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Monetary and Economic Department

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Long-term debt propagation and real reversals*

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Abstract

We examine a propagation mechanism that arises from households' long-term borrowing and show that it accounts for real reversals after credit booms. An impulse to new borrowing boosts output in the short run, but long-term debt generates a predictable hump-shaped path of debt service that depresses output far into the future. We confirm these patterns empirically using a novel multi-country dataset of debt flows. We embed long-term debt propagation in a New Keynesian model and show how credit shocks generate predictable reversals that are difficult for policymakers to counteract.

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1 Introduction

Mechanisms that capture how disturbances propagate through the economy over time are central to macroeconomic modeling. Such mechanisms determine how well models reproduce observed data dynamics, lead to reliable forecasts, and help us understand the transmission of shocks. Unfortunately, many macro-models suffer from weak internal propagation and instead rely on external propagation, such as exogenous shocks with strong auto-correlation, to match the data (Cogley and Nason (1995) and Beaudry et al. (2020)).[1]

In this paper, we highlight a natural *internal propagation mechanism* implied by long-term debt and document its importance in explaining endogenous medium-term reversals in GDP. The starting point is simple: new borrowing under long-term debt contracts generates a highly predictable path of future debt service payments (consisting of interest payments and amortizations). This dynamic leads to predictable real reversals if transfers between lenders and borrowers affect output. We show that this is the case empirically. An increase in new household borrowing is associated with significantly positive output growth in the short term. But it also increases the stock of debt and associated debt service payments over time, which eventually depresses output. This propagation mechanism largely accounts for the well-documented fact that growth tends to systematically slow down for several years after a credit boom.[2] By embedding long-term debt propagation in a New Keynesian model, we show that it delivers impulse responses that closely reproduce our empirical estimates of the output effects of new borrowing and debt service.

Our paper starts by developing a novel cross-country database of new household borrowing and debt service payments for 16 advanced countries at an annual level over the past four decades. Existing cross-country databases only provide data on debt stocks but, as pointed out by e.g. Eberly and Krishnamurthy (2014) and Auclert (2019), it is the flows of new borrowing and debt service that enter budget constraints and thus encapsulate the contemporaneous and future liquidity effects of borrowing. To construct these two flow measures, we model amortizations of up to six different household debt categories, such as mortgages, credit card debt, student loans, and other household borrowing.

Using this dataset, we document both the interactions and the real implications of new borrowing and debt service. We find that an impulse to new borrowing is significantly autocorrelated and is followed by a predictable hump-shaped rise in debt service that peaks four to six years later. Initially, a one percentage point increase in new borrowing relative to GDP generates a significant positive real effect, raising output by 19 basis points over

[1] The case for viewing persistent exogenous shocks as central to business cycle fluctuations was made in Granger (1966) and Sargent (1987), among others.

[2] See e.g. Claessens et al. (2012), Jordà et al. (2013), Mian et al. (2013, 2017), and Mian and Sufi (2014, 2018).

two years, with nearly all of the positive impact in year one. But even accounting for the beneficial short-term impact, the seven-year cumulative effect is a 50 basis point reduction in output. As the average increase in new borrowing at the peak of past credit cycles is 4.6 percentage points, our estimates imply cumulative output losses over 7 years of approximately 2.3 percentage points. Both the debt-related and real impacts are robust and hold across a number of specifications and samples.

We also evaluate how much of the real effects of credit booms are explained by long-term debt propagation as opposed to other credit-related forces. We compare the full local projections from an increase in new borrowing on output with the counterfactual effects that would arise if an increase in new borrowing can only affect output via the long-term debt propagation channel. We find that the two are not significantly different from each other for at least five years after the initial impulse. This suggests that long-term debt propagation captures much of the real effects of credit-related shocks in the short and medium run.

Our next objective is to understand how the long-term debt propagation mechanism relates to the literature, which has proposed several complementary hypotheses to explain why credit booms lead to real economic reversals.

A first set of theories emphasizes the role of debt service and budget constraints, where credit expansions increase household liquidity and boost demand in the short run, but reduce disposable income and depress demand once debt service increases (e.g., Eggertsson and Krugman (2012), Korinek and Simsek (2016), Mian et al. (2021)). The empirical patterns we document align closely with these theories as the timing and magnitude of financial flows between borrowers and lenders explain the majority of credit-related fluctuations in aggregate demand and output. They also account for the persistent and non-monotonic output responses to credit booms found in earlier studies (e.g., Mian and Sufi (2018)).

A second set of theories focuses on collateral constraints and asset prices as drivers of booms and busts in borrowing and by extension spending (e.g., Kiyotaki and Moore (1997), Iacoviello (2005), Jeanne and Korinek (2019)). Our long-term debt propagation mechanism differs from these theories in ways that are important for our understanding of credit-driven reversals. In the basic model of Kiyotaki and Moore (1997, Section II), for instance, temporary shocks have persistent effects through asset prices and collateral constraints, but booms just fade out and do not lead to subsequent recessions. Empirically, under the collateral constraint view, the flow variables we consider should lose significance once the collateral channel is controlled for. Our empirical findings reject this hypothesis, establishing that we have identified a complementary mechanism.

A third view emphasizes bank lending channels, whereby credit booms are followed by contractions in credit supply due to either the repricing of risk or shifts in credit market sentiment (e.g. Bordalo et al. (2018), López-Salido et al. (2017), Farboodi and Kondor (2023), or Schaal and Taschereau-Dumouchel (2023)). Other theories focus on investment overhang, where credit booms fuel excessive accumulation of durable goods followed by prolonged demand slumps (e.g. Rognlie et al. (2018)), or on misallocation, where credit expansions reduce aggregate productivity by funding less productive investments (e.g. Gopinath et al. (2017)).

We evaluate the role of these additional theories in accounting for the non-monotonic real effects of credit booms by including a comprehensive set of controls in our empirical analysis. As an example, to capture the potential effects of bank lending channels, we include inter alia credit spreads as suggested by López-Salido et al. (2017) or Krishnamurthy and Muir (2025) and the indicator of banking sector stress proposed by Baron et al. (2021). But even controlling for such variables, we find that debt service flows account for the bulk of real reversals following credit booms. More generally, we find that both the magnitude and significance of the effects of new borrowing and debt service are very robust to the different controls. Our flow variables seem particularly important for anticipating real reversals over the medium to long run and deliver quantitatively larger output effects than the competing variables, highlighting the importance of long-term debt propagation.

Our final contribution is to embed long-term household debt in a parsimonious New Keynesian model with borrowers and lenders along the lines of Eggertsson and Krugman (2012), Gourinchas et al. (2017) and Martin and Philippon (2017) to conceptually understand the empirical patterns we have documented and disentangle the roles played by different factors. We replicate the long-term debt propagation channel in a framework that boils down to four independent equations, despite involving heterogeneous agents. We show that shocks to credit supply in our model deliver output responses that closely resemble the corresponding empirical linear projections of new borrowing and debt service. Our findings are consistent with the credit supply view proposed by Mian and Sufi (2018) – that exogenous credit supply shocks generate predictable reversals in aggregate demand that are difficult for policymakers to counteract. However, our model also shows that credit demand shocks that lead to a higher debt burden generate similar macroeconomic dynamics. Predictable reversals after credit booms arise naturally from the structure of long-term debt contracts and happen regardless of whether the initial credit expansion was driven by supply or demand factors. As such, our model provides a simple and elegant explanation for how credit affects output once a boom is underway.[3]

[3] Let us contrast our model with the extended model of Kiyotaki and Moore (1997, Section III), which also features endogenous reversals. Both models involve heterogeneous adjustment: Kiyotaki-Moore introduce staggered investment opportunities, where only fraction π of farmers can invest in land each period, but they maintain one-period debt contracts. Our model focuses on the natural turnover of debt vintages. As a result, the source of reversals differs in important ways. In Kiyotaki-Moore, reversals arise when the delayed adjustment in investment creates overshooting in aggregate debt relative to productive capacity followed by a reckoning. Any real reversals are tied directly to changes in collateral values. In our framework, reversals are mechanically predetermined by the maturity structure of debt: new borrowing at time t creates a schedule

The model also allows us to pinpoint three crucial ingredients for generating realistic debt propagation dynamics that give rise to real effects. The first ingredient is long-term debt with autocorrelation in new borrowing. This is what drives the drawn-out responses of new borrowing and debt service that give rise to non-monotonic dynamics of financial flows between borrowers and lenders.[4] Second, in order for these flow dynamics to drive fluctuations in aggregate demand, borrowers must be subject to financial constraints. The third ingredient is that monetary policy does not fully offset the resulting demand effects. This ensures that long-term debt propagation leads to booms and busts in real output. Removing either of these three ingredients in our model implies that there are no real effects or only degenerate real effects of credit booms and busts on output.

Correctly characterizing the internal propagation of credit booms and identifying the central role of financial flows for real economic activity is of crucial importance for theory, practice, and policy-making. It matters for theory because it improves our understanding of the underlying economic channels and informs us about what elements to incorporate in the models we craft so as to capture the powerful endogenous reversals entailed by credit booms. It matters for practitioners and policymakers because properly capturing the propagation mechanism behind credit booms and the resulting endogenous reversals allows us to better predict the real effects of credit booms and guide policy measures to counteract the financial cycle if this is desired. In particular, it highlights that policymakers face an important intertemporal trade-off when trying to stimulate the economy by encouraging the expansion of debt, since any new borrowing will over time increase debt service and generate a drag on future output growth. Finally, it should also guide measurement efforts towards a greater focus on the financial flows between borrowers and lenders.

The remainder of the paper is structured as follows. The ensuing section, Section 2, discusses how to measure debt service costs and new borrowing in the data. Our empirical analysis is performed in Section 3, where we show impulse response functions that capture long-term debt propagation and assess their implications for real outcomes. We also evaluate the role of debt propagation vis-a-vis the other channels proposed in the literature. In Section 4, we develop a theory model that incorporates long-term debt propagation to replicate our empirical findings and highlight its key driving forces. Section 5 concludes.

of debt service obligations that generates a predictable hump-shaped drag on future output. This distinction matters empirically: our results show that debt service flows can account for the observed real reversals, providing a critical quantitative channel for understanding credit cycles.

[4] Garriga et al. (2017, 2021) and Gelain et al. (2017) also introduce long-term debt in macroeconomic models. However, their focus is on monetary policy transmission and housing market dynamics, respectively, rather than on systematically studying the long-term propagation effects of debt service over time.

2 Data and measurement

To study long-term debt propagation empirically, we need data on new borrowing and debt service payments. We measure new borrowing, $B_{i,t}$, in country i at time t by the change in the stock of debt plus amortizations, whereas debt service payments, $S_{i,t}$, is the sum of interest payments and amortizations. While data on debt stocks and interest payments are available, data on amortizations are typically not recorded and need to be estimated, as we lay out in more detail in the following.

We focus our attention on the household sector. This sector typically holds the largest share of long-term credit, making it ideal for our purposes. Moreover, data availability on debt maturities – which we need to infer amortizations – is considerably better than for the corporate sector. All in all, we end up with an unbalanced panel of annual data on household sector new borrowing and debt service payments for 16 countries from 1980 to 2019.[5] Information on data availability, definitions and sources are provided in Appendix A. For the ensuing empirical analysis, we normalize both variables by nominal GDP, $Y_{i,t}$, and denote the resulting variables by $b_{i,t} = B_{i,t}/Y_{i,t}$ and $s_{i,t} = S_{i,t}/Y_{i,t}$.[6]

We are interested in the real effects of these financial flow variables. Our primary outcome variable is real output (in logs), $y_{i,t} = \ln(Y_{i,t}/P_{i,t})$, where $P_{i,t}$ is the GDP deflator. This series ends in 2020. For robustness, we also analyze the effects on real consumption (in logs), $con_{i,t}$ and unemployment, $u_{i,t}$.

2.1 Estimating amortizations

We model the repayment streams of up to six different categories of household debt. First, we split household debt into mortgages and other household debt. If possible, we break out interest-only mortgages and distinguish between credit card debt, student loans and auto loans as separate categories within other household debt. We follow the methodology of Luckett (1980) and Dynan et al. (2003) to model repayments. This methodology is used by the US Fed and the Bank of Canada to construct time series of aggregate debt service ratios. For each of the l different categories of household debt, except interest-only mortgages and credit card debt, we assume that the amortization rate, $\delta^l_{i,t}$, follows that of an installment loan according to

$$\delta^l_{i,t} = \frac{r^l_{i,t}}{\left(1 + r^l_{i,t}\right)^{m^l_{i,t}} - 1} \tag{1}$$

[5]The countries included in the analysis are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom and the United States.

[6]The time series of both variables are shown in Figure D.1 in Appendix D for the countries in the sample.

where $m^l_{i,t}$ is the average remaining maturity and $r^l_{i,t}$ is the average interest rate paid on the outstanding stock of debt for debt category l (see Appendix B). For credit card debt, we follow Dynan et al. (2003), we set the amortization rate equal to the minimum required payment rate of 2.5% per quarter, i.e. $\delta^{credit\,card}_{i,t} = 0.1$.

Equation (1) uses $m^l_{i,t}$ and $r^l_{i,t}$ as input. We collect these data from a wide range of sources (see Tables A.3 and A.4 in Appendix A). Observations on mortgage maturities are infrequent but available for most countries.[7] For other household debt and student loans, data on maturities are even more scarce. We only have time varying information for auto-loans in the United States. For other countries, we assume fixed 5-year and 10-year initial maturities for other household debt and student loans, respectively, in line with data from Belgium, Italy and the United States.

Aggregate amortizations at time t for country i are then simply the sum of the amortization rate times the stock of debt, $D^l_{i,t}$ for the different debt categories l, i.e.

$$amortizations_{i,t} = \sum_{l=1}^{L} \delta^l_{i,t} D^l_{i,t}. \tag{2}$$

We discuss potential sources of measurement error associated with (2), and their impact on our main results, in Appendix C.

2.2 Other channels and variables

All our estimations include a *baseline* set of controls. These consists of real GDP growth, the real three-month money market rate, $r_{i,t}$, the annual CPI inflation rate, $\pi_{i,t}$, and the term spread, $spr^{term}_{i,t}$. Notably, these variables ensure that the debt service effects that we identify are not confounded with conventional real (or nominal) interest rate effects. The term spread also controls for market expectations of the future economic outlook. We also add dummy variables controlling for the Great Financial Crises in 2009 and the onsets of banking crises in individual countries.[8] In our real specifications we add a dummy for the onset of the Covid-19 pandemic as our real GDP growth series ends in 2020.

We use several variables to control for other channels that have been suggested in the literature as explanations for debt-related real reversals. We organize these into three sets

[7] These data mostly relate to contractual maturities on new loans. We linearly interpolate missing observations and extend the initial (last) observation backward (forward) to obtain complete annual series. We then relate the contractual maturity to the average maturity of the outstanding stock of debt as detailed in Appendix B.

[8] Crises dates are taken from the official ECB/ESRB EU crises database for the European countries in our sample (Lo Duca et al. (2017)). For the remaining countries, we rely on Laeven and Valencia (2020) and Drehmann and Juselius (2014).

Control variables
Baseline controls:
Real GDP growth, real 3m money market rate, CPI inflation, term spread, crisis dummy (1 if banking crisis), GFC dummy (1 in 2009), Covid-19 dummy (1 in 2020), country fixed effects
Collateral channel:
Real residential property price growth, real household net worth growth
Bank lending channel:
Change in the corporate credit spread, change in the lending spread on mortgages, bank lending standards for the household sector, indicator of banking sector stress
Other channels:
Three-year growth in real property investment, 5 year average productivity growth, growth in credit to the tradable/ non-tradable corporate sector to GDP, growth in the real effective exchange rate

Table 1: Control variables. Detailed definitions and sources are listed in Appendix A, Tables A.1–A.2.

(Table 1).[9] The first two proxy for the collateral and bank lending channel, respectively, and the last set captures other channels such as debt overhang and capital misallocation.

The *collateral channel* works through feedback effects between asset prices and borrowing limits (e.g., Kiyotaki and Moore (1997); Iacoviello (2005)). We use two variables to proxy for this channel: the change in (log) real residential property prices, $p^{res}_{i,t} - p^{res}_{i,t-1}$ and the change in (log) real household net worth, $nw^{hh}_{i,t} - nw^{hh}_{i,t-1}$, i.e., the difference between total household assets and total household debt.

We consider four proxies for credit market tightness in line with different manifestations of the *bank lending channel* (e.g., López-Salido et al. (2017), Bordalo et al. (2018), Krishnamurthy and Muir (2025)): The change in corporate credit spreads, $spr^{nfc}_{i,t} - spr^{nfc}_{i,t-1}$, the change in lending spreads on mortgages, $spr^{hh}_{i,t} - spr^{hh}_{i,t-1}$, lending standards for the household sector, $lst_{i,t}$, and an indicator of banking sector stress proposed by Baron et al. (2021), which equals one if bank equity prices have fallen more than 30% and zero otherwise.

The last set of controls proxies for *other channels* proposed in the literature. We include the three-year change in (log) real property investments, $inv^{res}_{i,t} - inv^{res}_{i,t-3}$, to capture the effects of investment overhangs that could depress medium-term growth following a credit boom (see e.g., Rognlie et al. (2018)). We use the 5-year change in (log) productivity, $prod_{i,t} - prod_{i,t-5}$ to control for credit misallocation, following Gorton and Ordoňez (2019) who showed that low productivity makes it more likely that a credit boom ends in a crisis. To capture the regularity that credit booms in the non-traded corporate sector are more strongly associated with reversals (Müller and Verner (2024)), we add changes in (log) credit to the non-tradable and tradable sectors (as share of GDP), $cr^{ntrd}_{i,t} - cr^{ntrd}_{i,t-1}$ and $cr^{trd}_{i,t} - cr^{trd}_{i,t-1}$, respectively. Finally, we include the change in the (log) real effective exchange rate, $fx_{i,t} - fx_{i,t-1}$, in line with Rodrik and Subramanian (2009) who argue that credit booms may lead to exchange rate appreciation, which in turns dampens growth via depressed competitiveness.

[9] We also employed several close alternatives to the variables in the Table 1 and found similar results.

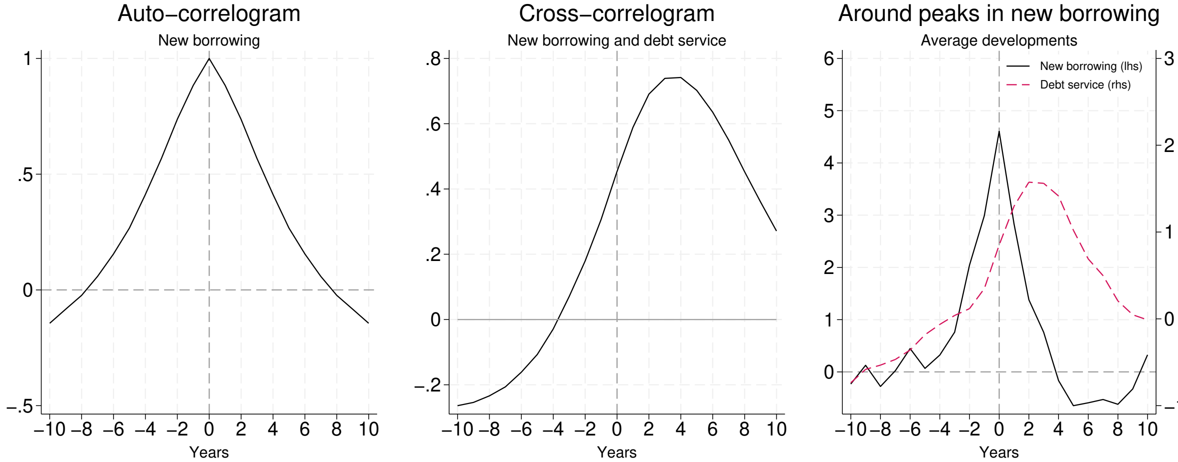

Figure 1: Raw patterns between household sector new borrowing and debt service. The left-hand panel shows the auto-correlation profile of new borrowing and the central panel shows the cross-correlation between new borrowing and debt service. The right-hand panel shows the average evolution of the two variables around peaks in new borrowing. Peaks are defined as local maxima in a 5-year window. We remove country-specific averages from new borrowing and debt service.

