A Simple Model of Financial Crises: Household Debt, Inequality and Housing Wealth

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Abstract

In the aftermath of the 2008 financial crisis, the GDPs of the US and the eurozone have grown astonishing slowly and have not yet recovered their pre-crisis rates, as of 2016. Here, we argue that, in order to escape further sluggish growth, we need to diagnose the present ailments as rooted in the characteristics of growth regimes prior to the crisis. To do so, we use key stylized facts to develop a simple stock-flow-consistent (SFC) macroeconomic model that incorporates a financial and a real economic circuit, household credit and distributive dynamics. As such, it is able to trace stylized growth patterns over the last decades, taking non-linear dynamics into account. The model leads to three main findings. First, positive feedback between financialization and rising income inequality leads, over time, to credit-burdened growth (the Perpetual Money Machine regime). Second, households either consume or speculate with the newly created money giving rise to a bubble, which endogenously bursts in a financial crisis. The GDP collapses, asset prices fall, and the private sector deleverages. Third, in the after-crisis period, the government has room to stabilize GDP temporarily by acting as a borrower of last resort. In so doing, we find that recovering a solid growth requires the government to observe the golden wage rule, namely to re-couple wages and output.

Keywords: Financial Crises, collateral, credit creation, housing wealth

JEL codes: G01, E64, E51

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1 Introduction

The uncomfortable truth is this: The reason we don't really know why recessions happen, or how to fight them, is that we don't have the tools to study them properly. The fact is, there are just some big problems that mankind doesn't know how to solve yet. (Noah Smith, 2014[1])

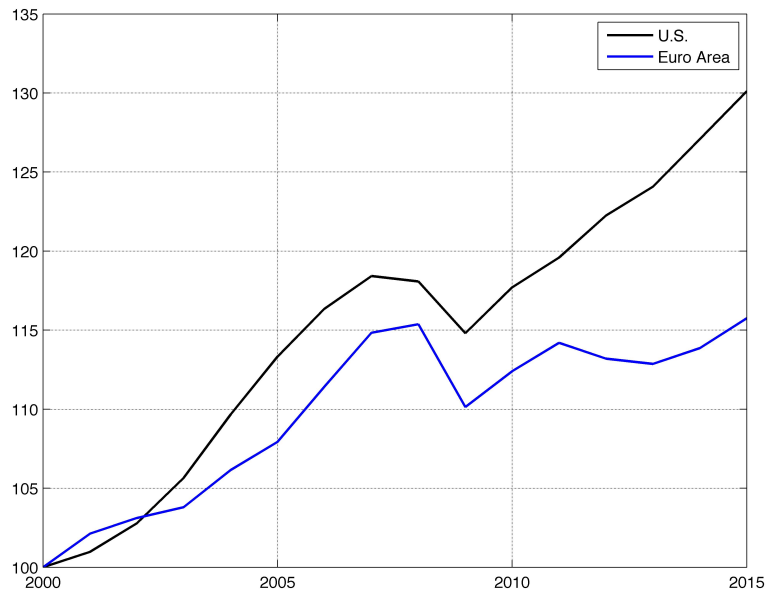

Fig. 1: Real GDP in the United States and the euro area; Index (2000 Q1 =100). While both economies recover similarly until 2011, growth remains particularly subdued in the euro area after 2011. Source: Ameco, authors' calculations.

Since 2008, GDP growth is subdued compared to the pre-crisis years in most advanced economies, including the US and the euro area. This challenges common conceptions of post-crisis recovery, according to which global GDP should have been long back to the pre-crisis trend. In 2008, the IMF for example predicted growth in the US and in particular the euro area to be only a few percentage points below the pre-crisis trend.[2] These growth forecasts, however, have since been (continuously) corrected downwards: In its recent World Economic Outlook[3], the IMF expects the global economy to grow by 3.2 percent in 2016, 0.2 percentage points down compared to the January forecast, 0.4 percentage points lower than the estimate from October 2015 and 0.6 percent points lower than its forecast from July 2015. Similarly, in May 2016, the GDP of the euro area is predicted to grow at 1.5 percent, a downward correction from 1.7 percent in January 2016.

[1] Assistant professor of finance at Stony Brook University, quote from an article on Bloomberg View.
[2] See for example IMF World Economic Outlook Oct. 2013, Fig. 1.13, Real GDP projections: Past and Current.
[3] World Economic Outlook, International Monetary Fund (IMF), April 2016

In the same spirit, the FED continuously revises growth forecasts downwards[4]. Moreover, the OECD announced in 2009[5] that "a recovery is in sight but damages from the crisis are likely to be long-lasting" (OECD (2009)).
However, as Figure 1 shows, real GDP in 2015 in the euro area is barely back to its 2007 level and yet there is no recovery in sight. Indeed, even unconventional monetary policy tools, such as Outright Monetary Transactions (OMTs), have not been able to revive the eurozone, let alone implement the inflation target. The situation is likely to persist as renowned economists warn.[6]
The pattern in the US appears only slightly more favourable with growth estimations for real GDP of merely 0.8% annualized based on the first quarter 2016.[7] However, in contrast to stagnating growth in the eurozone, growth in the US continued to recover slowly after 2011 (see Figure 1).

Why has growth in both economies not gained momentum? What explains the particularly unfavourable situation in the eurozone? The preceding discussion suggests that what happened in 2008 cannot be seen as a 'short-term shock' or an exclusively 'cyclical' phenomenon that will recover automatically. Instead, this situation appears to be the result of a fundamental change in the underlying economic growth regime. In order to escape sluggish growth, we need to take a step back in time and understand the characteristics of growth regimes before the 1980s, between the 1980s and 2008, and in the post-crisis period.
Conventional macroeconomic models in the spirit of the Ramsey Model fall short in capturing major characteristics of these different growth regimes. We take a different modelling approach that builds on the seminal work of Godley and Lavoie (2007) and exploits the only known invariance in economics, namely the stock-flow consistency (SFC). In addition, the analysis builds on i) stylized facts including financialization, income inequality and household debt and ii) a proper understanding of the feedbacks and associated endogenous risks between credit creation and asset prices. Particular attention is paid to potentially non-linear interplays between the financial and the real circuit of a monetary economy. The ultimate objective of this paper is to incorporate these concepts into a new coherent macro-financial model.
This model focuses on the dynamics that lead to a crisis while also addressing the question of optimal post-crisis policy. To this end, different government interventions are simulated and their effects on other economic sectors, as well as on overall growth, are analysed. Based on insights from these simulations, we then discuss the policy measures taken so far and look at optimal future policies to foster growth.

The paper is structured as follows: Section 2 discusses the conceptual and empirical literature. Section 3 presents descriptive statistics for the US and the euro area. Section 4 introduces the model, relates it to the relevant literature and presents the model's simulations. Section 5 critically discusses the model and its policy implications in light of the stylized facts. Section 6 concludes.

[4] Compare the 'Economic Projections of Federal Reserve Board Members and Federal Reserve Bank Presidents'. In January 2012, real GDP was expected to grow between 3.3% and 4% per cent in 2014, while actual real GDP growth in 2014 was 2.4%. Directly after the crash the projections were even worse: In November 2009, real GDP growth was expected to be 3.4-4.5% in 2011 (actual growth rate: 1.6%) and 3.5-4.8% in 2012 (actual growth rate: 2.2%).
[5] Organization for Economic Cooperation and Development (OECD) Economic Outlook 2009
[6] Baldwin et al (2015)
[7] Source: U.S. Department of commerce

2 Literature

"The macroeconomics that dominates serious thinking, certainly in our elite universities and in many central banks and other influential policy circles seems to have absolutely nothing to say about the problem. One single combination worker-owner-consumer-everything else simplified economy has nothing useful to say about anti-recession policy because it has built into its essentially implausible assumptions the conclusion that there is nothing for macroeconomic policy to do". Solow, when the octogenarian gave evidence to the US Congress on the state of mainstream economics in July 2010.

This section discusses the conceptual and empirical literature that focuses on macroeconomic characteristics of advanced economies over the last decades. The literature centers around the following four points: i) financialization, ii) income inequality and debt, iii) credit, and iv) risks and feedbacks in monetary economies. Existing models related to the one presented in this paper are discussed in section 4.

2.1 Financialization

Financialization describes the process by which financial firms, institutions and markets increase in influence and size relative to the non-financial economy. Philippon and Reshef (2012) document the strong increase in wages in the financial industry relative to wages in other sectors: "Workers in finance earn the same education-adjusted wages as other workers until 1990, but by 2006 the premium is 50% on average" (ibidem). Another common indicator to measure financialization is to look at the share of financial profits in overall profits. van Treeck (2009) documents that this share has increased since the 1980s in the US. He further shows that this was accompanied by shareholder value orientation (high dividend-payout ratio) and reluctance to invest in real physical capital. Similarly, Davis (2013) finds econometrically that "[s]hareholder value norms inhibit fixed investment by inducing a shift in managerial priorities towards financial targets." In the same spirit, Sornette and Cauwels (2014) document empirical evidence that the 1980s represent a regime shift away from a productive regime towards what the authors call a "perpetual money machine", where economic growth increasingly relies on financial innovation rather than real productivity. The authors document that, due to a climate of deregulation and strong growth in financial derivatives[8], the growth of the financial sector decoupled from real economic activity - a process inherently unsustainable in the long run. According to these authors, this financial instability is aggravated by incentive structures that turn funding away from the real economy, that is from research and development and the acquisition of new machineries, into financial instruments and financial acquisitions.

[8] The belief that derivatives would spread and diversify risk globally and enhance control was too optimistic: While small risks can be reduced through diversification, non-linear feedback effects between a large number of different risks can give rise to an increase in extreme risks. The recent Financial Crisis is one witness of their existence.

2.2 Demand Patterns: Wages, Profits and Debt

Financialization was coupled with, amongst other factors, rising income inequality. In order to discuss the literature on changing compositions and patterns of aggregate demand over the last decades, we build on the conceptual framework of so-called wage- and profit-led growth regimes of economies (see Lavoie and Stockhammer (2012) for an overview).

In a nutshell, a country is said to be in a wage-led regime if a higher wage share leads to higher economic growth. This is opposed to a country being in a profit-led regime, where a lower wage-share, i.e. a higher profit share, leads to higher economic growth. If a country is in a profit-led growth regime, this does not imply that 'profits are driving growth' but rather that, given the current conditions of the economy, a change in the income distribution in favour of profit recipients boosts economic growth. Given the fact that propensities to consume are higher for wage recipients than for profit recipients[9] and given that firms' investments depend on sales and expected profitability, "a higher real wage increases consumption but reduces investment, in so far as investment depends on the profit margin" (Bhaduri and Marglin, 1990)). Put differently, in theory, an increase in the wage share can lead to both a rise or a fall in national income.[10] Lavoie and Stockhammer (2012) survey the empirical literature on this topic and find that some countries are in a wage-led regime while others are in a profit-led regime. In particular, two studies find that the euro area is in a wage-led regime and five out of eight other studies find that the US is also in a wage-led regime.[11] In this context, it is worth mentioning Naastepad and Storm (2012) who provide an extensive discussion of the different regimes and argue in particular that the world economy at its current stage is in a wage-led regime. These findings are in line with the previous discussion on financialization, where rising profits crowd out fixed investment instead of boosting it.

Following this analysis, growth in the US and in the euro area can be expected to slow down once wage shares fall. According to the ILO (2015) report, wage shares in most countries actually have fallen since the 1980s. In particular, the wage share in the US has continuously declined since the 1980s, as well as in the euro area since its formation (see next section's Figure 2 and Figure 3). However, opposing the slow-growth hypothesis due to falling wage shares, the world experienced growth rates around 3 percent. Moreover, the US and the euro area did not grow particularly slowly in the period between 2000 and 2007, as shown in Fig.1.

This raises the question of how a wage-led economy can grow at such rates while wage shares are declining. Several authors, including van Treeck (2009) and Zezza (2011), propose an explanation to solve this 'puzzle': Private-sector borrowing kicks in and replaces the lack of demand from wage income. In line with this diagnostic, already in 1999, Godley (1999) identified unstable processes developing in the US, putting particular emphasis on the dynamics of household credit. A necessary condition for such household-credit-driven growth is 'easy access to credit' provided by banks. Indeed, the above mentioned authors argue that, due to financial deregulation, securitization and political support for a new 'debt culture', households' access to credit has been increasingly simplified. Stagnating wage income of many households could thus potentially be compensated by

[9] See for example Bowles and Boyer (1995)

[10] Net exports and government spending also affect the outcome, see again Lavoie and Stockhammer (2012) for further reference and a detailed analysis, which lies beyond the scope of this paper.

[11] See table 10 in Lavoie and Stockhammer (2012).

debt.[12]

The question remains, however: why households in actual fact chose to take advantage of these conditions in order to borrow more? One of the answers is that demand for credit increased because households wanted to keep up with their past living standard and/or with the consumption level of households surrounding them. Concretely, van Treeck (2009) argues that the new debt culture was indeed fueled by the so-called 'Relative Income Hypothesis', that is by upward-looking households, who determine their preferred consumption path by comparing themselves to higher income classes. Zezza (2011) documents that these higher income classes gained profound income raises. The macroeconomic implication is that lower income groups dis-save and become net borrowers. In line with this assessment, Bezemer and Zhang (2014) documents that, since the 1990s, domestic bank credit has been reallocated away from lending to non-financial businesses towards lending to households. An expanding literature discusses negative effects on growth and stability of this change in credit allocation. Jorda et al (2014), for example, find that non-mortgage lending plays a minor role in financial crises. In order to understand why household-credit-driven growth has potentially negative effects, we will in the next section discuss another stream of the literature that emphasizes the role of asset prices, money creation backed by collateral, and feedbacks between those variables.

2.3 Credit Creation backed by Collateral

Where does money come from and does it matter? Various schools of thought including monetarism consider money as being 'neutral' in the sense that it does not affect economic activity (in the long run). Cripps and Godley (1984) respond to monetarism and the old system of national accounts in arguing that financial flows and stocks are inherently important for economic theory and economic policy. Along these lines, Schumpeter (1954) and Tobin (1963) emphasize that a large part of the money stock in a modern economy is created by individual commercial banks through credit creation, opposing the money multiplier theory. The Bank of England (see McLeay et al (2014)) supports and Werner (2014) empirically shows that money is indeed created in bank accounts whenever a commercial bank gives a loan, and destroyed whenever the loan is paid back. Von der Becke and Sornette (2014) review monetary theories in detail and stress that money is not literally created 'out of nothing' because it is (usually) backed up by some sort of collateral of the borrower.[13] At the same time, money creation by banks can be limited due to capital and other balance sheet constraints.[14]

Given these insights on money creation, what are the implications for macroeconomic activity? Borio and Disyatat (2015) argue that it is important to take financing seriously, that is to make a proper distinction between real resources needed for production and the means by which goods are traded. This is since, after all, goods are not exchanged for goods as in Ramsey-style mod-

[12] The discussion of two other important aspects that allowed households to compensate the decreasing real wages lie beyond the scope of this article, namely female labour participation and increasing working hours.

