cdot N \end{aligned} \tag{1.1}$$

Cycles in the Goodwin model are caused not by any imposed nonlinearity, but by the structural nonlinearity that the system states of the wage rate and the level of employment are multiplied by each other. Interactions between changes in the distribution of income (which emanate from changes in workers' relative bargaining power as employment levels rise and fall) and the rate of growth then cause cycles: a high level of investment causes high growth, so that unemployment falls—which leads to rising wages and a falling profit share; falling profit share then reduces investment and economic growth, leading to rising unemployment; this reduces wages and restoring profit share, leading the cycle to repeat (see Figs. 2 and 3).

5. Modeling Minsky II: nonlinear functions and debt

An essential first step in modeling Minsky's insights concerning the role of debt finance was to replace the unrealistic linear function for investment with a more realistic nonlinear relation, so that when the desire to invest exceeds retained earnings, firms will borrow to finance investment. An exponential function for the propensity to invest captures the most fundamental of Keynes's insights about the behavior of agents under uncertainty: that they behave as if:

> 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 (Keynes, 1937, p. 214)

Agents thus extrapolate current conditions into the future, a behavior that Keynes elsewhere describes as "unreasoning and yet in a sense legitimate where no solid basis exists for a reasonable calculation" (Keynes, 1936, p. 154). Thus desired investment exceeds profits at high rates of profit, and is less than profits at low rates, because agents extrapolate current

[4] The first of Minsky's two papers in the AER set out a mathematical model of a financially driven trade cycle developed during his PhD, but he never attempted to develop the model further (Minsky, 1957).

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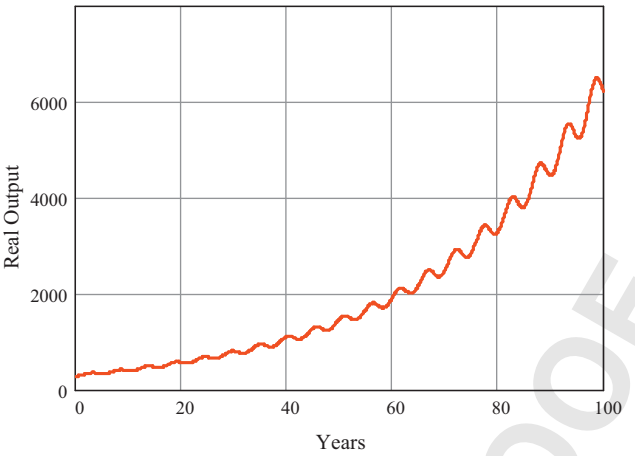

Fig. 2. Cyclical growth in the basic Goodwin model.

conditions into the future. Similarly, with a nonlinear Phillips curve, wages rise rapidly at high levels of employment and fall slowly at lower levels.

The same generalized exponential function is used for both the relationship between investment as a share of output, and the Phillips Curve:

$$GenExp(x, x_{val}, y_{val}, s, \min) = (y_{val} - \min) \cdot e^{s/(y_{val} - \min)\cdot(x - x_{val})} + \min \tag{1.2}$$

With suitable parameter values (see Appendix A), the two relationships are as shown in Figs. 4 and 5.

A banking sector that finances the gap between desired and investment is then introduced by the simple relationship that the gap between desired investment and actual profit caused a change in the level of debt:

$$\frac{dD}{dt} = I - \Pi \tag{1.3}$$

Profit is also redefined as output minus the sum of wages plus interest payments:

$$\Pi = Y - w \cdot L - r \cdot D \tag{1.4}$$

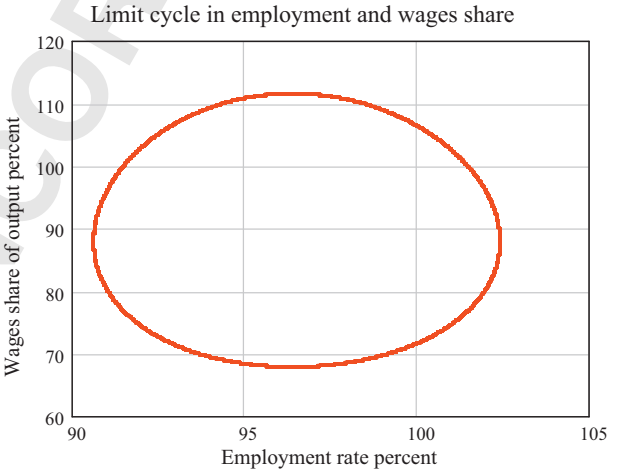

Fig. 3. A conservative system.