3 Long-term debt propagation in the data

In this section, we investigate the extent to which long-term debt propagation can account for both credit and real dynamics in the data.

3.1 Debt flow dynamics

The basic idea of the debt propagation mechanism is already evident in the raw flow data (Figure 1). New borrowing is autocorrelated and the debt service peaks on average three to four years after a peak in new borrowing.

To study this connection more formally, we use local projections. Suppose that the dynamics of new borrowing, $b_{i,t}$, and debt service, $s_{i,t}$, in country i at forecasting horizon $h \geq 1$ is captured by the following local projections based on information at time t:

$$b_{i,t+h} = \beta_{bb}^{(h)} b_{i,t} + \beta_{bs}^{(h)} s_{i,t} + \beta_{bx}^{(h)\prime} x_{i,t} + v_{b,i,t+h}^{(h)} \tag{3}$$

$$s_{i,t+h} = \beta_{sb}^{(h)} b_{i,t} + \beta_{ss}^{(h)} s_{i,t} + \beta_{sx}^{(h)\prime} x_{i,t} + v_{s,i,t+h}^{(h)} \tag{4}$$

where $x_{i,t}$ is the a vector of controls, and the superscript (h) distinguishes coefficient estimates at different forecasting horizons. The error terms also depend on the horizon and are generally auto-correlated for $h > 1$. We apply Driscoll-Kraay standard errors to account for possible correlation over time and across countries.

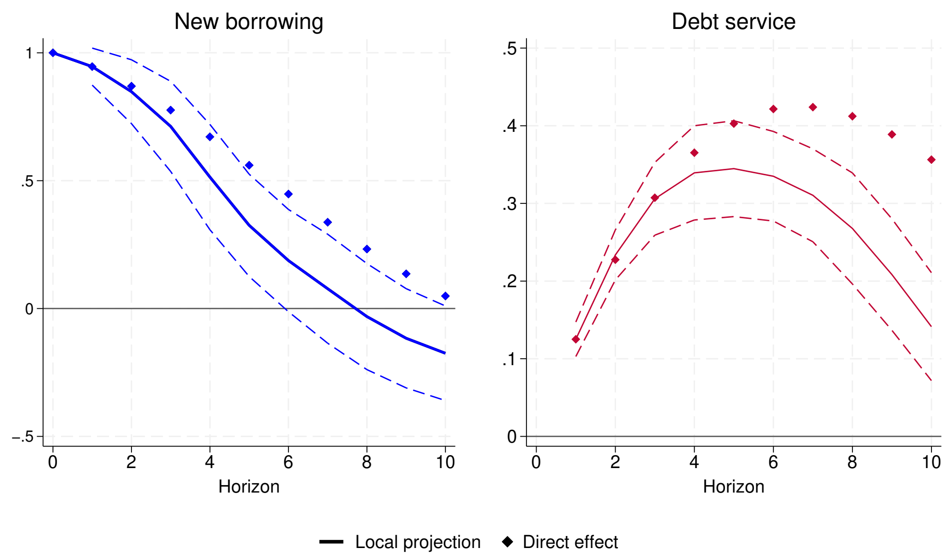

Figure 2: Local projections of new borrowing on future new borrowing and debt service. Solid lines: $\beta_{bb}^{(h)}$ and $\beta_{sb}^{(h)}$ from from local projections (3) and (4). Dashed- lines: 95 % confidence intervals. Diamonds: Direct effects of long-term debt propagation derived from equations (5) and (6). We include the baseline set of controls and apply Driscoll-Kraay standard errors.

Consider a unit increase in $b_{i,t}$ at time t, i.e., $\upsilon_{b,i,t}^{(0)} = 1$, while keeping all other error terms at zero.[10] The effect of this increase on $s_{i,t+h}$ is given by $\beta_{sb}^{(h)}$ (Jordà, 2005). For $h = 1$, the parameter $\beta_{sb}^{(1)}$ captures the *direct* effect of a unit increase in new borrowing on debt service. By contrast, for all $h > 1$, $\beta_{sb}^{(h)}$ incorporates both the direct effect of how much borrowing at time t mechanically increases debt service at $t+h$ and the impact of the systematic responses of the other variables in time periods from $t+1$ to $t+h-1$. For instance, new borrowing at time t may affect one of the variables in $x_{i,t+1}$ in the subsequent period, which in turn could affect debt service at date $t+h$.[11]

Figure 2 shows the estimated local projections of new borrowing on new borrowing (left hand panel) and debt service (right hand panel) up to 10 years ahead.[12] Two features stand out. First, new borrowing is highly persistent. Following the initial unit impulse, it only dies out after around eight years. Second, the initial increase in new borrowing is followed by a hump-shaped rise in debt service. In response to the impulse of new borrowing, debt service gradually builds up, peaks after 5 years and remains significantly elevated even in year ten.

How much of the *overall* effects of the impulse to new borrowing is due to the *direct*

[10] We focus on unit impulses to new borrowing through out our empirical analysis in line with Mian et al. (2017) who argue that these approximate credit supply shocks. We confirm this connection within our theory model in Section 4, where we also derive the exact theoretical analogues to our empirical impulse responses.

[11] A benefit of using local projections is that we do not have to specify a full VAR structure to capture the full effects of dynamic interactions between the variables. See e.g., Marcellino et al. (2006).

[12] The regression results for $h = 1$ are shown in tables D.1 and D.2 in Appendix D.

interactions between new borrowing and debt service, i.e., due to long-term debt propagation as opposed to all the other systematic forces captured in the local projections? To isolate the direct effects we iterate on the sub-system of the two variables

$$\tilde{b}_{i,t+h} = \beta_{bb}^{(1)}\tilde{b}_{i,t+h-1} + \beta_{bs}^{(1)}\tilde{s}_{t,t+h-1} \tag{5}$$

$$\tilde{s}_{i,t+h} = \beta_{sb}^{(1)}\tilde{b}_{i,t+h-1} + \beta_{ss}^{(1)}\tilde{s}_{t,t+h-1} \tag{6}$$

starting from $\tilde{b}_{i,t} = 1$ and $\tilde{s}_{i,t} = 0$. These responses should generally differ from the local projections given by $\hat{b}_{i,t+h} = \beta_{bb}^{(h)}$ and $\hat{s}_{i,t+h} = \beta_{sb}^{(h)}$.

The derived direct effects of debt propagation (Figure 2, diamonds) closely match the local projections. They are not significantly different from the local projections for the first four years. But the direct effects of new borrowing on its future values are more persistent, which also leads to a more drawn out debt service response. Hence, the direct effects increasingly differ from the local projections as the horizon increases. Nevertheless, the patterns are qualitatively the same.

Highly persistent new borrowing and a humped-shaped response of debt services are very robust features of the data (Figures D.2 and D.3, Appendix D). For instance, they are qualitatively the same even if we control for the alternative channels listed in Table 1 or add more lags to the specifications. They are also not driven by specific time periods and do not materially change if we allow for time-fixed effects and cross-country heterogeneity (mean group estimator). Interestingly, the match between the direct effects of debt propagation and the local projections is even closer in many of the robustness checks. This is, for example, the case where we control the collateral channel or use the mean group estimator.

Finally, we note that the loan type matters for the dynamics but the differences are not large (Figures D.4 and D.5, Appendix D). For instance, we find that consumer loans are less autocorrelated than mortgages, leading to slightly quicker and more pronounced reversals in terms of debt servicing. This seems reasonable because consumer loans have much shorter maturities than mortgages. Similarly, new borrowing is more autocorrelated, and the corresponding debt service effects bigger, in countries with predominantly flexible rate mortgages, but again the differences are small.[13] This may reflect a greater willingness to take up new debt when rates are low in such countries, but also greater vulnerability to rate changes.

[13]Flexible-rate mortgages are dominant with a market share of more than 75% in approximately half of the countries of our panel, and vice versa for fixed-rate mortgages. See Committee on the Global Financial System (2006) and European Central Bank (2000)).

3.2 Real reversals

How important are these debt dynamics for real reversals? To address this question, we examine the effects of new borrowing and debt service on output.[14] In line with other studies, we focus on their effects on cumulative output growth from t to $t+h$. That is, we use local projections of the form

$$y_{i,t+h} - y_{i,t} = \beta_{yb}^{(h)} b_{i,t} + \beta_{ys}^{(h)} s_{i,t} + \beta_{yx}^{(h)\prime} x_{i,t} + \upsilon_{y,i,t+h}^{(h)} \tag{7}$$

where $y_{i,t}$ is (log) real output as before. We begin by looking at the effects that the flow variables have on one year ahead output, ie $h = 1$.

The effects of new borrowing ($\beta_{yb}^{(1)}$) and debt service ($\beta_{ys}^{(1)}$) on next periods output growth are highly significant. New borrowing has a positive effect, while debt servicing has a negative effect (Table D.3, Appendix D). Following a unit increase in new borrowing, GDP growth increases by 13 basis points. A unit increase in debt service, on the other hand, decreases GDP growth by 28 basis points. This result is novel and highlights the value added of keeping track of aggregate debt service.[15]

These estimated one year ahead real effects of new borrowing and debt service are very robust (tables D.3 and D.4, Appendix D). Independent of the specification we use, new borrowing has a positive, and debt service a negative, impact on GDP growth in the next period. Both effects are significant.[16] Furthermore, the results remain intact if we account for several measurement errors associated with the construction of our debt service and new borrowing series (see Appendix C). This is, for instance, the case if we adjust the results for possible mismeasurement of average remaining maturity, which is a key input in Equation (1). The results also survive if we assume linear repayment structures or account for defaults. The effects are also robust to using alternative real indicators in place of real GDP growth, such as output gaps, unemployment and consumption growth, or when we look at different debt types (Table D.5, Appendix D).[17] In the case of unemployment growth, the effects are reversed as expected, but new borrowing becomes insignificant. The new borrowing effects are also weak and insignificant when we look at consumer loans and fixed rated mortgages.

[14] A complementary line of research also shows that debt service can serve as an early warning indicator for future financial distress. See, e.g., Drehmann and Juselius (2014); Drehmann et al. (2199) and Antunes et al. (2018).

[15] It also complements micro level evidence in e.g. Olney (1999), Johnson and Li (2010), Dynan (2012) and Cloyne et al. (2020) who document negative effects from debt service burdens on household expenditure.

[16] The estimate of $\beta_{ys}^{(1)}$ more than doubles compared to the baseline when we allow for full cross-country heterogeneity or control for the impact of the bank lending channel or the other channels – see Table D.3. This likely reflects the reductions in in sample size. If we run the baseline specification on the same samples as in columns (3), (4) and (5), the estimates of $\beta_{ys}^{(1)}$ are -0.601, -0.539, and -0.618, respectively.

[17] We use two different methods to derive output gaps using standard specifications for annual data: a two years ahead Hamilton projection filter and a HP filter with smoothing parameter 6.25.

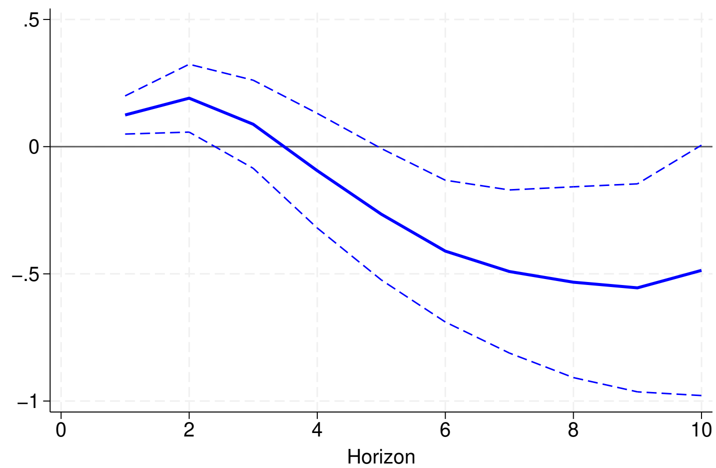

Figure 3: Cumulative output growth over horizon h, $y_{i,t+h} - y_{i,t}$, following a unit increase in new borrowing. Solid line: $\beta_{yb}^{(h)}$ equation (7). Dashed lines: 95 % confidence intervals. We include the baseline set of controls and apply Driscoll-Kraay standard errors.

These results together with the debt dynamics in Section 3.1 suggest that long term debt can give rise to real reversals. This would be the case if the accumulated negative effect from debt servicing outweighs the accumulated positive effect from new borrowing.

To assess if a unit increase in new borrowing gives rise to a real reversals, we estimate the cumulative impact of new borrowing on real GDP over a ten year horizon. Following a unit impulse to new borrowing, accumulated output growth is significantly positive for the first two years (Figure 3). But this short-term boost is reversed over the medium-term. The accumulated effects turn negative in year four and the reversal is significant from years six to nine. Over a seven year horizon, the cumulative drag on growth is close to 50 basis points increasing further until year nine. After that, the accumulated effects start to slowly converge back to zero and the effect becomes insignificant due to widening confidence bands.

The finding that new borrowing generates a real reversal is both qualitatively and quantitatively robust. The effect ranges from 40 to 100 basis points at its most intensive point across specifications. Importantly, the result remain the same regardless of whether we control for alternative channels or not (Figure 4). It is also invariant to sample splits, allowing for cross-country heterogeneity or including up to four lags. The reversal is always significant at the 5% level, except for two specifications where it is significant only at the 10% level: when we include all controls, and when we allow for time-fixed effects. In the first case, the drop in significance can be attributed to the limited number of observations. The second case may hint at the the importance of a global credit cycle as e.g. documented by Mian et al. (2017). Real reversals are also clearly evident if we look at output gaps in $t+h$ instead of cumulative real GDP growth.

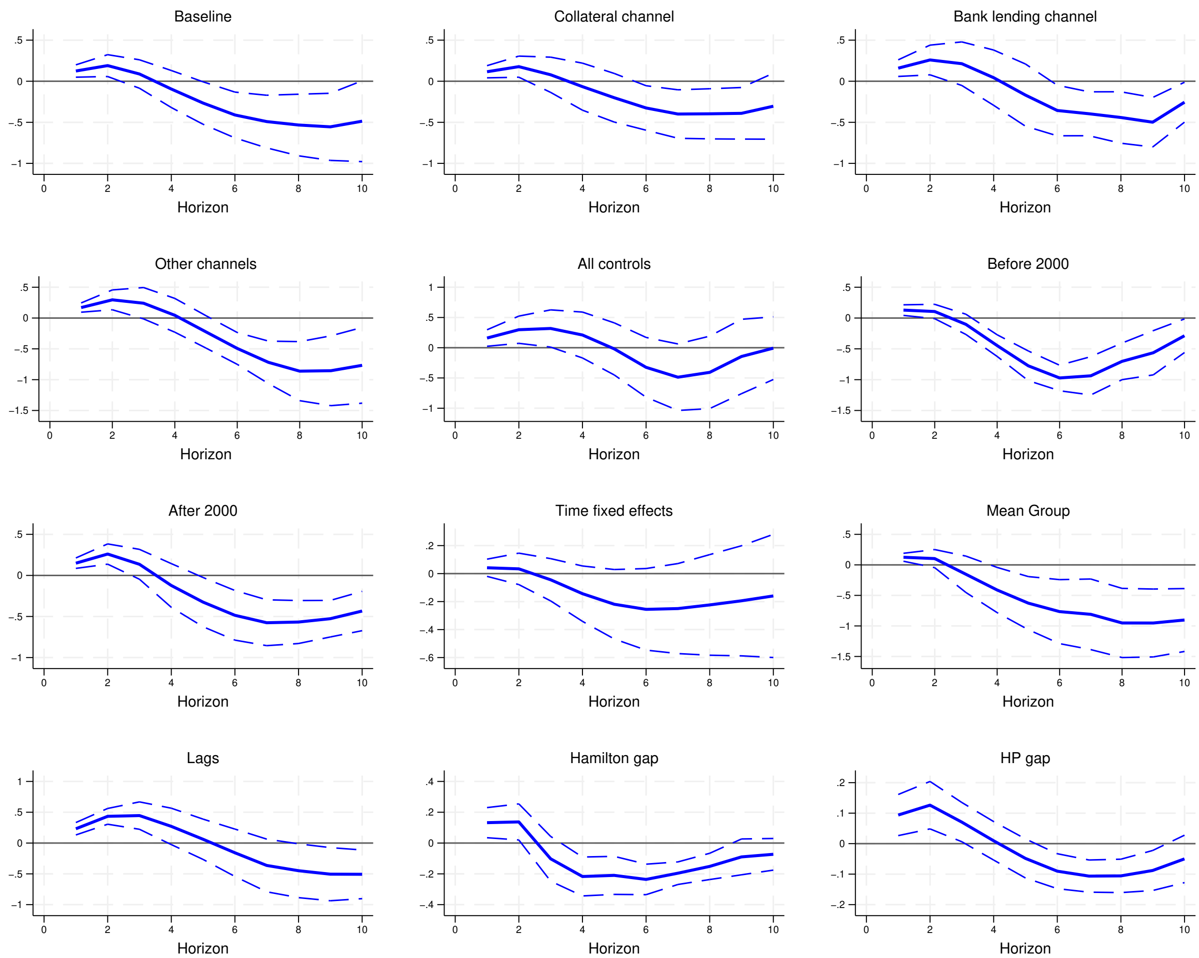

Figure 4: Cumulative output growth over horizon h, $y_{i,t+h} - y_{i,t}$, following a unit increase in new borrowing. Solid line: $\beta_{yb}^{(h)}$ from equation (7)). Dashed-lines: 95 % confidence intervals We always include the baseline set of controls and apply Driscoll-Kraay standard errors. The controls added in the different channels are listed in Table 1. *All controls* combine all controls, except lending standards. *Time fixed effects* adds time fixed effects to the specifications. *Before 2000* and *After 2000* use data up to or after the year 2000. *Mean Group* uses the Pesaran and Smith (1995) mean group estimator. *Lags*: estimates the local projections with four lags. *Hamilton* and *HP gap*: effects of new borrowing on the output gap at $t + h$ using local projections. Output gaps are estimated by a Hamilton filter and HP filter respectively.

The effects we estimate are economically meaningful. New borrowing is on average 4.6 percentage points higher than normal at the peak of a credit boom (see Figure 1). A boost of new borrowing by this size implies nearly 0.9 percentage point higher output growth two years later under the baseline specification in Figure 3. However, it also increases debt services over time. With the typical autocorrelation of new borrowing, debt service in year 6 would be approximately 1.5 higher. The accumulated net effect over seven years is minus 2.3 percentage points reaching minus 2.5 percentage points at the lowest point over nine years. That said, the magnitudes of credit booms can vary substantially across countries. At the extreme, during the credit boom preceding the Great Financial Crises in Spain, new borrowing went up by 11.5.

