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Beautiful Cycles: A Theory and a Model Implying a Curious
Role for Interest

by Marco Gross

***IMF Working Papers* describe research in progress by the author(s) and are published to elicit comments and to encourage debate.** The views expressed in IMF Working Papers are those of the author(s) and do not necessarily represent the views of the IMF, its Executive Board, or IMF management.

I N T E R N A T I O N A L M O N E T A R Y F U N D

IMF Working Paper

Monetary and Capital Markets Department

Beautiful Cycles: A Theory and a Model Implying a Curious Role for Interest *

Prepared by Marco Gross

Authorized for distribution by Vikram Haksar

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Abstract

Where do economic cycles come from? This paper contemplates an utmost minimalistic model and underlying theory that rest on two assumptions for letting them emerge endogenously: (1) the presence of interest-bearing debt; and (2) a degree of downward nominal wage rigidity. Despite its parsimony, the model generates well-behaved, self-evolving limit cycles and replicates six essential empirical facts: (1) booms are long- while recessions short-lived; (2) leverage is procyclical; (3) firm profit and wage shares in GDP are counter- and procyclical, respectively; (4) Phillips curves are downward-sloping and convex, and Okun's law relation is replicated; (5) default cascades arise endogenously at the turning points to recessions; (6) lending spreads are countercyclical. One can refer to the model as being of a Dynamic Stochastic General Disequilibrium (DSGD) kind.

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1. Introduction

Business cycles are cycling in a regular, far from purely stochastic manner. Figure 1 illustrates this for the US. Theory throughout the 20th century in the field of New Classical economics—real business cycle (RBC) theory (Kydland and Prescott 1982) as a sub-branch—as well as New Keynesian (NK) models and mixtures of the two (DSGE models following the New Consensus, since Goodfriend and King 1997 and Clarida et al. 1999), sought such behavior’s source in random shocks. Disequilibrium theory ensuing Keynes with Kalecki (1935/37), Kaldor (1940), Goodwin (1951/67), and Minsky (1975/86), aims to explain such dynamics through endogenous, self-evolving economic forces. System dynamics models (SDMs) represent one stream of nonlinear aggregative models to model disequilibrium processes (references follow in Section 2). Their drawbacks include that their dynamic behavior is sensitive to chosen functional forms and that they do not contain individual agents, for defaults of agents to be ruled out by design. Agent-based models (ABMs, LeBaron and Tesfatsion 2008) are an appealing alternative methodology for various reasons, including for the easy allowance of agent defaults. Macro-financial ABMs—despite being insightful—tend, however, to combine so *numerous* behavioral assumptions in one go. This disguises the root causes for cycles to emerge, opposed to factors that amplify or dampen them.

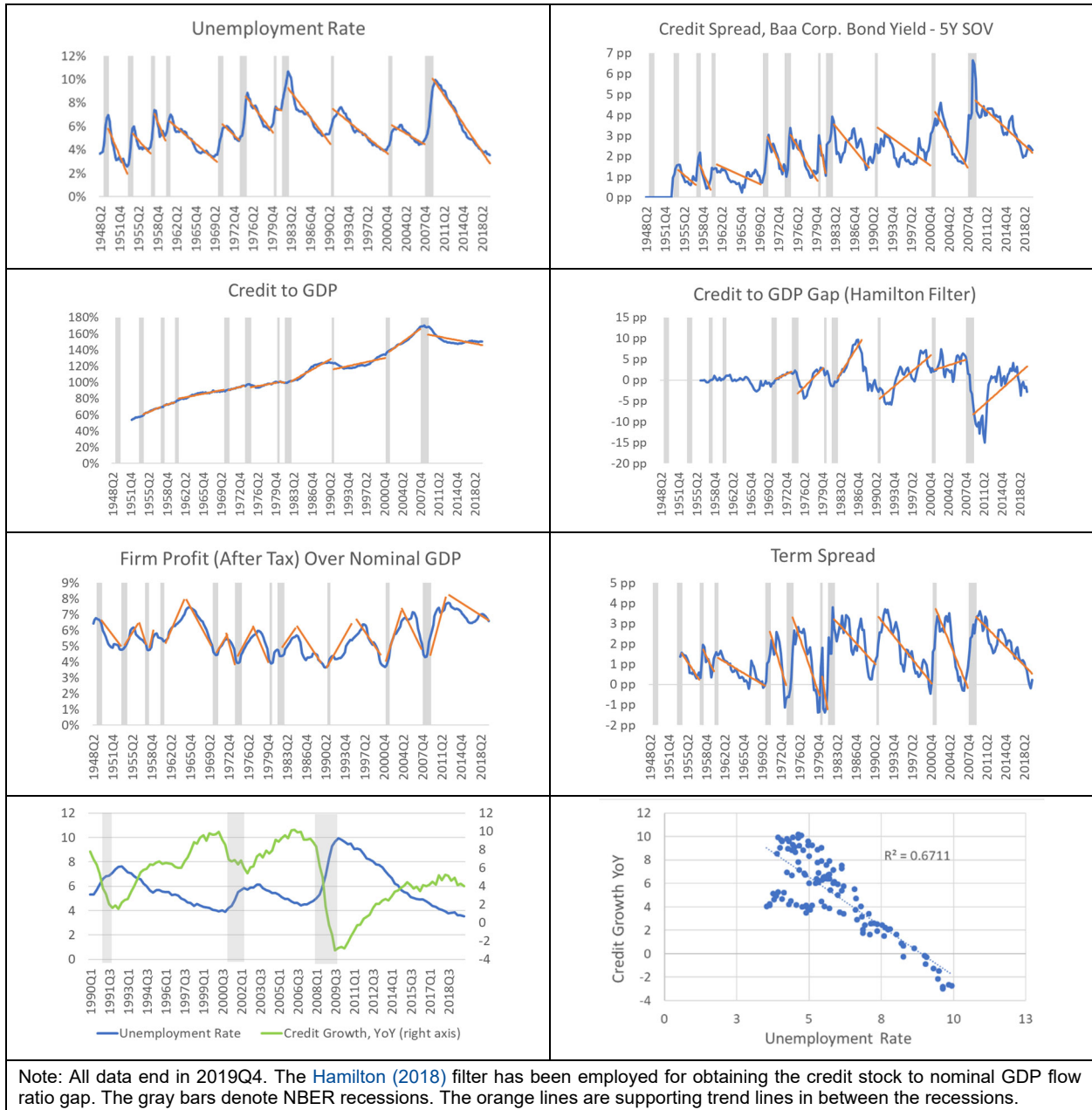
Against this backdrop, the objective of this paper is three-fold: (1) to develop a model and underlying theoretical rationale that generate endogenous cycles based on a *most minimal* set of assumptions, avoiding complexity by all means; (2) to delineate what *pre-conditions* for cycle emergence are, opposed to what *amplifies or dampens* cyclical behavior once present; and (3) to promote the use of stock-flow consistent ABM methodologies. The model in Section 3 is surrounded by a literature perspective in Sections 2 and 4, for relating it to existing SDMs, ABMs, sources of cycle amplification and dampening, and to the work of Hyman Minsky.

Despite its simplicity, the model generates self-evolving cycles and replicates six empirical facts. These include: (1) booms are long- while recessions short-lived; (2) leverage is procyclical; (3) firm profit shares and wage shares in GDP are counter- and procyclical; (4) wage and price Phillips curves are downward-sloping and convex, and Okun’s law is replicated; (5) default cascades arise endogenously at the turning points from expansions to recessions; (6) lending spreads are countercyclical. All this macro behavior from the model emerges endogenously “from the bottom up.” GDP growth and unemployment rates from the model exhibit fat tails (excess kurtosis) as in the data for the US and other countries.

The model can be seen as a theoretical grounding for the Growth-at-Risk (GaR) framework (Adrian et al. 2019). Its rationale—which GaR captures in an econometric fashion—has much in common with the endogenous cycle narrative presented here, and in turn with Minsky as well. Moreover, the model here rests on a strong demand-oriented propagation mechanism compatible with the business cycle “anatomy” conceived by Angeletos et al. (2020). The model’s narrative and quantitative behavior squares as well with the work of Schularick and Taylor (2012) and Jorda et al. (2013/15/16a) who document the empirically strong relationship between credit and real economic activity.

The paper concludes: The root causes of cyclical behavior can be seen in lying in (1) the presence of interest-bearing debt; and (2) a degree of downward nominal wage rigidity; which, respectively, reflect institutional and behavioral reality and serve to micro-found the model. The theory’s related implication is that *interest generates firm profits*, a precondition for which, in turn, is debt-financed investment. Various amplification and dampening mechanisms are discussed in Section 4, where four accelerator types are defined: a collateral, mispricing, policy, and herding accelerator. The model codes are made available along with this paper.

Figure 1. Cyclical Economic Dynamics in the US (1948Q1-2019Q4)



2. Literature

This section motivates which ingredients the model subsequently set up in Section 3 ought to comprise. These concern the choice of a model methodology that allows for disequilibrium dynamics to emerge (Section 2.1), the relevance of downward nominal wage rigidities (Section 2.2), and a perspective on existing ABMs (Section 2.3).

2.1 Equilibrium and Disequilibrium Theory

Twentieth century economic theory can be partitioned into an equilibrium and disequilibrium strand. Equilibrium theory is rooted in Neoclassical Economics of the early 1900s, splitting into New

Keynesian and New Classical streams, with RBC theory as a New Classical branch parallel to Monetarism.¹ Concerns about RBC and DSGE models are mounting: (1) in what they miss, inter alia, regarding incomplete markets, imperfect competition, endogenous money, and behavioral aspects; and (2) in what sense they are distorted more fundamentally, for example, regarding the rational expectations assumption and the representative agents paradigm. Kirman (1992), Akerlof (2002), Mankiw (2006), Howitt (2012), Blanchard (2016a/b, 2017), Stiglitz (2011/17), and Haldane and Turrell (2018) are some of those who explicate such concerns in detail.

In parallel, disequilibrium theory emerged since the early 20th century. A “pure” monetary theory of business cycles assigning a central role to credit was presented by Hawtrey (1919). The role of innovation for driving business cycles was conceived by Schumpeter (1912), explaining the emergence of cycles through the clustered occurrence of innovative firms. A series of research then emerged following the work of Keynes (1930/36), which served to anchor the ensuing endogenous business cycle (EBC) literature starting with Kalecki (1935/37), Harrod (1939), Kaldor (1940), and Goodwin (1951/67).

The disequilibrium theory stream widely acknowledges that money is endogenous. Money is created through bank lending, as a function of demand and with supply being bound by regulation, constraining bank leverage on the upside (Werner 2014a/b/2016, Mc Leay et al. 2014a/b, Gross and Siebenbrunner 2019). It does not preclude the on-lending of existing money stocks resting in the system by non-bank financial and nonfinancial agents, which creates additional leverage for some agents but leaves aggregate money stocks unchanged. Mistakenly modeling banks as intermediaries results in misperceiving the impact of monetary and macroprudential policy and underestimating the role of credit. In a DSGE model context this has been emphasized by Jakab and Kumhof (2015). The endogenous money reality is well acknowledged in Post-Keynesian economics (Lavoie 2014, Hein 2017), there referred to as the Horizontalists view (Moore 1988), and reflected in the model developed here.

Minsky augmented Keynes’s theory by introducing debt for financing investment as a basis for his cycle narrative. He considered neoclassical theory flawed in its equilibrium concept and the omission of debt finance (Minsky 1975/86). He agreed with Keynes on the importance of fundamental uncertainty, that expectations matter for investment decisions, and that fiscal and monetary policies are useful to contain cycles. His financial instability hypothesis posits that the financial system induces swings between stability and fragility and that these are responsible for driving business cycles endogenously (Minsky 1986/93). His writings are inspiring, including for the model here, though in one respect he drew a misled conclusion (see Section 4.1).

A system dynamics model (SDM) stream connected to the work of Kalecki, Harrod, Goodwin, and Minsky since the 1970s. Early entry points to this literature include Torre (1977), Taylor and O’Connell (1985), Foley (1987), Semmler (1987), Asada (1989), and Jarsulic (1989);² who developed aggregate nonlinear dynamic models, usually with three to five or sometimes more differential equations. Many of

¹ Such theories referring to shocks to generate half cycles back to steady state may be seen as unsatisfactory, as it amounts to assuming that shocks occur with systematically alternating signs to explain full cycles, which contradicts the concept of an exogenous shock and reveals that these models omit something essential. A DSGE-related literature stream concerned with sunspot shocks based on models grounded in equilibrium and the rational expectations paradigm motivate the emergence of indeterminacy and excess volatility through extrinsic, stochastic shocks to non-fundamentals (see the work of Woodford, Benhabib, Farmer, Blanchard, Carli, Modesto, and others). These do not generate endogenous cycles.

² The stream goes on with Gallegati and Gardini (1991), Delli Gatti et al. (1993), Palley (1994), Keen (1995), Asada (2001), Lima and Meirelles (2007), Le Heron (2011), and Nikolaidi (2014).

them are built around the Keynesian investment accelerator, and various expand in some form on the predator-prey model structure (that is, a Lotka-Volterra system) from mathematical biology as exemplified in [Goodwin \(1967\)](#). Numerous of them cite Minsky to motivate the role of credit. A survey of models with Minskyan elements can be found in [Nikolaïdi and Stockhammer \(2017\)](#). An in-depth review in [Zarnowitz \(1985\)](#) summarizes equilibrium and disequilibrium theories from the first two thirds of the 20th century, commenting on p. 546 that “purely stochastic explanations have no theoretical content, and it is the factors which can be integrated in an economic theory that are naturally of primary interest to any economist who attempts to understand the nature and causes of business cycles.” Moreover, linear time series model-based impulse responses being not very persistent for various macroeconomic variables should not be misinterpreted as meaning that more persistent cyclical behavior is irrelevant, but instead that relevant nonlinearities are likely missed ([Beaudry et al. 2017](#)).

Traces of Minsky’s mindset can be found outside the Post-Keynesian literature. A supply side-oriented model connecting to [Kalecki \(1939\)](#) in [Greenwald and Stiglitz \(1993\)](#) requires firms to finance investment before production, as in the model here. Their model has an RBC flavor in not allowing for unemployment, however, while it tells a narrative of cyclical wages, output, and investment. According to [Bernanke et al. \(1996/99\)](#)’s financial accelerator, shocks get amplified through debt-leveraged firms and the external finance premium is countercyclical. A land collateral-based model with a predator-prey structure was developed in [Kiyotaki and Moore \(1997\)](#). A stylized model of portfolio investment in [Bhattacharya et al. \(2015\)](#) usefully motivates the emergence of countercyclical risk premia. Models with endogenous procyclical leverage can be found in [Brunnermeier and Sannikov \(2014\)](#) and [Danielsson et al. \(2012/16a/b\)](#). Similar in spirit, the Growth-at-Risk model of [Adrian et al. \(2019\)](#) captures the time-varying relation between real activity and financial conditions in an econometric fashion.³ *None* of the models referenced here generate self-evolving economic cycles, since they employ equilibrium methodologies.

2.2 Downward Nominal Wage Rigidities

Downward nominal wage rigidities can be traced to Keynes. It is a real-world fact in his view, as workers assess their wages relative to reference groups and dislike wage cuts. In his view, “whether logical or illogical, experience shows that this is how labour in fact behaves” ([Keynes 1936, Ch. 2](#)). Three streams of theory approached the topic since Keynes: a first correlates with him in assigning a role to psychological factors and fairness ([Kahneman and Tversky 1979](#), [Kahneman et al. 1986](#), [Akerlof and Yellen 1990](#), [Fehr and Falk 1999](#)). It relates to the notion of money illusion ([Fisher 1928](#), [Patinkin 1965](#)) insofar as people perceive nominal dynamics, for example, regarding wages, as more relevant than real, for psychological reasons. A second theory assigns a role to unions and collective wage bargaining ([Calmfors and Driffill 1988](#), [Lindbeck and Snower 1988](#), [Layard et al. 1991](#), [Booth 1994](#), [Holden 1994](#)). Such labor market structures can be seen as a *consequence* of psychological factors and, hence, this stream be regarded as sub-ordinate to the one rooted in psychology and money illusion. Third are theories on efficiency wages that see the rationale for firms paying higher than market-clearing wages in disciplining workers and sustaining their productivity ([Shapiro and Stiglitz 1984](#), [MacLeod and Malcolmson 1998](#)).

Substantive evidence for downward wage rigidities can be found in three sub-branches of the empirical literature: (1) interview-based evidence for the relevance of downward wage rigidities through arguments of motivation, moral, and sustaining productivity can be found for the US in [Loewenstein and](#)

³ To motivate their econometric model structure, they cite [Brunnermeier and Sannikov \(2014\)](#) and Bernanke’s financial accelerator, but not Minsky.