[13] "Market-based finance creates money-like securities, which serve as collateral for more credit creation through the hierarchical money loop. From this perspective, most money creation is done by apparent non-money issuance of securities of all types, which acts as money and as the basis for the next level of credit creation [...] Within the hierarchy of money, potentially any asset can be and is generally used as a form of money as well as the collateral for credit. The use of assets, securities, and even derivatives, to create credit is the channel through which capital is used (rather than stored idle) for future innovations and growth." (von der Becke and Sornette, 2014)

[14] See "Where does money come from" by Greenham et al (2012) for an extensive discussion of banks' money creation. See Lipton (2016) for how banks become naturally interconnected in the process of lending.

els, but for claims on goods, i.e. for money. If the economy is expanding, additional purchasing power is needed, which can be created by commercial banks, in addition to the existing one. Put differently: If the resource/production constraint on economic growth is not binding, that is if the economy does not run at full capacity, credit creation and allocation by commercial banks allows the economy to expand its output.[15] Banks can thus fill the "ex-ante wedge between current aggregate income and planned expenditure" (Bernardo and Campiglio, 2013). If, however, no additional credit is created although the economy does not run at full capacity, then the financing constraint is binding and limits output. Such a limitation to output might indeed occur if for example the private sector is deleveraging, meaning if it is using its income to pay back debt instead of demanding goods and services.

The role of banks in creating money in the process of lending, as opposed to lending out pre-existing savings, is also important in the context of savings and investment. In this regard, it is worth quoting Terzi (2016): "The sum of all financial savings of the (resident) private sector can be seen as the total private stock of financial savings that is being matched by the net outstanding liabilities of private residents, the government, and non-residents. [...] This breaks the narrative of financial savings as a source of funds available for investment. In a real-exchange economy, a stored amount of output for consumption can fund the production of a real asset. In a monetary economy, financial savings do not fund production: they need to be validated by debt. A portion of the stock of private financial savings is typically stored in pension funds or private portfolios. Another portion is effectively 'in circulation,' that is, it is frequently transferred as producers (that is, workers and firms) compete for financial assets by selling their labor and their output, and as economic agents swap different financial assets when modifying their portfolio composition. The total existing stock of financial assets is validated by the willingness of other private entities, or the government, or non-resident entities to stay in debt with the domestic private sector. The stock is augmented when new liabilities are issued and diminishes when liabilities are paid off and not renewed."

Given the importance of the dynamics of the financial stock for economic activity, it is crucial to know the variables that determine the augmentation or reduction of financial assets, and credit in particular. Von der Becke and Sornette (2014) extensively discuss why first the amount of assets accepted as collateral, second the leverage, i.e. the amount of debt outstanding divided by the price of existing assets, and third trust or confidence are the three key variables along which credit creation evolves. We will see that the dynamics of these variables is driven by feedbacks between each other, and feedbacks between further economic factors that eventually give rise to an understanding of the financial crisis, opening solutions for growth recovery.

2.4 Feedbacks and Consecutive Risks between the Financial and the Productive Circuit

On a year-to-year basis, various factors can considerably change and affect economic performance including fiscal policy, monetary policy, natural disasters and other shocks, such as oil price shocks. Other variables like the slowly decreasing wage share that we discussed earlier do not visibly im-

[15] Additional purchasing power can also be created by a dis-saving of economic agents. However, this is only true if the dis-saved money is used to buy goods and services rather than to repay debt. Both mechanisms that create additional purchasing power, namely money creation and dis-saving, will be discussed in more detail in section 5.

pact the economy in the short run. Instead, their effect plays out in the long run. Similar to the frog that does not jump out of the water that is slowly being heated up, policy makers and economists frequently underestimate the impact of accumulated small changes that eventually lead to fundamental transformations and regime changes like financial crises.

This phenomenon can be related to the general process of creep in material sciences that precedes and prepares the incipient rupture (Sornette and Cauwels, 2015). It is inherent to many social and natural systems, where a stable phase accompanied by increasing creep can persist for many years or centuries before reaching a critical point that leads to a regime change. In this context, it is important not to get trapped in linear Granger-causality thinking or purely static analysis. The economy is a complex system that does not have room for arguments like 'financialization leads to financial crises'. Instead, typically, an initial instability is aggravated by complex non-linear feedbacks that put the system further away from stability or' equilibrium'. It is verbally challenging to describe, understand, and keep track of all the key dependencies in a monetary economy, which is why economists tend to develop coherent economic models like the one presented in section 4. Yet, several stylized feedbacks have been emphasized in the literature that will be discussed in the following.

Ideas of inherent financial instability go back to Minsky (1975, 1982), who argues that, in boom times, optimism leads to an extension of debt and leverage, which, triggered by the 'Minsky moment' (or tipping point) eventually comes to an end and contracts the economy due to low confidence, falling asset prices and deleveraging. This pro-cyclicality between asset prices and credit growth is also confirmed by Hofman et al (2015), who use historical data to show that significant changes in asset prices are linked to increased financial instability.

In the light of the previous discussion on credit creation backed by collateral, these results can be explained along the following lines. Once new credit is (partially) used for the acquisition of assets that qualify as collateral and are fixed in the short run, the credit creation process drives up collateral prices, thereby enabling more borrowing. Indeed, Greiber and Setzer (2007) argue that assets like houses are typically restricted in supply so that an extension in credit eventually leads to an increase in house prices, leaving consumer prices unaffected.[16] Similarly, if lending is backed by certain assets and channeled to financial vehicles and investors, these asset prices tend to increase. Iceland is a popular example, where credit creation expanded strongly in the 1990s and even more so in the 2000s. Consumer prices, however, were not affected because far-reaching financial deregulation inflated the financial sector, as documented in Sigurjonsson (2005). These findings are in line with Werner (2012), who stresses the importance of money creation as well as the effects of money allocation on economic growth.

Returning to financialization, Corsi and Sornette (2014) argue that the increased reliance on financial returns drives financial prices further up, which, as discussed before, increases collateral and bank lending capacity. As a consequence, a growing share of new credit will be channelled to financial investments. Moreover, Lin and Tomaskovic-Deve (2011), van Treeck (2009) and the ILO (2015) report emphasize that a marginalization of the role of the real economy and institutional deregulation are coupled with significant income inequality. As discussed before, income

[16] If housing collateral is used for productive investment of SMEs (Adelino et al (2015)), house prices might not increase. Ultimately the macroeconomic impact of credit creation backed by houses depends on the allocation of the newly created money. As we will see later, households do not directly invest in productive capacities but use mortgages to fund consumption or to purchase speculative assets like existing housing.

inequality and the relative income hypothesis, in turn, fuel credit demand while financialization and regulatory changes fuel credit supply. The resulting overall credit expansion along with rising asset prices and further financialization sustain the "perpetual money machine" (Corsi and Sornette, 2014). They do so, however, only temporarily because asset prices and debt-to-income ratios cannot grow forever.

Summing up the conceptual discussion, we have seen that the literature on wage- versus profit-led growth indicates that rising income inequality can slow down economic growth. This slowdown, however, can be weakened once excessive household debt kicks in and compensates for the lack of demand. Household debt, in turn, can lead to a bubble in the financial circuit because households' opportunities for productive investment are limited since households either consume or purchase speculative assets. Firms' borrowing for investment in innovative production capacities decreases as a share of overall borrowing. If households increase their leverage, only a fraction of household credit will enter the real economy via consumption - the other fraction will eventually enter the financial circuit. Speculative assets like houses, in turn, are used as collateral for households' borrowing, so that positive feedback eventually leads to an asset price bubble that bursts in finite time. Once the bubble bursts, households deleverage and consumption collapses, thereby contracting real investment and total GDP.
While considerable empirical and conceptual evidence exists to back up this narrative, a simple macroeconomic model that captures the key dynamics and allows one to test and discuss different hypotheses is still missing. This paper proposes a new model to narrow this gap. Before introducing the model, the next section presents empirical facts that support the stylized narrative outlined so far and that will be used to evaluate our model in section 5.

3 Key Empirics: Wage Share, Debt-to-Income and Sectoral Analysis

This section documents empirical evidence supporting the narrative developed in section 2. While there are numerous variables that are potentially relevant for the analysis, we will focus here on a few that we consider indispensable in the context of the US and the eurozone: i) the wage share, ii) households' debt-to-income ratio, and iii) sectoral balances.

The wage share is defined as the ratio between nominal compensation of employees and nominal GDP. Several studies have documented its decline in many advanced economies since the 1980s.[17] Figure 2 shows the wage share in the United States from 1960 to 2015. As we can see, the wage share in the US declined from roughly 62% before 1980 to 57% today. The wage share fell particularly strongly in the early 2000s. After 2008, a small rebound occurred, followed by a another period of decline.
Data for the euro area only go back to 1995. Since then, the wage share has decreased continuously until the global financial crisis hit in 2008 as seen from figure 3. The overall wage share fell from 58% in 1995 to 54% in 2007. Afterwards, a strong rebound can be observed that was followed by a small decline. Since 2010, the wage share has been roughly stable around 56%. Note, however, that considerable heterogeneity exists within the euro area: In Germany, the wage share

[17] See for example the ILO (2015) report

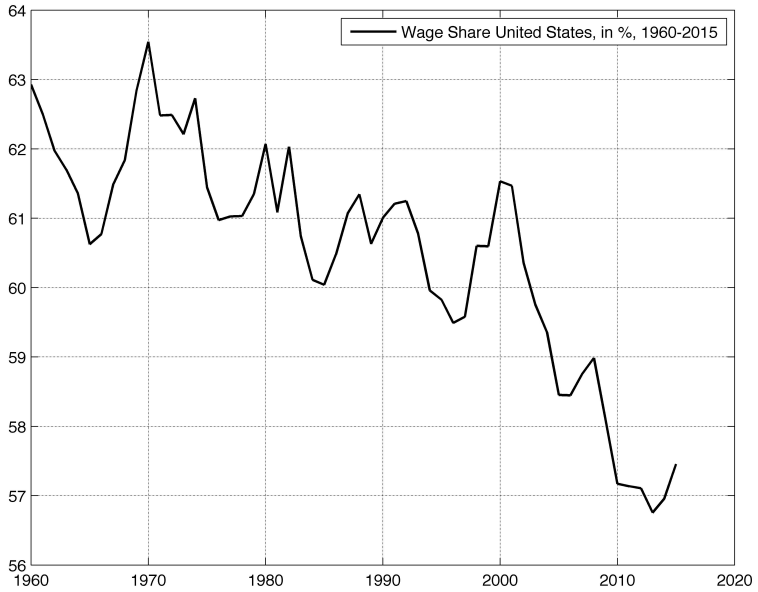

Fig. 2: Wage share in the US defined as employees compensation divided by GDP, as a percentage. The wage share declines continuously since the 1980s with an accelerated decline in the early 2000s. Source: Ameco

Fig. 3: Wage share in the euro area defined as employees compensation divided by GDP, as a percentage. The wage share falls continuously from 1995 before rebounding after 2008. Source: Ameco

decreased from 59% in 2000 to 54 % in 2008 while the wage share stayed constant or increased slightly between 2000 and 2008 in southern Europe.[18]

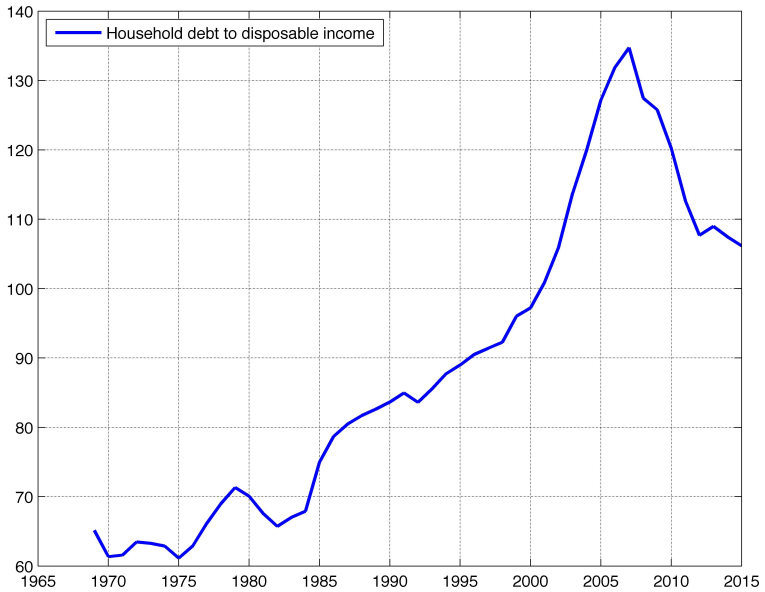

Fig. 4: US Household debt outstanding as a percentage of household disposable income, 1969-2015. The ratio rises continuously until 2008 and falls afterwards. Source: Flow of Funds and NIPA.

Motivated by the discussion in section 2, we are also interested in the magnitude of household borrowing. Figure 4 shows households' outstanding debt as a percentage of disposable income in the US. The ratio rose from slightly above 60% in the 1970s to over 130% in 2007. Note that the rise in the debt-to-income ratio was particularly strong between 2000 and 2007. Since then, the ratio has decreased but remained above 100% in 2015.

Concerning the euro area, household debt and income data are only available for the period after 2003. We can see in figure 5 that the ratio increased from 80% in 2003 to 97% in 2010, followed by a decrease to around 93% in 2015. Similar to the previous discussion on wage shares, debt-to-income dynamics vary considerably among the individual countries in the euro area. In Spain, for example, household debt-to-income increased from 60% to 130% over the mentioned period. In Germany, in contrast, the ratio continuously declined from 105% in 2001 to 80% in 2015.[19]
Finally, let us consider the sectoral balances of the two economies. Figure 6 shows the net financial balances, i.e. the net lending or borrowing of each economic sector in the United States between 1960 and 2015 as a percentage of GDP.[20] Note that corporations mostly ran an annual deficit

[18] For the purpose of this paper, Southern Europe is defined to consist of Spain, Italy and Greece. Source: Ameco.
[19] Source: Eurostat.
[20] The sum of all net financial balances is always zero for a country (taking the rest of the world into account). Clearly, this is not to be confused with *material* assets that usually do not sum up to zero.