To put these magnitudes into context, it is interesting to contrast them with estimates of output losses associated with financial crises. For instance, Cerra and Saxena (2008) estimate that such losses are about 7.5% of GDP on average over a ten year horizon. But not all credit booms end up in crises. Baron et al. (2021) look at large declines in aggregate bank equity and find that such events are followed by 3.4% lower real GDP after three years. When they exclude episodes of banking panics, they find declines of 2.7% of GDP.[18] These numbers are much closer to ours and suggest that long-term debt propagation may account for a large fraction of the systematic losses associated with credit booms.

3.3 Real effects from other channels

We draw two main conclusions from the results in previous section. First, the flows of new borrowing and debt service have robust real effects, which are both economically and statistically significant. Second, the flows interact in a way that generate real protracted reversals several years after a credit boom. This highlights the importance of long-term debt propagation as a channel through which credit booms can affect the real economy. As such, our results point to models which allow for long-term debt and heterogeneity between borrowers and lenders, such as Korinek and Simsek (2016) and Mian et al. (2021). But how do these effects compare to those of the other channels?

To assess how the long-term debt propagation mechanism relates to the literature, we assess the impact of several complementary hypotheses. The results are shown in Table 2, focusing on horizon $h = 6$ to ensure easy comparability.[19] Note that the first row shows the

[18] As an additional robustness test, we also assessed whether the output losses are driven by financial crises by blocking out the year of a crisis and the subsequent one individually, as well as, by considering a sub-sample of countries that had no crises before the GFC from 1980-2005 (Australia, Belgium, Canada, the Netherlands and Spain). For these two specifications, the cumulative impact of a unit increase in new borrowing on output over six years is -0.442 and -0.645 respectively and in both cases highly significant. This would give us reductions in output ranging from 2 to 3 percentage points for the average credit boom

[19] We choose horizon $h = 6$ as this is the fist horizon when the reversals are significant in the baseline

impact of new borrowing, which is simply the numerical representation of horizon $h = 6$ for the different specifications shown in rows 1 and 2 in Figure 4.

In addition to the impact of new borrowing on cumulative future output growth, the variables related to the collateral channel stand out in Table 2. This is broadly in line with the theories in e.g., Kiyotaki and Moore (1997) or Iacoviello (2005) that highlight that busts in asset prices can reduce spending through either tightened borrowing constrains or wealth effects. In our specification, we find that a unit increase in real residential property price growth lowers output growth by 0.2 percentage points six years into the future.[20] Growth in net worth also has a significant positive short-term effect on output but does not imply a predictable future decline in cumulative output growth.

The other variables, associated with the bank lending channel among others, cannot account for reversals at the six-year horizon. Only credit to the tradable and non-tradable sector have negative and significant coefficients (specification (4)). The latter effect is in line with the results in Müller and Verner (2024). But these coefficients turn insignificant when all controls are added simultaneously (specification (5)).[21] All other variables have consistently insignificant coefficients in Table 2. That said, many of the other variables have significant negative effects at shorter horizons (see Table D.6), such as the Baron et al. (2021) indicator of banking sector stress, lending standards, and the change in the exchange rate. Hence, these variables may help signal reversals in the near term.

Our flow variables can also to a large extent account for the results in Mian et al. (2017) who are among the first to comprehensively document that credit booms are followed by real reversals (see Appendix E). Specifically, when we add our flow measures to their specification, the household credit to GDP measure that they use becomes insignificant while both new borrowing and debt service are significant and account for the real reversals. However, their corporate sector credit to GDP measure remains significant, indicating that there is complementary information from this sector.

Taken together, the results in this section suggest that the variables used to capture other channels are largely orthogonal to the information contained in our flow variables. Nevertheless, they can have predictive power for both real and credit related dynamics, particularly at shorter horizons. Thus, these variables also contribute to our understanding of credit booms.

specification. We also show the results for horizon 3 and 9 in Tables D.6 and D.7, Appendix D.

[20]This implies an average output loss of up to 1.2 percent, given that residential property price growth is 5.8 percentage points higher than normal at the peak of the credit cycle.

[21]The effect of non-tradable credit growth is significant even in this specification at horizon 9. See Table D.7.

	Dependent variable: $y_{i,t+6} - y_{i,t}$				
	(1)	(2)	(3)	(4)	(5)
$b_{i,t}$	-0.411^{***}	-0.325^{**}	-0.356^{**}	-0.493^{***}	-0.324
	(0.142)	(0.138)	(0.157)	(0.132)	(0.252)
$s_{i,t}$	-0.926^{***}	-0.694^{**}	-1.516^{***}	-1.886^{***}	-2.148^{***}
	(0.171)	(0.309)	(0.490)	(0.231)	(0.499)
$y_{i,t} - y_{i,t-1}$	0.139	0.306	-0.254	-0.187	0.011
	(0.172)	(0.191)	(0.152)	(0.226)	(0.278)
$p^{res}_{i,t} - p^{res}_{i,t-1}$		-0.202^{**}			-0.250^{*}
		(0.081)			(0.123)
$nw^{hh}_{i,t} - nw^{hh}_{i,t-1}$		0.272^{***}			0.160^{**}
		(0.073)			(0.073)
$spr^{nfc}_{i,t} - spr^{nfc}_{i,t-1}$			-0.029		-0.040
			(0.019)		(0.036)
$spr^{hh}_{i,t} - spr^{hh}_{i,t-1}$			-0.213		0.353
			(0.413)		(0.491)
$I^{e}_{i,t}$			-1.409		-0.680
			(0.839)		(1.092)
$lst_{i,t}$			-0.010		
			(0.013)		
$inv^{res}_{i,t} - inv^{res}_{i,t-3}$				-0.017	-0.001
				(0.027)	(0.036)
$prod_{i,t} - prod_{i,t-5}$				-0.459	0.034
				(0.377)	(0.565)
$cr^{ntrd}_{i,t} - cr^{ntrd}_{i,t-1}$				-0.070^{**}	-0.078
				(0.034)	(0.049)
$cr^{trd}_{i,t} - cr^{trd}_{i,t-1}$				-0.100^{**}	-0.069
				(0.045)	(0.050)
$fx_{i,t} - fx_{i,t-1}$				-0.108	0.075
				(0.093)	(0.044)
N	548	428	153	281	171
R^2_w	0.412	0.434	0.531	0.592	0.577

Table 2: Real reversals and other theories. Coefficient estimates from local projections (equation (7)). *Collateral channel*: (log) residential property prices, $p^{res}_{i,t}$ and (log) household sector net worth, $nw^{hh}_{i,t}$. *Bank lending channel*:corporate credit spread, $spr^{nfc}_{i,t}$, prime lending spread $spr^{hh}_{i,t}$, banking sector stress indicator, $I^{e}_{i,t}$, and lending standards, $lst_{i,t}$. *Other channels*: (log) gross capital formation in dwellings, $inv^{res}_{i,t}$, (log) productivity, $prod_{i,t}$, (log) credit to the non-tradeable sector to GDP, $cr^{ntrd}_{i,t}$, (log) credit to the tradeable sector to GDP, $cr^{trd}_{i,t}$, and (log) effective exchange rate, $fx_{i,t}$. R^2_w refers to the within-panel coefficient of determination. Driscoll-Kraay standard errors in parentheses. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

4 Model of long-term debt propagation

The evidence in the previous section suggests that a household balance-sheet channel coupled with long-term borrowing might account for the debt related dynamics that we see in the data. To investigate if this is indeed a plausible explanation, we embed this channel in a stylized New Keynesian model in the spirit of Galí (2008), Eggertsson and Krugman (2012), and Martin and Philippon (2017). Specifically, our model features patient lenders who provide long-term funding to impatient constrained borrowers. We construct our model with the objective to be as parsimonious as possible while allowing for long-term debt propagation, boiling down to four independent equations. We evaluate to what extent this model can replicate the basic patterns observed in the data.

4.1 Setup

Agents. Suppose that there are two sets of private agents labeled borrowers, B, and lenders, L, in infinite discrete time who differ in their discount factor $\beta_B < \beta_L < 1$. Borrowers and lenders have mass χ and $1 - \chi$ respectively. We denote all variables except interest rates in real terms.

Each type of agent $i = B, L$ has standard additively separable CES preferences

$$U = E \sum_{t=0}^{\infty} \beta_i^t \left[\frac{C_{i,t}^{1-\sigma_i}}{1-\sigma_i} - \frac{N_{i,t}^{1+\eta}}{1+\eta} \right] \tag{8}$$

where $C_{i,t}$ is consumption of a composite good and $N_{i,t}$ is labour supplied. Following Eggertsson and Krugman (2012), we assume that $\sigma_i = \sigma \frac{C_i^*}{Y^*}$ where we use asterisks to denote steady-state values. This assumption simplifies aggregation of labor supply, as we shall see below, without detracting from the main message of our model.

Firms. Following the New Keynesian tradition, there is a unit mass of monopolistically competitive firms that produce differentiated intermediate goods and are subject to a Calvo pricing friction whereby only a fraction $(1 - \theta)$ of firms can adjust their prices in a given period. Each firm j uses a Cobb-Douglas production function that combines regular labor N_B supplied by borrowers and entrepreneurial labor N_L supplied by lenders:

$$Y_j = \left(\frac{N_{B,j}}{\chi} \right)^{\chi} \left(\frac{N_{L,j}}{1-\chi} \right)^{1-\chi} \tag{9}$$

The markets for regular and entrepreneurial labor are perfectly competitive.

A perfectly competitive final goods production sector combines the intermediate goods

Y_j to produce the composite consumption good using a CES aggregator with an elasticity of substitution $\psi > 1$. Firms are owned and managed by lenders with a profit-sharing arrangement under which they pay a fraction χ of their profits to borrowers. This structure implies that firms act according to the preferences of (unconstrained) lenders while ensuring that both agents receive the fractions χ and $1 - \chi$ of output, which makes the model more tractable.

Financial market structure. There are two financial assets in the economy that are in zero net supply. First, there is a risk-free one-period bond paying the nominal interest rate R_t, which is also the target rate of the central bank. Second, there is nominal long-term debt with amortization rate δ. This implies that a fraction δ of the outstanding debt, deflated by the rate of nominal price inflation, is repaid in each period, whereas the remaining fraction $(1 - \delta)$ is carried over to the following period. We denote the nominal interest rate for new long-term debt issued in period t by $R_{ND,t}$ and the average interest rate on all outstanding long-term debt by $R_{D,t}$.

Lenders have access to both financial assets. Borrowers only have access to long-term debt and are subject to two additional financial frictions. First, they access financial markets infrequently, captured by the assumption that only a fraction ϕ of them engage in new borrowing in a given period. Second, their borrowing D_t is limited by an exogenous debt limit $\bar{D}_t$. We assume that borrowers are sufficiently impatient so that they borrow up to the constraint whenever they access the financial market.

Applying the law of large numbers, the average real debt outstanding per borrower, D_t, reflects that a fraction ϕ of borrowers take on debt up to the limit whereas the remaining fraction $(1 - \phi)$ mechanically carries over the non-amortized share of their debt deflated by the increase in nominal prices,

$$D_t = \phi \bar{D}_t + (1 - \phi)(1 - \delta) D_{t-1} / (1 + \Pi_t) \tag{10}$$

The average interest rate on the stock of long-term debt outstanding, $R_{D,t}$, is a weighted average of the interest rate on new long-term debt and the rate on existing debt

$$R_{D,t} = \alpha_t R_{ND,t} + (1 - \alpha_t) R_{D,t-1} \tag{11}$$

where the weight α_t is the fraction of debt that is newly borrowed in period t.

Lender behavior. Lenders choose $C_{L,t}, N_{L,t}, B_{L,t}, D_{L,t}$ to maximize utility (8) subject to the budget constraint

$$C_{L,t} + B_{L,t} + D_{L,t} = W_{L,t}N_t + \frac{(1+R_{t-1})\, B_{L,t-1}}{1+\Pi_t} + \sum_{i=1}^{\infty} \frac{(R_{ND,t-i}+\delta)\,(1-\delta)^{i-1}}{\prod_{s=1}^{i}(1+\Pi_{t-s+1})} D_{L,t-i} + T_t$$

and a transversality condition, where $B_{L,t}$ and $D_{L,t}$ are lenders' purchases of one-period bonds and long-term debt at time t, respectively, $W_{L,t}$ is the real wage of entrepreneurial labor. The sum on the right-hand side of the budget constraint reflects the lenders at time t receive the sum of the debt service on all their long-term debt purchases of prior periods $t-i$.

The first-order optimality conditions for one-period bonds yields an Euler equation that pins down the short-term interest rate

$$u'(C_{L,t}) = \beta_L E\left[\frac{1+R_{t-1}}{1+\Pi_t} u'(C_{L,t+1})\right]$$

The optimality condition for long-term debt purchases delivers a no-arbitrage relationship between the interest rate on new long-term debt in period t, $R_{ND,t}$, and expected future short-term rates,

$$\frac{1}{R_{ND,t}+\delta} = E\sum_{i=0}^{\infty}\left[\frac{(1-\delta)^i}{\prod_{s=0}^{i}(1+R_{t+s})}\right] \tag{12}$$

Price-setting. The optimal price-setting decision of monopolistically competitive firms can be derived equivalently to Galí (2008). The optimal price, P_t^*, set by a fraction $1-\theta$ of firms every period, follows

$$\frac{P_t^*}{P_t} = \left(\frac{\psi}{\psi-1}\right)\frac{E_t\left[\sum_{i=0}^{\infty}\theta^i\beta^i C_{t+i}^{1-\sigma_L}\Phi_{t+i}\left(P_{t+i}/P_t\right)^{\psi}\right]}{E_t\left[\sum_{i=0}^{\infty}\theta^i\beta^i C_{t+i}^{1-\sigma_L}\left(P_{t+i}/P_t\right)^{\psi-1}\right]} \tag{13}$$

where Φ_t is firms' real marginal costs given by

$$\Phi_t = \left(\frac{W_{B,t}}{\chi}\right)^{\chi}\left(\frac{W_{L,t}}{1-\chi}\right)^{1-\chi} \tag{14}$$

where $W_{B,t}$ is the borrower's real wage.

Monetary policy. We assume that monetary policy follows a standard Taylor rule with gradualism (see Appendix F).

Aggregate demand. Market clearing for final goods requires that aggregate consumption equals output, or $C_t = Y_t$, which is also per-capita income for all agents. Since the respective masses of borrowers and lenders are χ and $1-\chi$ and the consumption variables $C_{B,t}$ and $C_{L,t}$ are in per-capita terms, aggregate consumption is given by

$$Y_t = C_t = \chi C_{B,t} + (1-\chi) C_{L,t}$$

Borrowers' combined consumption is fully determined by their income Y_t together with their new borrowing and debt service,

$$C_{B,t} = Y_t + \phi \bar{D}_t - \Lambda_{t-1} D_{t-1} / \left(1 + \Pi_t\right) \tag{15}$$

where we denote the repayment rate by $\Lambda_{t-1} = \phi\left(1-\delta\right) + \delta + R_{Bt-1}$. The term $\phi \bar{D}_t$ in (15) together with the first term in Λ_{t-1} capture that a fraction ϕ of borrowers retire their old debt and borrow up to the limit $\bar{D}_t$.

Price dynamics. Aggregate price level dynamics follow

$$P_t = \left[\theta P_{t-1}^{1-\psi} + (1-\theta)(P_t^*)^{1-\psi}\right]^{\frac{1}{1-\psi}} \tag{16}$$

following Galí (2008).

Calibration. We log-linearize the model around steady-state (see Appendix F) and calibrate its parameters to match the data (see Table 3).

We pick standard values for the preference, pricing, and policy parameters. We set $\beta_L = 1/1.04$, giving a steady-state real interest rate on bonds of 4%, and $\sigma = 2$ which corresponds to an elasticity of intertemporal substitution of 0.5. We also set $\eta = 1$ in line with e.g., Galí (2008). One third of firms are assumed to reset their prices each period, ie $\theta = 2/3$. Finally, to describe central bank behavior, we set $\xi = 0.8$, $\gamma_\pi = 1.5$, and $\gamma_y = 0.5$.

To calibrate the parameters related to long-term debt, we follow Kaplan et al. (2020) and set the fraction of constrained impatient borrowers to one third, i.e. $\chi = 1/3$. We also set $\phi = 0.25$ so that one quarter of borrowers can access debt in any given year based on household debt statistics from the Federal Reserve board (Aladangady et al. (2023)). We assume $\delta = 0.1$ to match the average amortization rate in our data and the persistence of the debt limit, ζ, is set to 0.75 based on the auto-correlation of for new borrowing in our sample.

Our linearized system of equations involve three independent steady-state values for $\bar{D}^*$, Y^* and Π^*. We set $\bar{D}^*$ to match D^* with the average household credit-to-GDP ratio in our

Parameter	Description	Value	Source / Target
Debt block			
ζ	Borrowing limit persistence	0.75	Auto-correlation of new borrowing[1]
ϕ	Debt access frequency	0.25	Aladangady et al. (2023)
δ	Amortization rate	0.1	Average repayment rate[1]
χ	% Constrained borrowers	1/3	Kaplan et al. (2020)
IS-curve			
σ	Inverse elasticity of substitution	2	Kaplan et al. (2020)
Phillips curve			
β_L	Lender discount factor	1/1.04	4% real rate in steady-state
θ	1 – Repricing frequency	2/3	Galí (2008)
η	Frisch elasticity	1	Galí (2008)
Taylor rule			
ξ	Policy gradualism	0.8	Christiano et al. (2005)
ϕ_π	Inflation response	1.5	Galí (2008)
ϕ_y	Output response	0.5	Galí (2008)
Steady-state values			
$\bar{D}^*$	Debt limit	1	Set to match $D^*$with average credit-to-GDP ratio[1]
Π^*	Inflation	0	Assumption
Y^*	Output	1	Normalization
Shocks			
$\psi_{\bar{d},t}$	Std. of borrowing limit	11.6	Match std. of d_t with std. of credit-to-GDP gap
$\psi_{y,t}$	Std. of output gap	0.7	Match std. of $\tilde{y}_t$ with std. of output gap
$\psi_{\pi,t}$	Std. of inflation	0.85	Match std. of π_t with std. of inflation gap
$\psi_{\pi,t}$	Std. of policy shock	1.6	Galí (2008)

Table 3: Parameters of the baseline calibration.[1] For the household sector.