Sicherman (1991), Campbell and Kamlani 1997, Bewley (1995/99), Shafir et al. (1997); (2) household and firm micro data-based analyses that confirm downward rigidities for the US can be found in Holzer and Montgomery (1993), Card and Hyslop (1997), Kahn (1997), Wilson (1999), Altonji and Devereux (2000), Lebow et al. (2003), Daly and Hobijn (2014); for Switzerland in Fehr and Goette (2005), and for Germany, Italy, and the UK in Goette et al. (2007); and (3) supportive macro time series-based analyses, using industry- or economy aggregate-level data, can be found for the US in Ghali (1999), Mehra (2000), and Banerji (2005), for Switzerland in Zanetti (2007); for 19 OECD countries in Holden and Wulfsberg (2008); and for Germany, France, Spain, and Italy in Bobeica et al. (2019). Wages are found to Granger-cause prices and the relation between them to be stronger at times of high inflation (booms), thereby supporting the hypothesis of downward rigidities. These findings conform with the Post-Keynesian cost-push view as well, unlike in neoclassical theory, where prices drive wages. Empirical evidence for downward wage rigidities being so numerous for the US, despite union and collective bargaining being far less prevalent, implies that psychological factors appear to determine wage dynamics even without such structures in place.

The theory streams on wage formation feed into the question of the shape of the Phillips curve (Phillips 1958) and more empirical literature whose findings square with downward wage rigidities. Regardless of their origin, downward wage rigidities would be a source of *convexity* in the Phillips curve (Fisher 1989, Akerlof et al. 1996).⁴ Other possible explanations for convexity in Phillips curves include capacity constraints (Macklem 1997, Dupasquier and Ricketts 1998). Empirical evidence for a convex Phillips curve shape is extensive: see Kumar and Orrenius (2015), Ball and Mazumdar (2011), and Huh and Jang (2007) for recent evidence for the US. Some 15 additional references supportive of convexity in the US Phillips curve are collected in Gross and Semmler (2019), alongside numerous additional ones for European and other countries.⁵

2.3 Macro-Financial ABMs

Early ABMs focused on firm distributional aspects and firm entry-exit dynamics. Delli Gatti et al. (2003/05) included elements of debt finance following Minsky and put forward the network-based accelerator through correlated firm defaults (Delli Gatti et al. 2010). These models were not yet built on stock-flow consistency principles, did not include a role for wages and price dynamics, and did not allow for defaults of agents. I interpret them as a bridge between SDMs and stock-flow consistent ABMs.⁶

A second macro ABM chain started adding elements of inventory management, target capital levels, and expectation formation rules for investment in Dosi et al. (2006). Their model structure reflects Keynesian multiplier and accelerator effects, the latter through adaptive demand expectations which drive investment, and not allowing for defaults. Dosi et al. (2006) and their follow-up model variants (Dosi et al. 2010/13/17) model wages as a function of goods price inflation, labor productivity, and unemployment. Their focus is on replicating basic stylized facts: investment (consumption) is more (less) volatile than output, investment and consumption are procyclical, and investment is influenced by firms' financial structure. Keynesian stabilization policies are seen to reduce output volatility (Dosi et al. 2010) and regarded as complementary with Schumpeterian innovation (Dosi et al. 2017).

⁴ The empirical Phillips curve analysis in Phillips (1958) also suggested a convex relationship, visually.

⁵ See Table 1 in the working paper version of the journal version of this paper.

⁶ Assenza et al. (2015) is a follow-up to the Delli Gatti et al. model chain. Wages are constant in their model.

The Eurace model stream forms a third ABM cluster. The Eurace model stream started with [Dawid et al. \(2008/09\)](#) and [Deissenberg et al. \(2008\)](#), as part of an EU-funded project initiated in 2006 involving academics from France, Germany, Turkey, and the UK.⁷ The Eurace model structure is quite massive, including, inter alia, complementarities between the quality of capital and employee skills, multi-round search and matching in the labor market, differentiated and endogenously evolving skills for workers, inventory planning, mark-up pricing, stocks and bond markets, governments that operate a tax and unemployment benefit scheme, buffer-stock savings behavior for households, firm equity issuance, spatial sub-regional structures, and wage formation structures that let employers' expectations about workers' skill level influence salaries.⁸

Other ABMs have evolved in parallel with these three streams. [Chiarella and Di Guilmi \(2011\)](#) link the valuation of capital assets to a stock market, where investors have heterogeneous expectations about firms' future profits. Prices are set as a mark-up over wages and wages set flexibly so that product markets clear. An extension of [Delli Gatti et al. \(2010\)](#)'s firm network-based accelerator in [Ricetti et al. \(2013\)](#) adds a variable leverage target mechanism for firms, which was further augmented with a dynamic trade off theory-based capital structure in [Ricetti et al. \(2015\)](#). Countercyclical capital rules stabilize the economy but lose their effectiveness when combined with interest rate policy ([Alexandre and Lima 2017](#)), where interest rate smoothing is seen to be beneficial. A triple mandate Taylor rule with credit growth next to an output and inflation gap performs best in stabilizing the economy in [Popoyan et al. \(2017\)](#), where wages are linked to prices and involving firm inventory management. Extended with an interbank market ([Popoyan et al. 2020](#)), interbank market freezes arise endogenously and the Basel III LCR spurs instability, as it may increase the procyclicality of reserves. ABMs are also shown to have the potential to outperform DSGE and time series model-based forecasts ([Poledna et al. 2021](#)). Very useful bird's-eye-view papers on macro ABMs and their use for policy analysis so far can be found in [Fagiolo and Roventini \(2017\)](#), [Hommes and LeBaron \(2018\)](#), and [Dosi and Roventini \(2019\)](#).

Seeing the model developed here in perspective: it follows a stock-flow consistent integrated balance sheet approach, as in the Eurace model family and others.⁹ It is in line with the Dosi et al. and the Eurace models in allowing wages to be a function of price inflation, but simplified in assuming constant labor productivity and augmented by having a downward wage rigidity. The Eurace models and others appear to be very comprehensive regarding agent types, markets, and behavioral features. This implies a disadvantage: one cannot easily explain the model dynamics or easily trace the root causes of cycles as opposed to mechanisms that amplify or dampen them.¹⁰ Against this background, the aim is to develop an utmost parsimonious ABM, which, despite its simplicity, generates well-behaved cyclical behavior and replicates a rich set of stylized facts in a way not seen in the literature, to the best of my reading.

⁷ Other follow-up variants, extensions, and applications of the Eurace model include [Cincotti et al. \(2012\)](#), [Raberto et al. \(2012\)](#), [Dawid et al. \(2016/18\)](#), and [Van der Hoog and Dawid \(2019\)](#).

⁸ An ABM that is similarly comprehensive as the Eurace models is in [Basu et al. \(1998\)](#), dated even before the early Delli Gatti et al. papers. It contains consumers, firms, banks, a government, and a central bank. It includes markets for goods, bonds, credit, and labor. It considers inventory management, loan-financed investment, CD production, learning, and constant wages. It does not generate endogenous cycles.

⁹ Stock-flow consistency shares similarities with flow of funds (FOF) analysis ([Duesenberry 1962](#), [Bê Duc and Le Breton 2009](#)), albeit at a micro-agent level in ABMs instead of at a sector level in FOF analyses. Stock-flow consistency is a defining feature of Post-Keynesian economics ([Godley and Lavoie 2007](#)).

¹⁰ One could in principle do so, but it becomes burdensome and existing papers have not done so, in my reading.

3. Model and Simulations

3.1 The Model

The model has three agent types: firms, households, and a banking system. Tables 1 and 2 show their integrated balance sheets and the net worth-non-neutral financial flows across agents. Figure 2 shows the sequence of the agents' (inter-) actions during one time period. The model has *multiple* firms ($f = 1 \dots F$) because explicit default on their debt will want to be allowed. Hence, assuming a representative firm sector is not an option, as the sector's default would imply for the whole economy to crash. Having many firms means that *multiple* households ($n = 1 \dots N, N > F$) are needed, as they work at the firms. The banks can be compressed to one banking system since the results will not depend on having one or many banks; thereby adhering to the "reduce complexity by all means" approach. The money creation ability, through granting credit to firms in the model, is no different in a one-bank or multi-bank system.¹¹

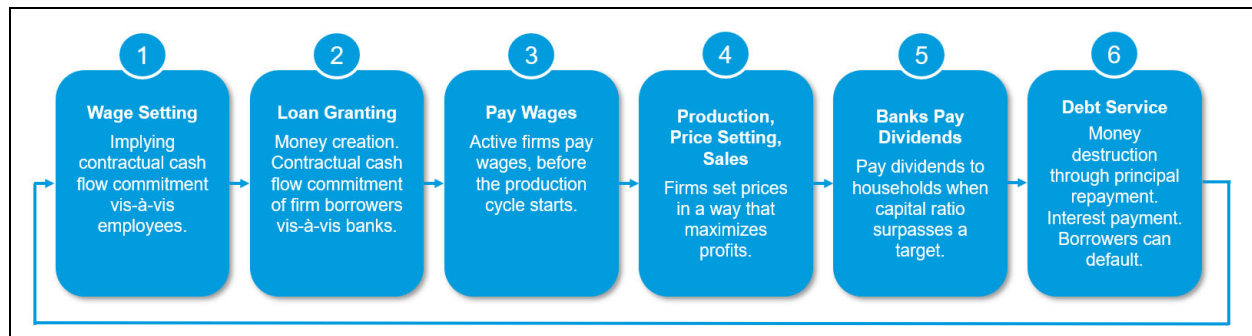
Table 1. Agents' Integrated Balance Sheets

	Assets	Liabilities
Firms ($f=1\dots F$)	M_f : Money holdings, deposited at bank	L_f , Loans E_b , Net worth
Households ($n=1\dots N$)	M_n : Money holdings, deposited at bank	E_n , Net worth
Banking System	$\text{sum}(L_f)$: Loans to firms	$\text{sum}(M_f) + \text{sum}(M_n)$: Households' and firms' money holdings E_b , Net worth

Table 2. Agent Net-Worth Non-Neutral Financial Flows Across Agents

		Recipient		
		Firms	Households	Banking System
Sender	Firms	-	Wages (w)	Debt interest payments (a^b)
	Households	Consumption expenditure (c)	-	-
	Banking System	-	Dividend payout (div)	-

Figure 2. Agent Actions and Interactions—Six Steps per Time Increment



The base version of the model operates with credit money only. There is no "off-the-leash," debt-free (outside) money in circulation. Firm and household money stocks, created endogenously through debt, are held in electronic form at the banking system's deposit pool (Table 1). The total money stock is defined to

¹¹ Some discussion follows later that assigns one source of cycle *amplification* to having multi-bank, interconnected systems.

equate to the size of the banking system balance sheet, hence to outstanding loans, as “off-the-leash” money is zero for now. It includes banks’ net worth by convention here, for loan interest payment flows to the bank to not imply money destruction.¹² Net worth neutral financial flows include principal debt issuance (money creation) here for firms, and principal debt repayment (money destruction). These flows are not depicted in Table 2, as it is confined to flows that change the agents’ net worth.

Step 1: Wage setting. Active firms set nominal wages ahead of a forthcoming production round. The logic to reflect a downward nominal wage rigidity entails that firms align wage growth for the forthcoming production round by indexing wages to recent price inflation if their profits were trending up from $t - 2$ to $t - 1$ and if price inflation in $t - 1$ was positive. If their profits trended down or price inflation was negative, they keep nominal wages flat. Defining wage per employee growth at the active firm-level as $w_{t,f}^g = w_{t,f}/w_{t-1,f} - 1$, this logic in equation form reads as:

$$(1) \quad w_{t,f}^g = \begin{cases} p_{t-1,(f)}^g & \text{when } p_{t-1,f}^g > w_{t-1,f}^g \text{ \& } p_{t-1,(f)}^g > 0 \\ 0 & \text{otherwise} \end{cases}$$

where $p_{t,f}^g = p_{t,f}/p_{t-1,f} - 1$ denotes goods price inflation. Firms and households, jointly as a matter of interpretation, thereby form price inflation expectations in an adaptive manner. Firms measure the previous period’s price growth either with reference to their own firm f or the economy-wide aggregate. If computed at the economy level, it is done for the subset of firms that were active in $t - 1$ and $t - 2$. Firms that were inactive in $t - 1$ set the forthcoming wage per employee in t to the average of the active firms’ wages in $t - 1$. At the outset in $t = 1$, all firms are set to be active and the initial wage per employee is set to an arbitrary nominal value for all firms. The model dynamics do not depend on this initial value. In period $t = 2$, wage and price growth as of $t = 1$ cannot be computed yet, for contractual wages to still stay at their $t = 1$ level. From period $t = 3$ forward, equation (1) is applied by each firm. The implication of the overall wage setting structure for the system behavior is explored in Section 3.3.

Step 2: Loan granting. New loans are granted to active firms in case they face a shortfall between the forthcoming wage bill and their current cash stock. This, by design, is the case in period $t = 1$, when no money is contained in the system yet and the wage bill is implied by the number of workers times the initial nominal wage per employee set in Step 1. Firms’ cash stocks can be positive but insufficient to cover a forthcoming wage bill, in which case their debt is “topped up.” They can be larger than the wage bill, in which case no additional credit is requested. The loans can be interpreted as working capital loans or loans for investment alike. This difference in interpretation is semantic in the model; a related discussion follows in Section 4.1. A loan pricing equation is designed for the effective interest rate to equate a loan’s expected interest income net of funding costs (i_t^d) with its expected loss ($PD_t \times LGD_t$), and adding a profit margin μ :

$$(2) \quad \frac{PD_t \times LGD_t}{\text{Expected Loss}} + \frac{(1 - PD_t)(\mu + i_t^d)}{\text{Expected Interest Expense}} = \frac{(1 - PD_t)i_t}{\text{Expected Interest Income}} \quad \leftrightarrow \quad i_t = \mu + i_t^d + \frac{PD_t \times LGD_t}{1 - PD_t}$$

The funding cost i_t^d is set to zero still in the base model version. The probability of default (PD) is measured through realized default flows; the loss given default (LGD) involves the defaulted loans’ recovery value:

¹² Conventional monetary aggregates defined by central banks exclude bank capital, for banks’ loan interest income (expense) to imply money destruction (creation). The interest flows between banks and their customers imply a bank “liability-equity swap.”

$$(3) \quad PD_t = \frac{\sum_f^F \text{Default Flow}_{f,t}}{L_{t-1}} \quad \text{and} \quad LGD_t = \frac{\sum_f^F [\text{Default Flow}_{f,t} - \min(\text{Default Flow}_{f,t}, M_{f,t})]}{\sum_f^F \text{Default Flow}_{f,t}}$$

Defaulted loans are written off immediately, so that nonperforming loan (NPL) stocks do not build up. There is no consideration of leverage constraints à la Basel, as it is not required for generating the model dynamics. There is no interest rate-based monetary policy reflected in the model yet; with the base rate being constant and equal to μ .

Step 3: Active firms pay wages. Wage payments flow from active firms to their employees' deposit accounts. Firms' net worth is reduced, households' net worth increased, and the banking system's net worth unaffected by these transfers.

Step 4: Production, price setting, and sales. Production is accomplished based on labor input, with constant labor productivity. A firm having $N_f = N/F$ workers hence either produces N_f real output units when active or 0 when being inactive after a default arose in a previous period (in Step 6):

$$(4) \quad y_{f,t}^{\text{real}} = N_f, \quad \forall f \in \text{active}$$

Households with a positive cash balance choose at random one firm from the active firm subset and communicate the amount, $c_{n \rightarrow f,t}^{\text{nom}}$, they plan to spend. Firms in turn set the unit price, $p_{f,t}$, so that all the communicated amount, summed across the relevant households, is received as sales revenue, thereby maximizing firm profit and not requiring any inventory or scrapping of real output:

$$(5) \quad p_{f,t} = \frac{c_{n \rightarrow f,t}^{\text{nom}}}{y_{f,t}^{\text{real}}}, \quad \forall f \in \text{active}$$

This pricing equation implies that supply shocks (if they were to be considered, for example, through a productivity parameter in eq. 4) result in conventional sign-opposite output-price responses (Blanchard 1989). Nominal consumption, $c_{n,t}^{\text{nom}}$, amounts to the wage received in the same period (Step 3):

$$(6) \quad c_{n,t}^{\text{nom}} = w_{n,t-}$$

where the within-period time lag is denoted by "t -" in the subscript to the wage flow variable. Households thereby do not accumulate money holdings across time increments yet, but only momentarily within a period, between wage receipt and consumption. There is a built-in price-wage dependency via the flow-consistent nature of the model. Wages are paid first (Step 3); prices are implied by households spending the wage income subsequently (Step 4). Prices are persistent to the extent that wages are sticky through having wage contracts in place.