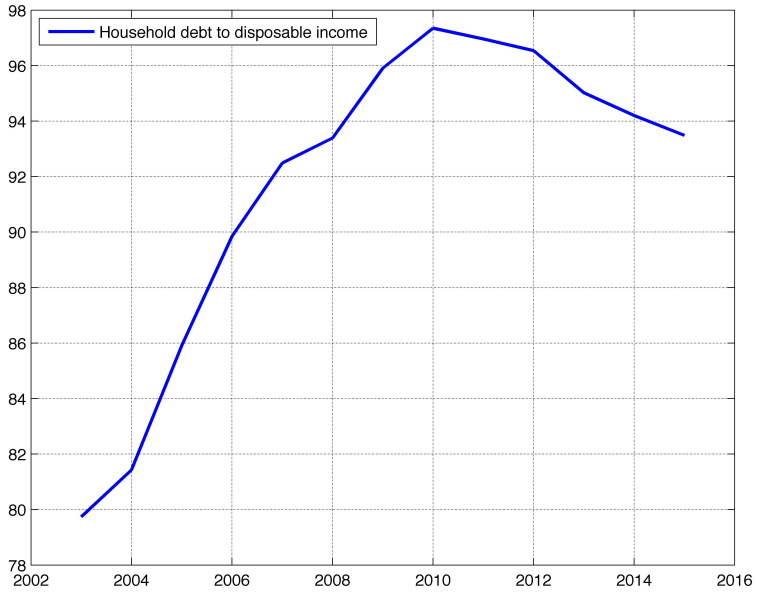

Fig. 5: Household debt outstanding to disposable income in the euro area, as a percentage. The ratio increases over time and peaks in 2010 followed by a slow debt reduction relative to income. Source: Eurostat

before 2000 but became net savers afterwards. Households were typically net savers although the magnitude of savings as a percentage of GDP has been decreasing continuously until 2008, when households became net borrowers. However, after the crisis, households quickly became net lenders again. Since all sectoral balances have to sum up to zero and households and firms became relatively large net lenders after 2008, some sector(s) must have increased their net borrowing. Indeed, the increasing savings of the private sector in the aftermath of the crisis were offset by a government deficit corresponding to 12% of GDP in 2009. The government deficit has since been reduced and was below 5% in 2015. This reduction was mirrored by a reduction in net savings of both the private sector and the rest of the world. The net lending position of the latter has been increasing since 1980 and reached its peak in 2008.

Figure 7 shows the net financial balances for the euro area from 1999 to 2015. The decrease in households' net lending has not been as strong as in the US prior to the crisis but is still visible. Immediately after 2008, households increased their net savings and firms did so even more strongly relative to their previous position. While households' net lending in 2015 was roughly back to its pre-crisis level, firms were still relatively high net savers. Once again, the remaining question is thus who mirrored the relatively high net savings of the private sector after 2008. Immediately after the crisis, the government sector ran a deficit of up to 6%. In the following years, however, the government deficit decreased until it reached 2% in 2015. This reduction in government spending since 2010 has been compensated by an increasing deficit run by the rest of the world.

Summing up the empirical evidence presented in this section, the emerging picture is a falling wage share that was partly offset by household debt. This offset was unsustainable once the debt burden became too large relative to wage income. After the crash, a deleveraging process started. The private sector suddenly became a relatively large net lender and the government (and the rest of the world) mirrored this net lending by increasing net borrowing. Overall this picture is less pronounced for the euro area due to the heterogeneity among its member countries. Consider Germany, the largest economy in the eurozone, where prior to the crisis the wage share as well as household debt-to-income decreased but the current account surplus increased. In Spain, on the other hand, the wage share did not decrease, households' debt-to-income increased more than in the US and the net lending of the rest of the world increased. In section 5, we will discuss in more detail the question of how to interpret the heterogeneity in the eurozone, using insights from the model's simulations.

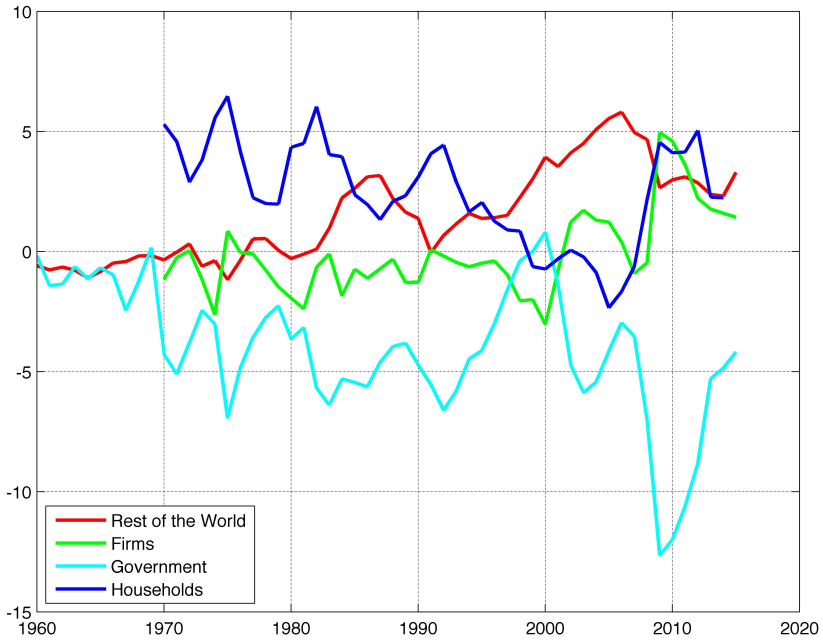

Fig. 6: Sectoral (net) balances of the US as a % of GDP. Increasing government deficit after the crisis mirrors increasing private-sector savings. Source: Ameco

4 The Model

"The fact that money stocks and flows must satisfy accounting identities in individual budgets and in an economy as a whole provides a fundamental law of macroeconomics analogous to the principle of conservation of energy in physics". (Cripps and Godley, 1984)

Motivated by the stylized facts in the last section, the aim of this section is to develop a consistent

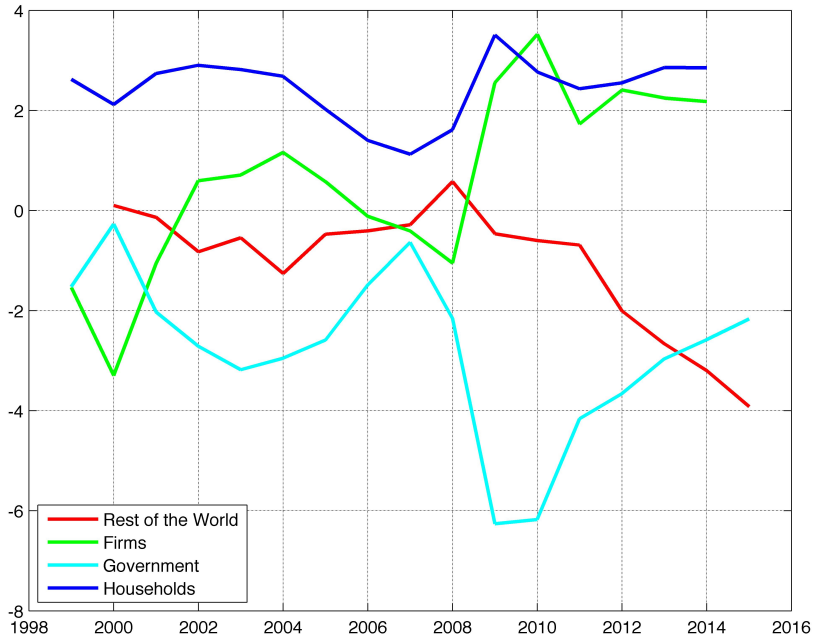

Fig. 7: Sectoral (net) balances for the euro area as a % of GDP. Rest of the world and government deficit mirrors increasing private savings after the crisis. Source: Ameco

analytical framework to test whether feedbacks between financialization, income distribution as well as asset prices are able to track major trends and economic regime shifts in a monetary economy like the US over the last decades. Non-linear feedbacks like the ones between asset prices, collateral and credit are taken into account to allow for criticalities like financial crises. We will see that our model uses only 7 behavioural equations to incorporate these ideas. Moreover, we will see that a crisis does not have to be triggered by exogenous shocks but can be endogenous to our model economy. In addition, and in line with the discussion on the importance of money in section 2, the model economy cannot be a pure exchange economy. Instead, the role of credit creation is incorporated and nominal variables are used. Against this backdrop the model focuses on distributional and compositional determinants of aggregate demand, not on supply-side factors.

4.1 In Search of a Holistic Modelling Framework: Key Model Ingredients and the Importance of Stock-Flow Consistency (SFC)

An interdisciplinary method that has proven useful in order to find a suitable modeling framework for a variety of systems is to look for a symmetry or invariance of the system. The system to be analysed in this paper is a modern macro-economy populated by various agents. The latter ones are typically classified into different sectors, namely households, firms, the government and the rest of the world. In this context, we have seen the importance of finance for economic analysis. Indeed, the only known invariance in economics builds on a trivial, and yet fundamental

insight about finance: every financial flow and every financial stock of one economic sector has a counterpart somewhere else in the economy. Using the words of Godley and Lavoie (2007), who formalized this invariance into so called stock-flow consistent (SFC) models, this can be put as follows: "Everything comes from somewhere and everything goes somewhere". Every purchase or sale by one sector implies another sale or purchase in another sector. And every financial asset in the economy has a corresponding liability somewhere else.[21] The stock-flow-consistency simply exploits double-entry bookkeeping for economic agents, sectors and countries.

In mathematical terms, the sum over all financial assets and liabilities is always zero. Let S_i be the net financial stock of sector i. We can then formulate the stock-consistency by requiring that the sum of all financial assets is zero at any given point in time

$$\sum_i S_i = 0$$

In the case of a closed economy, total household savings plus total firm liabilities plus total government liabilities are equal to zero.

Taking the derivative (or applying the discrete difference operator) with respect to time leads us to the mathematical formulation of the flow-consistency, i.e. of the law that every payment or reception of a financial asset in the economy has a counterpart somewhere else in the economy:

$$\sum_i \partial_t S_i = 0$$

In the context of a closed economy, equation (1) states that the sum of net household lending, net firm lending, and net government borrowing equals zero.[22] In line with this logic, the financial savings of the whole world also add up to zero. Note that if financial balances of all except one sector are known, the financial balance of the remaining sector is also known due to the stock-flow-consistency (the system is 'overdetermined').

The idea to use the described invariance as a basic framework for economic reasoning and modelling is connected to at least two streams in the literature. Economists at Cambridge around Keynes, Kalecki, Cripps, Kaldor and Godley laid the foundations in the anglo-saxon area, whose ground breaking state-of-the-art generalization can be found in Godley and Lavoie (2007). More recently, Bezemer (2009) argues that accounting for macroeconomics, that is incorporating the balance sheets of all sectors, is crucial for an understanding of the economy. Modern monetary circuit is a terminology adopted by a branch in the literature that largely overlaps with the stock-flow-consistent approach (see for example Lipton (2016)). Similar ideas have been developed by German economists in the early 20th century. The theory of bank credit by Hahn (1930) is extended by Lautenbach (1952) who extensively discusses the interplay of credit and production respecting aggregate consistencies. Stützel (1978) further developed the theory that is summarized in his seminal book "Saldenmechanik" ("Balances Mechanics", translation by the authors). Stützel's title suggests a similarity with mechanics in physics and emphasizes that his theory is not per se about

[21] As mentioned earlier, this does not hold true for "real" assets. The whole world has zero net financial wealth but positive real wealth.

[22] While households are typically net lending and the government and firms net borrowing, this pattern can vary over time and has important macroeconomic implications. Indeed, as we have already seen in Section 3, households and firms became net lenders in the post-crisis period.

behavioural economic relationships but also about fundamental and logic consistencies. Indeed, Stützel's work can be seen as the German counterpart of the anglo-saxon stock-flow-consistency. Acknowledging the value of this literature, Bezemer (2009, 2011) identifies four common features of models that predicted the recent crisis: i) having room for two kinds of assets, ii) taking credit flows, i.e. money creation into account, iii) tracing the debt stock, and iv) obeying accounting identities.[23] Most of these factors are traditionally found in SFC models. As we will see later, our model incorporates all of them.

Our model relates to several recent contributions to the SFC literature including Dos Santos and Zezza (2006), who discuss growth and the distribution of income. Similar to our model, wage earners have a higher propensity to consume out of income than firm owners. Dos Santos and Zezza (2008) provide a modern benchmark SFC growth model putting particular emphasis on the financial sector modelling. Van Treeck (2007) focuses on share-holder value orientation and financialization more generally. Similar to our approach, the model is able to trace feedbacks between a real and a financial (stock market) circuit. Lavoie (2008) also studies financialization and the propensity of households to take new loans. The propensity to take new loans for consumption or speculation is also part of our model and depends upon collateral, leverage, wage income and the relative income hypothesis. Finally, as we will see, one of our policy implications is very close to Zezza (2011), who uses a SFC model to emphasize the importance of a re-distribution towards median income households in order to get to a sustainable growth path.

While the stock-flow consistency provides a suitable modelling framework for our investigation, several elements that are not per se associated with the SFC literature are also important. Our model builds on Corsi and Sornette (2014), who propose a reduced form model for the joint dynamics of liquidity and asset prices. Non-linear feedbacks produce explosive dynamics that eventually result in a market crash.

More specifically, our model extends a model of Rozendaal et al (2016) by introducing two assets and by embedding their model into a stylized macroeconomic framework with endogenous GDP and different economic sectors, i.e. households, firms and a public sector. Rozendaal et al (2016) emphasize the importance of credit and in particular of asset prices, leverage and trust, the latter variable determining the fraction of assets that can be used as collateral. As we will see in the next section, introducing behavioural equations for consumption and investment will allow us to trace the inter-connectedness between the real and the financial circuit as well as to follow up on various key economic indicators like GDP, income distribution and sectoral financial flows.

[23] While standard neoclassical models can also be called SFC in some sense, the definition of stock-flow-consistency in the 'Godley' sense that we are using is more specific and does not apply to DSGE models. Zezza (2011) mentions the following crucial features of SFC models: "1. The model is dynamic, and the position of the system in a given period is crucially affected by its previous historical path; 2. The model is consistent, in that every monetary flow is recorded as a payment for one sector and a receipt for another sector. In addition to flow consistency, every relevant stock - of real or financial assets - is linked to a corresponding flow. For instance, the net stock of assets for the household sector changes its value in a given period through household saving and capital gains; 3. The banking system is explicitly represented; 4. Prices do not necessarily clear markets. At any moment in time, the stock of an asset may differ from its "desired" level. Quantity adjustments towards "desired" or "equilibrium" levels for model variables require some buffers; 5. The accounting structure of models adhere to the principles laid down in the System of National Accounts (SNA) for flows, flow of funds and stocks accounting, helping to move from theoretical models to applied models."