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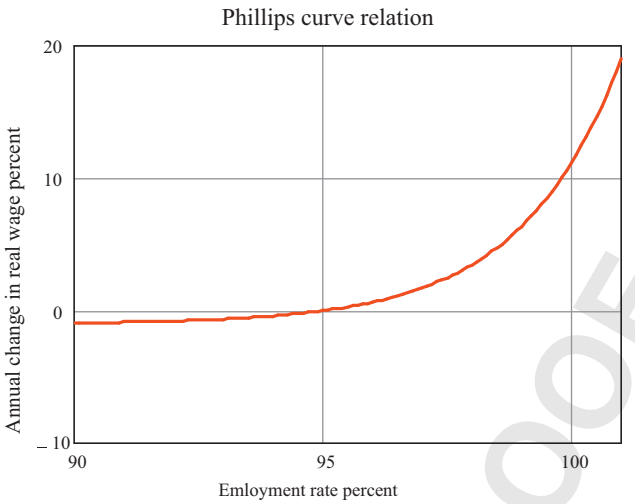

Fig. 4. The rate of change of real wages as a function of the employment rate.

This extension adds one more system state to the model, the debt level D. Substituting Y for the system state L, this results in the model shown in Eq. (1.5).

$$\begin{aligned}
&\frac{d}{dt}Y = \left(\frac{I\left(\frac{\Pi}{v\cdot Y}\right)}{v} - \gamma\right)\cdot Y \\
&\frac{d}{dt}w = P_h(\lambda)\cdot w \\
&\frac{d}{dt}D = I\left(\frac{\Pi}{v\cdot Y}\right)\cdot Y - \Pi \\
&\frac{d}{dt}a = \alpha\cdot a \\
&\frac{d}{dt}N = \beta\cdot N
\end{aligned} \tag{1.5}$$

This additional dimension converts the model from a conservative to a dissipative dynamical system, in which the model's dynamics display sensitive dependence on initial conditions. Specifically, the model has a stable equilibrium—defined in terms of the employment rate, the profit rate and the debt to output ratio—and will converge to this if the initial conditions

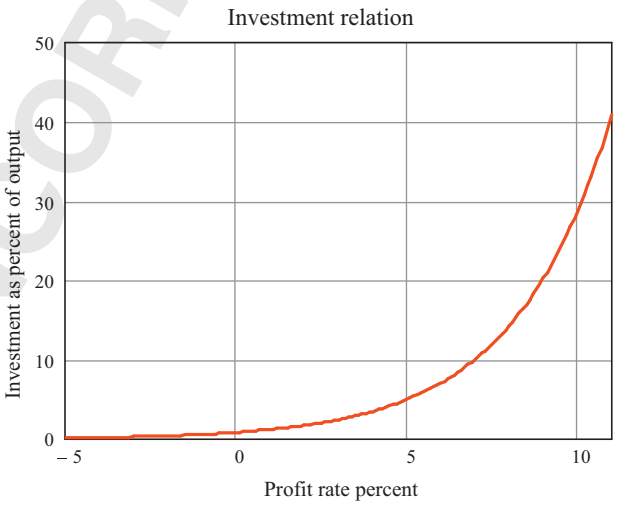

Fig. 5. The level of investment in GDP as a function of the rate of profit.

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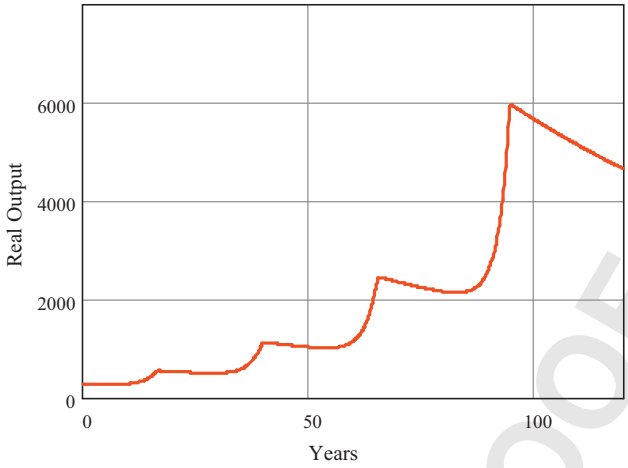

Fig. 6. Cyclical breakdown of growth in the basic Minsky model.

are sufficiently close to the equilibrium. But for other initial conditions, the model bifurcates (following what is known as the inverse tangent route to chaos; see Pomeau and Manneville, 1980), and the model undergoes an unstable cyclical breakdown (see Figs. 6 and 7).