Step 5: Banks pay dividends. The banking system pays dividends div_t whenever its capital ratio, $\text{CAR} = \text{NW}/L$, surpasses a self-defined threshold, CAR^{tar} .

$$(7) \quad \text{div}_t = \max(0, (\text{CAR}_{t-1} - \text{CAR}^{\text{tar}})L_t)$$

The dividend flows in equal shares to households' deposit accounts, thereby adding to their consumption spending in the following period. It subtracts from the banking system's net worth for its capital ratio to drop to target. Deposit rates are zero for now, without loss of generality of the model dynamics.

Step 6: Debt service. Debt-holding firms pay their full annuity if their cash stock suffices to do so. Principal debt is rolled over if a firm is not able to pay the full annuity, but only interest, in which case it does pay only interest. If a firm is not able to pay the full interest (partial coverage of interest is not allowed), it defaults and is "inactive" for the following, one period. In this case, its principal debt is written off the bank and firm

balance sheet, and the bank attempts to recover the debt by seizing the defaulted firm's remaining cash balances. Importantly, defining default in this way (no borrowing to cover interest) means that there is no Ponzi finance possible by design. An inactive firm does not pay wages in the period in which it is inactive. Its assigned workers are recorded as unemployed until they become active again, the period after inactiveness. After Step 6, the end-of-period balance sheet position of all agents is recorded and set as the starting point for the next period, following a next round of stock-flow consistent transactions across agents.

3.2 Base Simulation and Economic Cycle Narrative

The base simulation. The profit margin for banks was set to $\mu = 0.05$ and the target capital ratio beyond which banks pay out dividends is set to 10 percent.¹³ A base simulation was conducted with $F = 200$ firms, $N = 20,000$ households, and $T = 30,000$ periods; the first 800 periods are shown in Figure 3. The price and wage Phillips curves are downward sloping and convex, and Okun's law relation is obtained (Figure 4).

In $t = 0$, the economy stands still, and all agents' balance sheets are "empty", having zero money (debt) in the system. In period $t = 1$, the economy is actuated by defining a first wage bill (Step 1) and firms obtaining a first round of corresponding principal debt to cover the bill (Steps 2 and 3). The consumption expenditure flows in a stochastic manner *in terms of firm choice* back to the firms (Step 4), while the full initial principal influx returns as a firm sector sales revenue from an economy-wide viewpoint. The economy-wide sales revenue would suffice to repay precisely all principal, but not the interest. At the firm-level, due to firm choice stochasticity, some firms might be able to cover also interest, while others would not. Principal debt is rolled over if only interest can be covered (Step 6). Interest coverage ratios (ICRs) are defined as cash stocks before interest payments over interest payments. Firm profits are measured as sales revenue minus the wage bill. The following description of the cyclical dynamics all refers to Figure 3.

Boom times. The addition of principal *interest-bearing* debt implies a slowly rising debt stock, for firms to cover the loan interest. Whenever principal debt for a firm is rolled over, the earnings before interest generally well suffice to cover the interest; there prevails, though, a small level of frictional unemployment, reflective of a few firms being inactive due to their default, also during boom times. The downward wage rigidity meanwhile induces an upward momentum in the leverage process. Debt being *interest-bearing* implies that more principal debt keeps being added to the system for firms to cover their contractually set wage bill, which banks provide as firm profits and ICRs appear solid, supported by the continual influx of principal debt. The ICRs meanwhile slowly deteriorate. Firm profit shares slowly decrease, and mirror-wise, wage shares slowly increase. Whenever the banking system has accumulated a sufficiently high capital ratio, it pays dividends (or effectively equivalently, interest on deposits). This is when the household sector can spend more than what it receives through wages, and it is when profits at the aggregate level can become positive and positive price inflation occur. In any subsequent period of such a price rise, wage inflation follows suit, spurring the price-wage process and a related stronger pull for some more principal debt by firms whose cash stock after sales does not suffice to cover the next wage bill.

The interest income for the household sector as a source for firm profits is essential. It can be seen by relating the two from the base simulation and opposing it to US data over a 28-year period since 1992 (Figure 5). It is interesting to see not only the positive correlation in the US data, but the quantitative

¹³ A 10-period moving average of the point-in-time PDs and LGDs as input to equation (2) was considered for the interest rate and unemployment rate levels to not spike to too high levels during recessions. The conclusions drawn in this section do not depend on that choice.

approximate correspondence between firm profit flows and household interest income. The household sector interest income and firm profits would not equate perfectly, for various reasons; these include that a faster savings (dissaving) process from standing household savings stocks can drive firm profits temporarily down (up). Savings ratios in the US appear rather stable historically.¹⁴ A related experiment, allowing for household savings, follows later.

The turning point. The aggregate debt stock and related interest burden have grown so high, and firms' interest coverage ratios become so thin, that any small perturbation makes a first firm unable to cover its interest payments and hence default. The perturbation can be (1) a small interest rate rise, for example, resulting from further contracting monetary policy (not in the model yet)—which is not meant to induce a downturn, though it would—or a slight rise in risk premia; or (2) a small perturbation in demand, in relative terms due to stochastic firm choices or absolute in terms of firms or households saving more momentarily. In the base model, it is the relative demand disturbance through stochastic firm choice. Any external factor can induce such interest or demand fluctuations, which are the two fundamental channels through which any perturbation is induced at a turning point. They might be large, but it would suffice if they were small. They would be as unnoticeable as always but have the potential to induce the cycle to turn due to the system being so “stretched” (highly leveraged) at this juncture.

The downturn. The default of one or a small set of firms at the turning point induces a default cascade through various channels. First, the spending potential of those agents who became unemployed at the turning point falls, making them spend less at other firms that did not default at the turning point yet but now tend to default as well, as the entire firm population is rather highly indebted. This channel mirrors the one that [Guzman and Stiglitz \(2020\)](#) refer to as the “income effects as the consequence of bankruptcy.” Second, in parallel, rising loan interest rate risk spreads make firms' interest burden increase further, implying the materialization of more defaults, independent of the demand effect. These two most fundamental channels are captured in the model. Yet other amplification channels are discussed in Section 4.

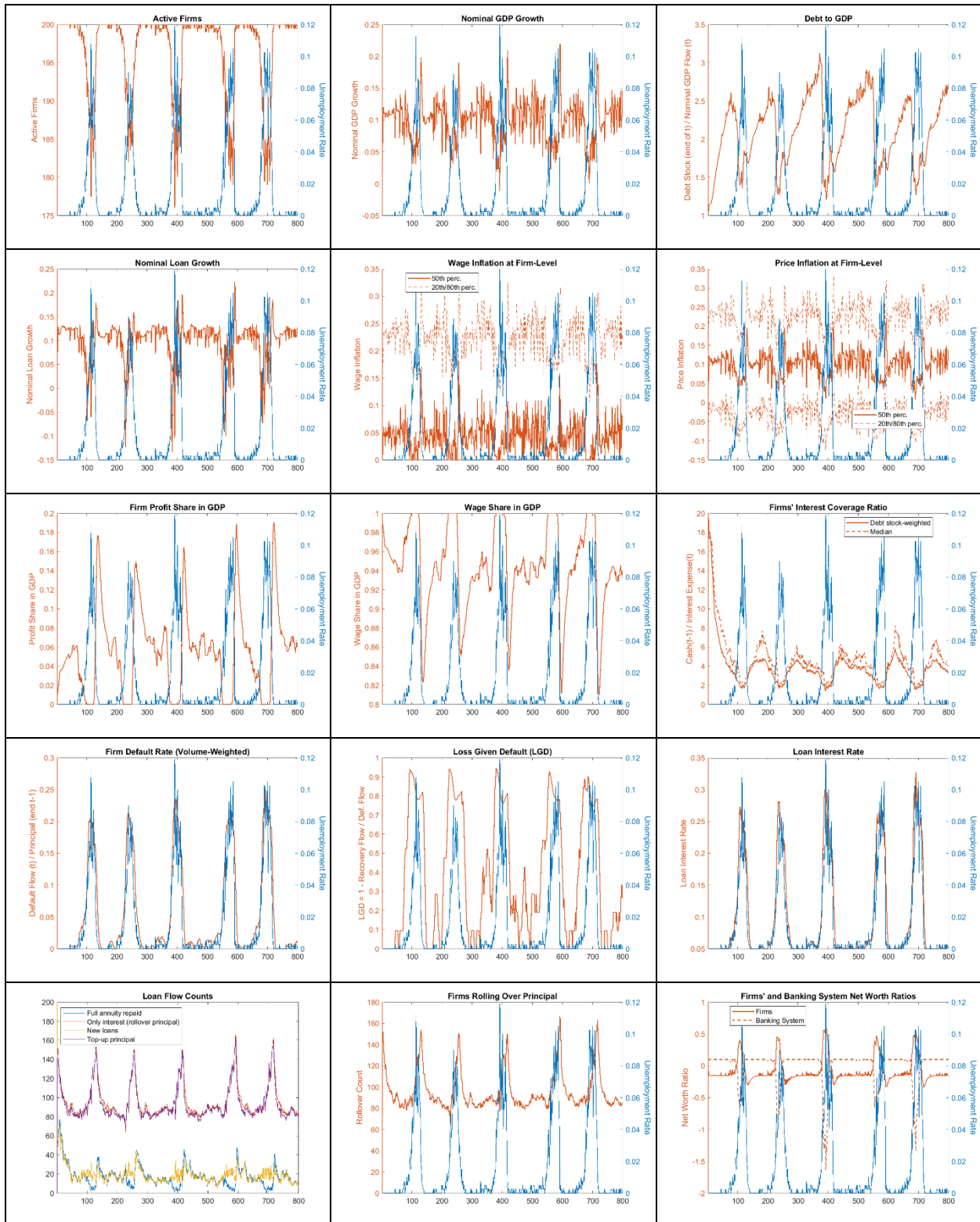
The new upturn. After enough firms have defaulted and their debt has been written off, the realized risk-based interest rate spread has fallen enough for a new debt accumulation process to start endogenously.

Six stylized facts are replicated by the model despite its high simplicity: (1) booms are long- while recessions short-lived; (2) leverage is procyclical; (3) firm profit and wage shares in GDP are counter- and procyclical; (4) wage and price Phillips curves are downward-sloping and convex, and Okun's law relation is replicated (Figure 4); (5) default cascades arise endogenously at the onset of recessions; (6) lending spreads are countercyclical. GDP growth and unemployment rates from the model exhibit excess kurtosis: 1.4 and 3.9 (in excess of 3), compared with the corresponding kurtosis estimates based on US data equaling 2.2 and 3.4; see [Fagiolo et al. \(2008\)](#) for empirical evidence on excess kurtosis in macro data. RBC and NK models are known to not be quite able to generate fat-tailed distributions ([Ascari et al. 2013](#)).

Profit shares in the US data (Figure 1) attain a local peak and start falling some quarters ahead of recessions. This “phase shift” is not entirely replicated by the model yet, but only the countercyclical behavior of profit shares during the later phase of a boom. A nonlinear price-wage pass-through, to reflect time-varying, state-dependent rigidities (beyond the regime-conditional linearity assumed here), could be one mechanism that could generate such behavior. Empirical evidence to support such state dependence would first have to be devised as an empirical micro foundation, however.

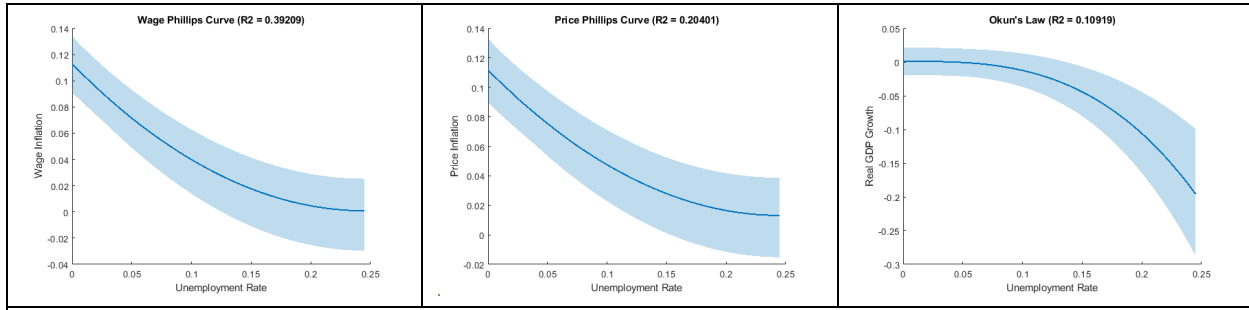
¹⁴ See US FRED St. Louis FED series code PSAVERT.

Figure 3. Base Model Simulation



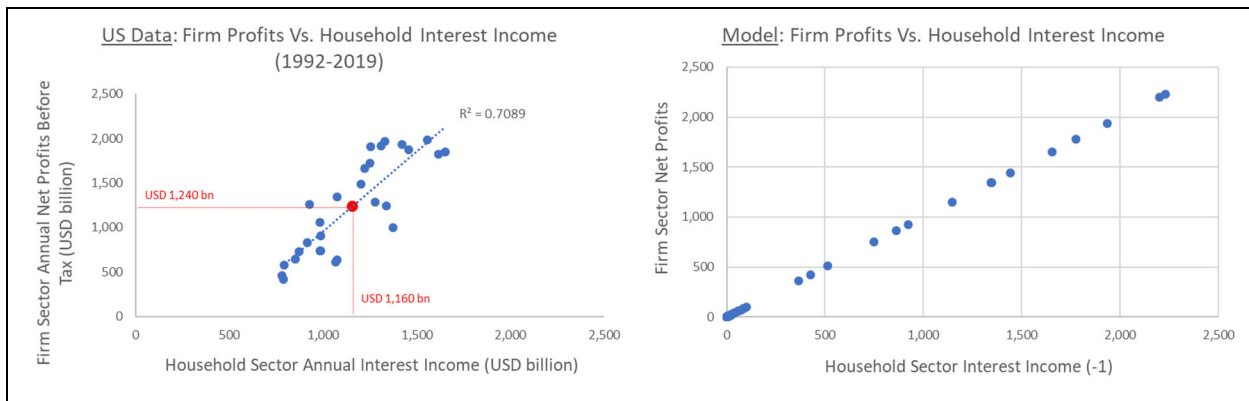
Note: This chart collection visualizes various model and derived variables from a representative simulation for T=800 periods. No initial burn-in period has been cut-off, that is, the simulation starts at t=0 with initially zero money/debt stocks. Each plot has the unemployment rate dynamics (blue) on the secondary axis as a visual support to gauge the variables' cyclical behavior.

Figure 4. Wage and Price Phillips Curves, and Okun's Law—Base Model Simulation



Note: The price and wage Phillips curves were estimated based on T=30,000 simulated periods, using second order polynomials. The error bounds mark the 10th and 90th confidence intervals.

Figure 5. Firm Profits and Household Sector Interest Income—Data Versus Model Outcome



Note: The US data were sourced from the US FRED database (profit shares after tax: W273RE1A156NBEA, converted to before tax assuming a tax rate of 35 percent for 1992–2017 and 21 percent for 2018–19, converted from profit shares to monetary profit by multiplying with nominal GDP: GDPA; household interest income: W383RC1A027NBEA). The red dot and corresponding USD billion amounts reflect the average profit and interest income flows over the 1992–2019 period. The household sector interest income was not lagged in the US data scatter, as the frequency is annual. Household sector interest income in the base version of the model (right chart) is generated through bank dividend flows.