4.2 The matrices of our model economy

As usual with the SFC modeling approach, we start out by presenting the stock and flow matrices of our economy. We have a closed economy model with four sectors, namely households, banks, firms and a public sector. As indicated in the balance sheet matrix in table 1, households and firms both can hold deposits M at banks. Moreover, households take loans D^{HH} from banks to finance consumption and to purchase speculative assets from other households. The speculative asset A is owned by households and we assume that it consists of a fixed amount of housing. [24] Firms finance investment out of their cash flow. [25] The commercial banking sector does not make any profits since interest rates are assumed to be zero. There are no bonds or cash in our economy. The only financial asset are deposits. The public sector's role is limited to the ability to bail out households (i.e. to take over their debt), or, interpreted differently, to transfer newly created liquidity to households (see more below).

Table 1: The stock matrix

	Private Sector				
	Households	Banks	Firms	Public Sector	Σ
Deposits	M^{HH}	$-M^{bank}$	M^{firm}		0
Loans	$-D^{HH}$	$+D$		$-D^{GG}$	0
Speculative Asset	A				$+A$
Net Worth (Balance)	$-V^{HH}$	0	$-V^{firm}$	$-V^{GG}$	$-A$
Σ	0	0	0	0	0

Table 2 shows all the transactions that occur between sectors in any given period of time Δt. All sources of funds appear with a plus sign, and all uses of funds have a minus sign. As usual, the first block of lines (first four lines) describes all the flows associated with the national income and product accounts. The subsequent two lines trace the change in stocks of financial assets and liabilities. Consistency is ensured because all columns and rows sum to zero. Firms produce whatever is demanded by households and there are no inventories. Finally, we have to describe the capital and current account of firms. Following Godley and Lavoie (2007, p.220): "Firms sell the fixed capital goods they produce, and this appears with a plus sign in the current account column, since this is a source of income. But they also acquire these fixed capital goods - their investment - and these appear with a minus sign in the capital account column, since these investment goods purchases are a use of fund."

[24] Note that the speculative asset could consist of a variety of assets, like for example tulips, IT companies or crypto coins. The speculative asset has the characteristics that its supply does not move much compared to the overall market capitalization, or that its supply increase is not very GDP-relevant (think of creating new crypto coins with a few mouse clicks that have no intrinsic value).

[25] Note that credit-financed investment can easily be included but does not change the important dynamics as will become clear later.

Table 2: Transactions-flow matrix

	Households	Banks	Firms		Public Sector	Σ
			Current	Capital		
Consumption	$-C$		$+C$			0
Wage income	$+W$		$-W$			0
Investment			$+I$	$-I$		0
Public Transfers	$+G$				$-G$	0
Δ deposits	$-\Delta M^{HH}$	$+\Delta M^{bank}$	$-\Delta M^{firm}$			0
Δ loans	ΔD^{HH}	$-\Delta D$			ΔD^{GG}	0
Σ	0	0	0		0	0
			(Profit + Fin. Assets)			

4.3 The Model - Equations

Time is discrete and indicated by subscript t. The following notation for the difference operator is used: $\Delta D = D_t - D_{t-1}$. We use $:=$ and $=$ to distinguish definitions from behavioural equations. We start with the usual income-demand identity: Nominal GDP is defined as consumption plus investment in a closed economy with no government (A government sector will be introduced in section 4.5 as an extension.):

$$Y_t := C_t + I_t \tag{1}$$

4.3.1 Household Sector

As we have just seen, households own housing. [26] Households can use their housing wealth as collateral to borrow money for consumption and to borrow for financial speculation. [27] Consumption plans are made prior to the realization of household income. Desired consumption is determined by the Relative Income Hypothesis, which states that the utility or satisfaction that individuals derive from a certain consumption level depends on the consumption level in relation to a weighted average of the consumption patterns of other people in the economy - and not solely on the absolute level of consumption. The Relative Income Hypothesis goes back to Duesenberry (1949). [28] Due to a boom in the literature on the economics of happiness and a growing body of empirical evidence (see for example Oswald (1997) and more recently Clark et al (2008)), interest in the Relative Income Hypothesis has increased over the last 20 years. Dijk et al (2010) build on Duesenberry and develop a theory of expenditure cascades, where context and evaluation affects consumption decisions. Along these lines, Bertrand and Morse (2016) create a trickle down consumption theory and Christen and Morgan (2005) show that desired consumption is such as to "keep up with the Joneses"(ibda). The Relative Income Hypothesis is modeled by assuming that households desire to consume a constant fraction $\bar{\lambda}$ of what the expected national income would be. Expected national income is a simple extrapolation from previous GDP growth. Put simply, if the overall economy recently grew by 5%, households desire to increase their consumption in a

[26] In the following we will use both terms, housing and speculative asset, in a substitutable way.

[27] Passarella (2011, 2014) follows a different approach and splits firms into two different sectors. Only one sector is allowed to invest in financial markets. Similar to our model, production and asset price evolution can be analysed simultaneously.

[28] "The strength of any individual's desire to increase his consumption expenditure is a function of the ratio of his expenditure to some weighted average of the expenditures of others with whom he comes into contact" (ibda)

proportional way. Desired consumption is thus

$$C_t^e := \bar{\lambda} \cdot (1 + g_{t-1}) \cdot Y_{t-1} \tag{2}$$

where $g = \frac{\Delta Y}{Y}$ is the growth rate of the economy. The feasibility of this consumption path is determined by households' available funds. In our model, households receive wage income in return for their labour, are able to borrow additional money from banks, and can use their savings (existing deposits). Potentially, there is an ex ante gap between current income and planned expenditure, similar to the dynamics of the model of Bernardo and Campiglio (2013).[29] If the financing constraint of households is binding, the actual realized consumption will be lower than desired consumption: [30]

$$C_t = \min\{C_t^e, W_t + \Delta D_t^{HH} + M_{t-1}^{HH}\} \tag{3}$$

where W_t is the wage bill determined by a bargaining process between workers and employers (see later),ΔD is the net increase in household debt, and M_t^{HH} is the amount of household deposits. We will see later that an increase in household deposits reflects speculation in the financial circuit, i.e. purchasing of houses from other households, driving up house prices. [31]
Since deposits are the only financial asset in our economy, households' financial balance is equal to net borrowing or lending (flow). Net borrowing or lending is

$$F_t^{HH} := W_t - C_t \tag{4}$$

and the net stock of financial assets of the household sector is the sum over all past flows:

$$S_t^{HH} := \sum_{i \leq t} F_i^{HH} \tag{5}$$

Note that the net stock of financial assets is not equal to D^{HH} because households also hold deposits for the purpose of speculating in the housing market.

4.3.2 Leverage, Debt and Trust

Household leverage is defined as

$$L_t^{HH} := \frac{D_t^{HH}}{A_t} \tag{6}$$

where D_t is the gross debt stock of households and A_t is housing wealth (or the price of the speculative asset more generally).

[29] The ex ante gap is also in line with Zezza's key ingredients for a 'crisis model': "At any moment in time, the stock of an asset may differ from its "desired" level." (Zezza, 2011)

[30] It is important to note that this budget constraint is a monetary one in line with the discussion on money in section 2, and more precisely in line with the call of Eeghen (2014) to prioritize the money budget equation over the real resource constraint. DSGE models, in contrast, primarily focus on the resource constraint.

[31] Withdrawal of money from the financial circuit is equivalent to a sale of houses. We will see later that such a withdrawal reduces the price of the speculative asset.

Household's credit expansion is limited by households' collateral. Collateral is equal to a fraction of housing wealth and we call this fraction trust T. High trust and high housing prices, for example, do allow for high levels of debt:

$$D_t^{HH} \leq T_t \cdot A_t \tag{7}$$

Building upon Rozendaal et al (2016), we introduce the dynamics for debt and trust. We assume that trust increases when it is above leverage. On the other hand, trust is expected to decrease if leverage is above trust:

$$T_t = T_{t-1} + k \cdot T_{t-1}(T_{t-1} - L_{t-1})(1 - T_{t-1}) \tag{8}$$

where k is a positive constant. This expression has the form of a discrete logistic equation (most common S-shaped function), whose fixed points are at $T = 0$, $T = L$ (for a constant L) and $T = 1$, thereby making sure that Trust stays within the range of 0 and 1. Similarly, debt tends to increase if collateral is larger than debt and vice versa:

$$D_t^{HH} = D_{t-1}^{HH} + a \cdot (T_{t-1} \cdot A_{t-1} - D_{t-1}^{HH}) \tag{9}$$

where a is a constant. Households are optimistic and willing to borrow more, that is increase leverage, if trust and/or asset prices are very high compared to the existing debt stock. [32] Note that the evolution of household debt (eq. (9)) incorporates the key concept that banks' loan supply is limited by collateral as described in eq. (7).
While demand and supply for debt could be modeled in more detail, the chosen functional form reflects stylized facts as discussed in section 3 and, at the same time, ensures traceability of the model.

4.3.3 Financial Circuit

As we have seen before, the economy is divided into households, banks and productive firms (and a public sector later on). What we call 'financial circuit' is part of the household sector and describes the dynamics of housing wealth. We assume that households use deposits within this financial circuit to buy and sell existing housing from other households. Given the debt dynamics D_t (eq.9), the consumption patterns of households C_t (eq.) as well as the wage bill W_t (will be determined later on), we can determine the net increase or decrease of households' deposits in

[32] Rozendaal et al (2016) also propose an alternative debt equation that takes the trend of assets and trust into account:

$$D^{HH} = D_{-1}^{HH} + a \cdot (T_{-1} \cdot A_{-1} - D_{-1}^{HH}) \cdot \Delta t + \Delta(TA) \tag{10}$$

The additional term $\Delta(TA)$ can boost or slow down the change in debt. Preliminary analysis shows that this additional term results in the same major outcome of the model, that is the economy enters the long-run growth regime or the financial crash regime. The intuition behind this similarity will become clear in section 4.3, where we discuss the simulation results of the model. Given that, in the SFC modelling spirit, most behavioural equations of our model take only previous flows and stocks into account, we follow this spirit and do not include the additional trend term. Future research, however, could focus on a more fundamental, behavioural justification for the functional form of the debt equation.

each period:

$$B_t^* := \Delta D^{HH} - (C_t - W_t) \tag{11}$$

If, by simple accounting, households borrow more than they need to fulfill the desired consumption path, gross deposits of the households sector increases by B^*. If, however, households' desired consumption cannot be satisfied by wage income and new debt, households can use existing deposits to finance consumption expenditures. The stock of households' deposits is thus given by:

$$M_t^{HH} := M_{t-1}^{HH} + B_t^* \tag{12}$$

4.3.4 Households portfolio choice

The higher households' deposits, the more funds chase a fixed amount of housing, thereby driving up the house price. Vice versa, a withdrawal of deposits from the financial circuit (caused by a need of funds for consumption) causes a reduction in the house price.
Housing wealth is

$$A_t = P_t \cdot e_t \tag{13}$$

where P_t is the price and e_t the number of housing. We assume the latter to be fixed, leaving GDP unaffected. GDP is only indirectly affected because asset prices influence households' consumption and firms' investment decisions. We build on Godley and Lavoie (2007) to determine households portfolio optimization. Housing wealth as a share of overall gross wealth is constant:

$$\frac{A_t}{A_t + M_t^{HH}} = \beta \tag{14}$$

or:

$$A_t = \frac{\beta}{1-\beta} \cdot M_t^{HH} \tag{15}$$

where M^{HH} is determined in equation (12), and β is a constant. [33]
The return r_t^A on the speculative asset is defined as

$$r_t^A := \frac{\Delta A_t}{A_t} \tag{16}$$

Decreasing interest rates played an important role in maintaining an increasing debt stock in the US and the euozone. [34] For simplicity, however, we assume zero interest rates. [35]

[33] Following Fisher (1911) and the Quantity Theory of Credit by Werner (2012), $\frac{\beta}{1-\beta}$ can also be seen as the velocity of money in the financial circuit, which we assume to be stable. See also Senner (2018) for a detailed discussion of the empirical estimation of the equation of exchange.

[34] Borio and Disyatat (2015) show in a voxeu.org article from 2014 that interest rates declined since the 1980s. At the same time the debt stock increased - the latter probably not being possible without the former. The authors also discuss how policy intervention keeps rates low in booms and lowers them after a crash, resulting in an overall downward bias of interest rates in the long run.

[35] We will see later, however, that this simplifying assumption is supporting one regime with long-run growth and ever increasing debt.

4.3.5 Firm Sector

The real production side of the economy has to be modeled in order to keep track of the spill-overs and feedback loops from the financial sector.
Firms (or business owners) form a group distinct from households. Firms can make profits and they invest in machinery and equipment according to aggregate demand and profit incentives. Motivated by the fact that the propensity to save out of profits is considerably higher than the propensity to save out of wages,[36]
we assume that firms do not consume at all but invest and eventually save retained earnings. Retained earnings cannot be invested in the speculative asset and are held in cash.[37] The financing of firms is not directly modeled, meaning it is not modeled how firms borrow money (limited by their capital stock, which serves as collateral). We assume that firms' financing constraint is never binding so that all desired investment plans are financially feasible.[38] Firms take investment decisions according to:

$$I_t = I_{t-1} + \alpha \cdot I_{t-1} \cdot g_{t-1} \tag{17}$$

While more sophisticated versions of an investment function are possible, [39] they do not add much value since we are interested in extracting the key interactions between collateral, household debt and housing. We thus take the most simple functional form for the investment function, where firms are backward looking on past GDP growth. In each period, the firms' profit bill equals:

$$\Pi_t := Y_t - W_t \tag{18}$$

Firms' net financial position (flow) is equal to the profit bill minus investment

$$F_t^{firm} := \Pi_t - I_t \tag{19}$$

Note that the flow-consistency of the model can be seen along the following lines. Plugging $\Pi_t = Y_t - W_t$ in the last equation and replacing Y_t with $C_t + I_t$, the net lending or borrowing of the firm sector becomes $C_t - W_t$, which is equal to the negative net borrowing or lending of the household sector. Unsurprisingly, the sum of the flows is equal to zero.