6. Endogenous money

Though debt was modeled in the preceding system, money was not explicitly considered, and therefore price dynamics were absent. To consider these, the model had to be extended to include an explicit monetary sector. The first step here was to develop a model of an established empirical datum, that credit money is created independently of base money.

The pioneering work on this was done by (Moore, 1979, 1983, 1988). Contrary to the standard 'money multiplier' model of credit money creation, where base money is created before credit money, Moore concluded (citing Holmes, 1969), that:

> "In the real world banks extend credit, creating deposits in the process, and look for the reserves later." (Alan Holmes, 1969, p. 73)

Kydland and Prescott concurred, noting that:

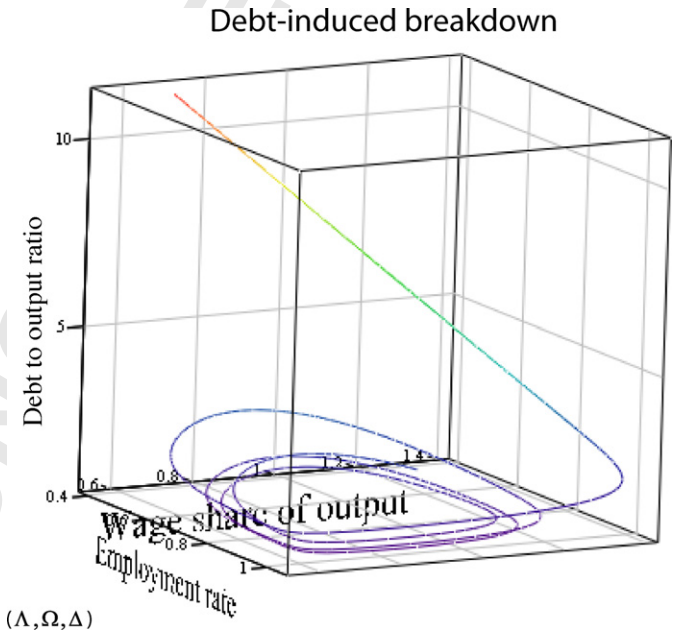

Fig. 7. A dissipative system with breakdown.

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Table 1
Basic Godley Table of monetary flows in a growing economy.

Row	Transaction	Type	Bank vault (B_V)	Bank transaction (B_T)	Firm loan (F_L)	Firm deposit (F_D)	House-hold deposit (H_D)
1	Lend money	Money transfer	$-a$			a	
2	Record loan	Ledger entry			a		
3	Compound debt	Ledger entry			b		
4	Pay interest	Money transfer		c		$-c$	
5	Record payment	Ledger entry			$-c$		
6	Deposit interest	Money transfer		$-d$		d	
7	Wages	Money transfer				$-e$	e
8	Deposit interest	Money transfer		$-f$			f
9	Consumption	Money transfer		$-g$		$g+h$	$-h$
10	Repay loan	Money transfer	i			$-i$	
11	Record repayment	Ledger entry			$-i$		
12	Investment finance	Money creation				j	
13	Record loan	Ledger entry			j		
	Sum of flows		$i-a$	$c-d-f-g$	$a+b-c-i+j$	$a-c+d-e+g+h-i+j$	$e+f-h$

> There is no evidence that either the monetary base or M_1 leads the cycle, although some economists still believe this monetary myth. . . if anything, the monetary base lags the cycle slightly. . . The difference of M_2–M_1 leads the cycle by even more than M_2, with the lead being about three quarters. (Kydland and Prescott, 1990, p. 12)

They further concluded that:

> The fact that the transaction component of real cash balances (M_1) moves contemporaneously with the cycle while the much larger nontransaction component (M_2) leads the cycle suggests that credit arrangements could play a significant role in future business cycle theory. Introducing money and credit into growth theory in a way that accounts for the cyclical behavior of monetary as well as real aggregates is an important open problem in economics. (Kydland and Prescott, 1990, p. 15)

This open problem was addressed by Graziani (2003, 1989, 1990, 1995) in a manner that clarified the emphasis that Keynes put on the importance of money,[5] and explained the well-known difficulties that have been encountered in introducing money into neoclassical models (Bhattacharjee and Thoenissen, 2007; Gutierrez, 2004; Magill and Quinzii, 1992; Wright, 2010). Graziani's simple but profound principle was that "A true monetary economy must. . . be using a token money" rather than a commodity as money, since "an economy using as money a commodity coming out of a regular process of production, cannot be distinguished from a barter economy" (Graziani, 1989, p. 3). From this he derived the proposition that banks, as the creators of these tokens, must be modeled as separate agents from firms and households, and that all transactions are single-commodity, monetary exchanges involving three agents:

> any monetary payment must therefore be a triangular transaction, involving at least three agents, the payer, the payee, and the bank. (Graziani, 1989, p. 3)

A model of a monetary production economy thus must (a) have at the minimum three agents; (b) model demand as the flows of a pure monetary token (which motivate counter-flows of commodities and labor) between bank accounts held by those agents, and (c) allow for the endogenous creation of money by the banking sector.