3.3 Structural Experiments

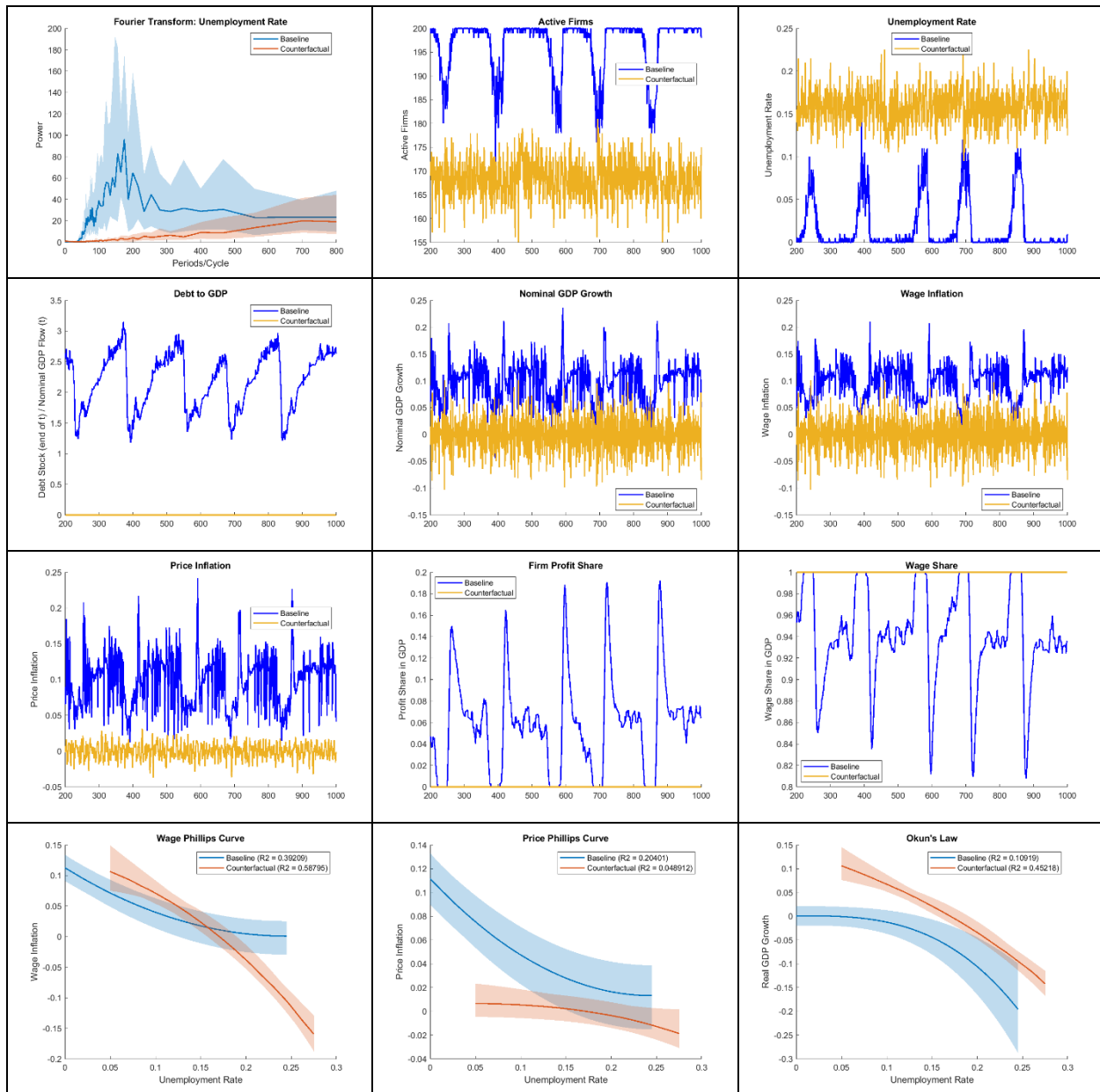
Ten structural experiments were conducted to further understand the model economy's dynamics. Table 3 shows a summary. A Fourier transform has been employed to compare the cycle frequency and amplitude based on the simulated unemployment rate under the base simulation and the various experiments. Applying the transform to other variables resulted in the same appearance of the power spectrum and hence the conclusions. The various structural experiments are referred to as "counterfactuals" in the charts throughout this section.

Table 3. Structural Experiments—Observations Relative to Base Simulation

Category	#	Experiment	Cycles	Active firms and unemployment	Debt to GDP	Nominal and real GDP growth	Wage and price inflation	PD, LGD, lending spread, and ICR	Bank and firm capital ratios	Wage and profit shares	Price and wage Phillips curves
Credit	1	No credit (outside money only)	Gone	Less active firms, higher unemployment	Zero	Lower NGDP growth, RGDP growth somewhat less volatile	Price inflation lower and less volatile, wage inflation lower	All zero	Zero for banks, 100% for firms	Wage share 100%, profit share 0%	Both still downward-sloping, though location shifted
	2	Initial outside money stock (endogenous credit provision subs.)	No change	No change	No change	No change	No change	No change	No change	No change	No change
Interest	3	Zero lending rate	Gone	All firms active, full employment	Unchanged regarding mean initially, but not cyclical anymore	Stochastic/explosive nominal GDP, real GDP growth flat at zero	Stochastic/explosive	All zero	Zero for both banks and firms	Wage share 100%, profit share 0%	Non-existent due to full employment at all times
	4	Zero risk spread (constant lending rate)	Frequency higher, amplitude much lower	More active firms, lower unemployment	Higher	NGDP growth about unchanged, RGDP growth less volatile	Left tails less deep	PD lower, LGD unchanged, risk spread zero by design, ICR less volatile	Less deep tails for banks, higher for firms	Smaller variance	Both still downward-sloping, though location shifted accordingly with smaller range of unemployment
Wage formation	5	Downward wage rigidity off	Gone	All firms active, full employment	Stabilizes at about 110%	NGDP growth persistent and surpassing 40%, RGDP growth 0%	Both persistent and surpassing 40%	PDs and LGDs zero, ICR higher and less volatile	Both much less volatile	Approaching 100% and 0%, respectively	Non-existent due to full employment at all times
	6	Set price inflation to 20%–80% mix of firm own and aggregate	Frequency increasing, cycle duration becoming more dispersed	Less active firms, higher unemployment	Lower	NGDP growth lower, RGDP growth less volatile	Both smaller and less volatile	PDs, LGDs, and risk spreads higher, ICRs lower	Bank CAPR lower, firm CAPR higher	Wage share higher, profit share lower	Both becoming less steep
	7	Price inflation reference set to economy aggregate	Frequency very high (appearance stochastic)	Less active firms, higher unemployment	Lower	NGDP growth lower, RGDP growth rather unaffected	Both much smaller and less volatile	PDs, LGDs, and risk spreads higher, ICRs lower	Bank CAPR lower, firm CAPR higher	Wage share 100%, profit share 0%	Both flattening out (becoming horizontal)
Other	8	Loan duration larger one period	No change	No change	No change	No change	No change	No change	No change	No change	No change
	9	Directed consumption	Gone (no stochasticity)	All firms active, full employment	Stable at about 120%	Stable at 0%	Both stable at 0%	PDs, LGDs, and risk spread all zero, ICR stable at 17	Bank (firm) CAPR stable at 15% (-18%)	Wage share stable at 94%, profit share stable at 6%	Non-existent, due to full employment at all times
	10	Households save	No change	No change	Higher	No change	No change	No change	Bank (firm) CAPR higher and lower, respectively	Wage share higher, profit share lower	Slopes unchanged

Not allowing for credit provision lets cycles disappear, while inducing a structural rise in unemployment (Table 3, Experiment #1, Figure 6). Switching the endogenous credit provision off, and instead allowing a constant “off-the-lease” money stock to initially endow the firms, implies that fewer firms are active, that unemployment is structurally higher, and that firms cannot generate net positive profits. PDs, LGDs, risk spreads, and ICRs are zero because there is no debt. In a system with wage-contractual cash flow commitments and related downward rigidities, endogenous money serves to sustain the production flow. Endowing firms with initial outside, “off-the-lease” money and then allowing endogenous debt creation has no impact on the cycle dynamics (Table 3, Experiment #2). The role of inside money rises fast enough, during a short transitory period, for it to dominate the system behavior amid an increasingly tiny and hence negligible outside money stock.

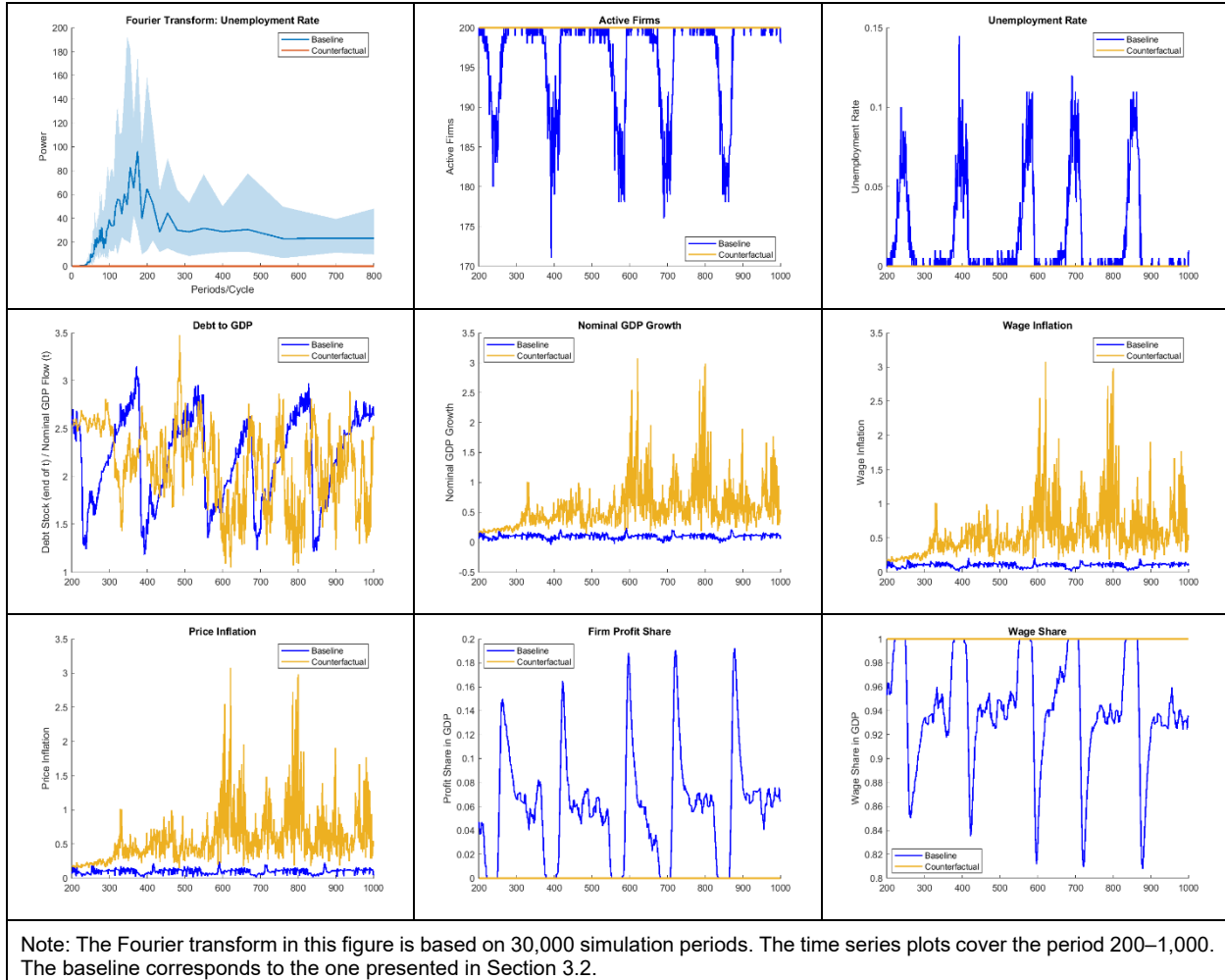
Figure 6. Switching Endogenous Credit Provision Off and Having Constant Outside Money Only



Note: The Fourier transform and the regressions at the end of the plot collection are based on 30,000 simulation periods. The time series plots cover the period 200–1,000. The baseline corresponds to the one presented in Section 3.2.

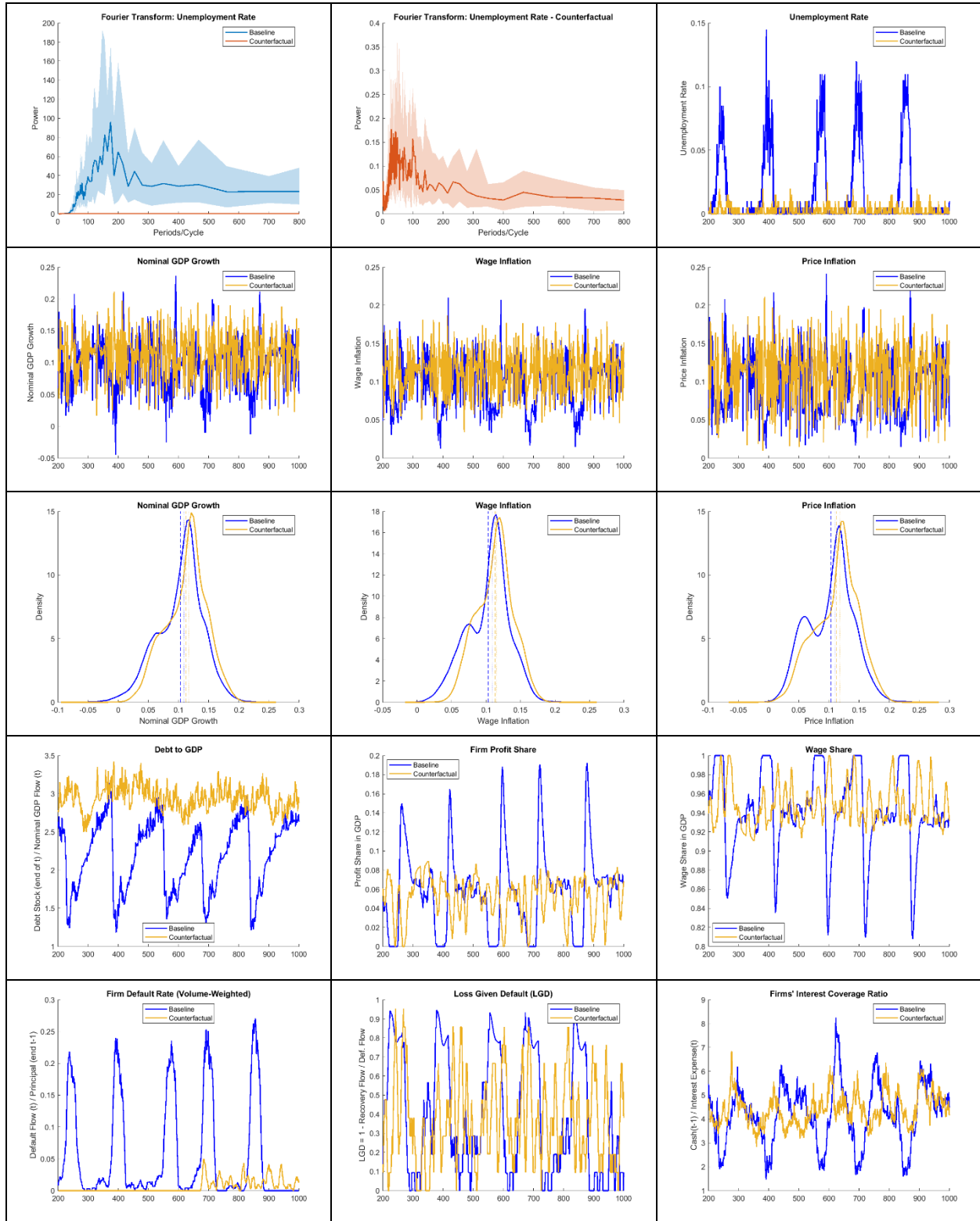
Forcing interest rates to zero lets cycles disappear and firm profits be zero (Table 3, Experiment #3, Figure 7). Debt does arise. The debt to GDP stock-flow ratio is lower, however, than in the base simulation. Despite debt arising, there are no defaults and hence full employment. The price and wage Phillips curves are, in turn, not defined. Firms cannot generate net positive profits, while the banking system's net worth stays at zero due to zero interest income. Nominal GDP growth and wage and price inflation appear “indeterminate” after a while; they oscillate widely. The experiment confirms the crucial role for interest as a pre-requisite for firm profits and cycles to arise.

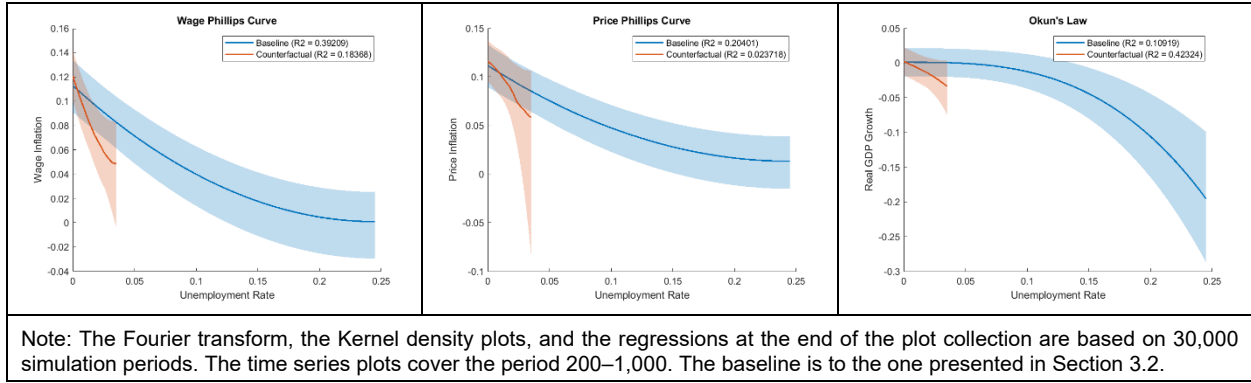
Figure 7. Setting Lending Rates to Zero



Considering a constant base lending rate but forcing realized risk-based spreads to zero lets the cycle amplitude fall significantly (Table 3, Experiment #4, Figure 8). Debt stock-to-GDP flow ratios increase to an extent. The tails of the wage and price inflation distributions become less deep. The Fourier power spectrum estimate falls to less than 0.2, while cyclical behavior remains at a frequency of about 20–50 periods per cycle. The price and wage Phillips curves are still downward sloping but shifted somewhat. The experiment corroborates that realized risk-based spreads are likely a major source of cycle amplification.