[36] Bowles and Boyer (1995) for example find that in several countries the propensities to save out of profits are 0.4 higher than out of wages.

[37] If the investment induced by demand incentives is smaller than income, firms will retain profits in cash and become net savers. While cash holdings of firms increased in the US (see for example research by the St. Louis FED), they still only make up a fraction of total non-financial firms' financial assets. By restricting firms to exclusively hold cash, we ignore the increasing financialization of real firms, i.e. the fact that non-financial firms also increasingly relied on financial profits over the last decades. Motivated by the literature discussion in section 2, however, we focus on the overall more important behaviour of private households (including speculators and financial firms).

[38] While firms' leverage increased in the US, it did not increase as much as household leverage. Firms' leverage is therefore ignored in order to focus on household debt.

[39] A more sophisticated version of the investment function could take into account that investment growth depends positively on the change in the profit share, and negatively on the return of the speculative asset: $I_t = I_{t-1} + \alpha_1 \cdot \Delta\tau \cdot I_{t-1} + \alpha_2 \cdot I_{t-1} \cdot g_{t-1} - \alpha_3 \cdot I_{t-1} \cdot r^A_{t-1}$ or formulated in growth rates: $g_I = \frac{\Delta I}{I} = \alpha_1 \Delta\tau + \alpha_2 g_{-1} - \alpha_3 r_{F,-1}$. The negative effect of the rise of the speculative asset on the investment decisions incorporates the idea of a human capital flight to the financial sector as well as a crowding out of real investment due to financialization more generally, in line with the discussion in section 2. However, this more complex investment function does not fundamentally change the dynamics of our model economy.

The net stock of claims or obligations towards the other sector in the economy is:

$$S_t^{firm} := \sum_{i \leq t} F_i^{firm} \tag{20}$$

Note more generally that a stable price level of the real economy is implicitly assumed so that GDP, for example, is a measure of real output of the economy and not subject to inflationary or deflationary distortions. The rationale behind this is best explained in Hofman et al. (2015). The authors argue that the CPI (Consumer Price Index) is not the main problem after a financial crash, but rather asset price deflators and in particular housing price deflators. In line with our model, the authors find that "the most damaging interaction appears to be between property price deflations and private debt" (Hofman et al., 2015). Constructing a model for advanced economies, where high levels of GDP inflation or deflation were rare over the last decades, this assumption does not appear to be very restrictive but simplifies the model a lot.
As a consequence, if households increase their borrowing to spend more on consumption, real GDP increases directly. This implies that the economy is not running under full capacity, i.e. we assume that the economy is not constrained with respect to production. If, however, households borrow for financial speculation, then asset prices are inflated immediately.

4.3.6 Collective Bargaining determines Income Distribution

Following Taylor (2010), the wage share is determined by historical forces and policy intervention - as opposed to the marginal productivity of labour on the 'perfect labour market'. Apel (2015) discusses income inequality promoting policies in the US and their connection to the decreasing bargaining power of workers and financialization. The author calls for the inclusion of such dynamics into macroeconomic models. We attempt to do this by modelling institutional, political, economic and lobbyistic forces through a wage share that depends a priori negatively on the financial savings of firms (or firm owners), and thereby reflects the relationship between financialization (characterised by a net saving firm sector) and income inequality. Workers (households) and firms bargain over the potential output of the next period and the workers receive ex ante a share λ^e:

$$\lambda_t^e = \lambda_{t-1} - \max(\sigma \cdot \frac{S_{t-1}^{firm}}{Y_{t-1}}, 0) \tag{21}$$

where σ is a non-negative constant. The max operator incorporates the asymmetry of financialization. This means that if firms are net borrowers, there is no increase in workers' bargaining power.
Based on this bargaining, the following wage bill is determined in the beginning of the period:

$$W_t := \lambda_t^e \cdot Y_{t-1} \cdot (1 + g_{t-1}) \ . \tag{22}$$

Put differently, based on a linear extrapolation of past GDP, workers and firms make a contract determining the wage bill for the coming period. The wage is thus determined in the beginning of the period and before GDP actually realizes.[40] Note, however, that for comparability with true

[40] In advanced economies, relatively few people work in the informal economy without a working contract. As a consequence, wages are sticky and pre-determined.

wage share data later on, it is important to consider the ex post wage share:

$$\lambda_t := \frac{W_t}{Y_t} \tag{23}$$

The actually realized wage share λ_t might differ from the ex ante wage share. The latter is the result of the bargaining process in equation 21. Equation 22 then determines the wage for the coming period before consumption and investment decisions are made. As a consequence, the actual wage share that realizes over the period can differ as households could suddenly deleverage and use all their income to repay debt. This, in turn, would contract consumption as well as the denominator of the wage share, i.e. GDP. As a consequence, the actual wage share would be higher than the initial bargaining outcome of firms and workers.

On a more general note, observe that the individual firm is always maximizing profits and tries to lower labour costs. For the individual firm, the wage is solely a cost and not a source of income. For the whole economy, however, wages are both, costs and sources of income. Equation 21 states that financialization gives the individual firm more power to pursue its profit maximization, while workers receive less power to argue for more spending power.[41]

[41] This argument reflects the basic idea of the popular 'Paradox of Thrift'. Note furthermore that Stützel's 'economic sentences', where one particular sentence for the individual firm might not be translated into a sentence for the whole economy.

4.4 Simulation Exercises

In this section, we feed the model developed in the previous section with concrete parameters to simulate the dynamic evolution of our economy. The economy has two different regimes: in the first case, a long-run growth regime occurs with ever increasing asset prices and debt levels; in the second case, a financial crisis with a total crash of the economy occurs. Our model economy can be in two different regimes depending on the parameter values. [42] These two regimes will be discussed in the following.

4.4.1 Regime 'Infinite Perpetual Money Machine'

For one set set of parameters the economy grows forever, with ever rising debt levels and household prices. Figure 8 shows such a scenario that we call the 'infinite Perpetual Money Machine'. [43] GDP, investment and consumption all grow steadily. At the same time, the decreasing wage share (Fig. 8 (f)) is compensated by growing household debt relative to income (Fig.8 (e)). This increasing debt is enabled by trust converging to its maximal value (Fig.8 (f)) and ever growing housing prices (Fig.8 (h)). As a consequence, households cumulate a growing deficit position vis-à-vis the firm sector. The return on housing wealth increases and remains considerably higher than GDP growth (Fig.8 (g)). Note furthermore that firms invest out of the cash flow. Their aggregate income is thus larger than their expenditures so that they become net savers.

How should the scenario 'Infinite Perpetual Money Machine' be interpreted? Within the modelling assumptions and for certain parameter constellations, no crisis occurs and real growth is stable. In reality, however, it is questionable whether ever rising income inequality along with high debt to income ratios are stable once, for example, (even small) interest rates are taken into account. Moreover, it is likely that the instability may come from channels not modeled here, such as unrest, insurrection, revolt, revolutions and political regime changes, as suggested from the historical record (Graeber, 2011).

4.4.2 Regime 'Financial Crisis'

If we increase sigma gradually we will enter a new regime where the ecoomy crashes after a finite time, see figure 9. [44] A financial crash occurs and the economy collapses. The wage bill falls back behind consumption (Fig. 9 (b)) and is, as in the previous scenario, compensated by growing household debt (Fig. 9 (e)). Household debt to income (Fig. 9 (e)) rises and reaches its peak *before* the crash.[45]

As opposed to the previous simulation the economy crashes. What is the underlying mechanism that creates this crash? Note that the crash is not caused by an exogenous shock to one of the parameters or variables. Rather, the crash is the outcome of a multidimensional interplay of different dynamics. The basic drivers can be understood along the following lines. Debt cannot grow at the desired speed to allow for the desired consumption. At some point, households are forced

[42] The model's matlab code, a documentation of the implementation and a sensitivity analysis is available from the authors upon request.

[43] A terminology adopted from Corsi and Sornette (2014) and Sornette and Cauwels (2014).

[44] A variety of different input parameters can lead to a crash. In the example shown, the only difference to the previous scenario is a higher sigma.

[45] This modeling result indicates that a close observation of the debt-to-income dynamics could potentially predict a crash.

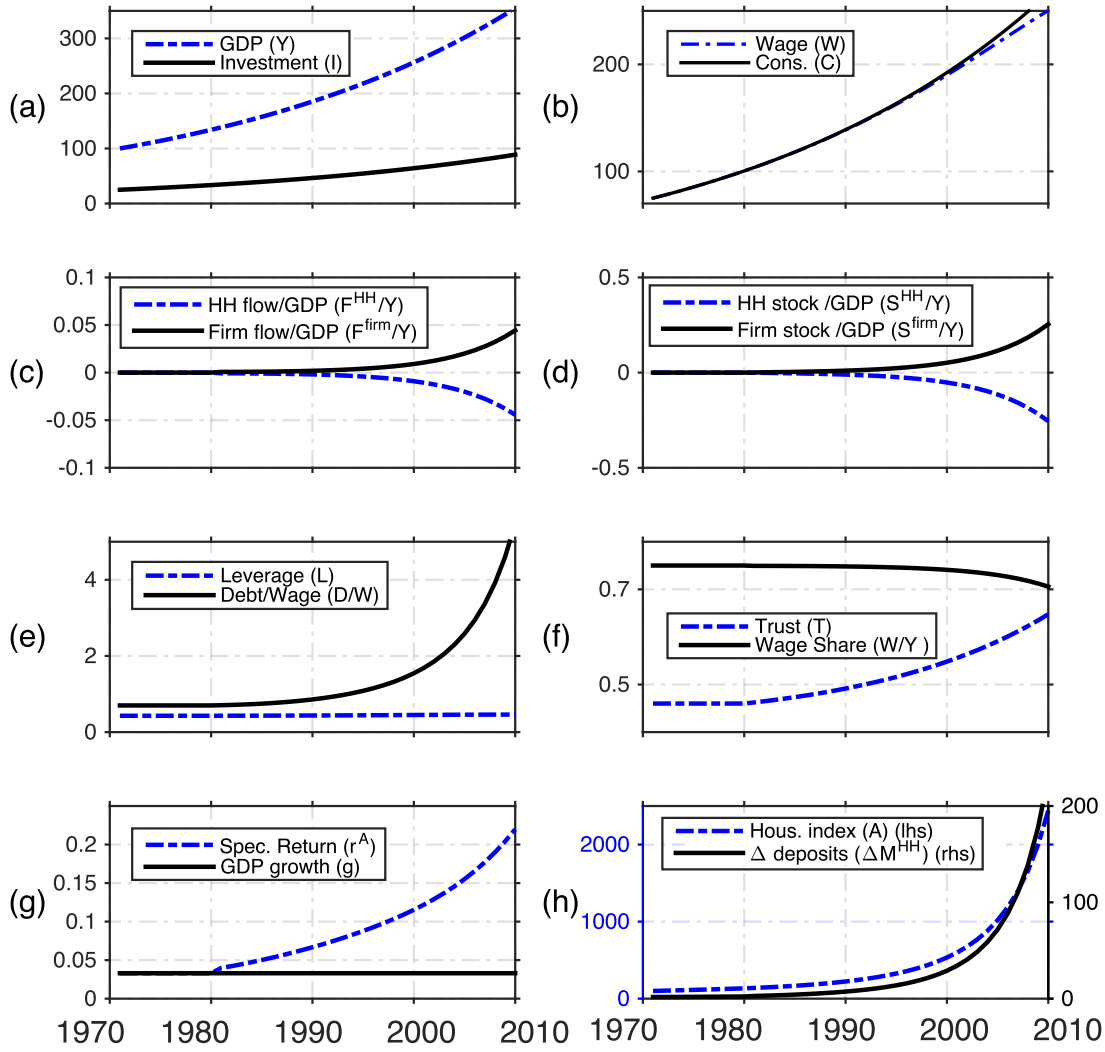

Fig. 8: Scenario 'Infinite Perpetual Money Machine' with long-run growth, ever increasing household debt and rising asset prices. Input Parameters: k=0.3, a=0.6, $\sigma = 0.03$, $T_0 = 0.5$

to use money from the financial circuit for their consumption expenditures. They thus withdraw money from the financial circuit, which can be seen by shrinking households' deposits (Fig. 9 (h)). As a consequence, the asset price falls and households are forced to withdraw even more money as the collateral shrinks. This means that households' leverage sky-rockets (Fig. 9 (e)). In order to decrease leverage, households use their labour income to repay debt, which contracts consumption expenditures (Fig. 9 (b)). Firms' income suddenly drops while they continue having to pay contractually pre-determined wages.[46] Firms react to lower demand by decreasing investment (Fig.

[46] Recap that the wage was determined in the beginning of the period, see section 4.2.