Table 1.

Steve Keen has developed dynamic disequilibrium models of monetary production that fulfil these conditions (Keen, 2009a,b, 2008, 2010), using a technique that combines double-entry book-keeping with systems dynamics. Each column of a "Godley Table" (named in honor of Wynne Godley; see Godley, 1999; Godley and Lavoie, 2007) is a bank account belonging to a specific class of agent (banker, firm, household), and each row represents financial transactions between these agents that either purchase a good or service, or compound, meet or record a financial obligation. The symbolic sum of the operations in each column then generates the differential equation for that account. In the next section, a simple model of a pure credit economy is combined with the preceding Minsky–Goodwin model to generate a monetary model of the Great Moderation and the Great Recession.

[5] "... as soon as we pass to the problem of what determines output and employment as a whole, we require the complete theory of a monetary economy... For the importance of money essentially flows from its being a link between the present and the future... It is when we have made this transition [to] . . . the real world in which our previous expectations are liable to disappointment and expectations concerning the future affect what we do to-day . . . that the peculiar properties of money as a link between the present and the future must enter into our calculations. . . Money in its significant attributes is, above all, a subtle device for linking the present to the future; and we cannot even begin to discuss the effect of changing expectations on current activities except in monetary terms." (Keynes, 1936, pp. 293–294).

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7. Modeling Minsky III: endogenous money

There are 5 accounts in the basic model[6]:

1. A Bank Vault (B_V) representing the banking sector's monetary assets;
2. A Bank Transactions Account (B_T) through which all expenditure and interest payments pass[7];
3. A Firm Loan ledger (F_L)—which is not an account that can store money, but a record of the amount of outstanding debt owed by the firm sector to the banking sector[8];
4. A Firm Deposit Account (F_D) into which money borrowed by the firm sector is deposited; and
5. A Household Deposit Account (H_D) into which wages are paid.

The operations specified in the rows below involve three types of operations: money transfers, accounting operations, and money creation. There are seven money transfers:

1. Lending of money from the bank vault to the firms' deposit accounts (row 1).
2. Payment of interest by firms to the bank's transactions account (row 4).
3. Payment of interest by the bank to firms' deposit accounts (row 6).
4. Payment of wages (row 7).
5. Payment of interest on workers' account balances (row 8).
6. Payment for consumption of the output of firms by bank and workers (row 9).
7. Repayment of loans by firms (row 10).

Five steps are ledger entries only, involving the recording of a money transfer related to the level of debt:

8. Recording the loans of the existing money stock to firms (row 2).
9. Compounding the debt at the rate of interest on loans (row 3).
10. Recording the payment of interest on loans (row 5).
11. Recording the repayment of loans (row 11).
12. Recording the endogenous creation of new money (row 13).

One is the crucial step of endogenous money creation in response to the investment desires of firms (in this simple model, all capital expansion is shown as funded by borrowing money from the banking sector):

The endogenous creation of new money in response to firms' investment plans (row 12).

The fundamental dynamic equations of the financial sector are the sums of the entries in this table, as shown in Eq. (1.6):

$$\begin{aligned}
\frac{d}{dt}B_V(t) &= i - a \\
\frac{d}{dt}B_T(t) &= c - d - f - g \\
\frac{d}{dt}F_L(t) &= a + b - c - i \\
\frac{d}{dt}F_D(t) &= a - c + d - e + g + h - i \\
\frac{d}{dt}H_D(t) &= e + f - h
\end{aligned} \tag{1.6}$$

Keen (2010) used constant parameters to demonstrate the innate viability of a monetary production economy—something that was disputed in the literature up to that point (Bellofiore et al., 2000; Rochon, 2005). To generate a monetary Minsky model, I use nonlinear functions for key monetary relationships: the rate at which existing money is circulated, the rate of loan repayment, and the rate of investment (and hence the rate of growth of the money stock) are all made nonlinear functions of the rate of profit.

The monetary functions are expressed as time constants[9] whose value at any given time depends upon the rate of profit. The investment function returns the proportion of nominal output devoted to producing investment goods.