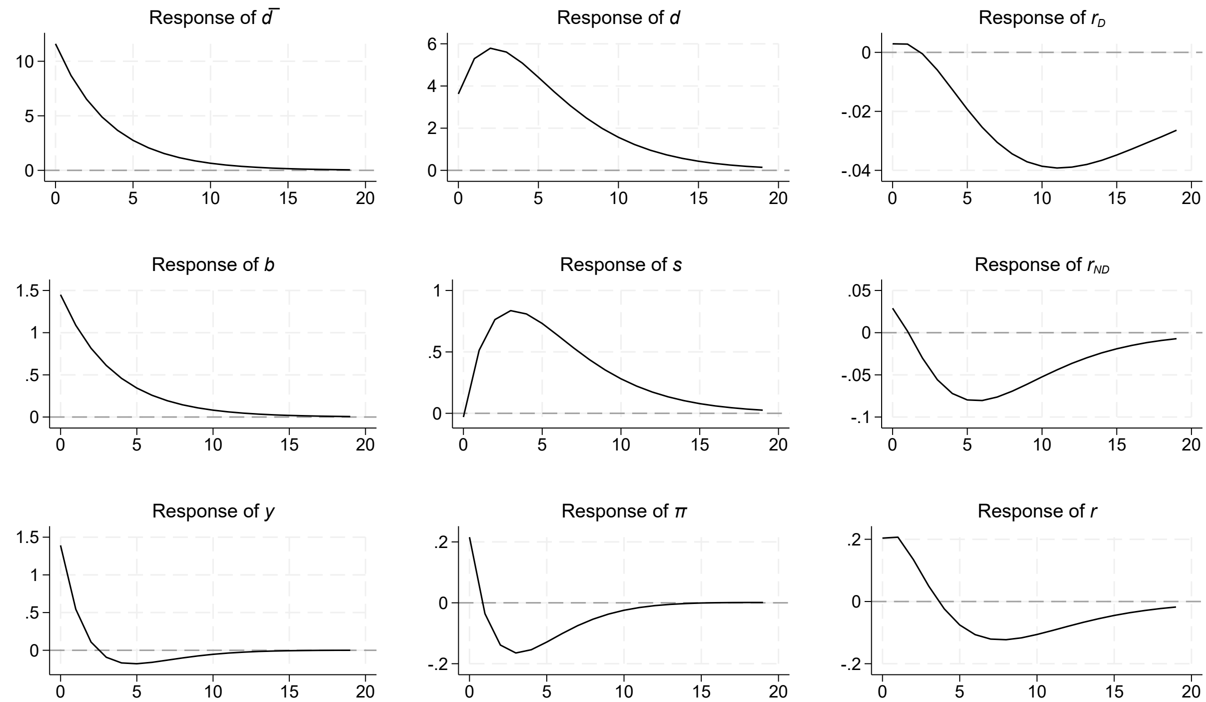

Figure 5: Impulse response functions of the model variables to a one standard deviation borrowing constraint shock. The parameter values are as in Table 3.

sample, which by coincidence happens when $\bar{D}^* \approx 1$. We also impose $\Pi^* = 0$ and normalize $Y^* = 1$. Finally, we calibrate the standard deviations of the shocks the borrowing limit, IS-curve, and Phillips-curve to match the estimated standard deviations of HP-filtered credit-to-GDP ($\lambda = 400K$), real GDP, and inflation rate, respectively.[22] We take the standard deviation of the policy shock from Galí (2008) which is set to match average rate changes over tightening and loosening cycles.

4.2 Model simulations

Our primary interest is in how long-term debt propagation works in our theoretical model. To study this, we focus on the impulse response functions to a standard deviation shock to the borrowing limit which directly drives new borrowing in our model (Figure 5).

The dynamics illustrate how long-term debt propagates through the economy via the interaction between new borrowing and accumulated debt service. A one-standard deviation shock to the borrowing constraint $\bar{d}$ (top row, left panel) generates an immediate expansion in new borrowing b (middle row, left panel), which gradually declines due to the assumed

[22] We use $\lambda = 400K$ for the credit-to-GDP ratio in line with Drehmann et al. (2012) and $\lambda = 1600$ for the other variables.

autocorrelation of the shock. This increased borrowing leads to a build-up in the aggregate debt stock d (top row, middle panel), peaking around period 3 before slowly reverting to steady state. Moreover, since constrained borrowers have a higher marginal propensity to consume than unconstrained lenders, new borrowing also increases aggregate demand in the short run. As monetary policy follows the – empirically relevant – case of a Taylor rule with gradualism (bottom right panel), it only partially offsets the shock to aggregate demand, resulting in both higher output and, via the New Keynesian Phillips curve, higher inflation in the short run (bottom row, left and center panel).

The key mechanism in our model operates through the interplay between new borrowing and debt service payments s (center panel). As debt accumulates, the rising debt service burden increasingly weighs on constrained borrowers' disposable income and by extension aggregate demand. This eventually causes output to turn negative around period 3-4, with the most pronounced contraction coinciding with the peak in debt service around period 4. Output gradually recovers thereafter as both the debt stock and service burden normalize.

Inflation dynamics π (bottom row, middle panel) closely track output through the Phillips Curve, though with a slight lead due to its purely forward-looking nature. The inflation response turns negative approximately one period before output, reflecting agents' anticipation of the coming economic slowdown.

The short-term interest rate r (bottom row, right panel) reflects the monetary policy response, which reacts to both inflation and output according to the Taylor rule. Due to policy gradualism, the interest rate adjustment is more muted and persistent than the underlying macroeconomic dynamics. The interest rate on new long-term borrowing r_{ND} (middle row, right panel) represents a discounted expectation of future short-term rates, while the average interest rate on outstanding debt r_D (top row, right panel) follows as a moving average of past long-term rates on new borrowing.

4.3 Real reversals in the model vs data

Although the goal of our model is to elucidate the mechanism for long-term debt propagation rather than perfectly matching the observed pattern in the data, our model generates debt-propagated real reversals of similar magnitude and timing as in the data (left-hand panels of Figure 6).[23] The upper panels show the reactions of new borrowing and debt service to a debt shock $\varepsilon_{\bar{d},t}$ at $t = 0$ in the theory model. The interplay between these variables help shape the output response visible in the lower panel (solid line). The reversal generated by

[23]The key parameters for capturing the debt related dynamics are the amortization rate, δ, and the persistency of the borrowing limit, ζ, as we discuss in more detail below. Several parameters are important for the magnitude of the effects including ϕ, χ, σ, and $\bar{D}^*$. Higher values for all of these increase the magnitude.

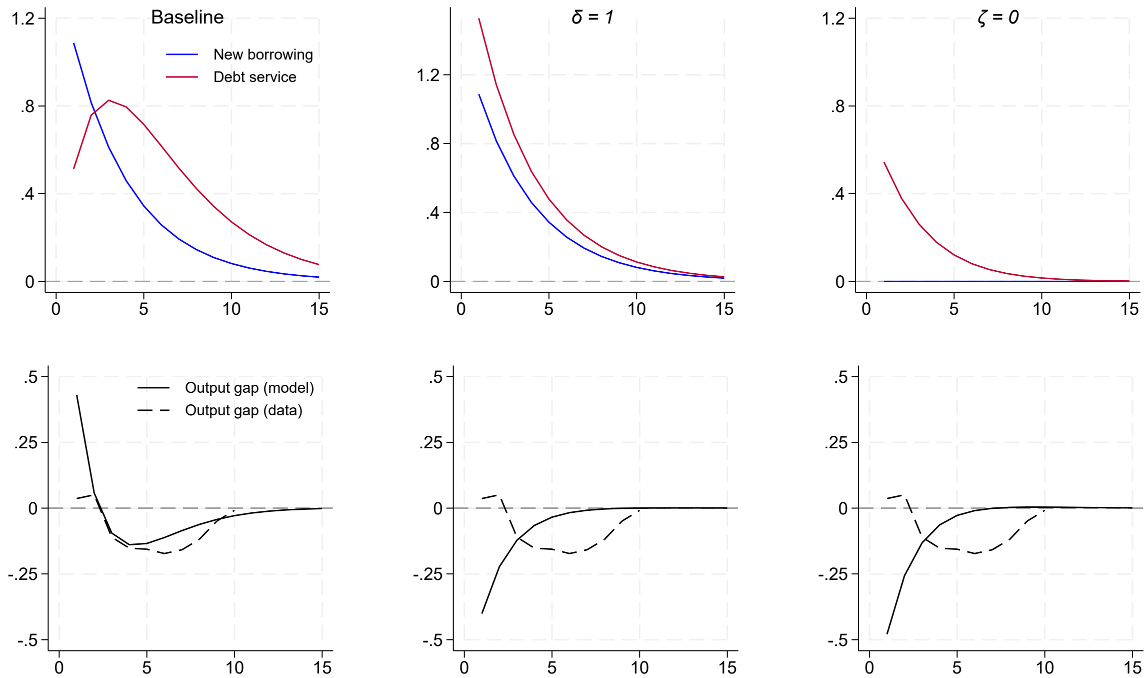

Figure 6: Debt dynamics and real reversals under different assumptions on borrowing limit persistence and the amortization rate. The left-hand panels use the baseline values in Table 3. The middle panels use $\delta = 1$ and the baseline values for the remaining parameters. The right-hand panels use $\zeta = 0$ and the baseline values for the remaining parameters.

the theory model is very similar in both shape and size to the empirical response from a unit increase in new borrowing (dashed line) on an estimated output gap.[24]

While the real effects track the empirical impulse responses surprisingly well in periods 2 to 5 despite the highly stylized nature of our model, we note that the positive output response in the initial period is significantly stronger in the model. This reflects the immediate spending of the liquidity received by borrowers and is a common feature of New Keynesian models with borrowing constraints.[25]

A reasonable objection is that we are comparing the wrong impulse responses. A unit impulse to new borrowing is not the same as a structural shock to the borrowing limit. This is true, but it turns out that the two are practically identical in our model in line with the arguments of Mian et al. (2021). We show this in Appendix G (the left panel, Figure G.1).

[24] We use Equation (7) with an estimated Hamilton-filtered output gap in instead of cumulated output growth on the left hand side. See bottom row, middle panel, Figure 4.

[25] Many quantitative New Keynesian models incorporate tricks such as habit formation to temper the immediate effects of shocks (see, e.g. Christiano et al., 2005). However, our goal here is to present the simplest possible model that captures the medium-term real reversals following a credit boom.

4.4 Drivers of debt propagation

Three main ingredients in our model are needed to generate predictable real reversals that are in line with what we see in the data.

The first ingredient is persistent borrowing in long-term debt, which generates nontrivial debt dynamics and the predictable reversal in the net flows between borrowers and lenders, as well as output. Figure 6 shows what happens if we remove either the persistence or the long-term nature of debt contracts. If debt is short-term, i.e. if $\delta = 1$, then any new borrowing is immediately repaid in the ensuing period (upper middle panel). After an impulse to the debt limit (at $t = 0$), debt service is highest in the period right after the shock. These effects exponentially decay thereafter, without interesting lead-lag dynamics. The resulting pattern in output is highly at odds with the pattern in the data. Similarly, if borrowing is not persistent, i.e., if we set the autocorrelation of the shock to the debt limit $\zeta = 0$ (right panels), then new borrowing rises for one period only, and debt service also decays exponentially thereafter, without generating a non-monotonic reversal.

The second ingredient is that borrowers are subject to financial constraints so that the predictable reversals in financial flows between borrowers and lenders affect aggregate demand. In a world of perfect financial markets, all agents would be perfectly insured, and the dynamics of aggregate demand would look akin to a New Keynesian model with a representative agent. In this case, there is no role for financial market shocks or any resulting real effects.

The third ingredient is that monetary policy does not fully offset the demand effects arising from the predictable reversals in debt flows. As a result, aggregate output experiences the non-monotonic boom-bust behavior that we identified in the empirical section. There is a long literature on why it is difficult in practice to set interest rates to what the theoretically optimal level would be and why Taylor rules of the sort we assumed (equation F.20) better describe the actual behavior of monetary policymakers. Reasons include the difficulty of identifying shocks in real time and – in the case of interest rate cuts – the presence of an effective lower bound on the nominal interest rate.[26]

4.5 Credit supply vs. demand

Our conceptual model also illustrates that the question of whether boom-bust dynamics are driven by credit supply or credit demand shocks is more nuanced than it appears at first sight. In our baseline calibration, we focus on shocks to the borrowing limit $\bar{D}_t$, which –

[26] The right-hand side of Figure G.1 in Appendix G simulates the level of the interest rate that would be required to set the output gap and inflation to zero after a shock to the debt limit. The figure shows that the rate would have to rise approximately seven-fold compared to what is implied by the standard Taylor rule to fully offset the effects of debt.

when interpreted literally – can be viewed as credit supply shocks that arise from changes in lenders' willingness or ability to extend credit.[27] The model also allows us to analyze shocks to the parameter ϕ, which captures the frequency at which borrowers access credit markets and can be interpreted as credit demand shocks. For example, if borrowers face non-monetary costs of accessing credit markets (such as time costs, hassle costs, or psychological costs) and these costs are stochastic, then a higher value of ϕ reflects that more borrowers in a given period find it worthwhile to pay these costs and demand new credit.

At the most fundamental level, both types of shocks enter equation (10) positively and mechanically give rise to a higher flow of resources from lenders to borrowers in the short term, accompanied by a reversal in the medium term because of the debt propagation dynamics. In our model, it turns out that shocks to $\bar{D}_t$ and ϕ both give rise to equivalent flows of resources between lenders and borrowers (see Appendix G). One interpretation of this finding is that the subsequent propagation through debt service flows and the associated output dynamics remain unaffected by whether a credit boom is initiated by increased credit supply (a higher $\bar{D}_t$) or increased credit demand (a higher ϕ_t). In both cases, the predictability of real reversals stems from the internal propagation mechanism of long-term debt rather than from the specific nature of the initial shock.

However, the mapping of credit demand and supply shocks to our framework is more subtle and less obvious than what the literal interpretation of shocks to $\bar{D}$ and ϕ two paragraphs above suggests. For example, if $\bar{D}$ rises because borrowers' collateral becomes more valuable and allows them to access more credit, it would be more natural to interpret this as a credit demand shock since it emanates from the side of borrowers. Likewise, if a shock to ϕ reflects changes in the financial system that provide expanded access to credit, then it might be natural to think of it as a credit supply shock. Ultimately, our analysis suggests that the predictable real reversals after credit booms arise from the long-term debt propagation mechanism that follows any expansion in credit – no matter whether the initial impulse originates on the supply or demand side.

5 Conclusions

This paper shows that the financial flows between borrowers and lenders associated with long-term debt are crucial for understanding how credit market developments propagate to the real economy. Using a novel cross-country dataset of financial flows for 16 countries from 1980 to 2019, we demonstrate that while new borrowing is associated with higher economic growth, its counterpart – debt service – accounts for much of the adverse real effects of

[27] See, e.g., Justiniano et al. (2019) for an analysis that suggests that a credit supply shock in the form of looser lending constraints was the key driver of the housing boom in the US in the 2000s.

credit, systematically linking past credit booms to predictable future slumps. Furthermore, we embed this mechanism in a parsimonious New Keynesian model with borrowers and lenders, and demonstrate that it replicates the patterns observed in the data.

Our paper provides three key insights that contribute to the literature. First, we show that it is the timing of debt service flows under long-term debt – not credit stocks or balance sheet positions – that drives real reversals, as it creates the necessary lag structure. This timing follows mechanically from typical mortgage maturities and amortization schedules, offering a parsimonious explanation for the observed 4-6 year lag in real reversals after credit booms. Second, we demonstrate the empirical predominance of this channel: it accounts for a substantial share of output losses following credit booms, while many variables capturing other proposed mechanisms become statistically or economically insignificant when debt flows are properly accounted for. Third, we establish that reversals are determined by the structure of debt contracts rather than behavioral responses. Unlike theories that attribute reversals to coordination failures (e.g., Kiyotaki and Moore (1997), Section III) or sentiment shifts (e.g., López-Salido et al. (2017)), we show that reversals are "baked into" the amortization schedules of contracts signed during credit booms. Thus, our mechanism provides a straightforward explanation for credit-related reversals.

Our findings raise several important questions related to both the measurement and theory of credit cycles. For one, given the important real effects of the flows between borrower and lenders, it is crucial to improve their measurement. It would be particularly beneficial to obtain more regular and granular information on maturity and amortization schedules. This applies to the household sector and even more to the corporate sector, where these data are not very reliable.

Our results also highlight the need for theory models to incorporate long-term debt propagation. As we have shown in Section 4, this requires that credit markets feature long-term debt with auto-correlated new borrowing. Moreover, the strong and systematic pattern in output that is generated by flows between lenders to borrowers suggests that lenders and borrowers have different marginal propensities to consume. And that borrowers are financially constrained so that they cannot offset high debt service by additional borrowing. Furthermore, it requires models in which monetary policy does not or cannot easily offset the resulting aggregate demand effects.

Long term debt propagation also highlights an important policy trade-off between current output concerns and future reversals due debt service obligations. Our mechanism implies that these reversals cannot easily be avoided through confidence-building or expectation management once the debt is in place. Hence, any policy that affects the economy by influencing the process of credit generation, for example monetary policy, needs to take this trade-off into account.

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A Internet Appendix: Data and sources

Variable	Description	Source
Credit ($d_{i,t}$, $d^{hh}_{i,t}$, $d^{nfc}_{i,t}$)	Credit to the household sector from all sources, including bank credit, cross-border credit and credit from non-banks deflated by the GDP deflator.	BIS
GDP ($y_{i,t}$)	Real GDP.	National Accounts
Real short rate ($r_{i,t}$)	3-month money market rate minus the CPI inflation rate.	Datastream
Inflation rate ($\pi_{i,t}$)	First difference of the logarithm of the CPI.	National sources.
Term spread ($spr^{term}_{i,t}$)	10 year government bond yield minus 3-month money market rate.	Global Financial Data
Property price ($p^{res}_{i,t}$)	Residential property price deflated by the CPI.	BIS
Net worth ($nw^{hh}_{i,t}$)	Total assets - total liabilities of the household sector.	National Accounts
Corporate credit spread ($spr^{nfc}_{i,t}$)	Spread between lending spread and a corporate credit spread. As Krishnamurthy and Muir (2025) it is calculated as the spread between the general corporate bond index and the weighted average of the five and 10 year government bond rates.	Global Financial Data Merrill Lynch, Moody's
Lending spread ($spr^{hh}_{i,t}$)	Prime lending rate minus 3-month money market rate.	Macrobond
Banking sector stress ($I^{e}_{i,t}$)	1 if bank equity prices have fallen by more than 30%	Baron et al (2021)
Residential investment ($inv^{res}_{i,t}$)	Gross fixed capital formation, dwellings	OECD
Labor productivity ($prod_{i,t}$)	Labor productivity growth.	OECD, FRED, World Bank
Tradable/non-tradable corporate credit ($cr^{x}_{i,t}$)	Credit to the tradable/non-tradable sector relative to GDP	Mueller and Verner (2024)
Real exchange rate ($fx_{i,t}$)	Real effective exchange rate.	BIS
Delinquency rates ($def_{i,t}$)	Delinquency rates for the household sector	Central banks
Provisions ($prov_{i,t}$)	Aggregate provisions of the national banking sector.	Bankscope, OECD, Pesola (2011)
Lending standards ($lst_{i,t}$)	Bank lending standards.	Central banks
Unemployment ($u_{i,t}$)	Unemployment rate.	Global Financial Data, OECD, central banks
Consumption ($con_{i,t}$)	Real private consumption.	National Accounts

Table A.1: Variable definitions and data sources. Table references: Pesola, J (2011), "Joint effect of financial fragility and macroeconomic shocks on bank loan losses: evidence from Europe", *Journal of Banking and Finance*, 35(11), pp 3134-3144.

country	$b_{i,t}$	$s_{i,t}$	$y_{i,t}$	$r_{i,t}$	$\pi_{i,t}$	$spr^{term}_{i,t}$	$p^{res}_{i,t}$	$nw^{hh}_{i,t}$	$spr^{nfc}_{i,t}$	$spr^{hh}_{i,t}$	$I^{e}_{i,t}$	$inv^{res}_{i,t}$	$prod_{i,t}$	$cr^{ntrd}_{i,t}$	$cr^{trd}_{i,t}$	$fx_{i,t}$	$def_{i,t}$	$prov_{i,t}$	Type
AU	1980	1980	1980	1986	1980	1986	1980	1988	1983	1986	1980	1980	1980	1981	1981	1980	2003	1991	float
BE	1981	1980	1980	1980	1980	1980	1980	1992	1980	1981	1980	1995	1980	1981	1981	1980		1981	fix
CA	1980	1980	1980	1980	1980	1980	1980	1980	1983	1980	1980	1980	1980		1981	1980		1988	fix
DE	1980	1980	1980	1980	1980	1980	1980	1991	1988	1980	1980	1980	1980	1981	1981	1980	2014	1980	fix
DK	1980	1980	1980	1980	1980	1980	1980	1990	1994	1980	1980	1980	1980	1987	1981	1980		1980	fix
ES	1981	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1995	1980	1993	1993	1980	1998	1980	float
FI	1980	1980	1980	1980	1980	1980	1980	1995	2008	1980	1980	1980	1980	1981	1981	1980		1980	float
FR	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	2007	2007	1980	2018	1988	fix
GB	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1981	1981	1980	2008	1987	float
IT	1980	1980	1980	1980	1980	1980	1980	1995	1980	1982	1980	1980	1980	1981	1981	1980	1999	1984	float
JP	1980	1980	1980	1980	1980	1980	1980	1980	1980		1980	1980	1980	1981	2000	1980		1989	fix
NL	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	2011	2011	1980		1980	fix
NO	1980	1980	1980	1980	1980	1980	1980	1981	2008	1980	1980	1980	1980	1981	1981	1980		1980	float
PT	1983	1983	1980	1983	1980	1983	1988	1994	2008	1983	1988	1980	1980	1981	1981	1980		2006	float
SE	1981	1980	1980	1980	1980	1980	1980	1995	1980	1980	1980	1980	1980			1980		1981	float
US	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980			1980	1987	1980	fix

Table A.2: Data sample. For variable names see Table A.1 and main text. Type: whether mortgages are predominately fix or floating rate in country i, see CGFS (2006): "Housing finance in the global financial market", *CGFS Paper*, no 26, and ECB (2009): "Housing fiance in the euro area", *Occasional Paper Series*, no 101.