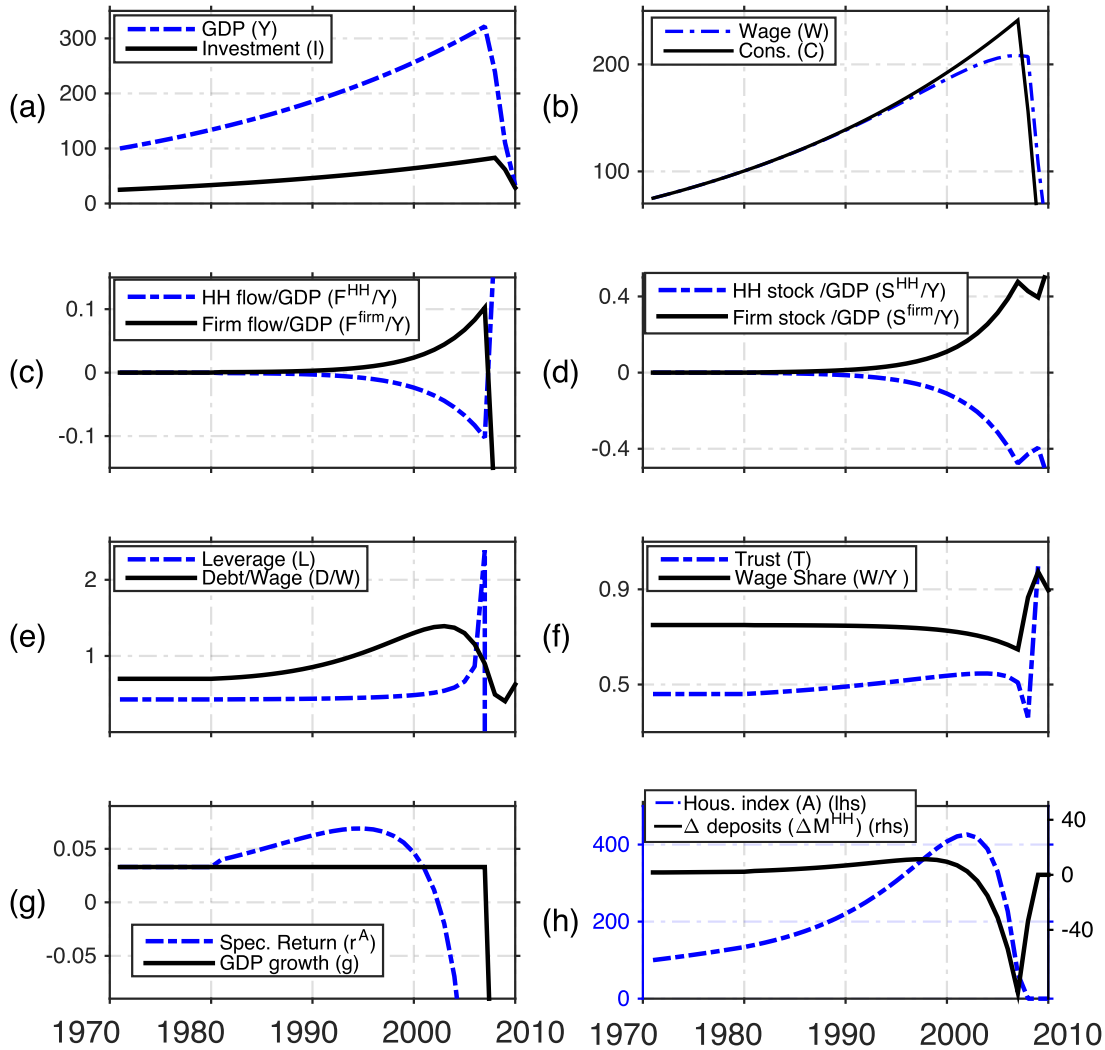

Fig. 9: Scenario: endogenous crash. Input Parameters: k=0.3, a=0.6, $\sigma = 0.05$, $T_0 = 0.5$

9 (a)). These factors ultimately force firms to become net borrowers (Fig. 9 (c)). The interplay of all these factors results in a total collapse of the economy.

From a households' perspective, there are two important forces at play. We know that the net increase or decrease of households' deposits in each period is $B^* = \Delta D - (C - W)$. If B^* turns negative, this means that the first component, namely increasing debt, cannot compensate for the second term, the wage-consumption gap. The first term (ΔD) can increase if asset prices and trust are supportive. At some point, however, the latter factors are not supportive enough so that ΔD becomes too small relative to the second term $(C - W)$. Indeed, the wage-consumption gap continues to grow as wages are further and further depressed relative to GDP. Once collateral,

consisting of trust and the speculative asset price, is no longer high enough to allow for a sufficient debt increase, households withdraw money from the financial circuit and thereby trigger a downwards spiral.
To put it yet another way, the purchasing power shortage in the real sector forces households to withdraw their money from the financial circuit. This action lowers the value of the speculative asset, which, in turn, lowers the collateral. This offsets a deflationary spiral because income is used to repay debt. The immediate contraction of GDP is contagious and followed by further contraction due to firms' investment decisions.
Before discussing these simulations in more detail in section 5, we will extend the model and introduce a public sector.

4.5 Extension: Introducing a Public Sector

So far, the model economy either grew forever in what we called an Infinite Perpetual Money Machine regime, or the economy ended in a financial crash. We will now focus on the latter scenario and consider the following question: What are the assumptions that hinder our model economy from exhibiting a (moderate) rebound after the crash? A total collapse of an economy rarely happens in the real world. The natural stabilizer in times of crisis is the government and the monetary authority, who serve as a spender and borrower/lender/dealer of last resort - both institutions have so far been ignored.
In this section, a very simple authority, consisting of a government and/or a central bank is introduced that intervenes as soon as consumption drops. [47] The public authority channels newly created liquidity to the financial circuit, which corresponds to the money withdrawn by households:

$$G_t = max(-B_t^*, 0) \tag{24}$$

As a consequence, compared to the model without an authority, the amount of funds in the financial circuit available to the household sector increases by G_t:

$$M_t^{HH} = M_{t-1}^{HH} + B_t^* + G_t \tag{25}$$

The economic rationale is that the central bank and the government buy the collapsing assets from households. A different interpretation of this modeling approach would be that households default on part of their debt and the authority takes over those liabilities, i.e. bails out households/banks. Note that this kind of authority intervention is not related to any direct purchase of goods or services and accordingly does not, by definition, directly affect GDP. Still, national income will indirectly be affected because the government takes over households' debt and thereby relaxes households' budget constraint (equation 4.3.3). The relaxed budget constraint will allow households to consume more during the deleveraging process compared to the scenario without a public authority.

[47] Both actors are modeled as one authority and the terms government and central bank or monetary authority are used interchangeably from now on.

Net financial borrowing or lending of the government sector (GG) is:

$$F_t^{GG} := -G_t \tag{26}$$

and the net stock of financial assets of the public sector is the sum over all past flows:

$$S_t^{GG} := \sum_{i \leq t} F_i^{GG} \tag{27}$$

The next section presents new simulations with the public authority.

4.6 Simulation Exercises with Public authority

4.6.1 Public sector bailout

Incorporating a government sector into the model requires no new initial parameters since the government's reaction, as defined above, is completely determined by the other economic agents' collective outcome. We use the same set of parameters as in the crash scenario above.

In (Fig. 10), the government starts intervening after the crash and bails out households. This policy allows households to deleverage, that is to repay debt and use wage income again for consumption expenditures (Fig. 10 (d) and (b)). At the same time, this policy results in a high public debt to GDP ratio (Fig. 10 (d)). Such a bailout is able to postpone the crash, but not able to avoid it. The reason is that firms' profits continue to increase after the crisis, and so does firms' bargaining power. As a consequence, the wage share falls dramatically. Wage income, and therefore demand, collapsed.

4.6.2 Adding Wage Policy to the Public Sector Bailout

Against this backdrop, we finally introduce a more powerful public authority in the sense that it is able to re-set the wage share to an earlier level as well as to set σ to zero. Fig. 11 shows the scenario that we call the 'golden wage rule scenario'. [48] In this scenario government intervention allows the private sector to become a net saver: while firms are net borrowers shortly after the crash due to sticky wages, they become net savers shortly afterwards like households (Fig. 11 (c)). The public sector takes the counter position for these savings and runs a deficit. The implementation of the golden rule allows the government to decrease deficit spending relative to GDP over time: households now receive a constant wage share out of the cash flow of firms, which is sufficient to achieve the desired consumption path. Government intervention allows households to repay their debt quickly and to use their income for consumption expenditures, which prevents consumption demand from collapse. Note furthermore that public debt-to-GDP decreases over time (Fig.11 (d)) because it is diluted by growing GDP ((Fig. 11 (a)). [49] On the other hand, firms dis-save due to the implementation of the golden rule, which decreases their savings ((Fig.11 (d)). Trust and asset prices are stabilized (Fig.11 (f) and (h)). Finally, as discussed earlier, the (ex-post) wage

[48] Following the German terminology of a golden wage rule ("goldene Lohnregel") where national wages increase with productivity (plus the desired inflation rate). The terminology is also used in a more recent article by Watt (2010) (see also (Watt, 2007)).

[49] Public sector debt is not repaid, but, rather, the economy 'grows out of debt'.

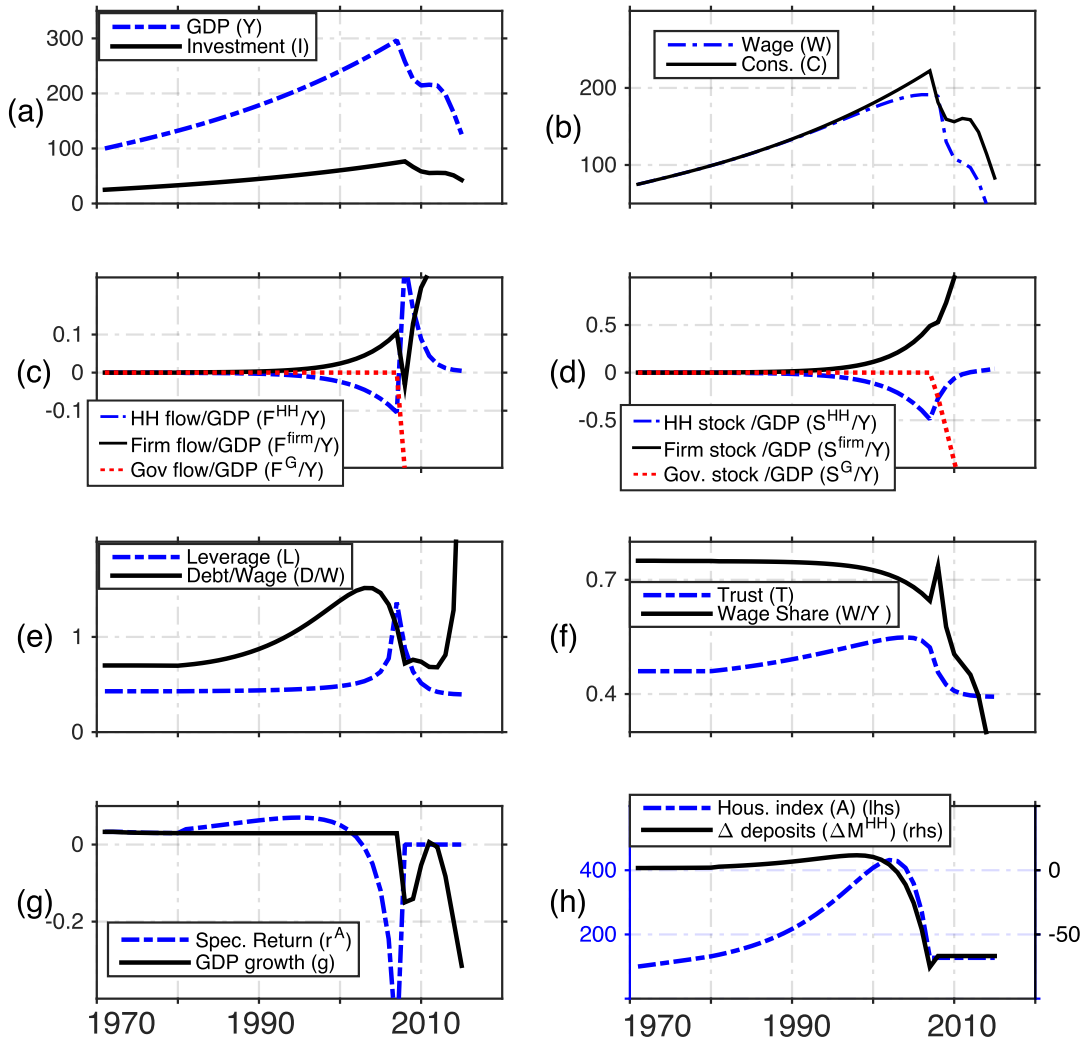

Fig. 10: Public Sector intervenes and bails out households. The collapse of the economy is postponed, but not prevented.

share increases immediately after the crash, and is afterwards stabilized via the golden wage rule. The next section discusses the simulations more generally, and puts them in context of empirical evidence.

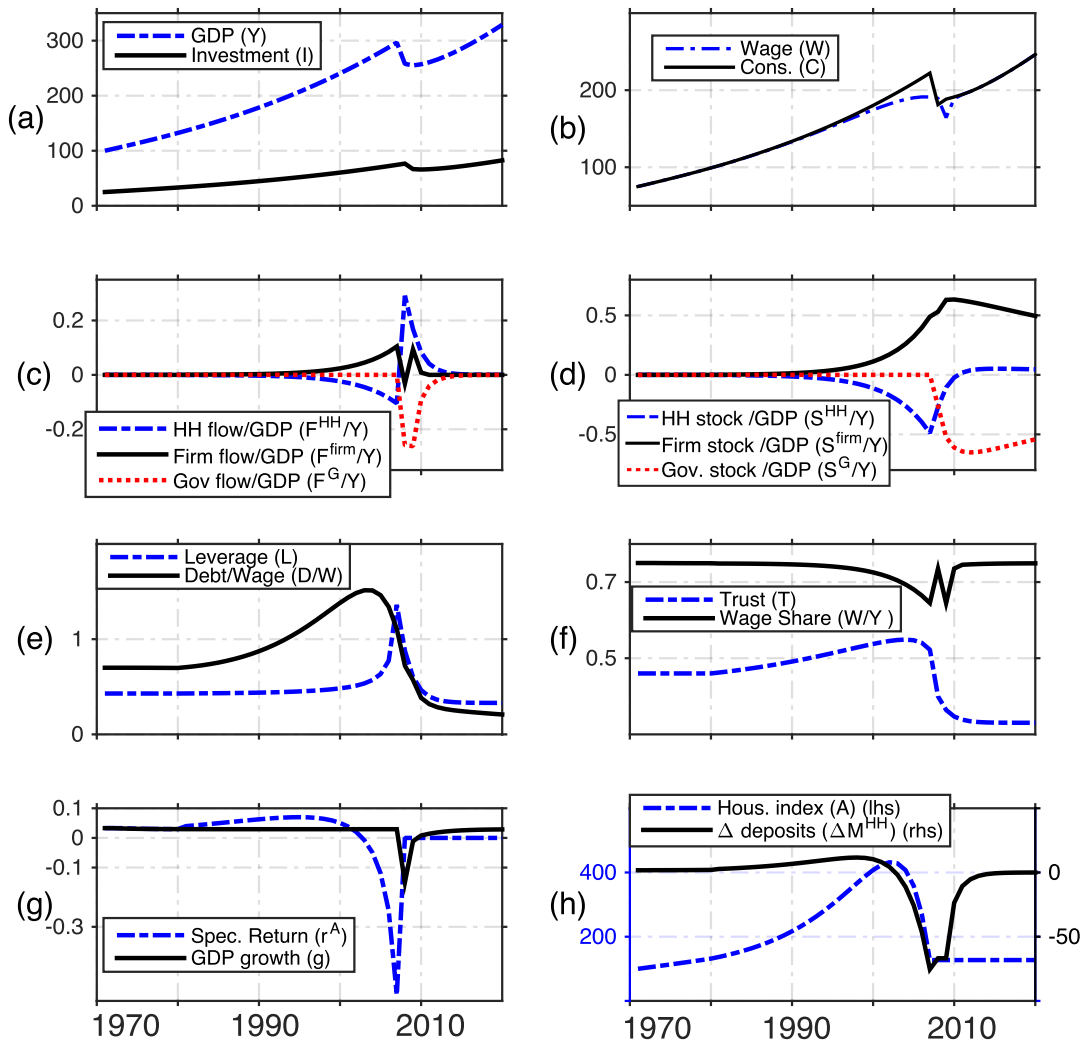

Fig. 11: Public sector bailout combined with the implementation of the golden wage rule after the crisis. The economy recovers and continues to grow. Government debt to GDP decreases over time and households' wage is sufficient for the desired consumption path.