[6] This is a simple stylized model that captures the essence of a monetary economy, and does not purport to reproduce the actual institutional structure of either a single modern bank or the modern banking sector. However the framework can ultimately be extended to these objectives, because the fundamental concepts of both the system and this modeling technique are the same: double-entry book-keeping.

[7] These accounts are kept separate to avoid seignorage, which would occur if banks used their monetary reserves for direct expenditure (Graziani, 1989, p. 3).

[8] Loans to households are not modeled in this basic system, but can easily be added.

[9] The time constants are expressed in years, and provide an intuitive way of describing the speed at which a process occurs. See http://en.wikipedia.org/wiki/Time_constant for a more thorough explanation.

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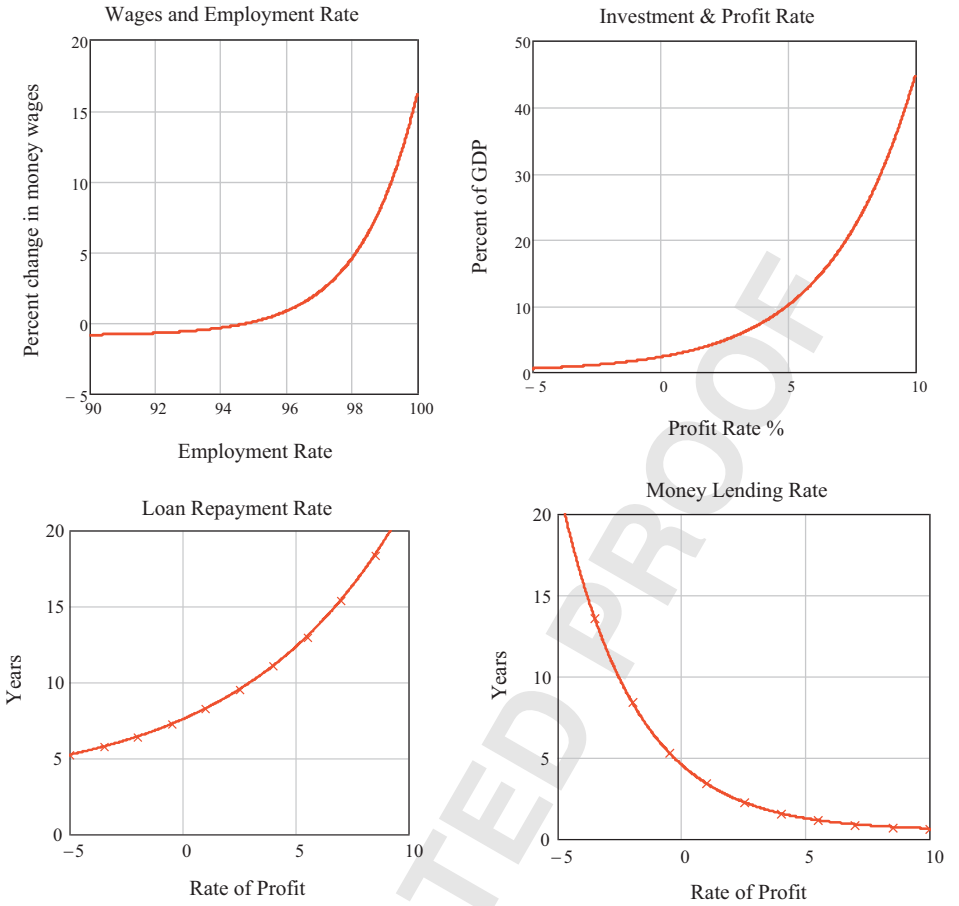

With the definitions provided in Table 2, the financial dynamics of the system are given by Eq. (1.7).

$$
\begin{aligned}
\frac{d}{dt}B_V &= \frac{F_L}{\tau_L(\pi_r)} - \frac{B_V}{\tau_V(\pi_r)} \\
\frac{d}{dt}B_T &= r_L \cdot F_L - r_D \cdot (F_D + H_D) - \frac{B_T}{\tau_B} \\
\frac{d}{dt}F_L &= \frac{B_V}{\tau_V(\pi_r)} - \frac{F_L}{\tau_L(\pi_r)} + Y \cdot Inv(\pi_r) \\
\frac{d}{dt}F_D &= (r_D \cdot F_D - r_L \cdot F_L) - W \cdot L + \left(\frac{B_V}{\tau_V(\pi_r)} - \frac{F_L}{\tau_L(\pi_r)}\right) + \left(\frac{B_T}{\tau_B} + \frac{H_D}{\tau_H}\right) + Y \cdot Inv(\pi_r) \\
\frac{d}{dt}H_D &= r_D \cdot H_D + W \cdot L - \frac{H_D}{\tau_H}
\end{aligned}
\tag{1.7}
$$

Table 2
Flow rates for the entries in the Godley Table.