	Household debt (stock)					
	Total	**Mortgages**		**Other household debt**		
		Total Mortgages	**Interest-only loans**	**Total other household debt**	**Credit card and revolving debt**	**Student & auto loans**
AU	BIS	Reserve Bank of Australia	Australian Prudential Regulation Authority (2017)	Reserve Bank of Australia	Reserve Bank of Australia	
GB	BIS	National Accounts (1987-); Bank of England (-1986)		Total minus mortgages	Bank of England	Student Loan Company (2011-); Bolton (2017) (-2011)
NL	BIS	National Accounts (1990-); Jorda et al (2017) (-1990)	De Nederlandsche Bank (2015); van Dijkuizen (2005)	Total minus mortgages		
CA	BIS	National Accounts		National Accounts	National Accounts	
DE	BIS	Deutsche Bundesbank		Deutsche Bundesbank	Deutsche Bundesbank	
JP	BIS	National Accounts		National Accounts	National Accounts	
ES	BIS	Bank of Spain		National Accounts	National Accounts	
FR	BIS	Banque de France		Banque de France	Banque de France	
IT	BIS	National Accounts		National Accounts	National Accounts	
PT	BIS	Banco de Portugal (2007-); OECD (-2007)		OECD	OECD	
US	BIS	Federal Reserve Bank of New York (2003-); FRED (-2003)		Federal Reserve Bank of New York (2003-); FRED (-2003)	Federal Reserve Bank of New York (2003-); FRED (-2003)	Federal Reserve Bank of New York (2003-); Federal Reserve Board (-2003)
DK	BIS	Danish Central Bank	Danish Central Bank	Danish Central Bank	Danish Central Bank	
SE	BIS	Statistics Sweden	ölcer and van Santen (2016); Nordman (2005)	Statistics Sweden	Statistics Sweden	Statistics Sweden
BE	BIS	European Central Bank		European Central Bank	European Central Bank	
NO	BIS	Statistics Norway		Statistics Norway	Statistics Norway	Statistics Norway
FI	BIS	Bank of Finland		Bank of Finland	European Central Bank (2010-)	

Table A.3: Data sources on debt stocks for the construction of amortization rates. Table references: Australian Prudential Regulation Authority, (2017), Quarterly ADI property exposures statistics March; Bolton, P (2017), "Student loans statistics", House of Commons Briefing Paper, no 1079; CGFS (2006): "Housing finance in the global financial market", *CGFS Paper*, no 26; De Nederlandsche Bank (2015), "Dutch mortgages in the DNB loan level data", Occasional Studies, no 13-4; Jordà, Ò, Schularick, M, and A M Taylor (2017), "Macrofinancial History and the New Business Cycle Facts." in NBER Macroeconomics Annual 2016, volume 31; Nordman, N (2005), "Swedish country note", supplementary material for CGFS (2006); Van Dijkhuizen, A (2005), "Dutch housing finance market"; Öelcer, D, and P van Santen (2016), "The indebtedness of Swedish households: Update for 2016", Economic Commentaries, Sveriges Riksbank, no 5.

	Average interest rate on the stock of debt		**Maturities**
	Total	**Sub-components**	**Mortgages; other household debt**
AU	National accounts	Reserve Bank of Australia	Cerutti et al (2015); RBA staff
GB	National accounts		Bank of England (2017)
NL	National accounts		Cerutti et al (2015)
CA	National accounts	Bank of Canada	Bank of Canada
DE	National accounts	Deutsche Bundesbank	vdpResearch (2015)
JP	National accounts		Cerutti et al (2015)
ES	National accounts	Bank of Spain	Bank of Spain
FR	National accounts		Banque de France (2016, 17)
IT	National accounts		Cerutti et al (2015)
PT	National accounts		Banco de Portugal
US	National accounts	Bureau of Economic Analysis	American Housing Survey; Federal Reserve Board (auto loans)
DK	Danish Central Bank	Danish Central Bank	Cerutti et al (2015)
SE	National accounts	Statistics Sweden; Central Bank of Sweden	Cerutti et al (2015); Ölcer and van Santen (2016)
BE	European Central Bank (2003-); OECD economic outlook (-2003)	European Central Bank (2003-); OECD economic outlook (-2003)	Zachary (2009), Meel (2017)
NO	National accounts	Statistics norway (1988 onward); OECD economic outlook (before 1988)	Cerutti et al (2015)
FI	Bank of Finland	Bank of Finland	Finanssiala (2017)

Table A.4: Data sources on interest rates and maturities for the construction of amortization rates. Table references: Bank of England. (2017), Financial stability report, June; Banque de France (2016) Assessment of risks to the French financial system, December. Banque de France. (2017). Enquête annuelle sur le financement de l'habitat en 2015; Cerutti, E, J Dagher, and G Dell'Ariccia (2015), "Housing finance and real-estate booms : A cross-country perspective", IMF Staff Discussion Notes no no 15/12; Finanssiala (2017), "Säästäminen, luotonkäyttö ja maksutavat", Finance Finland technical report; Meel, F (2017), EU 28 country reports, Belgium European mortgage federation hypostat; vdpResearch (2015), "Strukturen der Wohneigentumsfinanzierung 2015", Verband Deutscher Pfandbriefbanken; Zachary, M-D (2009), "The Belgian mortgage market in a European perspective", Economic Review, National Bank of Belgium, September; Ölcer, D, and P van Santen (2016), "The indebtedness of Swedish households: Update for 2016", Economic Commentaries, Sveriges Riksbank, no 5.

B Debt service on installment loans

Consider a debt in the principal amount of D at interest rate r that is to be repaid in m equal future installments. The value of debt must equal the present discounted value of m future debt service payments S, discounted at the interest rate r. This gives rise to the geometric series

$$D = \frac{S}{1+r} + \cdots + \frac{S}{(1+r)^m} = \frac{S}{(1+r)^m} \cdot \left[1 + \cdots + (1+r)^{m-1}\right] = \frac{S}{(1+r)^m} \cdot \frac{1-(1+r)^m}{1-(1+r)}$$

or equivalently

$$S = \frac{rD}{1-(1+r)^{-m}} \tag{B.1}$$

Debt service as a fraction of the stock of debt can be decomposed into the corresponding interest and amortization rate, $S/D = r + \delta$. Using this in equation (B.1), the amortization rate can be expressed as

$$\delta = \frac{S}{D} - r = \frac{r}{1-(1+r)^{-m}} - r = \frac{r - r + r(1+r)^{-m}}{1-(1+r)^{-m}} = \frac{r}{(1+r)^m - 1}$$

To derive the average remaining maturity $\widetilde{m}$ on the outstanding stock of debt for an environment in which the initial maturity of new borrowing is given by m, we make another simplifying assumption and consider an economy with m overlapping generations of households. Each period, a new generation engages in D units of new borrowing of maturity m. Loans are structured as installment loans, resulting in debt service S as given by equation (B.1) over the following m periods. At any given time, there is a generation that is obliged to make debt service payments S for k more periods and thus owe a market value of debt outstanding

$$D_k = \frac{S}{1+r} + \cdots + \frac{S}{(1+r)^k} = \frac{S}{r}\left[1 - \left(\frac{1}{1+r}\right)^k\right]$$

with weighted average remaining maturity (or duration) of

$$\widetilde{m}_k = \frac{1 \cdot \frac{S}{1+r} + 2 \cdot \frac{S}{(1+r)^2} \cdots + k \cdot \frac{S}{(1+r)^k}}{D_k}$$

The average weighted maturity of debt outstanding of all m generations, indexed by $k = 1, .., m$ is then simply given by

$$\widetilde{m} = \frac{\sum_{k=1}^{m} \widetilde{m}_k D_k}{\sum_{k=1}^{m} D_k}.$$

C Measurement errors

Our two key variables, new borrowing and debt service, are likely to be imperfectly measured. In this section, we investigate three specific sources of measurement error with respect to these variables and their impacts on our main results.

The first source relates to the average remaining maturity input series in our amortization formula (1). The underlying series are both patchy and often use imperfect proxies for the intended concepts. The second source relates to the assumed installment loan formula which is used to impute amortizations. Deviations from this approximation may generate measurement errors in our variables. The third source is loan defaults which we have not taken fully into account. The reason is that data on loan defaults are often lacking and therefore have to be proxied.

Average remaining maturity and simulated errors. To study how measurement errors with respect to our average remaining maturity series might impact our results, we estimate their likely size using simulated data and then feed the result into an errors-in-variables approach which allows us to correct for a potential bias. For each country c and loan category i we draw pseudo maturity series $\widetilde{mat}_{c,i,t}$ using the following relation $\widetilde{mat}_{c,i,t} = mat_{c,i,t-1} + \mu_i + \nu_{c,i,t}$ for $t = 1, ..., T_c$, where $mat_{c,i,t-1}$ is the maturity series that we use in Section 2, $T_c + 1$ is its length, and $\nu_{c,i,t} \sim N(0, \sigma_i^2)$. We use the initial maturity observation, $mat_{c,i,0}$ as the starting point.

We calibrate μ_i and σ_i for the different debt categories as follows: We set $\mu_{mortg} = 0.08$ and $\sigma_{mortg} = 0.66$ based on the average change in the mortgage maturities and its standard deviation in the data. Similarly, we set $\mu_{auto} = 0.03$ and $\sigma_{auto} = 0.09$ for auto loans, based on US data. We also use these values for consumer loans, but scale them based on observations on contractual maturities (relative to average contractual maturity on auto loans) for countries where such data is available. For student loans, we set $\mu_{student} = 0$ and $\sigma_{student} = 0.45$ based on UK data. For credit cards, where we assume that 10% of outstanding debt is repaid annually in line with the approach in Dynan (2012), we randomly draw a new repayment rate from a uniform distribution that ranges from 5% to 15%.

We draw 10000 pseudo maturity series for each country and use them to construct associated new borrowing and debt service series. Based on this we then calculate the measurement error variance relative to the original series for each country (Table C.5).[28]

The variances are small compared to the overall variance of the constructed series. Across countries, they range from below 0.01 (Italy) to close to 0.09 (Norway). These differences arise from country-specific maturities and variation with respect to the shares of each debt

[28] As the maturities only affect amortizations, which enter new borrowing and debt service equally, the measurement error variance is the same for both variables.

Country	AU	BE	CA	DE	DK	ES	FI	FR
Variance	0.059	0.025	0.047	0.046	0.062	0.038	0.082	0.042
Country	GB	IT	JP	NL	NO	PT	SE	US
Variance	0.034	0.0049	0.084	0.019	0.088	0.023	0.015	0.066

Table C.5: Simulated measurement error variances compared to overall variance for *new borrowing* and *debt service* across countries.

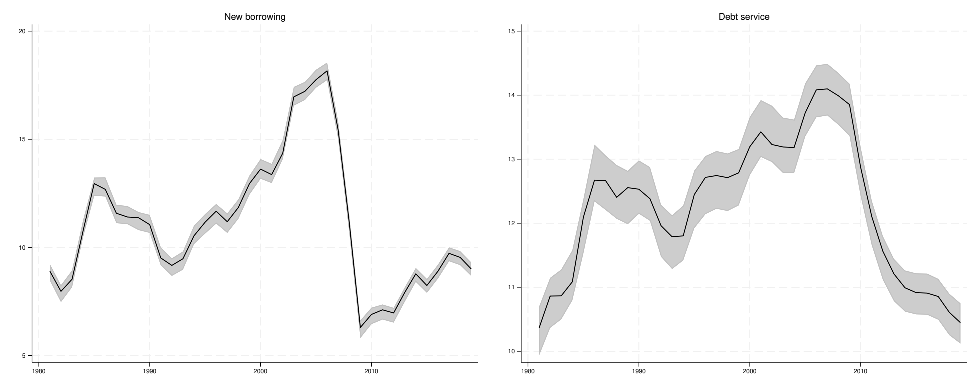

Figure C.1: Actual and simulated series for new borrowing and debt service for the United States

category in total household debt. The limited impact of the measurement errors can, for example, be seen by looking at the US series (Figure C.1) where the solid line is the baseline constructed series and the gray area provides a 95% confidence intervals around it.

These results are in line with similar findings in the literature. For instance, Elvery and Schweitzer (2020) build aggregate debt service to income ratios from micro data for the United States. The correlation between the micro-data derived debt service to income ratios and aggregate Fed series (Dynan et al. (2003)) is 0.98 for total household debt, 0.99 for mortgage debt, and 0.91 for total consumer debt. We find equally high correlations (0.91) between new mortgage borrowing derived by our approach and recorded new mortgage borrowing in Australia, which is constructed from Australian micro data (see Figure C.2). Although the levels of our series are somewhat lower, they closely match the dynamics of the Australian series.

We use errors-in-variables regression to check if the measurement errors affect the estimated real effects of long-term debt propagation. To do so, we rewrite (7) for $h = 1$ to

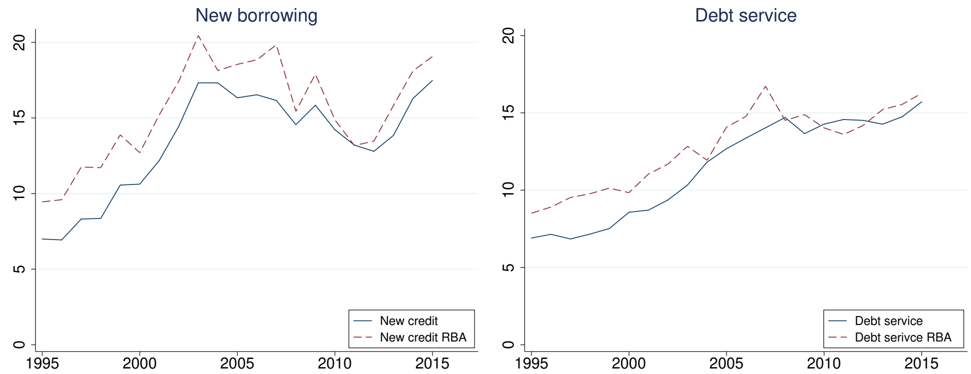

Figure C.2: Comparison of our measures of new borrowing and debt service for Australian mortgages with data from the Reserve Bank of Australia. The Reserve Bank of Australia reports data on the stock of mortgages outstanding, newly issued mortgages, refinanced mortgages and mortgage interest payments which we use to we calculate new borrowing and debt service as a percent of GDP.

explicitly account for measurement errors as:

$$y_{i,t+1} - y_{i,t} = \beta_{yb} b^*_{i,t} + \beta_{ys} s^*_{i,t} + \beta_{yy}(y_{i,t} - y_{i,t-1}) + \beta'_{yx} x_{i,t} + \upsilon_{y,i,t+1} \tag{C.2}$$

$$b_{i,t} = b^*_{i,t} + \nu_{b,i,t} \tag{C.3}$$

$$s_{i,t} = s^*_{i,t} + \nu_{s,i,t} \tag{C.4}$$

where $x^*_{i,t}$ and $x_{i,t}$ are the true values and observed values, respectively, of $x = b, s$, and $\nu_{x,i,t}$ are i.i.d. with finite fourth moments. To adjust for the bias from the measurement error in (C.2)-(C.4) it is sufficient to know the reliability, r, defined as $r = 1 - \text{var}(\nu_{x,i,t})/\text{var}(x_{i,t})$. We use both the mean and the max, 0.046 and 0.088 respectively, of the error variances in Table C.5 as estimates for $\text{var}(\nu_{x,i,t})$. In both cases, the coefficients for new borrowing and debt service become slightly larger but the results remain intact otherwise (Table C.6, second and third column).

Alternative repayments. Given the non-linearities inherent in equation (1), relying on average maturities and modeling broader loan categories matters for the derived repayments. To account for the potential impact of miss-specifying the repayment structure of amortisations, we assume a linear repayment schedule as an alternative to the installment loan formula. For example, if the maturity of new mortgages is 30 years, $1/30^{th}$ of the outstanding amount gets paid pack each year. We do this for all the different debt categories to build up total debt servicing and new borrowing with this assumption. This reduces the effects of new borrowing and debt service slightly (Table C.6, fourth column).

As another robustness check, we replace our series with those published by the US Fed,

	Dependent variable: $y_{i,t+1} - y_{i,t}$					
	Baseline	*Error-in-Var Mean*	*Error-in-Var Max*	*Linear*	*Defaults Delinquency*	*Defaults Provision*
$b_{i,t+1}$	0.125^{***} (0.038)	0.127^{***} (0.024)	0.130^{***} (0.024)	0.091^{**} (0.039)	0.120^{*} (0.060)	0.102^{**} (0.041)
$s_{i,t+1}$	-0.283^{***} (0.059)	-0.286^{***} (0.045)	-0.292^{***} (0.046)	-0.241^{***} (0.056)	-0.313 (0.189)	-0.260^{***} (0.071)
$y_{i,t} - y_{i,t-1}$	0.235^{**} (0.111)	0.233^{***} (0.048)	0.230^{***} (0.048)	0.256^{**} (0.116)	0.261^{*} (0.151)	0.239^{*} (0.120)
Controls	✓	✓	✓	✓	✓	✓
FE	✓	✓	✓	✓	✓	✓
DK errors	✓			✓	✓	✓
N	628	628	628	627	105	540
Within R^2	0.606	0.606	0.606	0.600	0.748	0.626

Table C.6: Real effects of long-term debt propagation and measurement errors. *Controls*: baseline control variables included. *FE*: country fixed effects included. *DK errors*: Driscoll-Kraay standard errors. *Error-in-Var Mean* and *Error-in-Var Max*: Error-in-variables regression with $\text{var}(\nu_{x,i,t})$ equal to 0.046 and 0.088, respectively. *Linear*: New borrowing and debt service derived by assuming debt is amortised linearly. *Defaults Delinquency* and *Defaults Provision*: Delinquency rate respectively provisions used as proxy for defaults. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

the Bank of Canada and the BIS. All econometric results, are largely unaffected.