5 Discussion

5.1 Discussion of the Model Simulations

Since one unit's liability is another unit's asset, changes in leverage represent no more than a redistribution for one group (debtors) to another (creditors)... and should have no significant macroeconomic effects. Bernanke (2000)

Which insights can be gained from the model's simulations? Incorporating financialization, distributive dynamics, as well as a real and a financial circuit with collateral-backed credit creation into the model gives endogenously rise to a financial crisis. The crisis finds its origin in the fact that, with the goal of achieving its desired consumption level, the household sector builds up massive debt levels to finance consumption and to speculate. Once this bubble bursts, households stop borrowing because falling asset prices force households to deleverage. This kind of financial crisis [50]has been labelled a "balance sheet crisis" by Koo (2011) who emphasizes that financing, not supply-side shocks or resource scarcity, is limiting growth. If the economy is in a balance sheet recession, this does not mean that certain supply side or structural adjustments are useless. It simply means that the by far largest obstacle to economic growth is financing and demand more generally.[51]
Note, however, that while it is important to understand that agents who repair their balance sheets contribute to the economic collapse, it is also crucial to understand the dynamics that led to the crisis. In this regard, attention should be paid to distributive dynamics prior to the crisis. Rising income inequality is compensated by household debt. The insight is that this compensation cannot last forever and is inherently unstable. [52] Indeed, as discussed earlier, small persistent changes can ultimately lead to a significant break down of the whole system. The wage share for example drops by only 5 percentage points over several years (not annualized). This risk, which slowly creeps upward, ultimately reaches a critical point: when the financial crash occurs, GDP collapses by 10-15% in just one year. It is important to take this asymmetry between the time scale of the build up of the bubble and the time scale of the crash into account in order to design effective economic policy.

Once the financial crash occurred, what can be done to put the economy back on a growth path? How can the financing constraint that is limiting growth be loosened so that growth becomes possible again? In a broader context, we know that, while certain natural resources are finite, the resource for purchasing power, namely money or credit, is not naturally limited. It is therefore up to a proper political and institutional management to prevent major shortcomings with respect to financing.
In the scenarios with a government sector, it became evident that a purely reacting authority, which restricts its actions to bailing our the private sector, but does not implement the golden rule (Fig.10), is not able to deal with the balance sheet crisis. Such a government cannot prevent

[50] A financial crisis is to be distinguished from a 'real' or 'Schumpeterian' creative destructionist 'crisis'.
[51] Note, however, that several economists argue that capitalistic economies are characterized by constant excess supply, i.e. the economy is most of the time constrained from the demand side (Keen, 2011).
[52] At this stage, we do not discuss the Infinite Perpetual Money Machine scenario of our model, but focus on the crash scenarios.

a collapse. [53] The economy in the last scenario, where public authorities recouple wages and growth (Fig.11), does not crash. Note that overall debt levels are reduced, in line with Sornette and Cauwels (2014) who argue that "we need to go back to a financial system and debt levels that are in balance with the real economy".[54] While Terzi (2016) argues that new debt is (in the aftermath of a financial crisis) necessary, we argue that this is only true as long as the private sector is deleveraging.[55] In the long run, the implementation of the golden rule forces firms to channel their savings back into the economic circuit, which allows the public authority to step back. Put differently, this last scenario solves the so-called twin peak crisis, where i) agents with high savings do not spend their money and ii) other agents have high levels of debt but cannot repay it because they lack access to the other agents' savings. Indeed the golden rule is one mechanism that helps to channel money to consumers - followed by lower overall debt levels and economic growth.[56] This reasoning is very much in line with Zezza (2011), who argues that a shift in the income distribution is needed to regain a sustainable growth path.

Summing up, the simulations show that monetary economies give naturally rise to regime changes. Initially the growth regime is 'productive' with an efficient distribution of income and low overall debt. Inherent instabilities in the feedback between the financial and the productive circuit give rise to a growth regime that is increasingly debt-burdened with inflated asset prices and high debt levels. Part of the growth of this new regime is not sustainable and finds its sudden end with the burst of the bubble. Afterwards, a new growth regime is needed that builds on both, fiscal and wage policy.

6 Concluding Remarks

This paper reviewed a number of stylized facts together with micro- and macroeconomic behavioural insights and incorporated them into a new stock-flow consistent model of modern monetary economies. The model's key assumptions are i) financial savings of business owners decrease the bargaining power of workers, and thereby raise the profit share in the economy, ii) the relative income hypothesis determines the desired consumption plan of households, and iii) households' borrowing depends on credit creation, which is backed by collateral.
The simulations exemplified the effect of non-linear feedbacks and we discussed their effect on the real economy as well as on the financial circuit. With only seven behavioural equations our model

[53] In this scenario the government enables households to freely use their wage income for consumption. But the government does not compensate for the loss in debt-financed consumption. Future research could focus on fiscal stimulus that goes beyond the bail out that we modeled.

[54] The idea that one agent's liability is another agent's asset with the consequence that overall debt levels do not matter for economic performance is fundamentally flawed. See also Keen (2011) for further discussion. Moreover, note that increasing gross debt to GDP is not necessarily a bad indicator for economic stability because a growing economy that relies increasingly on the division of labour might well need more liquidity in relative terms. An increase in banks' assets to GDP can indicate inflated asset prices or excessive speculation, but it can also go hand in hand with a more productive and innovative economy. A single focus on world gross debt thus does not provide much insight, unless analysed together with the structural changes of the economy.

[55] "This means that an increase in spending can only be obtained with greater private borrowing, greater government debt, or greater net exports." (Terzi 2016). But Terzi might be well aware of the effect of a dis-saving of firms because the author also writes that "savings reduce spending unless offset by new debt" - and of course the opposite is also true: financial dis-saving of one sector increases spending unless used to pay back debt (that would destroy the financial savings). Terzi furthermore writes that "[p]olicies that aim at fostering private spending can [...] try to pull private saving desires lower" which is exactly what the golden rule achieves for the firm sector.

[56] Note that higher economic growth also includes higher absolute profits for the firm sector.

remains very traceable while at the same time providing important insights. For a large set of parameters, we find that our model economy is inherently unstable and eventually produces an endogenous financial crisis. The crash indicates the end of a debt-burdened growth period that was unsustainable. We further find that a public authority can prevent the total collapse of the economy. However, one key insight is that, in order to avoid (another) period of debt-burdened growth, the public authority should not only provide initial stimulus but also implement the golden wage rule, that is re-establish the link between productivity and employee's compensation. A successful implementation of this rule results in long-run growth without excessive private and public debt. Put differently, public stimulus in the aftermath of a financial crisis is necessary but not in itself sufficient for long-term growth - unless complemented by a re-coupling of wages and productivity. Finally, one important finding is that, in our model economy, neither debt nor inequality, nor finance on its own 'caused' the crisis. Instead, spill-overs, feedbacks and 'creeping risks' appear to have played a role, suggesting that policies based on mono-causal thinking may be misleading.

How serious should the model's implications be taken? Our simulation results are overall consistent with many stylized facts in the US and the euro area. In the latter, however, further analysis is needed to properly take the huge heterogeneity amongst member countries into account. We have argued that in these economies the credit-driven growth came to an end in 2008. Since then, growth has been weak, motivating the search for a new growth regime. Our analysis suggests that demand is still limiting growth in both economic areas.

The important question is thus: Which sector of the economy should increase its demand in what proportions and how should this demand be funded? We argued that public stimulus of the real economy, not the financial one, remains necessary and needs to be complemented by a re-coupling of wages and productivity. Alternatives, including a long-time recession or another period of debt-burdened growth, carry a high risk - both economically and politically. Another alternative, namely export-driven growth, is subject to the fallacy of composition and therefore not a useful strategy for larger economic areas, let alone the world.

Against this backdrop, it appears vital to further develop the approach sketched in this paper. A next step could be to build a two-country or multi-country model to better analyse the interplay of growth strategies in different countries.In a wider context, this paper emphasized the importance of 'traditional' economic policy tools like public investment, labour policies and international economic cooperation - as opposed to an illusionary belief that the central banks can solve problems that lie beyond their means. [57]

[57] Having that said, further unconventional monetary policies like negative interest rates in combination with central bank digital currency can clearly increase the effectiveness of monetary policy transmission mechanisms, and should therefore carefully be studied (see Grasselli and Lipton (2017)).

Appendix A Summary of the Model Equations with Public Sector

$$Y_t \coloneqq C_t + I_t \quad \text{(National Income)} \tag{1}$$

Households

$$C_t^e \coloneqq \bar{\lambda} \cdot (1 + g_{t-1}) \cdot Y_{t-1} \quad \text{(Desired Consumption,} \;\; g \coloneqq \frac{\Delta Y}{Y}\text{)} \tag{2}$$

$$C_t = \min\{C_t^e, W_t + \Delta D_t^{HH} + M_{t-1}^{HH}\} \quad \text{(Actual Consumption)} \tag{3}$$

$$F_t^{HH} \coloneqq W_t - C_t + G_t \quad \text{(Net Borrowing flow)} \tag{4}$$

$$S_t^{HH} \coloneqq \sum_{i \leq t} F_i^{HH} \quad \text{(Net Financial Stock)} \tag{5}$$

Leverage, Debt and Trust

$$L_t^{HH} \coloneqq \frac{D_t^{HH}}{A_t} \quad \text{(HH Leverage)} \tag{6}$$

$$T_t = T_{t-1} + k \cdot T_{t-1}(T_{t-1} - L_{t-1})(1 - T_{t-1}) \quad \text{(Trust)} \tag{7}$$

$$D_t^{HH} = D_{t-1}^{HH} + a \cdot (T_{t-1} \cdot A_{t-1} - D_{t-1}^{HH}) \quad \text{(Debt)} \tag{8}$$

Financial Circuit

$$B_t^* \coloneqq \Delta D^{HH} - (C_t - W_t) \quad \text{(Net change in HH deposits)} \tag{9}$$

$$M_t^{HH} \coloneqq M_{t-1}^{HH} + B_t^* + G_t \quad \text{(Money stock)} \tag{10}$$

$$A_t = \frac{\beta}{1 - \beta} \cdot M_t^{HH} \quad \text{(Speculative Asset)} \tag{11}$$

$$r_t^A := \frac{\Delta A_t}{A_t} \quad \text{(Speculative Return)} \tag{12}$$

Firm Sector

$$I_t = I_{t-1} + \alpha \cdot I_{t-1} \cdot g_{t-1} \quad \text{(Investment)} \tag{13}$$

$$\Pi_t := Y_t - W_t \quad \text{(Profit Bill)} \tag{14}$$

$$F_t^{firm} := \Pi_t - I_t \quad \text{(Net Borrowing)} \tag{15}$$

$$S_t^{firm} := \sum_{i \leq t} F_i^{firm} \quad \text{(Net Financial Stock)} \tag{16}$$

Wage Bargaining

$$\lambda_t^e = \lambda_{t-1} - \max(\sigma \cdot \frac{S_{t-1}^{firm}}{Y_{t-1}}, 0) \quad \text{(Ex ante Wage Share)} \tag{17}$$

$$W_t := \lambda^e \cdot (Y_{t-1} \cdot (1 + g_{t-1})) \quad \text{(Wage Bill)} \tag{18}$$

$$\lambda_t := \frac{W_t}{Y_t} \quad \text{(Actual Wage Share)} \tag{19}$$

Government

$$G_t = max(-B_t^*, 0) \quad \text{(Public spending)} \tag{20}$$

$$F_t^{GG} := -G_t \quad \text{(Net lending)} \tag{21}$$

$$S_t^{GG} := \sum_{i \leq t} F_i^{GG} \quad \text{(Net Fin. Stock)} \tag{22}$$

Appendix B Implementation of the Model

To implement the model, initial values for all level variables as well as all parameters are fed to the model's simulation. Given the simplicity of the model, a conventional empirical estimation of the model is not possible. For example, net imports in the US increased a lot over the last decades. Since our model does not incorporate an external sector, these dynamics cannot easily be matched to our model economy. Nevertheless, we use stylized facts to feed the model's simulation. Throughout all simulations, the following initial values are used:

$$g_1 = 0.03;\ \beta = 2.3;\ Y_1 = 100;\ Y_2 = g_0 \cdot Y_1;\ C_1 = 75;\ Y_2 = g_0 \cdot C_1;$$
$$W_1 = 75;\ W_2 = g_0 \cdot W_1;\ C_1^e = 100;\ C_2^e = g_0 \cdot C_1^e;\ D_1 = 0.7 \cdot W_1;$$

The other variables are determined by accounting identities. The initial money stock, for example, is determined by the initial debt stock. Initial values are taken from US data over the period from 1970 to 2000. For example, initial GDP growth g_1 is assumed to be 3.3 percent, in line with worldbank data. Similarly, the value for beta β is estimated using data from FRED data. Along these lines, initial debt (and deposits) is assumed to be 70 percent of the wage bill. In the first ten years, the model economy is in a steady growth path. At $t = 11$, lambda is shocked lambda negatively by 0.01 percent which initiates the different feedback loops described in section 5.

Parameters a, k, α, T_0 and σ are subject to variations along different simulations. The model's sensitivity to these parameters is tested in appendix C.

A matlab file with all computations is available upon request to the authors. Future research could build a consistent dataset that matches, and potentially adapts our model economy.