Operation	Description	Equation
a	Lending of the existing money stocknot in circulation B_V is a function of the rate of profit	$\frac{B_V(t)}{\tau_V(\pi_r(t))}$
b	The debt F_L is compounded at the rate of loan interest r_L	$r_L \cdot F_L(t)$
c	Payment of interest on the loan	$r_L \cdot F_L(t)$
d	Interest on Firm deposits F_D is paid at the deposit rate r_D	$r_D \cdot F_D(t)$
e	Wage payments depend on the money wage W and the employment level L	$W(t) \cdot L(t)$
f	Interest on household deposits H_D at the rate r_D	$r_D \cdot H_D(t)$
g	Bank consumption with a time constant τ_B	$\frac{B_T(t)}{\tau_B}$
h	Household consumption with a time constant τ_H	$\frac{H_D(t)}{\tau_H}$
i	The rate of loan repayment is a nonlinear function of the rate of profit	$\frac{F_L(t)}{\tau_L(\pi_r(t))}$
j	The investment share of output is a nonlinear function of the rate of profit	$Inv(\pi_r(t)) \cdot Y(t)$

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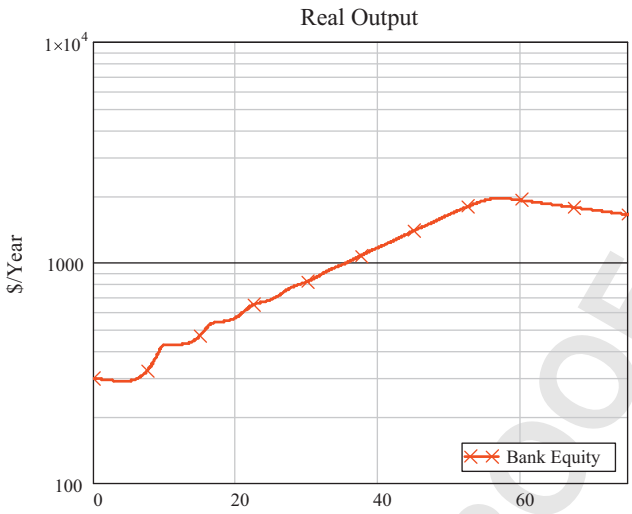

Fig. 8. Cycles in real output diminish, followed by a sudden change to declining output.

This financial system is coupled to the physical production model via prices. Physical measures of capital and output are now specified as being in real terms:

$$Y_R = \frac{K_R}{v}$$
$$L = \frac{Y_R}{a} \tag{1.8}$$

The dynamic disequilibrium price equation is consistent with empirical research into actual price setting behavior (Blinder, 1998; Lee, 1998) and is derived analytically in (Keen, 2010) from the equilibrium condition for physical output and the physical demand for commodities. Prices converge to a markup over the monetary cost of production, where the markup factor $(1-\sigma)$ is equivalent to the equilibrium workers' share of real output:

$$\frac{d}{dt}P = -\frac{1}{\tau_P}\cdot\left(P - \frac{1}{1-\sigma}\frac{W}{a}\right) \tag{1.9}$$

The money wage setting relation is fully consistent with Phillips's original paper, in which he specified not one but three factors that determine the rate of change of money wages: the relationship between the rate of change of money wages and level of unemployment, which is "highly non-linear"; the "rate of change of the demand for labor, and so of unemployment"; and "the rate of change of retail prices, operating through cost of living adjustments in wage rates" (Phillips, 1958, p. 283). The full wage-setting equation is thus:

$$\frac{d}{dt}W = W\cdot\left(P_h(\lambda) + \omega\cdot\frac{1}{\lambda}\frac{d}{dt}\lambda + \frac{1}{P}\frac{d}{dt}P\right) \tag{1.10}$$

where $\omega < 1$ is a weighting factor for the impact of the change in the employment rate on the wage rate.