Accounting for defaults. Accounting for the impact of defaults is conceptually straightforward. On the one hand, defaults DF_t reduce debt service so that the flow of debt service payments becomes $S_t = (\delta + r)D_{t-1} - DF_t$. On the other hand, lenders need to write down this amount, so that new borrowing is given by $B_t = D_t - (1 - \delta)D_{t-1} + DF_t$.

Unfortunately, defaults are not widely and systematically recorded across countries, making it difficult to control for them when constructing debt service and new borrowing series. Nevertheless, we try two proxies: household delinquency rates, which are available for seven countries,[29] and loan loss provisions which are more widely available.

Our results are also robust when accounting for defaults (column 6, Table C.6). The impact of new borrowing on real GDP growth remains positive and that of debt service negative. The significance of debt service on growth is lower when we use delinquency rates, but this is due to the small sample.

[29] The countries are Australia, France, Germany, Italy, Spain, the United Kingdom and the United States. Except for the United States, where we have data from 1987 onward, these data start from around 2000 or only after the GFC.

D Additional empirical results

	Dependent variable: $b_{i,t+1}$								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$b_{i,t}$	0.946^{***}	0.943^{***}	0.947^{***}	0.897^{***}	0.817^{***}	0.878^{***}	0.949^{***}	0.907^{***}	0.862^{***}
	(0.037)	(0.044)	(0.053)	(0.056)	(0.061)	(0.032)	(0.052)	(0.026)	(0.045)
$s_{i,t}$	-0.204^{***}	-0.239^{***}	-0.520^{***}	-0.432^{***}	-0.314^{**}	-0.208	-0.445^{***}	-0.119^{**}	-0.579^{***}
	(0.063)	(0.072)	(0.135)	(0.072)	(0.129)	(0.135)	(0.122)	(0.050)	(0.082)
$\Delta y_{i,t}$	0.026	0.000	-0.015	-0.045	-0.091	0.057	-0.103	0.136^{***}	-0.110^{***}
	(0.042)	(0.058)	(0.034)	(0.062)	(0.107)	(0.078)	(0.065)	(0.045)	(0.036)
N	614	494	181	281	171	292	322	614	614
R^2_w	0.808	0.823	0.836	0.829	0.798	0.685	0.801	0.839	

Table D.1: The impact on new borrowing at time $t+1$ for different specifications: (1) baseline, (2) baseline and collateral controls, (3) baseline and bank lending controls, (4) baseline and misallocation controls, (5) all controls (except lending standards), (6) before year 2000 (7) including and after year 2000, (8) baseline with time fixed effects, (9) baseline using mean group estimator. R^2_w refers to the within-panel coefficient of determination. Driscoll-Kraay standard errors in parentheses. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

	Dependent variable: $s_{i,t+1}$								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$b_{i,t}$	0.125^{***}	0.116^{***}	0.080^{***}	0.113^{***}	0.050^{***}	0.163^{***}	0.105^{***}	0.132^{***}	0.133^{***}
	(0.011)	(0.012)	(0.008)	(0.017)	(0.017)	(0.019)	(0.011)	(0.011)	(0.011)
$s_{i,t}$	0.873^{***}	0.885^{***}	0.877^{***}	0.873^{***}	0.969^{***}	0.840^{***}	0.857^{***}	0.857^{***}	0.871^{***}
	(0.018)	(0.020)	(0.032)	(0.022)	(0.033)	(0.027)	(0.025)	(0.018)	(0.019)
$\Delta y_{i,t}$	0.031^{***}	0.030^{**}	0.031^{***}	0.013	0.031^{**}	0.040^{**}	0.015	0.008	0.056^{***}
	(0.007)	(0.011)	(0.011)	(0.014)	(0.015)	(0.014)	(0.011)	(0.012)	(0.013)
N	614	494	181	281	171	292	322	614	614
R^2_w	0.961	0.960	0.951	0.951	0.941	0.933	0.941	0.966	

Table D.2: The impact on debt service at time $t+1$ for different specifications: (1) baseline, (2) baseline and collateral controls, (3) baseline and bank lending controls, (4) baseline and misallocation controls, (5) all controls (except lending standards), (6) before year 2000 (7) including and after year 2000, (8) baseline with time fixed effects, (9) baseline using mean group estimator. R^2_w refers to the within-panel coefficient of determination. Driscoll-Kraay standard errors in parentheses. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

	Dependent variable: $y_{i,t+1} - y_{i,t}$								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$b_{i,t}$	0.125^{***}	0.116^{***}	0.159^{***}	0.170^{***}	0.160^{**}	0.129^{***}	0.149^{***}	0.042	0.125^{***}
	(0.038)	(0.038)	(0.052)	(0.038)	(0.070)	(0.044)	(0.032)	(0.031)	(0.033)
$s_{i,t}$	-0.283^{***}	-0.250^{***}	-0.588^{***}	-0.647^{***}	-0.586^{***}	-0.353^{***}	-0.351^{***}	-0.145^{***}	-0.609^{***}
	(0.059)	(0.070)	(0.107)	(0.105)	(0.155)	(0.085)	(0.075)	(0.048)	(0.077)
$\Delta y_{i,t}$	0.235^{**}	0.121	-0.069	0.183	-0.056	0.262^{**}	0.059	0.386^{***}	0.046
	(0.111)	(0.089)	(0.090)	(0.150)	(0.080)	(0.104)	(0.102)	(0.080)	(0.038)
N	628	508	181	281	171	292	336	628	628
R^2_w	0.606	0.658	0.687	0.595	0.701	0.470	0.716	0.725	

Table D.3: The impact on output growth at $t+1$, $y_{i,t+1} - y_{i,t}$, for different specifications: (1) baseline, (2) baseline and collateral controls, (3) baseline and bank lending controls, (4) baseline and misallocation controls, (5) all controls (except lending standards), (6) before year 2000 (7) including and after year 2000, (8) baseline with time fixed effects, (9) baseline using mean group estimator. R^2_w refers to the within-panel coefficient of determination. Driscoll-Kraay standard errors in parentheses. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

Dep. var.:	$b_{i,t+1}$	$s_{i,t+2}$	$y_{i,t+1} - y_{i,t}$
$b_{i,t}$	0.953^{***}	0.109^{***}	0.232^{***}
	(0.064)	(0.016)	(0.051)
$b_{i,t-1}$	0.039	0.008	-0.058
	(0.100)	(0.012)	(0.080)
$b_{i,t-2}$	-0.092	-0.028	-0.060^{*}
	(0.073)	(0.018)	(0.033)
$b_{i,t-4}$	-0.018	0.012	0.008
	(0.050)	(0.014)	(0.054)
$s_{i,t}$	-0.233	1.167^{***}	-0.753^{***}
	(0.287)	(0.064)	(0.152)
$s_{i,t-1}$	-0.058	-0.406^{***}	0.824^{***}
	(0.350)	(0.079)	(0.197)
$s_{i,t-2}$	0.436	0.157^{*}	-0.493^{***}
	(0.364)	(0.093)	(0.167)
$s_{i,t-3}$	-0.265	-0.033	0.248^{*}
	(0.189)	(0.044)	(0.137)
$\Delta y_{i,t}$	0.088^{*}	0.031^{***}	0.254^{**}
	(0.049)	(0.010)	(0.124)
$\Delta y_{i,t-1}$	0.093^{**}	-0.002	-0.027
	(0.035)	(0.019)	(0.046)
$\Delta y_{i,t-2}$	-0.012	-0.003	0.119^{***}
	(0.035)	(0.011)	(0.041)
$\Delta y_{i,t-3}$	0.073^{**}	-0.006	0.009
	(0.031)	(0.006)	(0.043)
N	566	566	580
r^2_w	0.825	0.969	0.706

Table D.4: The impact on new borrowing, debt service and output growth at $t+1$ when estimating the local projections with four lags. R^2_w refers to the within-panel coefficient of determination. Driscoll-Kraay standard errors in parentheses. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

Dep. var.:	$u_{i,t+1}$	$con_{i,t+1} - con_{i,t}$	$y_{i,t+1} - y_{i,t}$	$y_{i,t+1} - y_{i,t}$	$y_{i,t+1} - y_{i,t}$	$y_{i,t+1} - y_{i,t}$	$Gap_{i,t+1}$	$Gap_{i,t+1}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$b_{i,t}$	-0.253	0.114^{***}	0.115^{***}	0.108	0.049	0.125^{***}	0.125^{***}	0.126^{***}
	(0.216)	(0.029)	(0.031)	(0.083)	(0.037)	(0.046)	(0.010)	(0.011)
$s_{i,t}$	1.407^{***}	-0.316^{***}	-0.343^{***}	-0.231^{**}	-0.493^{***}	-0.189^{**}	0.872^{***}	0.865^{***}
	(0.312)	(0.057)	(0.063)	(0.101)	(0.113)	(0.093)	(0.017)	(0.016)
$\Delta y_{i,t}$			0.236^{**}	0.236^{**}	0.098	0.295^{**}		
			(0.113)	(0.113)	(0.098)	(0.118)		
$u_{i,t}$	-0.781^{**}							
	(0.386)							
$\Delta con_{i,t}$		0.012						
		(0.103)						
$Gap_{i,t}$							0.029^{***}	0.118^{***}
							(0.008)	(0.017)
N	611	589	628	628	319	309	575	614
R_w^2	0.532	0.646	0.605	0.605	0.634	0.631	0.965	0.965

Table D.5: Real effects, additional specifications. (1) unemployment, $u_{i,t+1}$, on the left-hand side, (2) consumption growth, $con_{i,t+1} - con_{i,t}$, on the left-hand side. Output growth, $y_{i,t+1} - y_{i,t}$, on the left-hand side with:(3) $b_{i,t}$ and $s_{i,t}$ calculated based on mortgage debt only, (4) $b_{i,t}$ and $s_{i,t}$ calculated based on consumer debt only, (5) only countries with predominantly fixed interest rate loans, (6) only countries with predominantly flexible interest rate loans. Output gaps on the left-hand side with (7) Hamilton gap, and (8) HP filtered gap. R_w^2 refers to the within-panel coefficient of determination. Driscoll-Kraay standard errors in parentheses. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

	Dependent variable: $y_{i,t+3} - y_{i,t}$				
	(1)	(2)	(3)	(4)	(5)
$b_{i,t}$	0.088	0.079	0.214	0.241^{*}	0.319^{*}
	(0.088)	(0.109)	(0.135)	(0.130)	(0.157)
$s_{i,t}$	-0.844^{***}	-0.736^{***}	-1.818^{***}	-1.934^{***}	-1.967^{***}
	(0.164)	(0.198)	(0.429)	(0.216)	(0.381)
$\Delta y_{i,t}$	0.237^{**}	0.150	-0.338^{**}	0.023	-0.338^{**}
	(0.106)	(0.138)	(0.123)	(0.177)	(0.126)
$\Delta \ln(p^{res}_{i,t})$		-0.091			-0.157^{**}
		(0.054)			(0.076)
$\Delta \ln(nw^{hh}_{i,t})$		0.232^{***}			0.195^{***}
		(0.063)			(0.041)
$\Delta spr^{nfc}_{i,t}$			-0.021		-0.060
			(0.040)		(0.039)
$\Delta spr^{hh}_{i,t}$			-0.334		-0.178
			(0.318)		(0.368)
$I^{e}_{i,t}$			-1.239		-1.229^{**}
			(0.813)		(0.577)
$lst_{i,t}$			-0.033^{**}		
			(0.014)		
$\Delta_3 \ln(inv^{res}_{i,t})$				-0.050	0.002
				(0.031)	(0.023)
$\Delta_5 \ln(prod_{i,t})$				0.246	0.599
				(0.334)	(0.389)
$\Delta \ln(cr^{ntrd}_{i,t})$				-0.068^{*}	-0.085^{***}
				(0.034)	(0.024)
$\Delta \ln(cr^{trd}_{i,t})$				-0.067^{*}	-0.030
				(0.036)	(0.026)
$\Delta \ln(fx_{i,t})$				-0.023	0.119^{**}
				(0.076)	(0.047)
N	596	476	181	281	171
R^2_w	0.383	0.445	0.500	0.547	0.615

Table D.6: Real reversals and other theories. *Collateral channel*: residential property prices, $p^{res}_{i,t}$ and household sector net worth, $nw^{hh}_{i,t}$. *Bank lending channel*: Krishnamurthy and Muir corporate credit spread, $spr^{nfc}_{i,t}$, prime lending spread $spr^{hh}_{i,t}$, Baron et al banking sector stress indicator, $I^{e}_{i,t}$, and lending standards, $lst_{i,t}$. *Other channels*: gross capital formation in dwellings, $inv^{res}_{i,t}$, productivity, $prod_{i,t}$, credit to the non-tradeable sector to GDP, $cr^{ntrd}_{i,t}$, credit to the tradeable sector to GDP, $cr^{trd}_{i,t}$, and effective exchange rate, $fx_{i,t}$. R^2_w refers to the within-panel coefficient of determination. Driscoll-Kraay standard errors in parentheses. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

Dependent variable: $y_{i,t+9} - y_{i,t}$					
	(1)	(2)	(3)	(4)	(5)
$b_{i,t}$	-0.555^{**}	-0.390^{**}	-0.499^{***}	-0.855^{***}	-0.145
	(0.209)	(0.160)	(0.154)	(0.289)	(0.314)
$s_{i,t}$	-0.886^{***}	-0.526	-0.837^{*}	-1.294^{***}	-2.322^{***}
	(0.191)	(0.393)	(0.470)	(0.287)	(0.740)
$\Delta y_{i,t}$	0.056	0.267	-0.139	-0.290	0.347
	(0.292)	(0.327)	(0.245)	(0.304)	(0.350)
$\Delta \ln(p_{i,t}^{res})$		-0.226^{**}			-0.389^{**}
		(0.100)			(0.181)
$\Delta \ln(nw_{i,t}^{hh})$		0.288^{***}			0.108
		(0.088)			(0.100)
$\Delta spr_{i,t}^{nfc}$			-0.042		-0.105^{**}
			(0.046)		(0.041)
$\Delta spr_{i,t}^{hh}$			0.516		1.174
			(0.472)		(0.949)
$I_{i,t}^{e}$			-1.133		0.195
			(0.830)		(1.038)
$lst_{i,t}$			-0.007		
			(0.016)		
$\Delta_3 \ln(inv_{i,t}^{res})$				0.013	-0.050
				(0.032)	(0.033)
$\Delta_5 \ln(prod_{i,t})$				-0.290	-0.868
				(0.750)	(1.099)
$\Delta \ln(cr_{i,t}^{ntrd})$				-0.062	-0.185^{***}
				(0.040)	(0.062)
$\Delta \ln(cr_{i,t}^{trd})$				-0.062	0.008
				(0.056)	(0.069)
$\Delta \ln(fx_{i,t})$				-0.113	0.076
				(0.109)	(0.066)
N	500	380	113	245	137
R_w^2	0.494	0.505	0.563	0.650	0.653

Table D.7: Real reversals and other theories. *Collateral channel*: residential property prices, $p_{i,t}^{res}$ and household sector net worth, $nw_{i,t}^{hh}$. *Bank lending channel*: Krishnamurthy and Muir corporate credit spread, $spr_{i,t}^{nfc}$, prime lending spread $spr_{i,t}^{hh}$, Baron et al banking sector stress indicator, $I_{i,t}^{e}$, and lending standards, $lst_{i,t}$. *Other channels*: gross capital formation in dwellings, $inv_{i,t}^{res}$, productivity, $prod_{i,t}$, credit to the non-tradeable sector to GDP, $cr_{i,t}^{ntrd}$, credit to the tradeable sector to GDP, $cr_{i,t}^{trd}$, and effective exchange rate, $fx_{i,t}$. R_w^2 refers to the within-panel coefficient of determination. Driscoll-Kraay standard errors in parentheses. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

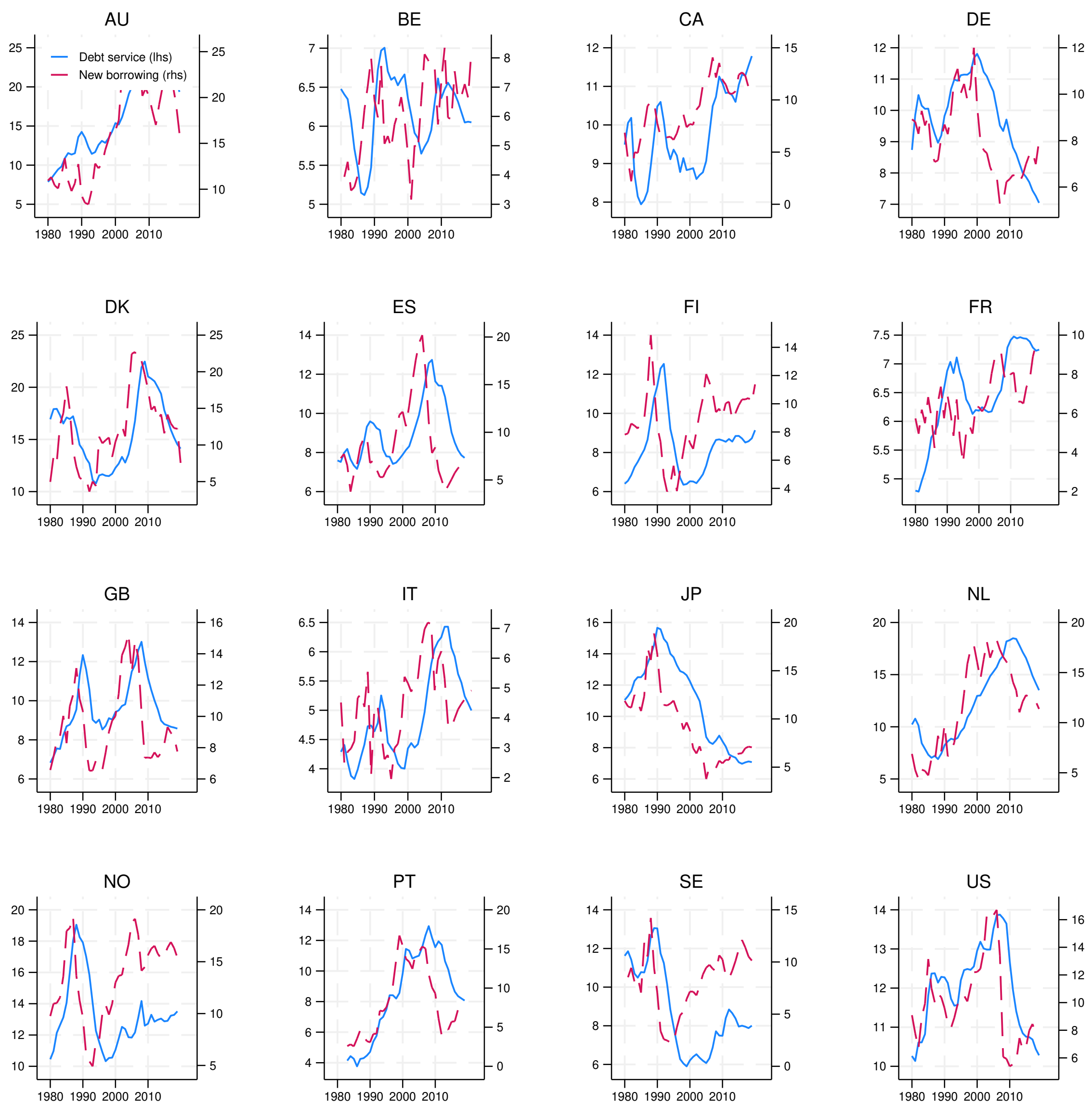

Figure D.1: New borrowing and debt service for the household sector in different countries.

