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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 empirically that it has sizable real effects. The mechanism recognises that when there is long-term debt, an impulse to new borrowing generates a predictable hump-shaped path of future debt service. We confirm this pattern using a novel multi-country dataset of debt flows. Whereas new borrowing boosts output contemporaneously, debt service depresses output. Credit booms thus lead to predictable reversals in real economic activity several years later. This long-term debt propagation channel is the main reason for why indicators of credit cycles have predictive power for future economic activity.

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1 Introduction

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

In this paper, we highlight a natural *internal propagation mechanism* implied by long-term debt and document its empirical importance for endogenously explaining 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 and amortizations). It also turns out that new borrowing boosts output growth while debt service reduces it. Together these two observations imply predictable real reversals. In particular, in the short term, an increase in new household borrowing is associated with significantly positive output growth together with an increase in the stock of debt. Over time, a growing stock of debt increases debt service payments, which eventually reverses the net financial flow and 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.[1]

To characterize the propagation mechanism, we lay out a simple analytic framework of debt compounding. We formally show that long-term debt and auto-correlation in new borrowing – two features that we document in the data – give rise to a non-trivial lead-lag relationship between new borrowing and debt service. The lag between peaks in new borrowing and peaks in debt service increases in both the maturity of debt and the degree of auto-correlation of new borrowing.[2]

Our next contribution is to develop a novel cross-country database of new household borrowing and debt service payments for 16 advanced countries over the past four decades. To construct our flow measures, we model amortizations of up to six different household debt categories of different maturities, such as mortgages, credit card debt, student loans and other household borrowing. Existing cross-country databases only provide data on debt stocks, but as pointed out by 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 financial transactions.

Using the data on financial flows, we first quantify our propagation mechanism, and ask to which extent it can account for systematic debt-related patterns in the data. To do so, we derive empirical analogues to the impulse response functions implied by the debt compounding framework. We find that new borrowing is significantly autocorrelated. Moreover, an increase in new borrowing is followed by a predictable hump-shaped rise in debt service that peaks five to seven years later, in line with our analytic framework. Moreover, what is captured by the debt propagation mechanism closely matches the local projections of new

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

[2] A related strand of theoretical literature emphasizes the role of long-term debt in the transmission of monetary policy. See e.g. Garriga et al. (2017, 2021).

borrowing and debt service in response to an increase in new borrowing. This suggests that long-term debt propagation dominates other potential counter-acting channels through which an increase in new borrowing may affect future financial flows, such as monetary policy responses or productivity effects that may reduce future debt service.

We next investigate the real implications of debt flows. We find that a unit increase in new borrowing increases one-year ahead output growth by a significant 12 basis points in our baseline specification, whereas debt service reduces output by a significant 19 basis points. These effects are economically meaningful. New borrowing was on average 4.6 percentage points higher than normal at the peak of past credit booms. Such levels imply a 0.55 percentage point boost to economic output under the baseline specification. The subsequent peak in debt service is on average 2 percentage points higher, depressing output by approximately 0.4 percentage points. These effects accumulate as both new borrowing and debt service are persistent and therefore give rise to substantial fluctuations in output.

Over time, long-term debt propagation gives rise to predictable *real reversals*. This reflects the real effects of new borrowing and debt service on output in the short run together with the non-trivial lead-lag relationship between new borrowing and debt service when borrowing is long-term and auto-correlated.

The propagation dynamics and their real effects are very robust. They are unaffected by the inclusion of a range of control variables, such as additional macroeconomic factors or financial variables. The results also hold in different sub-samples of the data, e.g. a sample leaving out the Great Recession, or when we allow for time fixed effects and cross-country heterogeneity.

Finally, we document that other variables highlighted in the macro-finance literature have less explanatory power for real output growth than new borrowing and debt service. For example, measures such as 3-year credit-to-GDP growth, corporate credit spreads and the net-worth-to-GDP ratio lose explanatory power once we include them in a horse race with the two flow variables, new borrowing and debt service. The latter two, by contrast, have significant explanatory power over cumulative real GDP growth – even at horizons of up to six years. These effects hold both in the full sample and across recursive sub-samples from 2000 onward, suggesting that they are useful for real-time forecasting as well. We document that the two flow variables can largely account for the persistent and non-monotonic output responses to credit booms found in earlier studies.[3] Taken together, our results provide a natural propagation mechanism for the real effects of credit booms and busts.