The rate of inflation is given by Eq. (1.9) above. The rate of change of the employment rate λ is:

$$\frac{d}{dt}\lambda = \lambda\cdot(g - (\alpha+\beta)) \tag{1.11}$$

where as before, α is the rate of technical change, β is the rate of population growth, and δ is the depreciation rate. g is the real growth rate, which is determined by the rate of investment and depreciation, which in turn determine the rate of growth of the real capital stock K_r:

$$g = \frac{Inv(\pi_r)}{v} - \delta$$
$$\frac{d}{dt}K_R = g\cdot K_R \tag{1.12}$$

The profit rate is now defined in fully monetary terms:

$$\pi_r = \frac{P\cdot Y_R - W\cdot L - (r_L\cdot F_L - r_D\cdot F_D)}{P\cdot K_R} \tag{1.13}$$

Together with the technical change and population growth equations specified in Eq. (1.5), these equations provide a strictly monetary model of Minsky's Financial Instability Hypothesis. The qualitative behavior of this model reproduces the features

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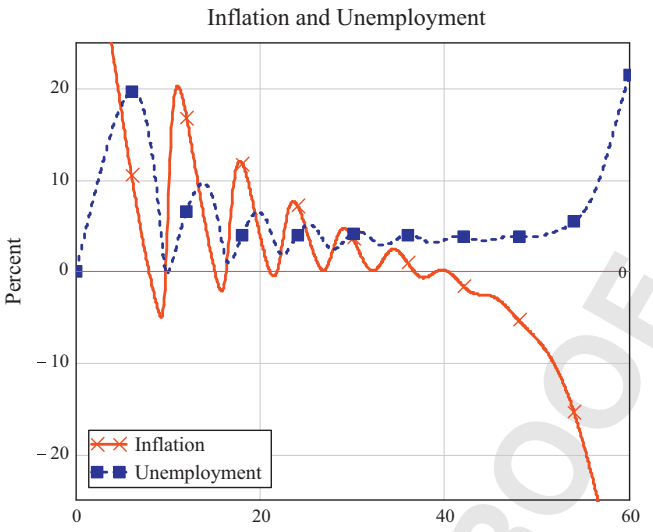

Fig. 9. Apparent economic tranquility gives way to a deflationary collapse.

of the last 30 years: a period of strong cycles in real output is followed by a period when the business cycle appears a thing of the past, but then suddenly a crisis breaks out with declining real output (see Fig. 8).

Similarly, declining cycles in unemployment and inflation appear to imply that the system is becoming more stable, when suddenly inflation gives way to deflation and unemployment grows dramatically (see Fig. 9).

The cause of this breakdown is the level of debt (which has been growing cyclically in the manner predicted by Minsky), which reaches a level where it is no longer possible for the debt to be serviced by capitalists. Absent bankruptcy provisions (which are not yet modeled) the debt ratio grows exponentially, leading to a terminal economic breakdown—a Great Depression (see Fig. 10).

The income distribution dynamics of the model also match the empirical record, and maintains the analytic result shown in Keen (2000, p. 93) that, though capitalists are the ones who incur debt in this model, the dynamics of the system transfer this cost to workers. The wages share of output declines as debt levels rise, while the profit rate cycles around its equilibrium value before the final collapse (when exponential growth in the debt ratio means that bankers' share of income explodes as income collapses).

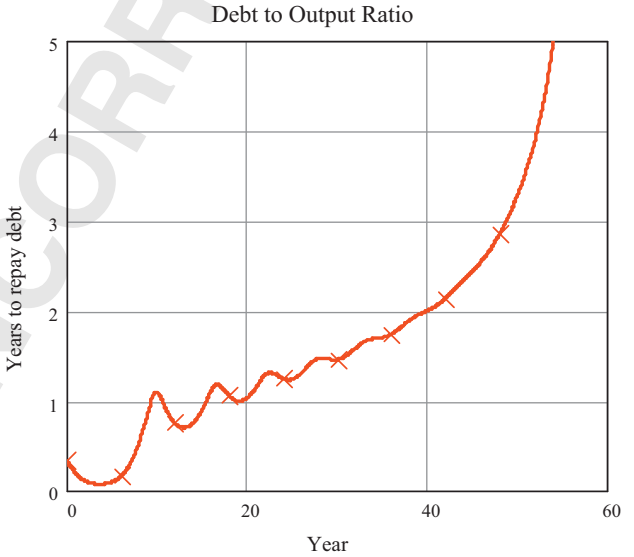

Fig. 10. Cyclical growth in the debt to output ratio, followed by exponential growth.