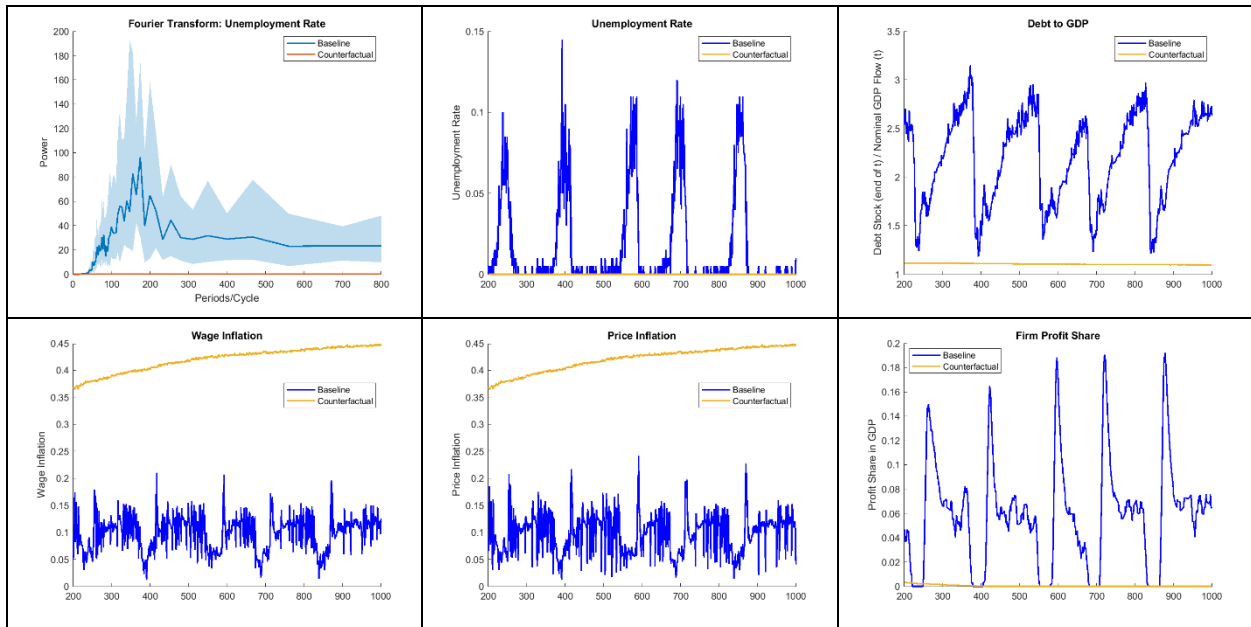
Figure 8. Setting Realized Risk-Based Lending Spreads to Zero

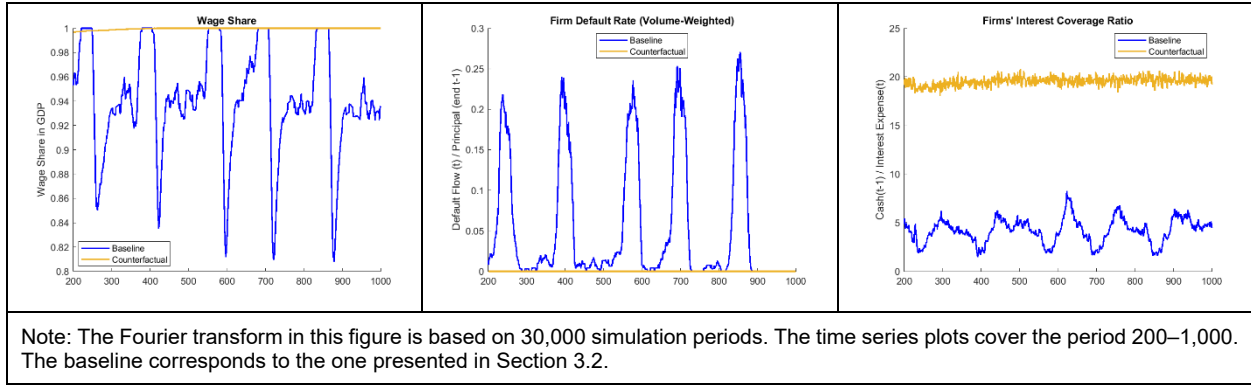




Switching downward nominal wage rigidities off lets cycles disappear and firm profit shares converge to zero (Table 3, Experiment 5, Figure 9). Cycles vanish, full employment is obtained, and hence the wage and price Phillips curves become undefined (vertical). Debt to GDP stabilizes at about 110 percent. No defaults occur. The experiment suggests that downward nominal wage rigidities are among the essential sources for cyclical economic dynamics to arise, and that relaxing them can help reduce structural unemployment. The goods and labor markets in the model are not of a local matching kind, as, for example, in [Guerini et al. \(2018\)](#), where due to that local structure, even in the absence of wage asymmetries a small level of frictional unemployment can arise as a result of market frictions and coordination failures.

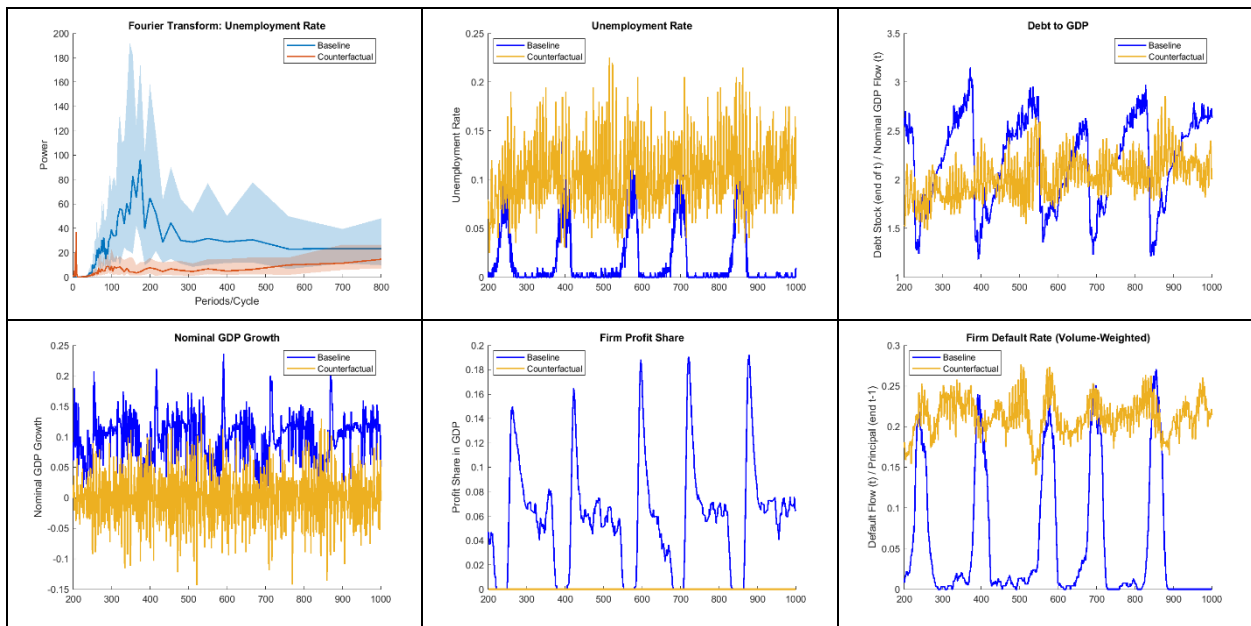
Figure 9. Switching Downward Nominal Wage Rigidities Off

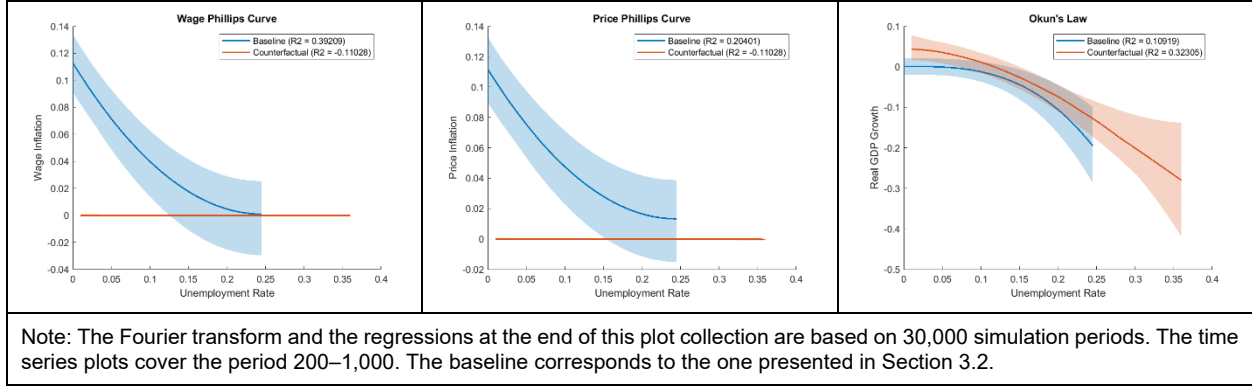




Changing the price inflation reference for setting wages from firm-specific toward the economy aggregate lets the cycle frequency increase notably (Table 3, Experiment 7, Figure 10). Experiments #6 and #7 suggest that increasing the weight on aggregate price inflation to determine wage inflation (while maintaining the downward rigidity) lets unemployment rise and the cycle frequency increase. Wage and price Phillips curves become increasingly flat. Firms “embracing” and perfectly measuring economy-wide price inflation to set their own wages therefore removes one source of a slow-moving cyclical dynamic of economic activity, through firms internalizing in every period the sector-aggregate externality of their previous wage decisions. Information rigidities were considered as a result of partial information (Coibion and Gorodnichenko 2015), sticky information (Mankiw and Reis 2002), and noisy information (Woodford 2003, Sims 2003). How variation in those information rigidities influence cyclical behavior at large, as illustrated here, should deserve more examination in future research.

Figure 10. Changing Inflation Reference for Wage Setting from Firm-Specific to Aggregate





Considering multi-period loans and operating with a conventional, nonlinear amortizing repayment schedule implies for the cyclical model dynamics to not change in any notable way (Table 3, Experiment #8, Figure 11). Any new loan dispersed in Step 2 (Section 3.1) is now granted with a randomly chosen duration, drawing it from a log normal distribution with mean 2 and standard deviation 0.2 and rounding the draws up to the nearest integer. With this calibration, the median and standard deviation of the level duration amount to 7.4 and 1.5, respectively. In case loans are topped up instead of newly granted after a firm is debt-free, the current residual duration just before the top-up and the newly drawn one are combined using a weighted average of the current and top-up loan duration, using the current principal debt outstanding and the top-up principal as weights, and rounding up to the next integer. Conditional on a firm's current principal outstanding $L_{f,t-1}$, a residual duration counter d_f , and the current interest rate $i_{f,t}$, the total annuity $a_{f,t}$ (due in Step 6, Section 3.1) is computed every period as:

$$(8) \quad a_{f,t} = \frac{L_{f,t-1} \times i_{f,t} (1+i_{f,t})^{d_f}}{(1+i_{f,t})^{d_f-1}}$$

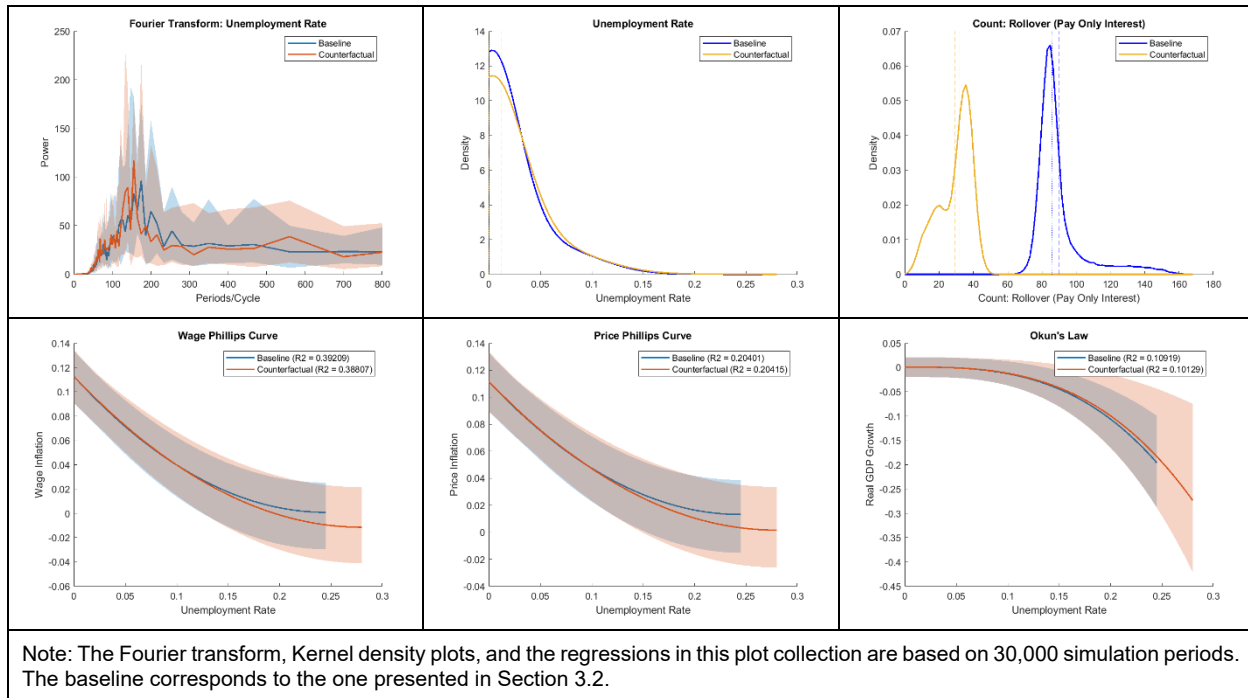
The formula nests the case of initial durations equal 1, as in the base model version. The interest payment flow due is $a_{f,t}^I = i_{f,t} L_{f,t-1}$. The principal repayment flow due is $a_{f,t}^P = a_{f,t} - a_{f,t}^I$. The principal balance falls period by period: $L_{f,t} = L_{f,t-1} - a_{f,t}^P$. This multi-period loan scheme makes hardly any difference for the model dynamics (Figure 11). The cycle frequency and amplitude remain rather unaffected. The unemployment rate distribution has slightly deeper right tails. Otherwise, only the counts of required rollovers and top-up requests fall.

Replacing households' stochastic firm choice for consumption by a "directed," constant firm choice lets cycles disappear and a non-stochastic steady state arise (Table 3, Experiment #9). This is the only experiment considered here that results in a deterministic steady state after a short transitory period; Table 3 reports the steady state estimates. All firms remain indebted, never default, do not require any debt top-up, and precisely roll over their principal every period (paying interest only). The experiment confirms that a minimal source of internal stochasticity is instrumental for the cyclical behavior, as described in Section 3.2, to unfold. Importantly, these are *small* disturbances numerically, and independent of the business cycle state.

Letting households save lets the cycle amplitude rise and its frequency fall (Table 3, Experiment #10). Letting households spend an assumed 75 percent of their stock of savings inclusive of any period's latest wage income flow (when entering Step 4 in Figure 2) implies for the cycle amplitude to rise and its frequency to fall to an extent. Debt stock-to-GDP flow ratios rise a bit. Nominal and real GDP growth and wage and price inflation dynamics are not affected in any notable way. The experiment suggests

that allowing for household saving does not affect the cyclical behavior in a fundamental manner and lets the conclusions from all other experiments still hold up.

Figure 11. Multi-Period Debt Contracts



4. Discussion

4.1 Minsky and Markups

Minsky (1986)'s chapters 7–9 are central to his financial instability hypothesis, laying out the role of prices, profits, and cash flow commitments. Four observations result from seeing his work in light of the model and its theoretical grounding developed here.

First, he argues that “for a capitalist system to function well, prices must carry profits” (ibid., p. 158). The model here conforms with this statement.

Second, he separates two price systems, for current output and for capital assets, which is distractive to an extent. Capital assets relate to an investment sector that he considers next to consumption goods producers. The model here does not require such a distinction. Paying wages is a form of investment to keep the labor force working instead of its effort depreciating to zero if wage payments were to stop. Likewise, the production of capital investment goods also requires employees to be paid *wages*. Hence, while it is fine to consider an investment sector in a model, one can save oneself this feature to create space for introducing other elements as long as there is no specific need for the distinction. One can reinterpret Minsky's two price systems as being about goods prices versus *wages* more generically and let “capital assets” encapsulate labor. Separating investment and consumption goods producers in the model results in the same dynamic behavior and conclusions as presented in Section 3.