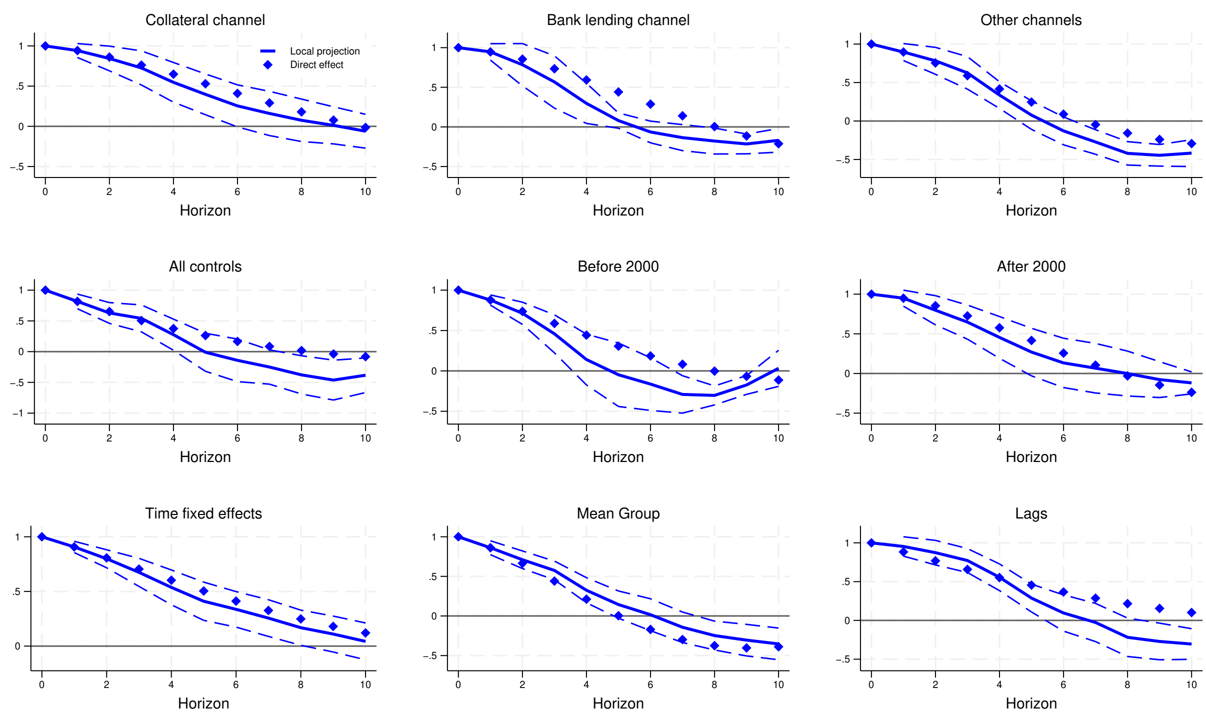

Figure D.2: Impact of a unit increase in new borrowing at $t = 0$ on future new borrowing for different specifications. Solid lines: $\beta_{bb}^{(h)}$ from equation (3). Dashed lines: 95 % confidence intervalls. Diamonds: Long-term debt propagation derived from equation (5). We include the baseline set of controls and apply Driscoll-Kraay standard errors. *Collateral channel*, *Bank lending channel* and *Other channels* add the respective controls for each channel. *All controls* combine all controls, except lending standards as including them reduces sample size too much. *Before 2000* and *After 2000* use data up to or after the year 2000. *Time fixed effects* adds time fixed effects to the specifications. *Mean Group* uses the Pesaran and Smith (1995) mean group estimator. *Lags* estimates the local projections with four lags.

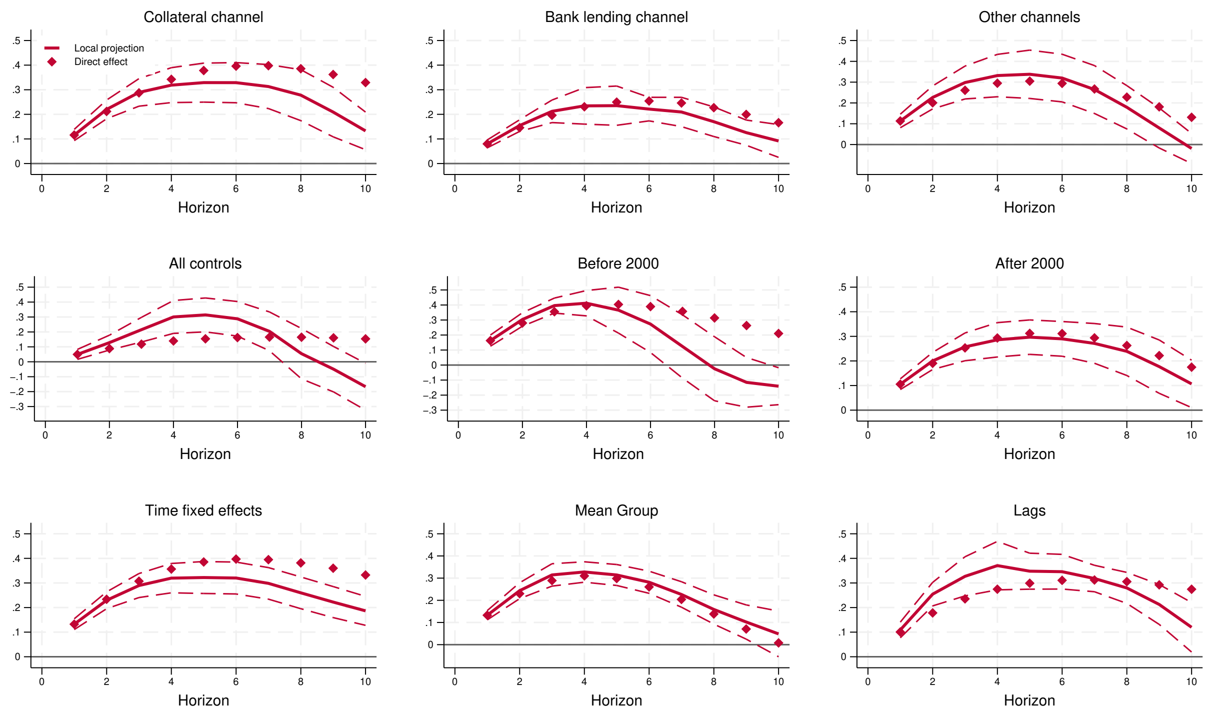

Figure D.3: Impact of a unit increase in new borrowing at $t = 0$ on future debt service for different specifications. Solid lines: $\beta_{sb}^{(h)}$ from equation (4). Dashed lines: 95 % confidence intervalls. Diamonds: Long-term debt propagation derived from equation (6). We include the baseline set of controls and apply Driscoll-Kraay standard errors. *Collateral channel*, *Bank lending channel* and *Other channels* add the respective controls for each channel. *All controls* combine all controls, except lending standards as including them reduces sample size too much. *Before 2000* and *After 2000* use data up to or after the year 2000. *Time fixed effects* adds time fixed effects to the specifications. *Mean Group* uses the Pesaran and Smith (1995) mean group estimator. *Lags* estimates the local projections with four lags.

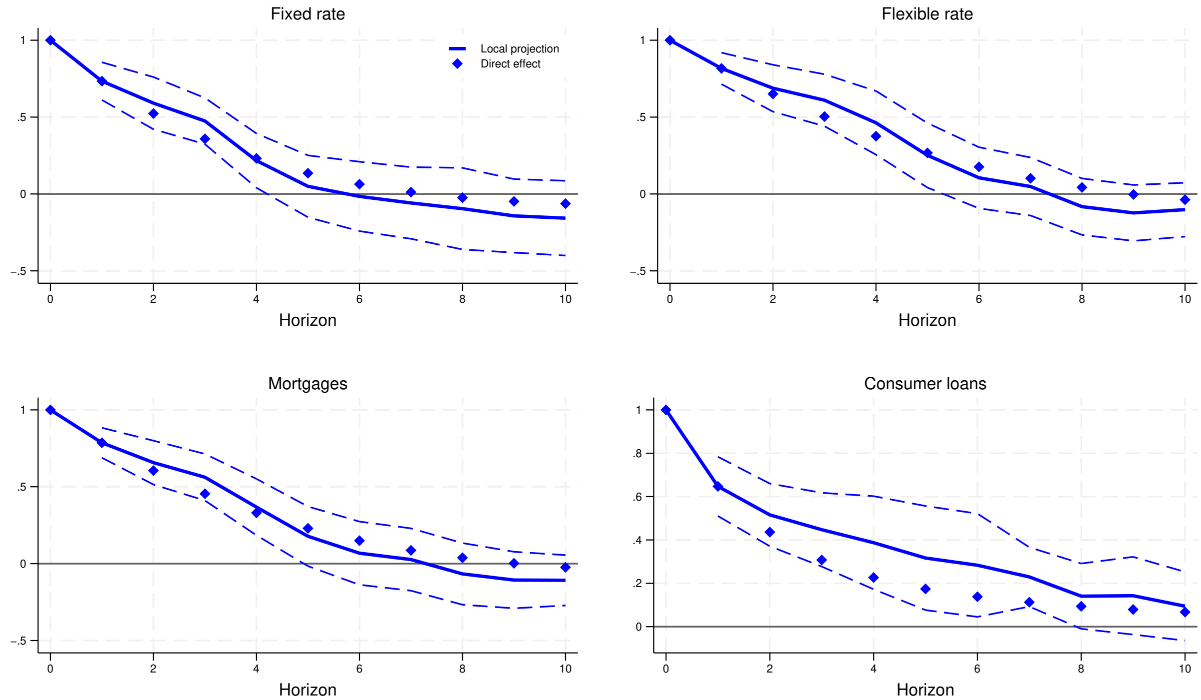

Figure D.4: Impact of a unit increase in new borrowing at $t = 0$ on future new borrowing for different credit types. Solid lines $\beta_{bb}^{(h)}$ from equation (3). Dashed lines: 95 % confidence intervalls. Diamonds: Long-term debt propagation derived from equation (5). We include the baseline set of controls and apply Driscoll-Kraay standard errors. *Fixed rate* and *Flexible rate*: only countries with predominantly fixed rate or flexible rate mortgages. *Mortgages* and *Consumer loans*: only new borrowing for mortgage and consumer loans respectively.

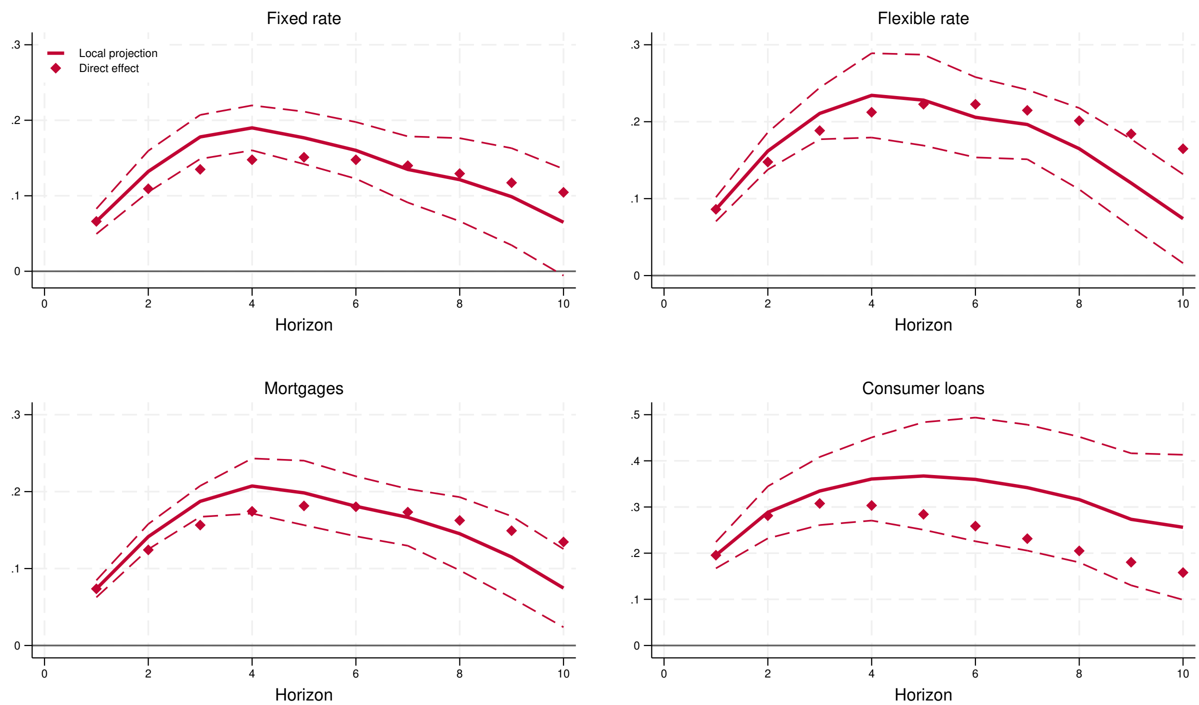

Figure D.5: Impact of a unit increase in new borrowing at $t = 0$ on future debt service for different credit types. Solid lines: $\beta_{sb}^{(h)}$ from equations (4). Dashed lines: 95 % confidence intervalls. Diamonds: Long-term debt propagation derived from equation (6). We include the baseline set of controls and apply Driscoll-Kraay standard errors. *Fixed rate* and *Flexible rate*: only countries with predominantly fixed rate or flexible rate mortgages. *Mortgages* and *Consumer loans*: only debt service for mortgage and consumer loans respectively.

E Comparison with Mian et al. (2017)

In this section we replicate the main result of Mian et al. (2017) and check to which extent our flow variables can account for the patterns. Mian et al. (2017) decompose the three-year change in the credit-to-GDP ratio into the components related to the household (indexed *HH*) and non-financial corporate (indexed *NFC*) sectors, and run regressions of the form:

$$\Delta_3 y_{i,t+k} = \alpha_i + \beta_{1,k}\Delta_3 d_{i,t}^{HH} + \beta_{2,k}\Delta_3 d_{i,t}^{NFC} + \upsilon_{i,t+k} \tag{E.1}$$

for $k = 0, 1, ..., 6$, where $\Delta_3 d_{i,t}^X = D_{i,t}^X / Y_{i,t} - D_{i,t-3}^X / Y_{i,t-3}$ and $X = \{HH, NFC\}$. We first replicate the main results in their Table II, using our sample. We only show the results for horizons for $h = 1, 3, 6$, as these are sufficient to convey the main message, but comment on the other below horizons when relevant.

The results from estimating Equation (E.1) on our sample are very similar to the ones reported by Mian et al. (2017). In particular, the coefficients show the same signs and roughly equal magnitudes and significance levels (Table E.1). This holds for the other horizons as well. As in their paper, an increase in household credit-to-GDP, in particular, initially has a positive effect which increasingly turns negative as the horizon increases. An increase in the corporate sector credit-to-GDP ratio has significant negative effects for the first three years and then reverts signs and becomes significantly positive by the end of the horizon.

In order to assess the value added of our flow variables, we next run expanded versions of (E.1) the form:

$$\Delta_3 y_{i,t+k} = \alpha_i + \beta_{1,k}\Delta_3 d_{i,t}^{HH} + \beta_{2,k}\Delta_3 d_{i,t}^{NFC} + \beta_{3,k} b_{i,t} + \beta_{4,k} s_{i,t} + \upsilon_{i,t+k} \tag{E.2}$$

where we have added new borrowing and debt service.

When we add our flow measures, the effects of three-year household credit growth become insignificant at all horizons (Table E.1, specifications 2, 4, and 6). Instead, new borrowing initially has significant positive effects for horizons 0 to 2, which then turns significantly negative by horizon 4, and has its largest negative effects at $h = 6$ (shown in specification 6). Debt service has also strong negative effects for horizons 0 to 3 and then becomes insignificant for remaining horizons. Moreover, within R^2 values more than double when we add the two flow variables. These effects are qualitatively and quantitatively similar to those we found in relation to our propagation channel in Section 3.2, with the caveat that they are somewhat convoluted given that we have 3-year rather than 1-year changes in real GDP on the left hand side.

The effects of 3-year changes in the corporate credit-to-GDP ratio remain largely intact, albeit are slightly muted, when we add the two flow measures. This suggests, perhaps

Dep.	$\Delta_3 y_{i,t+1}$		$\Delta_3 y_{i,t+3}$		$\Delta_3 y_{i,t+6}$	
Spec.	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta_3 d_{i,t}^{HH}$	$0.153^{\star}$	-0.085	-0.065	-0.050	$-0.253^{\star\star\star}$	0.081
	(0.077)	(0.074)	(0.063)	(0.072)	(0.070)	(0.064)
$\Delta_3 d_{i,t}^{NFC}$	$-0.158^{\star\star}$	$-0.100^{\star\star}$	$-0.115^{\star\star\star}$	$-0.080^{\star\star}$	$0.073^{\star\star}$	$0.068^{\star\star}$
	(0.061)	(0.045)	(0.036)	(0.030)	(0.027)	(0.030)
$b_{i,t}$		$0.744^{\star\star\star}$		0.029		$-0.763^{\star\star\star}$
		(0.161)		(0.181)		(0.149)
$s_{i,t}$		$-1.042^{\star\star\star}$		$-0.637^{\star\star\star}$		0.126
		(0.145)		(0.176)		(0.190)
FE	✓	✓	✓	✓	✓	✓
R_w^2	0.107	0.292	0.092	0.171	0.087	0.200
Obs.	568	568	536	536	488	488

Table E.1: The flow variables and the main results from Mian et al. (2017). The variables from the specification in Mian et al. (2017) are the 3-year change in the household credit-to-GDP ratio, $\Delta_3 d_{i,t}^{HH}$, and the 3-year change in the non-financial corporate sector credit-to-GDP ratio, $\Delta_3 d_{i,t}^{NFC}$. The table presents results from estimating (E.1) and (E.2) for $k = 1, 3, 6$. R_w^2 refers to the within-panel coefficient of determination. Driscoll-Kraay standard errors in parentheses. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

unsurprisingly, that there is some complementary information in corporate sector credit data. Thus, it appears that long-term debt propagation – as captured by our flow measures – is a good candidate for explaining real reversals related to household credit booms.

F Log-linearization of the theory model

In this section we log-linearize the theory model around the flexible price steady-state. We denote steady-state values with asterisks and use lower-case variables for percentage deviations from the steady-state values of upper-case variables.

Demand side

Aggregate consumption equals aggregate output in our model, i.e. $C_t = Y_t$, which can be log-linearized as $c_t = y_t$ where $c_t = \ln(C_t/C^*)$ and $y_t = \ln(Y_t/Y^*)$. Furthermore, log-linearization of expression (4.1) implies

$$\begin{aligned} c_t &= \chi \frac{C_B^*}{C^*}\tilde{c}_{B,t} + (1-\chi)\frac{C_L^*}{C^*}\tilde{c}_{L,t} \\ &\approx \chi c_{B,t} + (1-\chi)c_{L,t} \end{aligned} \tag{F.1}$$

where $\tilde{c}_{i,t} = \ln(\frac{C_{i,t}}{C_i^*}) \approx (C_{i,t} - C_i^*)/C_i^*$ and $c_{i,t} = (C_{i,t} - C_i^*)/Y^*$ since $Y^* = C^*$.