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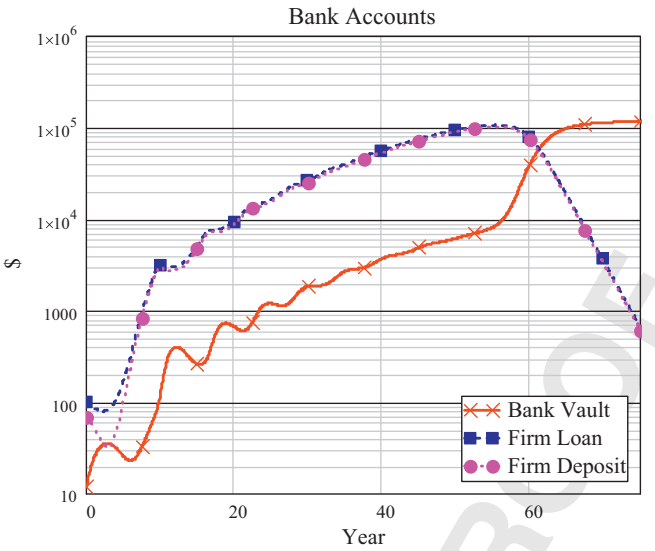
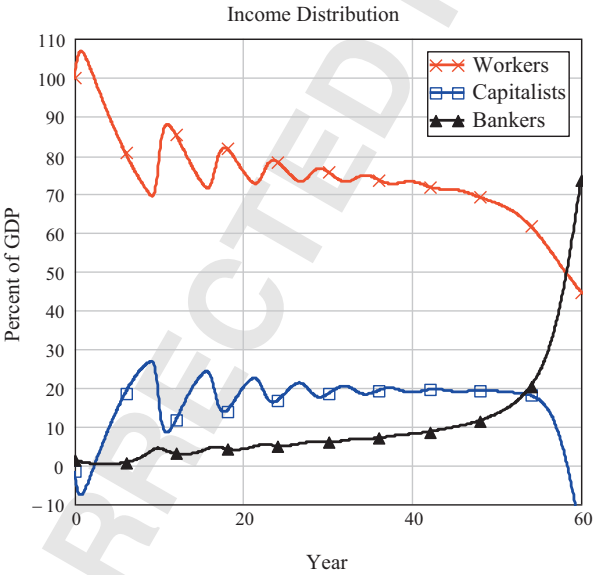


Fig. 11. Loans and deposits fall and unlent reserves rise as the crisis unfolds.



As a strictly monetary system, the model also captures another real-world phenomenon that has perplexed standard economic analysis: the reduction in business debt and the dramatic growth in bank reserves during the economic collapse (see Fig. 11).

8. Conclusion

The results of this model are more extreme than our actual economic situation, partly because aspects of Minsky's hypothesis have been omitted for simplicity (such as the proposition that the price level for capital goods is set in a different manner to that for ordinary commodities; Minsky, 1982, p. 79), partly because aspects of reality have been omitted for the same reason (such as interest rates varying with the rate of inflation), and partly because the impact of government spending has not been considered (it is considered in the simpler non-monetary model in Keen, 2000, pp.100–105).

However, though much could be done to enhance its realism, in its present form it provides an explanation not only of the Great Recession, but also the Great Moderation that preceded it. The fact that this model is relevant to today's economic predicament vindicates Minsky's stricture from 1982 that, if we are to fully comprehend how market economies really behave, "it is necessary to have an economic theory which makes great depressions one of the possible states in which our type of capitalist economy can find itself." (Minsky, 1982a, p. 5)

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Bellofiore and Ferri (2001).

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Appendix A. Appendix

Variable or parameterDescriptionValueνAccelerator relation3αRate of change of labor productivity2 percent p.a.βRate of population growth1 percent p.a.γDepreciation rate1 percent p.a.$P_h(\lambda) = -c + d \cdot \lambda$Linear Phillips curve for Goodwin model$c = 4.8$, $d = 5L_0$, w_0, a_0, N_0Initial conditions for Labor, real wage, labor productivity and population in the Goodwin model300, 0.95, 1, 300 resp.D_0Initial condition for debt in the Minsky model0$P_h(\lambda) = GenExp(\lambda, 0.95, 0, 0.5, -0.01)$Parameters for nonlinear Phillips curve in the Minsky model$I(\pi_r) = GenExp(\pi_r, 0.05, 0.05, 1.75, 0)$Parameters for nonlinear investment function in the Minsky modelB_{V0}, B_{T0}, F_{L0}, F_{D0}, H_{D0}Initial conditions for financial variables in the monetary Minsky model12, 5, 100, 70, 13L_0, W_0, a_0, N_0, K_{R0}, Y_{R0}, P_0Initial conditions for physical variables in the monetary Minsky model300, 300, 1, 300, 900, 300, 1r_L, r_D, σ, τ_B, τ_H, τ_PLoan and deposit interest rates, markup coefficient, time constants for bank and household consumption and price setting5 percent, 1 percent, 20 percent, 1, 1/26, 1ωWeighting factor on impact of change in the employment rate on wage setting10 percent

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