Third, Minsky is not clear as to whether firm market power or debt-financed investment generates firm profits. On one side, he suggests that for a firm to cover its contractual expenses, it requires a markup that it can “control [...] to the extent that it has *market power*” (ibid., p.159, emphasis added). On the other

side, he suggests that *debt-financed investment* be the source of markups (ibid., p.161, and equations on p.163). Both statements appear misled in view of the model here, which suggests that firm profits at the economy level arise under perfect competition, not requiring market power, in line with a profit-maximizing price setting as in the conceptually identical equation (8) in his book (ibid., p.163) and equation (5) herein. Profits here arise due to a lagged wage-price dependence coupled with debt-financed investment and, crucially, with debt bearing *interest* (Section 3.3, Experiment #3). The place where his exposition stumbles is on p. 163 (ibid.), eqs. (3)–(6), where he suggests that profits are generated through investment. To see why that is a fallacy: Let an investment goods firm sector income (I) equal its wage bill (WB_I). Thus, its profits, $\pi_I = I - WB_I$, are 0 by assumption. Let a consumption goods firm sector expense consist of investment (I) and its wage bill (WB_C). Its income equates to consumption (C). Its profits are $\pi_C = C - WB_C - I$. Since $C = WB_C + WB_I$ and $WB_I = I$, the consumption goods firm sector profits are $\pi_C = WB_C + I - WB_C - I = 0$. Hence, just introducing a detour of wage flows via investment goods firms cannot generate profits, for neither the components nor the aggregate of the firm sector.¹⁵

Fourth, related, he suggests that an “increasing dominance of markets by firms with market power [...] produces inflationary pressures” (ibid., p. 174, emphasis added). Implied by the previous point, also price inflation here does not arise due to market power but due to the same wage-price process coupled with interest-bearing debt-based investment.

While Minsky lightly addresses the role of interest as part of his taxonomy of cash flows (ibid., p. 223 ff.), he does not integrate interest more fundamentally with the endogenous cycle process.¹⁶ He contemplates that the shares of speculative and Ponzi-financed firms increase throughout boom times, but does not explain *why* this behavior emerges. The theory developed here attempts to do so. While Ponzi finance dynamics might matter in reality to an extent, they are shown here to not be a requirement for regular debt-driven business cycle behavior to arise, as the model rules that possibility out by design.

Regular debt-driven economic cycles as generated by the model evolve parallel to lower-frequency cycles due to slower-moving structural change (not in-scope of the model). A slower-moving transformation of institutions, conventions, and market structures—jointly referred to as “thwarting institutions” by [Ferri and Minsky \(1992\)](#)—can be seen as a cause for otherwise regular debt-driven recessions to occasionally (at lower frequency) be deeper, in which case they deserve the tag “financial crisis” (Great Depression 1929-33, Global Financial Crisis 2007-09). These entail more significant defaults of financial institutions than regular downturns. One may say that the financial system, banks in particular, “survive” a few regular downturns with leverage not entirely correcting, and only after sufficient structural change has weakened it, it crashes more materially along with a downturn that would have anyways occurred. Slow-moving structural change manifests itself, for example, through the slow tightening and relaxation of bank regulation, or the slowly rising relevance of mortgage debt throughout the 20th century ([Jordà et al. 2016b](#)). Structural change implying lower frequency cycles may square with the empirical

¹⁵ Further, if firms (whether consumption or investment goods producers) were to not pay all income back to workers, then that retained income would flow to firm owners who are also part of the household population themselves and would also spend subsequently. So, that consideration would not change any of the conclusions here. As noted earlier, these flow relationships abstract from a dynamically moving savings and dissaving process, that is, from the dynamics of monetary savings *stocks*. With a horizon that is sufficiently long to imply a stationary savings rate, such savings/dissaving dynamics also do not change any of the above conclusions, that is, long-run firm profits would be zero still, as long as debt is not interest-bearing.

¹⁶ There is no special mention of interest in his Section 7 either, except for one subsection toward its end (p. 185) where interest payments are merely mentioned as part of a set of items that form overall cash flow commitments.

finding that financial cycles have longer durations than business cycles (Strohsal et al. 2019). Others conclude, however, that such evidence is not that strong and that the estimates are generally surrounded by notable uncertainty (Cagliarini and Price 2017).

Further related to firm markups, the theory here resembles some rationale of Monetary Circuit Theory (MCT) but goes beyond it. MCT (Graziani 1989, 2003) focuses on monetary flow processes, considering bank lending for firms to cover their wage bill ahead of production; in line with the model structure here. MCT has moved into stalemate, however. Rochon (2005, p.125) notes: “The existence of monetary profits at the macroeconomic (aggregate) level has been a conundrum for theoreticians of the monetary circuit. [...] Not only are firms unable to create profits, they also cannot raise sufficient funds to cover the payment of interest.” Bellofiore et al. (2000, p.410) suggest that in the circuit approach, “firms in the aggregate can only obtain the wage bill they advanced to workers and, as a result, it is impossible for all firms to obtain money profits.” I could not find a persuasive answer to this open question in such papers and their surrounding literature. The model here suggests that the answer lies in banks’ interest income being paid out to private sector agents, through deposit interest and dividend flows, and consumers spending such income beyond their wage income to thereby create positive markups for firms at a system level. The system is kept afloat by debt being rolled over, while charging interest on such quasi-perpetual at-the-leash credit money, which leads to an ever-growing nominal money stock. Here, we connect back to the fuller endogenous cycle narrative laid out in Section 3.2.

How the markup dynamics across firms and firm sectors behave as a function of evolving competition is beyond the scope of the model here. Blanchard (2018, p.18) opines: “How markups move, in response to what, and why, is however nearly terra incognita for macro... we are a long way from having either a clear picture or convincing theories, and this is clearly an area where research is urgently needed.” This statement may have two dimensions: cross-firm and cross-sector, as opposed to macro. From a macro viewpoint, the theory here suggests an insight. The cross-firm and cross-sectoral perspective to markup dynamics is beyond its scope, but addressed in Seppecher et al. (2018), where monetary and real, multisector interdependencies are considered in a model with debt-financed investment and inventory management, as in other macro-financial ABMs cited earlier.

4.2 Amplification of Cycles Upon Their Existence

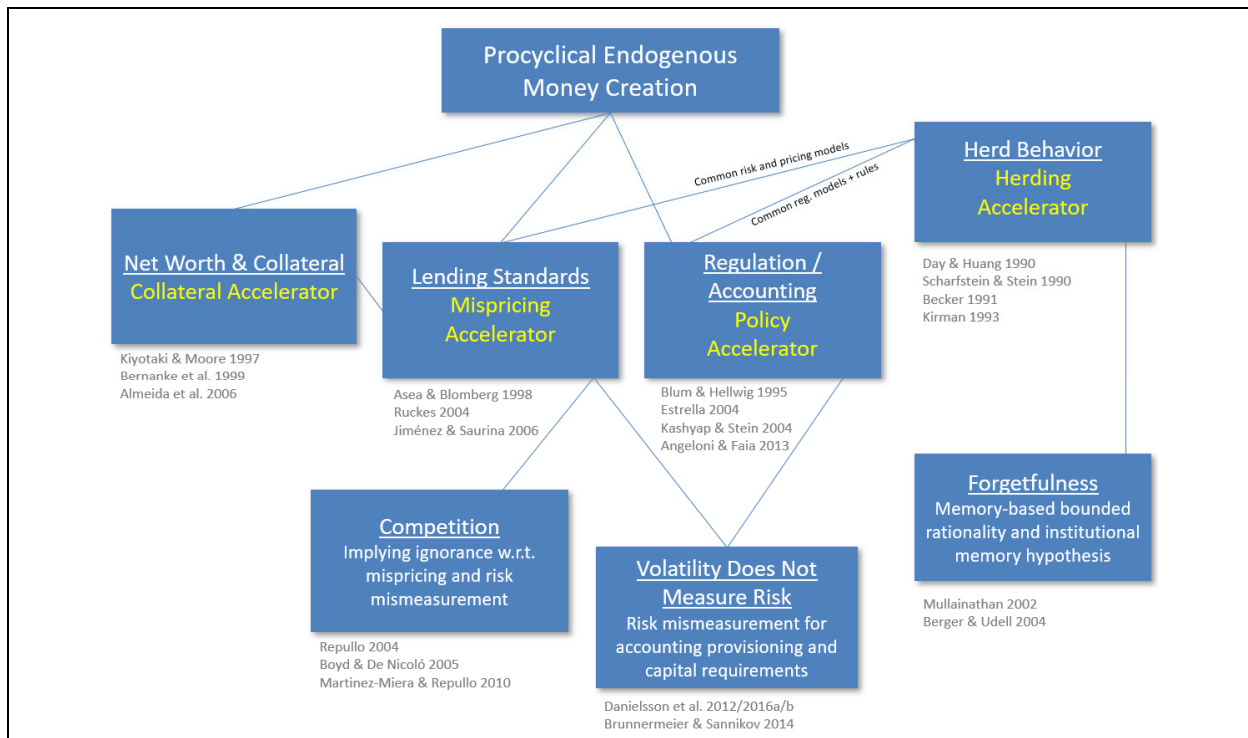
A perspective on four amplification and dampening mechanisms is shown in Figure 12.

The Collateral Accelerator. It rests on the presence of collateral, or firm net worth generically speaking, whose value is procyclical and amplifies (compresses) lending during booms (recessions). The related literature was cited in Section 2 (Bernanke et al., Kiyotaki and Moore, and so on).

The Mispricing Accelerator. It relates to counter-cyclical lending standards (Asea and Blomberg 1998, Ruckes 2004, Jimenez et al. 2006). High-risk loans are granted during boom periods, when the borrower-risk component of lending rates tends to fall, while borrower risk in fact increases when seeing the economy through an endogenous cycle lens. This mispricing during expansions can be traced, in turn, to two sources. Competition is a first. Stronger competition leads to lower lending rates and higher deposit rates, hence lower net interest income (NII) for banks and thus higher incentives for risk taking (Boyd and De Nicolo 2005). Bank capital ratios tend to fall due to higher competition during booms, due to structural shifts in competition (Keeley 1990) and certainly due to cyclical variation in demand and implied cyclical competition for the supply of loans, too. The margin effect (Martinez and Repullo 2010), whereby loan spreads and banks’ NII fall due to rising competition, dominates in competitive markets. The reason for connecting the

Collateral and Mispricing Accelerator in Figure 12 is that some borrower-risk measures, such as a loan-to-value (LTV) ratio, involve the (procyclical) value of collateral, for that metric to have implications for pricing. A second cause of the Mispricing Accelerator relates to the notion that “volatility does not measure risk” (Danielsson et al. 2012/16a/b). Risk measurement in the banking industry involves PDs; Moody’s KMV-like PDs are widely used, for instance (Crosbie and Bohn 2003). They are based on a realized variance rationale (as in equation (2) in the model) and may not measure risk in a sufficiently forward-looking way, in particular nearby a cycle’s turning point when longer duration loans such as mortgages are prone to be underpriced, when low variance dominates high leverage in Merton-type models. This mismeasurement may lead to too low (high) loan prices and insufficient (too sizable) loss provisioning as well as inflated (too low) risk weights during booms (recessions). Competition may imply that this is intentionally overlooked as deviating to a higher loan price, better reflecting actual risk, and would imply for a bank to “price itself out of the market” and face a loss in profit and market share. Another way for banks to misprice longer-term loans may lie in their use of maturity-insensitive pricing models, which a survey of UK banks revealed (Cadamagnani et al. 2015). The presence of competition also may make such model choice intentional.

Figure 12. Sources of Economic Cycle Amplification and Dampening



The Policy Accelerator. A third source of procyclical lending stems from regulatory policy (Blum and Hellwig 1995). Models of optimal bank capital were developed to help see the procyclical effects of regulation (Estrella 2004, Angeloni and Faia 2013). The Basel II framework has been assessed to be more procyclical than Basel I (Kashyap and Stein 2004), as the former is risk-based, while the risk measures may not properly measure actual risk. Countercyclical policy as considered in Basel III regulation is meant to dampen procyclical effects.¹⁷ On the accounting side, the International Financial Reporting Standard 9

¹⁷ Some work related to the “role of competition” strand connects to capital-based policy: Hellmann et al. (2000) and Repullo (2004). Capital requirements help induce prudent behavior through the “capital at risk” effect, while generating Pareto inefficient outcomes as

(IFRS 9) and the Current Expected Credit Loss (CECL) methodology have been introduced, motivated in large part by their intention to compress procyclical lending.

The Herding Accelerator. Herding behavior in investment can arise despite being socially inefficient (Scharfstein and Stein 1990) and swings of optimism and pessimism can be due to people mimicking the actions of others (Becker 1991, Kirman 1993).¹⁸ The Herding Accelerator operates on top of the Mispricing and Policy Accelerator, insofar as banks tend to herd on the same models (model philosophy generally), leading to mispricing and misprovisioning in a synchronized way for all banks. Regulation is imposed on the banking system and is in that sense a built-in herding mechanism, too. Memory-based bounded rationality (Mullainathan 2002) and, related, the institutional memory hypothesis (Berger and Udell 2004) suggest that economic agents tend to forget the lessons of past recessions and crises, including through new generations replacing older ones. Along a boom period, they forget that the models used for pricing and provisioning underestimate risk, while competition implies little incentive to remember and counteract. It is rational from a micro perspective to herd, which links to the notion of “sharing the blame” (Scharfstein and Stein 1990) and Keynes noting that “worldly wisdom teaches that it is better for reputation to fail conventionally than to succeed unconventionally” (Keynes 1936, p.157).

Additional, structural sources of cycle amplification stem from interconnectedness. These include firm interconnectedness through supply chains (Delli Gatti et al. 2010), bank interconnectedness via interbank reserve lending relationships (Krug et al. 2015, Popoyan et al. 2020), and firm-bank cross-interconnectedness through banks’ lending to the economy. All three forms imply for default cascades arising in some part of the economy to propagate in a more amplified manner than otherwise. A form of indirect firm network connectedness through the demand side has been reflected in the model here. From among the four accelerator types in Figure 12, the realized risk-based mispricing accelerator is embedded in the model (equation 2).

5. Conclusions

The model developed here is of a rather pure monetary cycle kind and can be called a “Dynamic Stochastic General Disequilibrium” (DSGD) model. The “small shocks, large cycles puzzle,” so called in Bernanke et al. (1996), is not a puzzle in this model, but easily explained (Section 3). The list of what the model did *not* require includes, for example, rational expectations, demand expectation-driven investment, external habit formation regarding consumption, inventory management, Calvo price setting, a distinction between producers and retailers with the latter acting under monopolistic competition to generate price stickiness, and so on. The disequilibrium model instead reflects two assumptions: the presence of interest-bearing debt and a degree of downward wage rigidity, which, respectively, reflect institutional and behavioral reality and serve to micro-found the model.

capital requirements would need to be inefficiently high. Pareto efficient outcomes can be achieved by a combination of capital requirements and deposit rate controls, or by speed limits on growth for certain assets. The latter two options fall into the “borrower-based macroprudential policy” category.

¹⁸ Endogenous shifts between optimism and pessimism have been referred to as animal spirits—a notion tracing to Keynes (1930) and appearing in Minsky (1986), De Grauwe and Macchiarelli (2015), and others. There is a related sizable behavioral macroeconomics literature promoting the relevance of heuristics (Simon 1955) and boundedly rational expectations (Simon 1979, Kahneman and Tversky 1979, Brock and Hommes 1997). Heuristics can be economical and effective (Tversky and Kahneman 1974), may improve accuracy, and handle uncertainty more efficiently and robustly (Gigerenzer and Brighton 2009). A recent very useful survey paper on behavioral macroeconomics can be found in Hommes (2021).

Unlike suggested by Minsky, it is not debt-financed investment as such that generates firm profits at the macro level, but it is *interest that generates profits*. The stock-flow consistent model with its system-wide scope reveals this aspect. Principal debt for investment (wages) just flows forth to consumers and back to firms, rendering economy-wide net profits nil. The continual addition of *interest-bearing* debt and lenders paying some of the interest income to consumers, and them spending it, is a prerequisite for profits to arise dynamically over time.

Despite its simplicity, the model generates endogenous cycles and replicates six stylized facts. These are summarized in the abstract and introduction of the paper and laid out in detail in Section 3.

The meaning of “stochastic” (S) in DSGD is different from what it is in DSGE. In DSGE models, shocks are sizable and required to generate half-cycles back to steady state. In the DSGD model here, shocks are of a small, unnoticeable kind (demand perturbations, small endogenous base rate or credit spread moves), which nearby a turning point cause downturns before another upturn emerges endogenously.