Borrowers' consumption is determined by (15) which can be linearized as

$$\tilde{c}_{B,t} = \frac{1}{C_B^*}\left[Y^* y_t + \phi \bar{D}^* \bar{d}_t - \frac{\Lambda^* D^*}{1+\Pi^*}(\lambda_{t-1} + d_t - \pi_t)\right]$$

with

$$\lambda_t = R^*/\Lambda^* r_{D,t} \tag{F.2}$$

where $\Lambda^* = \phi\,(1-\delta) + \delta + R^*$, $D^* = \phi(1+\Pi^*)\left((1+\Pi^*) - (1-\phi)(1-\delta)\right)^{-1}\bar{D}^*$ and $r_{D,t} = R_{D,t} - R^*$, as R^* is the common steady-state value of all interest rates in the model, or

$$c_{B,t} = y_t + \frac{\phi \bar{D}^*}{Y^*}\bar{d}_t - \frac{\Lambda^* D^*}{(1+\Pi^*)Y^*}(\lambda_{t-1} + d_t - \pi_t) \tag{F.3}$$

where $x_t = \ln(X_t/X^*)$ for $X_t = Y_t, \bar{D}_t, \Lambda_t, D_t$, and $\pi_t = \Pi_t - \Pi^*$.

Substituting F.3 into F.1, using $c_t = y_t$, and solving for $c_{L,t}$ yields

$$\begin{aligned} c_{L,t} &= y_t - \frac{\chi}{(1-\chi)}\left[\frac{\phi \bar{D}^*}{Y^*}\bar{d}_t - \frac{\Lambda^* D^*}{(1+\Pi^*)Y^*}(\lambda_{t-1} + d_{t-1} - \pi_t)\right] \\ &= y_t - b_t + s_t \end{aligned} \tag{F.4}$$

where we have defined normalized new borrowing, b_t, and debt servicing, s_t, according to

$$b_t = \frac{\chi}{(1-\chi)} \cdot \frac{\phi \bar{D}^*}{Y^*} \bar{d}_t \tag{F.5}$$

$$s_t = \frac{\chi}{(1-\chi)} \cdot \frac{\Lambda^* D^*}{(1+\Pi^*)Y^*} (\lambda_{t-1} + d_{t-1} - \pi_t) \tag{F.6}$$

The lenders linearized Euler equation is

$$\tilde{c}_{L,t} = E\tilde{c}_{L,t} - \frac{1}{\sigma_L}(r_t - E\pi_{t+1})$$

where $r_t = R_t - R^*$ which together with $\sigma_L = \sigma \frac{C_L^*}{Y^*}$ can be re-expressed as

$$c_{L,t} = Ec_{L,t} - \frac{1}{\sigma}(r_t - E\pi_{t+1}) \tag{F.7}$$

Substituting F.4 into F.7, we can obtain a dynamic IS equation given by

$$\tilde{y}_t = E\tilde{y}_t + E(b_t - b_{t+1}) - E(s_t - s_{t+1}) - \frac{1}{\sigma}(r_t - E\pi_{t+1}) \tag{F.8}$$

where we have exploited the relation $\tilde{y}_t = c_t = y_t$, which follows from market clearing, the definition of the output gap $\tilde{y}_t = y_t - y_t^n$, and the normalization $y_t^n = 0$ in the absence of productivity shocks.

Supply side

Log-linearizing (13) and (16) and rearranging yields the following New Keynesian Phillips curve

$$\pi_t = \beta_L E\pi_{t+1} + \kappa\varphi_t \tag{F.9}$$

where $\kappa = (1-\theta)(1-\beta_L\theta)\theta^{-1}$ and φ_t is the deviation of real marginal costs from its steady-state.

Linearzing (14) we have

$$\varphi_t = \chi w_{B,t} + (1-\chi)w_{L,t} \tag{F.10}$$

where

$$\begin{aligned} w_{i,t} &= \sigma_i \tilde{c}_{i,t} + \eta \tilde{n}_{i,t} \\ &= \sigma c_{i,t} + \eta \left(\frac{Y^*}{N_i^*}\right) n_{i,t} \end{aligned} \tag{F.11}$$

which follows from optimal labor supply of both agents with $w_{i,t} = \ln(W_{i,t}/W_i^*)$ and $\tilde{n}_{i,t} =$

$\ln(\frac{N_{i,t}}{N_i^*}) \approx \frac{Y^*}{N_i^*} n_{i,t}$ for $i = B, L$.

Log-linearizing the production function yields

$$y_t = \chi \tilde{n}_{B,t} + (1-\chi)\tilde{n}_{L,t}$$
$$= \chi \left(\frac{Y^*}{N_B^*}\right) n_{B,t} + (1-\chi)\left(\frac{Y^*}{N_L^*}\right) n_{L,t} \tag{F.12}$$

Substituting (F.11) in (F.10) yields

$$\varphi_t = \chi(\sigma c_{B,t} + \eta \left(\frac{Y^*}{N_B^*}\right) n_{B,t}) + (1-\chi)(\sigma c_{L,t} + \eta \left(\frac{Y^*}{N_L^*}\right) n_{L,t})$$
$$= \sigma(\chi c_{B,t} + (1-\chi) c_{L,t}) + \eta(\chi \left(\frac{Y^*}{N_B^*}\right) n_{B,t} + (1-\chi)\left(\frac{Y^*}{N_L^*}\right) n_{L,t})$$
$$= (\sigma + \eta) y_t \tag{F.13}$$

where the last step uses (F.1) and (F.12).

Finally, susbtituting (F.13) in (F.9), and again using $\tilde{y}_t = y_t$ we obtain

$$\pi_t = \beta_L E \pi_{t+1} + \tilde{\kappa} \tilde{y}_t \tag{F.14}$$

where $\tilde{\kappa} = \kappa(\sigma + \eta)$.

Debt block

The law of motion of debt (10) can be linearized as

$$d_t = \phi \frac{\bar{D}^*}{D^*} \cdot \bar{d}_t + \frac{(1-\phi)(1-\delta)}{1+\Pi^*} \cdot (d_{t-1} - \pi_t) \tag{F.15}$$

and, at a first-order approximation, the nominal rate on new long-term borrowing and the rate on the stock of debt outstanding satisfies

$$r_{D,t} = \alpha^* r_{ND,t} + (1-\alpha^*) r_{D,t-1} \tag{F.16}$$

where $r_{ND,t} = R_{ND,t} - R^*$ and $\alpha^* = \phi(\bar{D}^* - (1-\delta)D^*/(1+\Pi^*))/(\phi\bar{D}^* + (1-\phi)(1-\delta)D^*/(1+\Pi^*))$.

The interest rate on new long-term debt, $R_{ND,t}$, is linked to the expected future short-term interest rates, R_{t+s}, via the no-arbitrage condition (12). We linearize this expression around the common steady-state interest rate R^*.

Linearization of the left-hand side of (12) produces:

$$\frac{1}{R_{ND,t}+\delta} \approx \frac{1}{R^*+\delta} - \frac{r_{ND,t}}{(R^*+\delta)^2}. \tag{F.17}$$

Denote the function on the right hand-side of (12) by $\Gamma(R_t, R_{t+1}...)$, ie

$$\Gamma\left(R_t, R_{t+1}...\right) = E\sum_{i=0}^{\infty} \frac{(1-\delta)^i}{\prod_{s=0}^{i}\left(1+R_{t+s}\right)}$$

and then note that

$$\frac{\partial\Gamma\left(R_t, R_{t+1}...\right)}{\partial R_{t+i}} = -E\sum_{k=i}^{\infty} \frac{(1-\delta)^k}{\left(1+R_{t+i}\right)\prod_{s=0}^{k}\left(1+R_{t+s}\right)}.$$

Evaluating this expression at R^* produces

$$\begin{aligned}
\frac{\partial\Gamma\left(R^*, R^*...\right)}{\partial R_{t+i}} &= -\sum_{k=i}^{\infty} \frac{(1-\delta)^k}{(1+R^*)^{k+2}} \\
&= -\frac{(1-\delta)^i}{(1+R^*)^{i+2}} \sum_{k=0}^{\infty}\left(\frac{1-\delta}{1+R^*}\right)^k \\
&= -\frac{(1-\delta)^i}{(1+R^*)^{i+1}}\left(\frac{1}{R^*+\delta}\right).
\end{aligned}$$

Lienarization of the right-hand side around R^* therefore produces:

$$\begin{aligned}
\Gamma\left(R_t, R_{t+1}...\right) &\approx \sum_{i=0}^{\infty}\left[\frac{(1-\delta)^i}{(1+R^*)^{i+1}}\right] + \sum_{i=0}^{\infty}\frac{\partial\Gamma\left(R^*, R^*...\right)}{\partial R_{t+i}} E r_{t+i} \\
&= \frac{1}{R^*+\delta} - \frac{1}{\left(R^*+\delta\right)\left(1+R^*\right)}\sum_{i=0}^{\infty}\left(\frac{1-\delta}{1+R^*}\right)^i E r_{t+i}. \qquad \text{(F.18)}
\end{aligned}$$

Equating (F.17) and (F.18) yields:

$$r_{ND,t} = \left(\frac{R^*+\delta}{1+R^*}\right)\sum_{i=0}^{\infty}\left(\frac{1-\delta}{1+R^*}\right)^i E_t r_{t+i}$$

which can be written as a forward-Looking Difference Equation of the form:

$$r_{ND,t} = \left(\frac{1-\delta}{1+R^*}\right) E_t r_{ND,t+1} + \left(\frac{R^*+\delta}{1+R^*}\right) r_t. \tag{F.19}$$

Closing the system

Equations (F.2), (F.5), (F.6), (F.8), (F.14), (F.15), (F.16), and (F.19) define a system in the variables d_t, $\bar{d}_t$, $r_{NL,t}$, $r_{L,t}$, $\tilde{y}_t$, π_t, and r_t. We still need to specify r_t and $\bar{d}_t$ in order to close the system.

First, we assume that the central bank follows a a standard Taylor rule with gradualism according to

$$r_t = \xi r_{t-1} + (1-\xi)(\phi_\pi \pi_t + \phi_y \tilde{y}_t) + \varepsilon_{r,t} \tag{F.20}$$

where $\varepsilon_{r,t}$ is a monetary policy shock.

Second, we assume a law of motion for the exogenous credit constraint according to

$$\bar{d}_t = \zeta \bar{d}_{t-1} + \varepsilon_{\bar{d},t} \tag{F.21}$$

where $\varepsilon_{\bar{d},t}$ is a credit supply shock.

Summary

The complete linearized system is given by:

$$\begin{aligned}
\bar{d}_t &= \zeta \bar{d}_{t-1} + \varepsilon_{\bar{d},t} \\
d_t &= \phi \frac{\bar{D}^*}{D^*} \cdot \bar{d}_t + \frac{(1-\phi)(1-\delta)}{1+\Pi^*} \cdot (d_{t-1} - \pi_t) \\
r_{D,t} &= \alpha^* r_{ND,t} + (1-\alpha^*) r_{D,t-1} \\
b_t &= \frac{\chi}{(1-\chi)} \cdot \frac{\phi \bar{D}^*}{Y^*} \bar{d}_t \\
s_t &= \frac{\chi}{(1-\chi)} \cdot \frac{\Lambda^* D^*}{(1+\Pi^*)Y^*} (R^*/\Lambda^* r_{D,t-1} + d_{t-1} - \pi_t) \\
r_{ND,t} &= \left(\frac{1-\delta}{1+R^*} \right) E_t r_{ND,t+1} + \left(\frac{R^*+\delta}{1+R^*} \right) r_t \\
\tilde{y}_t &= E\tilde{y}_t + E(b_t - b_{t+1}) - E(s_t - s_{t+1}) - \frac{1}{\sigma}(r_t - E\pi_{t+1}) + \varepsilon_{y,t} \\
\pi_t &= \beta_L E\pi_{t+1} + \tilde{\kappa}\tilde{y}_t + \varepsilon_{\pi,t} \\
r_t &= \xi r_{t-1} + (1-\xi)(\phi_\pi \pi_t + \phi_y \tilde{y}_t) + \varepsilon_{r,t}
\end{aligned}$$

where $D^* = \phi(1+\Pi^*)\left((1+\Pi^*) - (1-\phi)(1-\delta)\right)^{-1} \bar{D}^*$, $\alpha^* = \phi(\bar{D}^* - (1-\delta)D^*/(1+\Pi^*))/(\phi\bar{D}^* + (1-\phi)(1-\delta)D^*/(1+\Pi^*))$, $\Lambda^* = \phi(1-\delta) + \delta + R^*$, $\tilde{\kappa} = (1-\theta)(1-\beta_L\theta)(\sigma+\eta)\theta^{-1}$, $R^* = 1/\beta_L - 1 + \Pi^*$ and $\varepsilon_{x,t} \sim N(0, \psi_x^2)$.

G Additional theoretical results

In this Appendix, we discuss three additional aspects of our theory model briefly touched upon in the main text. We first show that a shock to the borrowing limit and a unit impulse to new borrowing generate almost identical reversals. Next we compute the path interest rates when the central bank fully offsets the demand implications of new borrowing. Finally, we prove that (supply) shocks to the borrowing limit and (demand) shocks to the debt access frequency imply the same debt dynamics and real reversals.

Reduced and structural shocks to new borrowing. We use our theoretical model generate a unit increase in new borrowing from a linear combination of structural shocks. To do so, we focus on the endogenous variables b_t, π_t, $\tilde{y}_t$, and r_t,[30] and obtain the inverse structural matrix, B^{-1}, from the model solution. The columns of this matrix provides the contemporaneous impact from each structural shock on the endogenous variables of the model. The "reduced form" vector of theory residuals $e_t = (e_{b,t}, e_{\tilde{y},t}, e_{\pi,t}, e_{r,t})'$ is then given by $e_t = B^{-1}\varepsilon_t$, where $\varepsilon_t = (\varepsilon_{\bar{d},t}, \varepsilon_{\tilde{y},t}, \varepsilon_{\pi,t}, \varepsilon_{r,t})'$ are the associated structural shocks. In the baseline case, the linear combination of structural shocks that gives a unit increase in new borrowing is $\varepsilon_{b=1} = B \cdot (1, 0, 0, 0)'$. The response function to this combination of structural shocks is plotted in the left hand side of Figure G.1 (dotted line). This impulse response is the exact theoretical correspondence to our empirical local projections. As can be seen from the figure, the match between the two is close both qualitatively and quantitatively, confirming the intuition of Mian et al. (2021) that a unit impulse to new borrowing approximates a structural shock to credit supply.

Optimal monetary policy. As a thought experiment, the right-hand panel of Figure G.1 simulates the level of the interest rate that would be required to set the output gap and inflation to zero after a shock to the debt limit. This would also perfectly stabilize output and prices. As the figure shows, the rate would have to rise approximately seven-fold compared to what is implied by the standard Taylor rule to fully offset the effects of debt. This suggests that at least in theory, more aggressive monetary policy responses could mitigate the real effects of credit fluctuations.

Shocks to credit supply and demand. The following lemma establishes that the aggregate implications of shocks to the credit limit $\bar{D}_t$ that lenders extend and shocks to borrowers' frequency of accessing credit markets ϕ are observationally equivalent in our framework since both mechanically affect aggregate debt flows (10) and give rise to equivalent flows of resources between lenders and borrowers:

[30] There are only four independent endogenous variables in the model.

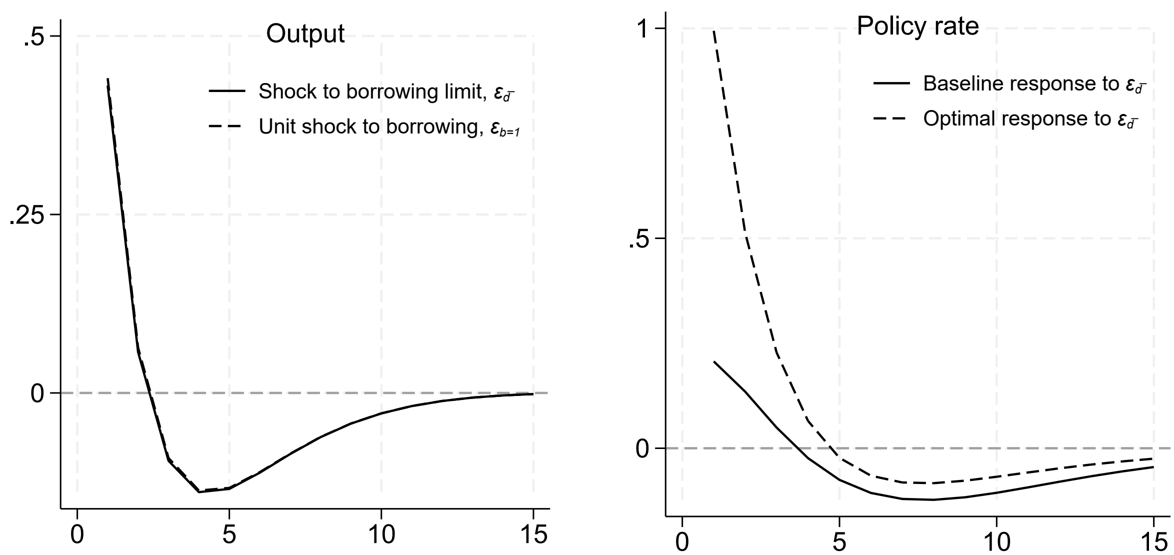

Figure G.1: Left panel: Theory-model output responses from a one std shock to the credit limit ($\varepsilon_{\bar{d}}$), and to a linear combination of shocks that generate a unit increase in new borrowing ($\varepsilon_{b=1}$). Right panel: Impulse response functions of the bond rate, r_t, to a one standard deviation borrowing constraint shock under the baseline specification (solid line) and optimal policy, where the central bank fully offsets the demand implications of borrowing (dashed line).

Lemma (Equivalence of Credit Supply and Demand Shocks)**.** *For any path of credit supply shocks* $\{\bar{D}_t\}_{t=0}^{\infty}$ *with constant* ϕ*, there exists a path of credit demand shocks* $\{\phi_t\}_{t=0}^{\infty}$ *with constant credit limit* $\bar{D}^*$ *that generates the same equilibrium path for aggregate debt* $\{D_t\}_{t=0}^{\infty}$ *and all other aggregate variables, where for each* t*:*

$$\phi_t = \frac{\bar{D}_t - (1-\delta)D_{t-1}/(1+\Pi_t)}{\bar{D}^* - (1-\delta)D_{t-1}/(1+\Pi_t)}$$

The equivalence holds as long as the implied path satisfies $\phi_t \in [0,1]$ *for all* t*.*

Proof. The law of motion for debt in our model is $D_t = \phi_t \bar{D}_t + (1-\phi_t)(1-\delta)D_{t-1}/(1+\Pi_t)$. The path $\{\phi_t\}$ above is derived by setting $\bar{D}_t = \bar{D}^*$ and solving for the value of ϕ_t that generates the same D_t in each period. Given that D_t determines the financial flows between borrowers and lenders, and these flows are the only channel through which credit affects aggregate variables in our model, the equivalence extends to all aggregate variables. □

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