Appendix C Robustness Analysis

In this appendix, the model's sensitivity to changes in parameters is analysed in order to assess the robustness of the simulation results. The time it takes until a crisis occurs or whether no crisis at all occurs will be the target variable of interest. The key parameters to be analysed are:

- σ (bargaining parameter)
- T_0 (initial trust)
- k (convergence speed of trust)
- a (convergence speed of debt)
- α (investment parameter on GDP)
- β (household portfolio parameter)

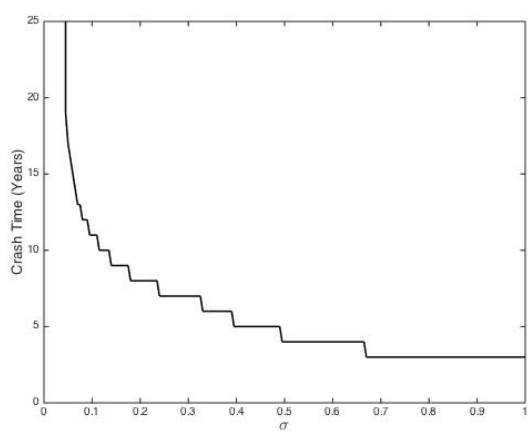

Fig. 12: Time to crash as a function of sigma (σ). The curve is truncated at small values of σ but is diverging as $\sigma \to 0$, as indicated in log-log plot. Input parameters: k=0.3, a=0.3, α=1, $\beta = 0.7$, $T_0 = 0.4$

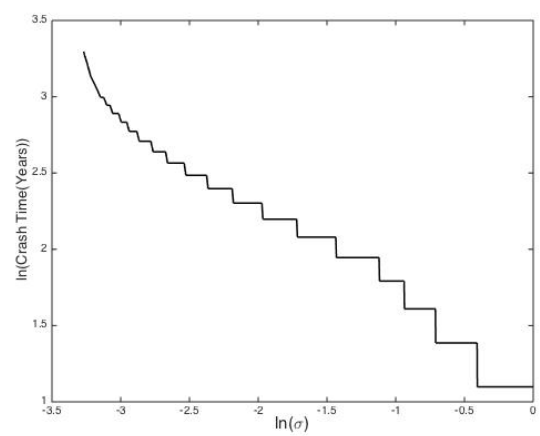

Fig. 13: Log-log scale of sigma and time to crash. Relationship is approximately linear, indicating power law relationship between both variables. Input parameters: k=0.3, a=0.3, α=1, $\beta = 0.7$, $T_0 = 0.4$

The parameter σ determines the wage share via a bargaining process as described in section 4.3.6. What is the influence of σ on the dynamics and the regime? Figure 12 plots the time until a crisis occurs as a function of σ. The higher σ, the faster the wage share gets reduced, the larger the gap between desired consumption and income, and the sooner a financial crash occurs. The stepped shape occurs because the variable time on the y-Axis is discrete (in years) throughout the model and

its simulations. Within the limits of discrete computational possibilities, the result shows that even for very small values of sigma, a crisis occurs - although at a relatively late stage. Figure 13 shows that the logarithm of the time to crash versus the logarithm of sigma is approximately linear, indicating a power law relationship between both variables. This result can be understood in light of non-linear feedbacks that are inherent to the model so that even small disruptions build up and destabilize the economy. More generally, such a phenomenon is called a singular perturbation: a small parameter within a model cannot be approximated by setting the parameter to zero (see Sornette (2006)). If sigma is approximating zero but still unequal to zero, a (late) crash will occur. If sigma is exactly zero ($\sigma = 0$) no crash occurs. This has important policy implications since any attempt to lower sigma will not be very successful unless sigma is strictly set equal to zero. The idea of putting sigma to zero to achieve a sustainable growth path is related to 'the golden wage rule' and is discussed in section 5 in more detail.

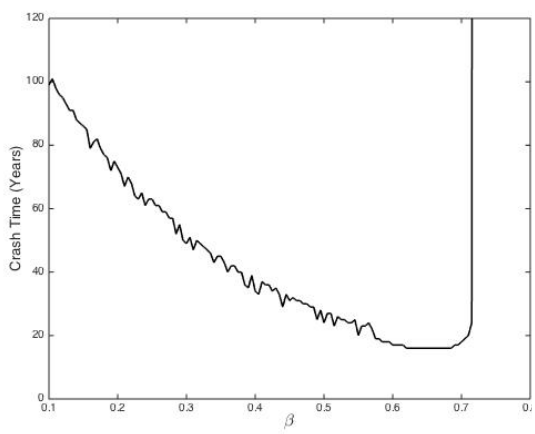

Fig. 14: Time to crash as a function of beta β. Bifurcation at the critical value $\beta = 0.72$. Input parameters: k=0.3, a=0.3, α=1, $T_0 = 0.4$, $\sigma = 0.04$

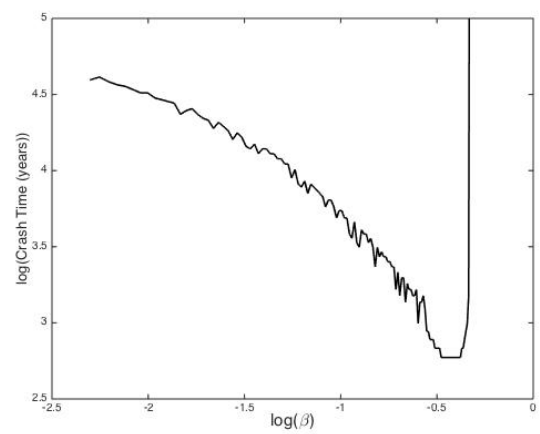

Fig. 15: Log-log scale of beta and time to crash. Two opposing forces at work, see text. Input parameters: k=0.3, a=0.3, α=1, $T_0 = 0.4$, $\sigma = 0.04$

Figure 14 plots the crash time as a function of β, i.e. the share of housing wealth in overall households' assets. As we can see, the relationship between both variables is not monotonous globally. This is because an increase in β has two opposing effects on the crash time: On the one hand, a higher beta drives up the return of the speculative assets, thereby reduces the wage share faster and ultimately favors an earlier crash (similar to the effect of σ). On the other hand, a higher beta causes housing wealth to rise faster, thereby increasing collateral value and allowing house-

holds for a longer period (potentially until infinity) to finance desired consumption expenditures with higher debt levels. As we can see in figure 14, for small but rising beta, the first effects dominates. However, once beta passes a critical value, the economy enters a no-crash regime. Put differently, at the critical value of beta (in the figure it is 0.72) a bifurcation occurs.
Figure 15 plot the logarithm of beta against the logarithm of the crash time: this time, there is no power law distribution, which is not surprising given two opposing forces. Let us now look at the parameter T_0, which determines the initial level

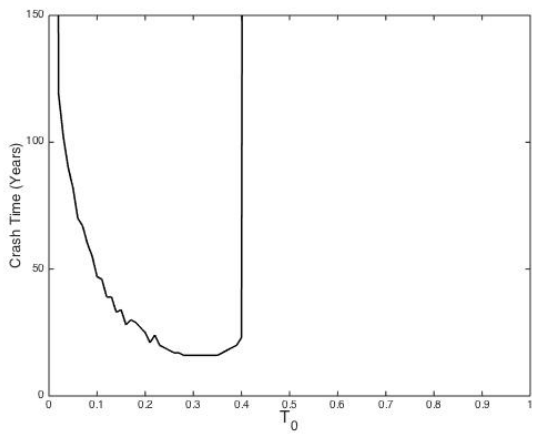

Fig. 16: Time to crash as a function of initial trust T_0. Input parameters: k=0.3, a=0.3, α=1, $\sigma = 0.04$

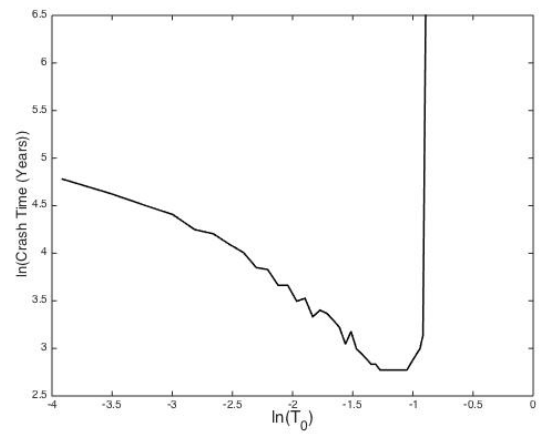

Fig. 17: Log time to crash versus log of initial trust. Input parameters: k=0.3, a=0.3, α=1, $\sigma = 0.04$

of trust in the economy, i.e. the fraction of housing wealth that can be used as collateral in the beginning. Figure 16 shows that the economy enters the infinite growth regime for high levels of initial trust, and the crash regime for low levels of trust. The intuition is that, for high values of initial trust, debt and collateral grow fast enough to make desired consumption always feasible. More precisely, figure 16 illustrates the existence of a bifurcation, in the mathematical sense of the term, which separates two qualitatively different regimes. Similar to the preceding discussion about beta, a change in initial trust has two opposing forces: On the one hand, higher initial trust allows for faster rise of household debt, making desired consumption plans feasible. On the other hand, higher initial trust also causes excess flushing of the housing market with new money, thereby increasing house prices, causing both, a lower wage share and an earlier crash.

Next, the sensitivity of the model to the parameter of the investment function α is analysed. In figure 18 we vary α around 1 and look at the influence on the crash time

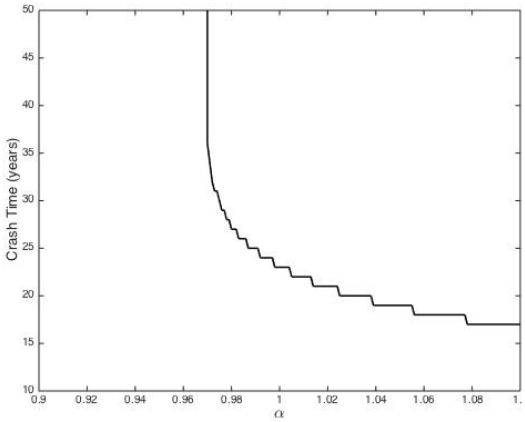

Fig. 18: Crash time versus parameter α of the investment function. Divergence as α approaches $\alpha_{crit} = 0.96$. Input parameters: k=0.3, a=0.3, $\beta = 0.7$, $\sigma = 0.04$, $T_0 = 0.4$.

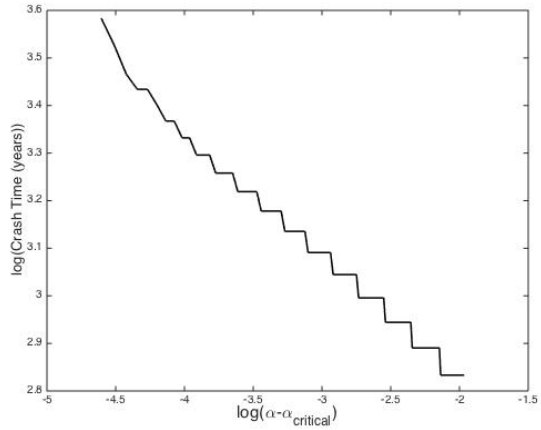

Fig. 19: Log(crash time) versus log(α minus α_{crit}). Linear shape indicates a power law functional relationship. Input parameters: k=0.3, a=0.3, $\beta = 0.7$, $\sigma = 0.04$, $T_0 = 0.4$.

(α=1 means that investment grows at a constant proportion of past GDP). Large values of α lead to an earlier crash because the economy, and thus households' debt demand grows faster than collateral value. For small values of α, the economy grows slower so that asset prices have more time to build up and sustain the relatively small gap between disposable income and desired consumption expenditure. Figure 19 plots the logarithm of the crash time versus logarithm of α minus critical alpha. Critical alpha α_{crit} is 0.97. The linear relationship indicated that the crash time follows a power law functional relationship. The parameter alpha thus controls the bifurcation: alphas above the critical value result in the crash regime, while alphas smaller than the critical value result in the infinite growth regime.

Let us finally turn to how a and k affect the model's simulations. The parameters a and k are rates of changes that control the dynamics of debt and trust in the economy. For large values of a and k, debt and trust converge quickly, resulting in the no-crash regime (see Figure 20). Indeed, the two domains (crash and no crash) are separated by a hyperbolic-like boundary, one in white and the other in variations of grey. The system thus exhibits bifurcations between the no crash infinite growth dynamics and the regime with a crisis occurring in finite time. The bifurcation is controlled similarly by both parameters a and k, i.e. the transition from no crash to the crisis regime can be obtained by decreasing either a or k from large values. More generally, both parameters appear to be substitutable to some extend with respect to their affect on the occurrence of a crisis: small values of k

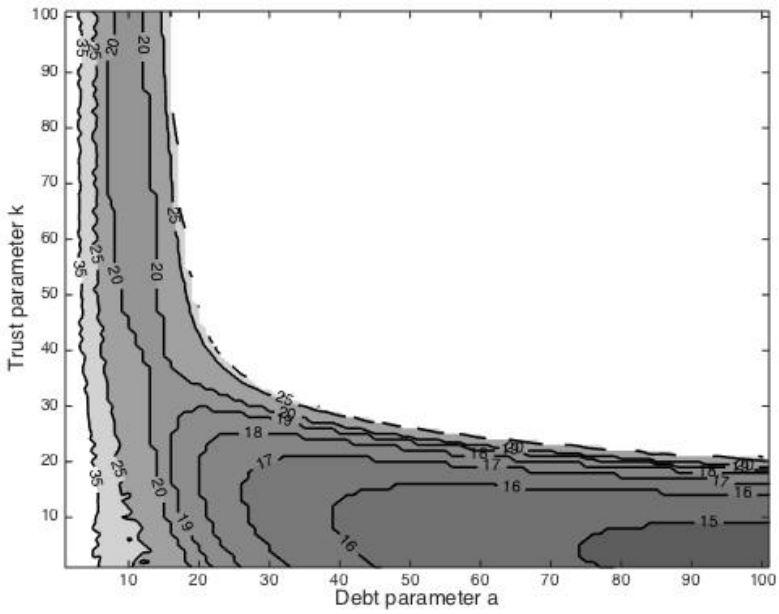

Fig. 20: Crash time contours as a function of debt parameter k and trust parameter a. The lighter the color of the hyperbolic-like areas, the later the crash occurs. 'White' indicates no crash. Other input parameters are fixed: $\sigma = 0.04$, α=1, $T_0 = 0.4$

can be compensated by large values of a and vice versa. It is furthermore interesting to see that, for a wide range of parameters corresponding to the crisis regime, the time until the crash occurs is quite similar (around 25 years) and does not vary significantly. While a and k are able to change the regime, within the crash regime, the simulation results are not very sensitive to both parameters. Note that the transition from crisis (finite time to crash) to no crisis (infinite time to crash) occurs abruptly at the hyperbolic-like boundary and not via a divergence of the time to the crash. This suggests an underlying sub-critical bifurcation rather than a continuous bifurcation.

Summing up the preceding analysis, most parameters can not only affect the time until a crisis occurs, but also change the regime of the economy, i.e. control the bifurcation separating the two regimes. Within each regime, changing the values of the parameters in general lead only to smooth continuous modifications of the dynamics. A more sophisticated robustness analysis would change several or all parameters simultaneously and analyze the behavior in the high-dimensional parameter space.

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