A literature perspective was meant: (1) to relate to system dynamics models, concluding that they are not well suited for allowing for explicit agent default as they built on a representative agent structure just as much of the DSGE model stream, and that their dynamic behavior is sensitive to functional assumptions and parameters; (2) to note that ABMs are amenable to stock-flow consistent dynamic modeling, allowing for agent defaults (which is key for achieving the aim of generating cycles), while they have become very comprehensive, not yet focused on the fundamental drivers of endogenous cycles, and not yet generating cycles of a so regular kind as illustrated here; and (3) to reflect on sources of amplification and dampening of cycles upon their existence, which led to the suggested categorization of four accelerator types: collateral, mispricing, policy, and herding, next to structural sources of amplification stemming from network interconnectedness. The mispricing accelerator and a demand-side feedback from firm defaults are reflected in the model.

Robert Lucas suggested that good models shall necessarily be “abstract” and “patently unreal” (Lucas 1980, p. 697), with which I strongly disagree. The model here, just as numerous emerging macro-financial ABMs, is not abstract and meant to be reflective of institutional and behavioral reality, disciplined by the stock-flow consistency principle as prevalent in Post-Keynesian economics, and with a system-wide perspective. For the latter reason, “general” (G) is suggested to be included in DSGD. It is in line with Stiglitz’s perspective that theories are valuable if reflective of “how firms and households actually behave and markets actually work” (Stiglitz 2017, p. 4). As a next step, the bare bones model structure can be extended to examine the fundamental channels for monetary, fiscal, and macroprudential policies to influence cycle dynamics, and the model subsequently be estimated on empirical data.

References

- Adrian, T., N. Boyarchenko, and D. Giannone. 2019. "Vulnerable Growth." *The American Economic Review*, 109(4):1263–89.
- Akerlof, G.A. 2002. "Behavioral Macroeconomics and Macroeconomic Behavior." *The American Economic Review*, 92(3):411–33.
- , W.T. Dickens, and G.L. Perry. 1996. "The Macroeconomics of Low Inflation." *Brookings Papers on Economic Activity*, 27(1):1–76.
- , and J.L. Yellen. 1990. "The Fair Wage-Effort Hypothesis and Unemployment." *The Quarterly Journal of Economics*, 105(2):255–83.
- Alexandre, M., and G.T. Lima. 2017. "Combining Monetary Policy and Prudential Regulation: An Agent-Based Modeling Approach." *Journal of Economic Interaction and Coordination*, 15(2):385–411.
- Altonji, J.G., and P.J. Devereux. 2000. "The Extent and Consequences of Downward Nominal Wage Rigidity." *Research in Labor Economics*, 19:383–431.
- Angeloni, I., and E. Faia. 2013. "Capital Regulation and Monetary Policy with Fragile Banks." *Journal of Monetary Economics*, 60(3):311–24.
- Angeletos, G.-M., F. Collard, and H. Dellas. 2020. "Business-Cycle Anatomy." *The American Economic Review*, 110(10):3030–70.
- Asada, T. 1989. "Monetary Stabilization Policy in a Keynes-Goodwin Model of the Growth Cycle." In *Financial Dynamics and Business Cycles*, edited by W. Semmler, 145–62. New York: M.E. Sharpe.
- . 2001. "Nonlinear Dynamics of Debt and Capital: A Post-Keynesian Analysis." In *Evolutionary Controversies in Economics: A New Transdisciplinary Approach*, edited by Y. Aruka and Japan Association for Evolutionary Economics, pp. 73–87. Tokyo: Springer.
- Ascari, G., G. Fagiolo, and A. Roventini. 2015. "Fat-Tail Distributions and Business-Cycle Models." *Macroeconomic Dynamics*, 19(2):465–76.
- Asea, P.K., and B. Blomberg. 1998. "Lending Cycles." *Journal of Econometrics*, 83(1):89–128.
- Assenza, T., D.D. Gatti, and J. Grazzini. 2015. "Emergent Dynamics of a Macroeconomic Agent Based Model with Capital and Credit." *Journal of Economic Dynamics & Control*, 50:5–28.
- Banerji, A. 2005. "The Relationship Between Labor Costs and Inflation: A Cyclical Viewpoint." Economic Cycle Research Institute, US Bureau of Labor Statistics.
- Basu, N., R. Pryor, and T. Quint. 1998. "ASPEN: A Microsimulation Model of the Economy." *Computational Economics*, 12:223–41.
- Bê Duc, L., and G. Le Breton. 2009. "Flow of Funds Analysis at the ECB—Framework and Applications." Occasional Paper 105, European Central Bank.
- Beaudry, P., D. Galizia, and F. Portier. 2017. "Is the Macroeconomy Locally Unstable and Why Should We Care?" *NBER Macroeconomics Annual*, pp. 479–530.
- Becker, G.S. 1991. "A Note on Restaurant Pricing and Other Examples of Social Influences on Price." *Journal of Political Economy*, 99(5):1109–16.
- Berger, A.N., and G.F. Udell. 2004. "The Institutional Memory Hypothesis and the Procyclicality of Bank Lending Behavior." *Journal of Financial Intermediation*, 13(4):458–95.
- Bernanke, B.S., M. Gertler, and S. Gilchrist. 1996. "The Financial Accelerator and the Flight to Quality." *The Review of Economics and Statistics*, 78(1):1–15.
- . 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." In *Handbook of Macroeconomics*, (1):1341–93. Elsevier.
- Bewley, T.F. 1995. "A Depressed Labor Market as Explained by Participants." *The American Economic Review*, 85(2):250–54.

- . 1999. *Why Wages Don't Fall During a Recession*. Cambridge, MA: Harvard University Press.
- Bhattacharya, S., C.A. Goodhart, D.P. Tsomocos, and others. 2015. "A Reconsideration of Minsky's Financial Instability Hypothesis." *Journal of Money, Credit and Banking*, 47(5):931–73.
- Blanchard, O. 1989. "A Traditional Interpretation of Macroeconomic Fluctuations." *The American Economic Review*, 79(5):1146–64.
- . 2016a. "Do DSGE Models Have a Future?" Policy Brief, Peterson Institute for International Economics.
- . 2016b. "Further Thoughts on DSGE Models: What We Agree on and What We Do Not." Blog Post, Peterson Institute for International Economics.
- . 2017. "The Need for Different Classes of Macroeconomic Models." Blog Post, Peterson Institute for International Economics.
- Blum, J., and M. Hellwig. 1995. "The Macroeconomic Implications of Capital Adequacy Requirements for Banks." *European Economic Review*, 39(3):739–49. Papers and Proceedings of the Ninth Annual Congress European Economic Association.
- Bobeica, E., M. Ciccarelli, and I. Vansteenkiste. 2019. "The Link Between Labor Cost and Price Inflation in the Euro Area." ECB Working Paper No. 2235.
- Booth, A. 1994. *The Economics of the Trade Union*. Cambridge, UK: Cambridge University Press.
- Boyd, J.H., and G.D. Nicolo. 2005. "The Theory of Bank Risk Taking and Competition Revisited." *The Journal of Finance*, 60(3):1329–43.
- Brock, W.A., and C.H. Hommes. 1997. "A Rational Route to Randomness." *Econometrica*, 65(5):1059–95.
- Brunnermeier, M.K., and Y. Sannikov. 2014. "A Macroeconomic Model with a Financial Sector." *The American Economic Review*, 104(2):379–421.
- Cadamagnani, F., R. Harimohan, and K. Tangri. 2015. "A Bank Within a Bank: How a Commercial Bank's Treasury Function Affects the Interest Rates Set for Loans and Deposits." *Quarterly Bulletin 2015Q2*, Bank of England.
- Cagliarini, A., and F. Price. 2017. "Exploring the Link between the Macroeconomic and Financial Cycles." In *Monetary Policy and Financial Stability in a World of Low Interest Rates*, edited by Hambur, J. and J. Simon, Reserve Bank of Australia.
- Calmfors, L., and J. Driffill. 1988. "Bargaining Structure, Corporatism and Macroeconomic Performance." *Economic Policy*, 3(6):13–61.
- Campbell, C., and K. Kamlani. 1997. "The Reasons for Wage Rigidity: Evidence from a Survey of Firms." *The Quarterly Journal of Economics*, 112(3):759–89.
- Card, D., and D. Hyslop. 1997. "Does Inflation 'Grease the Wheels of the Labor Market'?" In *Reducing Inflation: Motivation and Strategy*, National Bureau of Economic Research, Inc., pp. 71–122.
- Chiarella, C., and C.D. Guilmi. 2011. "The Financial Instability Hypothesis: A Stochastic Microfoundation Framework." *Journal of Economic Dynamics & Control*, 35(8):1151–71.
- Cincotti, S., M. Raberto, and A. Tegli. 2012. "The Eurace Macroeconomic Model and Simulator. In Agent-based Dynamics, Norms, and Corporate Governance." Proceedings of the 16th World Congress of the International Economic Association, Palgrave.
- Clarida, R., J. Galí, and M. Gertler. 1999. "The Science of Monetary Policy: A New Keynesian Perspective." *Journal of Economic Literature*, 37(4):1661–1707.
- Coibion, O., and Y. Gorodnichenko. 2015. "Information Rigidity and the Expectations Formation Process: A Simple Framework and New Facts." *The American Economic Review*, 105(8):2644–78.
- Crosbie, P., and J. Bohn. 2003. "Modeling Default Risk." Moody's Analytics.
- Daly, M.C., and B. Hobijn. 2014. "Downward Nominal Wage Rigidities Bend the Phillips Curve." *Journal of Money, Credit and Banking*, 46(S2):51–93.

- Danielsson, J., H.S. Shin, and J.-P. Zigrand. 2012. "Procyclical Leverage and Endogenous Risk," unpublished. London School of Economics, <http://www.riskresearch.org>.
- , M. Valenzuela, and I. Zer. 2016. "Learning from History: Volatility and Financial Crises." LSE Research Online Documents on Economics 66046, London School of Economics.
- , and Zhou, C. (2016b). Why is Risk so Hard to Measure. DNB Working Papers 494, Netherlands Central Bank.
- Dawid, H., S. Gemkow, P. Harting, K. Kabus, M. Neugart, and K. Wersching. 2008. "Skills, Innovation, and Growth: An Agent-Based Policy Analysis." *Journal of Economics and Statistics*, 228(2/3):251–75.
- , S. Gemkow, P. Harting, and M. Neugart. 2009. "On the Effects of Skill Upgrading in the Presence of Spatial Labor Market Frictions: An Agent-Based Analysis of Spatial Policy Design." *Journal of Artificial Societies and Social Simulation*, 12(4):1–5.
- , P. Harting, S. van der Hoog, and M. Neugart. 2016. "A Heterogeneous Agent Macroeconomic Model for Policy Evaluation: Improving Transparency and Reproducibility." Bielefeld University Working Papers No. 06-2016.
- , S. Gemkow, P. Harting, S. van der Hoog, and M. Neugart. 2018. "Agent-Based Macroeconomic Modeling and Policy Analysis: The Eurace@Unibi Model." In *Handbook on Computational Economics and Finance*, edited by S.-H. Chen and M. Kaboudan. Oxford University Press.
- Day, R.H., and W. Huang. 1990. "Bulls, Bears and Market Sheep." *Journal of Economic Behavior & Organization*, 14(3):299–329.
- De Grauwe, P., and C. Macchiarelli. 2015. "Animal Spirits and Credit Cycles." *Journal of Economic Dynamics & Control*, 59:95–117.
- Deissenberg, C., S. van der Hoog, and H. Dawid. 2008. "Eurace: A Massively Parallel Agent-Based Model of the European Economy." *Applied Mathematics and Computation*, 204(2):541–52.
- Delli Gatti, D., M. Gallegati, and L. Gardini. 1993. "Investment Confidence, Corporate Debt, and Income Fluctuations." *Journal of Economic Behavior & Organization*, 22:161–87.
- , M. Gallegati, G. Giulioni, and others. 2003. "Financial Fragility, Patterns of Firms' Entry and Exit and Aggregate Dynamics." *Journal of Economic Behavior & Organization*, 51:79–97.
- , C. Di Guilmi, E. Gaffeo, and others. 2005. "A New Approach to Business Fluctuations: Heterogeneous Interacting Agents, Scaling Laws and Financial Fragility." *Journal of Economic Behavior & Organization*, 56:489–512.
- , M. Gallegati, B. Greenwald, and others. 2010. "The Financial Accelerator in an Evolving Credit Network." *Journal of Economic Dynamics & Control*, 34(9):1627–50.
- Dosi, G., G. Fagiolo, and A. Roventini. 2006. "An Evolutionary Model of Endogenous Business Cycles." *Computational Economics*, 27:3–34.
- , G. Fagiolo, and A. Roventini. 2010. "Schumpeter Meeting Keynes: A Policy-Friendly Model of Endogenous Growth and Business Cycles." *Journal of Economic Dynamics & Control*, 34:1748–67.
- , G. Fagiolo, M. Napoletano, and others. 2013. "Income Distribution, Credit and Fiscal Policies in an Agent-Based Keynesian Model." *Journal of Economic Dynamics & Control*, 37(8):1598–1625.
- , M. Napoletano, A. Roventini, and others. 2017. "Micro and Macro Policies in the Keynes+Schumpeter Evolutionary Models." *Journal of Evolutionary Economics*, 27(1):63–90.
- , G., and A. Roventini. 2019. "More is Different ... and Complex! The Case for Agent-Based Macroeconomics." Forthcoming in the *Journal of Evolutionary Economics*.
- Duesenberry, J. 1962. "A Process Approach to Flow-of-Funds Analysis." In *The Flow-of-Funds Approach to Social Accounting: Appraisals, Analysis, and Applications*, NBER Chapters, pp. 173–94. National Bureau of Economic Research, Inc.
- Dupasquier, C., and N. Ricketts. 1998. "Nonlinearities in the Output-Inflation Relationship: Some Empirical Results for Canada." *Price Stability, Inflation Targets, and Monetary Policy*, 14:131–73.

- Estrella, A. (2004). "The Cyclical Behavior of Optimal Bank Capital." *Journal of Banking & Finance*, 28(6):1469–98.
- Fagiolo, G., M. Napoletano, and A. Roventini. 2008. "Are Output Growth-Rate Distributions Fat-Tailed? Some Evidence from OECD Countries." *Journal of Applied Econometrics*, 23(5):639–69.
- , and A. Roventini. 2017. "Macroeconomic Policy in DSGE and Agent-Based Models Redux: New Developments and Challenges Ahead." *Journal of Artificial Societies and Social Simulation*, 20(1).
- Fehr, E., and A. Falk. 1999. "Wage Rigidity in a Competitive Incomplete Contract Market." *Journal of Political Economy*, 107(1):106–34.
- , and L. Goette. 2005. "Robustness and Real Consequences of Nominal Wage Rigidity." *Journal of Monetary Economics*, 52(4):779–804.
- Ferri, P., and H.P. Minsky. 1992. "Market Processes and Thwarting Systems." *Structural Change and Economic Dynamics*, 3(1):79–91.
- Fisher, I. 1928. *The Money Illusion*. Adelphi Company.
- Foley, D.K. 1987. "Liquidity-Profit Rate Cycles in a Capitalist Economy." *Journal of Economic Behavior & Organization*, 8(3):363–76.
- Gallegati, M., and L. Gardini. 1991. "A Nonlinear Model of the Business Cycle with Money and Finance." *Metroeconomica*, 42(1):1–32.
- Ghali, K.H. 1999. "Wage Growth and the Inflation Process: A Multivariate Cointegration Analysis." *Journal of Money, Credit and Banking*, 31(3):417–31.
- Gigerenzer, G., and H. Brighton. 2009. "Homo Heuristicus: Why Biased Minds Make Better Inferences." *Topics in Cognitive Science*, 1(1):107–43.
- Godley, W., and M. Lavoie. 2007. *Monetary Economics: An Integrated Approach to Credit, Money, Income, Production and Wealth*. Cheltenham, UK: Edward Elgar.
- Goette, L., U. Sunde, and T. Bauer. 2007. "Wage Rigidity: Measurement, Causes and Consequences." *The Economic Journal*, 117(524):499–507.
- Goodfriend, M., and R. King. 1997. "The New Neoclassical Synthesis and the Role of Monetary Policy." In *NBER Macroeconomics Annual 1997*, Vol. 12, NBER chapters, 231–96. National Bureau of Economic Research, Inc.
- Goodwin, R.M. 1951. "The Nonlinear Accelerator and the Persistence of Business Cycles." *Econometrica*, 19(1):1–17.
- . 1967. "A Growth Cycle." In *Socialism, Capitalism and Economic Growth*, edited by C.H. Feinstein, pp. 54–8. Cambridge, UK: Cambridge University Press.
- Graziani, A. 1989. "The Theory of the Monetary Circuit." Thames Papers in Political Economy. Reprinted in *The Money Supply in the Economic Process*, edited by M. Musella and C. Panico. 1995. Aldershot, England: Edward Elgar.
- . 2003. *The Monetary Theory of Production*. Cambridge, UK: Cambridge University Press.
- Greenwald, B.C., and J.E. Stiglitz. 1993. "Financial Market Imperfections and Business Cycles." *The Quarterly Journal of Economics*, 108(1):77–114.
- Gross, M., and W. Semmler. 2019. "Mind the Output Gap: The Disconnect of Growth and Inflation During Recessions and Convex Phillips Curves in the Euro Area." *Oxford Bulletin of Economics and Statistics*, 81(4):817–48.
- , and C. Siebenbrunner. 2019. "Money Creation in Fiat and Digital Currency Systems." IMF Working Paper No. 19/285. Forthcoming in *Central Banking, Monetary Policy and the Future of Money*, edited by S. Kappes, L.-P. Rochon, and G. Vallet. Edward Elgar.
- Guerini, M., M. Napoletano, and A. Roventini. 2018. "No Man is an Island: The Impact of Heterogeneity and Local Interactions on Macroeconomic Dynamics." *Economic Modelling*, 68:82–95.

- Haldane, A., and A. Turrell. 2018. "An Interdisciplinary Model for Macroeconomics." *Oxford Review of Economic Policy*, 34(1-2):219–51.
- Hamilton, J.D. 2018. "Why You Should Never Use the Hodrick-Prescott Filter." *The Review of Economics and Statistics*, 100(5):831–43.
- Harrod, R.F. 1939. "An Essay in Dynamic Theory." *The Economic Journal*, 49(193):14–33.
- Hawtrey, R.G. 1919. *Currency and Credit*. London and New York: Longmans, Green and Co.
- Hein, E. 2017. "Post-Keynesian Macroeconomics since the Mid-1990s: Main Developments." *European Journal of Economics and Economic Policies: Intervention*, 14(2):131–72.
- Hellmann, T.F., K.C. Murdock, and J.E. Stiglitz. 2000. "Liberalization, Moral Hazard in Banking, and Prudential Regulation: Are Capital Requirements Enough?" *The American Economic Review*, 90(1):147–65.
- Holden, S. 1994. "Wage Bargaining and Nominal Rigidities." *European Economic Review*, 38(5):1021–39.
- , and F. Wulfsberg. 2008. "Downward Nominal Wage Rigidity in the OECD." *B.E. Journal of Macroeconomics*, 8(1).
- Holzer, H.J., and E.B. Montgomery. 1993. "Asymmetries and Rigidities in Wage Adjustments by Firms." *The Review of Economics and Statistics*, 75(3):397–408.
- Hommes, C. 2021. "Behavioral & Experimental Macroeconomics and Policy Analysis: A Complex Systems Approach." Forthcoming in the *Journal of Economic Literature*. Available as ECB Working Paper No. 2201 (2018).
- Hommes, C.H., and B. LeBaron. 2018. *Handbook of Computational Economics*, Vol. 4, *Heterogeneous Agent Modeling*. North-Holland, Amsterdam: Elsevier.
- Howitt, P. 2012. "What have Central Bankers Learned from Modern Macroeconomic Theory?" *Journal of Macroeconomics*, 34(1):11–22.
- Huh, H., and I. Jang, 2007. "Nonlinear Phillips Curve, Sacrifice Ratio, and the Natural Rate of Unemployment." *Economic Modelling*, 24(5):797–813.
- Jakab, Z., and M. Kumhof. 2015. "Banks Are Not Intermediaries of Loanable Funds—And Why This Matters." Bank of England Working Paper No. 529.
- Jarsulic, M. 1989. "Endogenous Credit and Endogenous Business Cycles." *Journal of Post Keynesian Economics*, 12(1):35–48.
- Jiménez, G., V. Salas, and J. Saurina. 2006. "Determinants of Collateral." *Journal of Financial Economics*, 81(2):255–81.
- Jordà, Ò., M. Schularick, and A.M. Taylor. 2013. "When Credit Bites Back." *The Journal of Money, Credit and Banking*, 45(S2):3–28.
- . 2015. "Leveraged Bubbles." *Journal of Monetary Economics*, 76(S):S1–S20.
- . 2016a. "Macrofinancial History and the New Business Cycle Facts." *NBER Macroeconomics Annual*, 31:213–263.
- . 2016b. "The Great Mortgaging: Housing Finance, Crises and Business Cycles." *Economic Policy*, 31(85):107–152.
- Kahn, S. 1997. "Evidence of Nominal Wage Stickiness from Microdata." *The American Economic Review*, 87(5):993–1008.
- Kahneman, D., J.L. Knetsch, and R. Thaler. 1986. "Fairness as a Constraint on Profit Seeking: Entitlements in the Market." *The American Economic Review*, 76(4):728–741.
- , and A. Tversky. 1979. "Prospect Theory: An Analysis of Decision Under Risk." *Econometrica*, 47(2):263–291.
- Kaldor, N. 1940. "A Model of the Trade Cycle." *The Economic Journal*, 50(197):78–92.

- Kalecki, M. 1935. "A Macrodynamic Theory of Business Cycles." *Econometrica*, 3(3):327–44.
- . 1937. "The Principle of Increasing Risk." *Economica*, 4(16):440–47.
- . 1939. *Essays in the Theory of Economic Fluctuations*. London: George Allen & Unwin.
- Kashyap, A.K., and J.C. Stein. 2004. "Cyclical Implications of the Basel II Capital Standards." *Economic Perspectives*, 28(Q1):18–31.
- Keeley, M.C. 1990. "Deposit Insurance, Risk, and Market Power in Banking." *The American Economic Review*, 80(5):1183–1200.
- Keen, S. 1995. "Finance and Economic Breakdown: Modeling Minsky's 'Financial Instability Hypothesis'." *Journal of Post Keynesian Economics*, 17(4):607–35.
- Keynes, J.M. 1930. *A Treatise on Money*. London: Macmillan and Co.
- . 1936. *The General Theory of Employment, Interest and Money*. London: Palgrave Macmillan.
- Kirman, A. 1992. "Whom or What Does the Representative Individual Represent?" *Journal of Economic Perspectives*, 6(2):117–36.
- . 1993. "Ants, Rationality, and Recruitment." *The Quarterly Journal of Economics*, 108(1):137–56.
- Kiyotaki, N., and J. Moore. 1997. "Credit Cycles." *Journal of Political Economy*, 105(2):211–48.
- Krug, S., M. Lengnick, and H.-W. Wohltmann. 2015. "The Impact of Basel III on Financial (In)Stability: An Agent-Based Credit Network Approach." *Quantitative Finance*, 15(12):1917–32.
- Kumar, A., and P.M. Orrenius. 2016. "A Closer Look at the Phillips Curve Using State-Level Data." *Journal of Macroeconomics*, 47(A):84–102.
- Kydland, F.E., and E.C. Prescott. 1990. "Business Cycles: Real Facts and a Monetary Myth." *FED Minneapolis Quarterly Review*, 14(2):3–18.
- Lavoie, M. 2014. *Post-Keynesian Economics: New Foundations*. Cheltenham, UK: Edward Elgar.
- Layard, R., S. Nickell, and R. Jackman. 1991. *Unemployment—Macroeconomic Performance and the Labor Market*. Oxford University Press.
- LeBaron, B., and L. Tesfatsion. 2008. "Modeling Macroeconomies as Open-Ended Dynamic Systems of Interacting Agents." *The American Economic Review*, 98(2):246–50.
- Lebow, D.E., P.E. Saks, and B.A. Wilson. 2003. "Downward Nominal Wage Rigidity: Evidence from the Employment Cost Index." *The B.E. Journal of Macroeconomics, Advances in Macroeconomics*, 3(1):1–30.
- Le Heron, E. 2011. "Confidence and Financial Crisis in a Post-Keynesian Stock Flow Consistent Model." *European Journal of Economics and Economic Policies: Intervention*, 8(2):361–87.
- Lindbeck, A., and D.J. Snower. 1988. "Cooperation, Harassment, and Involuntary Unemployment: An Insider-Outsider Approach." *The American Economic Review*, 78(1):167–88.
- Lima, G.T., and A.J.A. Meirelles. 2007. "Macrodynamics of Debt Regimes, Financial Instability and Growth." *Cambridge Journal of Economics*, 31(4):563–80.
- Loewenstein, G., and N. Sicherman. 1991. "Do Workers Prefer Increasing Wage Profiles?" *Journal of Labor Economics*, 9(1):67–84.
- Lucas, R.E. 1980. "Methods and Problems in Business Cycle Theory." *Journal of Money, Credit and Banking*, 12(4):696–715.
- Macklem, T. 1997. "Capacity Constraints, Price Adjustment, and Monetary Policy." *Bank of Canada Review*, pp. 39–56.
- MacLeod, W.B., and J.M. Malcomson. 1998. "Motivation and Markets." *The American Economic Review*, 88(3):388–411.
- Mankiw, N.G. 2006. "The Macroeconomist as Scientist and Engineer." *Journal of Economic Perspectives*, 20(4):29–46.

- , and R. Reis. 2002. "Sticky Information Versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve." *The Quarterly Journal of Economics*, 117(4):1295–1328.
- Martinez-Miera, D., and R. Repullo. 2010. "Does Competition Reduce the Risk of Bank Failure?" *The Review of Financial Studies*, 23(10):3638–64.
- McLeay, M., A. Radia, and R. Thomas. 2014a. "Money Creation in the Modern Economy." *Bank of England Quarterly Bulletin*, 54(1):14–27.
- . 2014b. "Money in the Modern Economy: An Introduction." *Bank of England Quarterly Bulletin*, 54(1):4–13.
- Mehra, Y. 2000. "Wage-Price Dynamics: Are They Consistent with Cost Push?" *Federal Reserve Bank of Richmond Economic Quarterly*, 86(3):27–44.
- Minsky, H.P. 1975. *John Maynard Keynes*. London: Palgrave Macmillan.
- . 1986. *Stabilizing an Unstable Economy*. New Haven: Yale University Press.
- . 1993. "The Financial Instability Hypothesis." In *Handbook of Radical Political Economy*, edited by P. Arestis and M. Sawyer. Cheltenham, UK: Edward Elgar.
- Moore, B. 1988. *Horizontalists and Verticalists: The Macroeconomics of Credit Money*. Cambridge, UK: Cambridge University Press.
- Mullainathan, S. 2002. "A Memory-Based Model of Bounded Rationality." *The Quarterly Journal of Economics*, 117(3):735–74.
- Nikolaïdi, M. 2014. "Margins of Safety and Instability in a Macrodynamical Model with Minskyan Insights." *Structural Change and Economic Dynamics*, 31:1–16.
- , and Stockhammer, E. 2017. "Minsky Models: A Structured Survey." *Journal of Economic Surveys*, 31(5):1304–31.
- Palley, T.I. 1994. "Debt, Aggregate Demand, and the Business Cycle: An Analysis in the Spirit of Kaldor and Minsky." *Journal of Post Keynesian Economics*, 16(3):371–90.
- Patinkin, D. 1965. *Money, Interest, and Prices*. Second Edition. New York: Harper and Row.
- Phillips, A.W. 1958. "The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861–1957." *Economica*, 25(100):283–99.
- Poledna, S., M.G. Miess, and C. Hommes. 2021. Economic Forecasting with an Agent-Based Model. Unpublished.
- Popoyan, L., M. Napoletano, and A. Roventini. 2017. "Taming Macroeconomic Instability: Monetary and Macro-Prudential Policy Interactions in an Agent-Based Model." *Journal of Economic Behavior & Organization*, 134:117–40.
- . 2020. "Winter is Possibly Not Coming: Mitigating Financial Instability in an Agent-Based Model with Interbank Market." *Journal of Economic Dynamics & Control*, 117(C).
- Raberto, M., A. Tegliò, and S. Cincotti. 2012. "Debt, Deleveraging and Business Cycles: An Agent-Based Perspective." *The Open-Access, Open-Assessment E-Journal*, 6(27):1–49.
- Repullo, R. 2004. "Capital Requirements, Market Power, and Risk-Taking in Banking." *Journal of Financial Intermediation*, 13(2):156–82.
- Ricchetti, L., A. Russo, and M. Gallegati. 2013. "Leveraged Network-Based Financial Accelerator." *Journal of Economic Dynamics & Control*, 37(8):1626–40.
- . 2015. "An Agent Based Decentralized Matching Macroeconomic Model." *Journal of Economic Interaction and Coordination*, 10(2):305–32.
- Rochon, L.-P. 2005. "The Existence of Monetary Profits within the Monetary Circuit." In *The Monetary Theory of Production*, edited by G. Fontana and R. Realforzo. London: Palgrave Macmillan.
- Ruckes, M. 2004. "Bank Competition and Credit Standards." *The Review of Financial Studies*, 17(4):1073–1102.

- Scharfstein, D.S., and J.C. Stein. 1990. "Herd Behavior and Investment." *The American Economic Review*, 80(3):465–79.
- Schularick, M., and A.M. Taylor. 2012. "Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises." *The American Economic Review*, 102(2):1029–1061.
- Schumpeter, J.A. 1912. *Theorie der wirtschaftlichen Entwicklung*. Berlin: Duncker & Humblot.
- Semmler, W. 1987. "A Macroeconomic Limit Cycle with Financial Perturbations." *Journal of Economic Behavior & Organization*, 8(3):469–95.
- Seppecher, P., I. Salle, and M. Lavoie. 2018. "What Drives Markups? Evolutionary Pricing in an Agent-Based Stock-Flow Consistent Macroeconomic Model." *Industrial and Corporate Change*, 27(6):1045–67.
- Shafir, E., P. Diamond, and A. Tversky. 1997. "Money Illusion." *The Quarterly Journal of Economics*, 112(2):341–74.
- Shapiro, C., and J.E. Stiglitz. 1984. "Equilibrium Unemployment as a Worker Discipline Device." *The American Economic Review*, 74(3):433–44.
- Simon, H.A. 1955. "A Behavioral Model of Rational Choice." *The Quarterly Journal of Economics*, 69(1):99–118.
- . 1979. "Rational Decision Making in Business Organizations." *The American Economic Review*, 69(4):493–513.
- Sims, C.A. 2003. "Implications of Rational Inattention." *Journal of Monetary Economics*, 50(3):665–90.
- Stiglitz, J.E. 2011. "Rethinking Macroeconomics: What Failed, and How to Repair It." *Journal of the European Economic Association*, 9(4):591–645.
- . 2017. "Where Modern Macroeconomics Went Wrong." NBER Working Papers 23795. National Bureau of Economic Research, Inc.
- Strohsal, T., C.R. Proaño, and J. Wolters. 2019. "Characterizing the Financial Cycle: Evidence from a Frequency Domain Analysis." *Journal of Banking and Finance*, 106:568–591.
- Taylor, L., and S.A. O'Connell. 1985. "A Minsky Crisis." *The Quarterly Journal of Economics*, 100:871–85.
- Tversky, A., and D. Kahneman. 1974. "Judgment Under Uncertainty: Heuristics and Biases." *Science*, 185(4157):1124–31.
- Van der Hoog, S., and H. Dawid. 2019. "Bubbles, Crashes, and the Financial Cycle: The Impact of Banking Regulation on Deep Recessions." *Macroeconomic Dynamics*, 23(3):1205–46.
- Werner, R.A. 2014a. "Can Banks Individually Create Money Out of Nothing? The Theories and the Empirical Evidence." *International Review of Financial Analysis*, 36(C):1–19.
- . 2014b. "How Do Banks Create Money, and Why Can Other Firms Not Do the Same? An Explanation for the Coexistence of Lending and Deposit-Taking." *International Review of Financial Analysis*, 36:71–7.
- . 2016. "A Lost Century in Economics: Three Theories of Banking and the Conclusive Evidence." *International Review of Financial Analysis*, 46:361–79.
- Wilson, B.A. 1999. "Wage Rigidity: A Look Inside the Firm." Finance and Economics Discussion Series 1999-22, Board of Governors of the Federal Reserve System, US.
- Woodford, M. 2003. "Imperfect Common Knowledge and the Effects of Monetary Policy." In *Knowledge, Information and Expectations in Modern Macroeconomics*, edited by P. Aghion, R. Frydman, J. Stiglitz, and M. Woodford. Princeton University Press.
- Zanetti, A. 2007. "Do Wages Lead Inflation? Swiss Evidence." *Schweizerische Zeitschrift fuer Volkswirtschaft und Statistik*, 143(1):67–92.
- Zarnowitz, V. 1985. "Recent Work on Business Cycles in Historical Perspective: A Review of Theories and Evidence." *Journal of Economic Literature*, 23(2):523–80.