Correctly characterizing the internal propagation of credit booms, and identifying the central role of financial flows in it, 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. As we show, the first step of the propagation mechanism relies on both long-term debt and auto-correlation in new borrowing; the second step relies on a mechanism through which financial

[3] These results are consistent with the credit supply view proposed by Mian et al. (2017) and Mian and Sufi (2018), i.e. the notion that an important part of the fluctuations in real variables are driven by exogenous credit supply shocks that first lead to positive aggregate demand effects but are followed by predictable reversals in aggregate demand that are difficult to counteract by macroeconomic policymakers.

transfers between borrowers and lenders generate real effects.[4] It matters for practitioners and policymakers because properly capturing the propagation mechanism behind credit booms and the resulting endogenous reversals allows 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 also should guide measurement efforts towards a greater focus on the financial flows between borrowers and lenders.

The paper is structured as follows. In the ensuing section, we illustrate long-term debt propagation in a simple accounting framework of debt accumulation and amortization. Section 3 discusses how to measure debt service costs and new borrowing in the data. Our main results appear in Section 4 where we derive empirical impulse response functions corresponding to long-term debt propagation and use them to assess its importance for both real and financial outcomes in the data. In Section 5, we study the predictive content of our flow variables and compare them to other frequently used measures in the literature. Section 6 concludes.

2 Long-term debt propagation

The propagation mechanism that we highlight builds on long-term debt. Specifically, when new borrowing occurs at long maturities and is auto-correlated, the net financial flow from lenders to borrowers exhibit both persistence and, importantly, non-trivial endogenous reversals. We illustrate these dynamics in a simple accounting framework of debt accumulation and amortization. Ultimately, we are interested in the extent to which this type of *long-term debt propagation* imparts predictability over both real and financial outcomes, which we analyse in in Sections 4 and 5 below.

To start, consider a borrower with zero debt who in period 1 takes up new borrowing, $B_1 \geq 0$, of long-term debt. Assume, for simplicity, a constant amortization rate δ and fixed interest rate r. In the following period, this new borrowing gives rise to debt service, S_2, consisting of interest payments and amortization, i.e. $S_2 = (r + \delta) B_1$. Hence, the remaining stock of debt outstanding at the end of period 2 is $(1 - \delta) B_1$, which is carried over to the next period. After k periods, a balance of $(1 - \delta)^{k-1} B_1$ is left of the original amount borrowed, implying debt service obligations of $(r + \delta)(1 - \delta)^{k-1} B_1$.

More generally, allowing for borrowing in each period, the total stock of debt outstanding at the end of period t, D_t, follows the law-of-motion

$$\begin{aligned} D_t &= (1 - \delta) D_{t-1} + B_t \\ &= \sum_{j=0}^{t} (1 - \delta)^{t-j} B_j \end{aligned} \tag{1}$$

[4]The academic literature has made significant progress in developing models in which financial transfers generate real effects in recent years. See e.g. Eggertsson and Krugman (2012), Farhi and Werning (2016), Korinek and Simsek (2016), Guerrieri and Lorenzoni (2017), Kaplan et al. (2018) and Mian et al. (2021).

given that $D_0 = 0$. Hence, the stock of debt can be represented as a moving average of new borrowing.

Total debt service, S_t, is given by the debt service obligations from all past borrowing that are due in period t, or equivalently, on the stock of debt, D_{t-1}, carried into period t,

$$S_t = (\delta + r)\, D_{t-1} \qquad (2)$$
$$= \sum_{j=0}^{t-1} (\delta + r)\,(1-\delta)^{t-j-1}\, B_j$$

Figure 1 illustrates how the simple forces of debt accumulation and amortization deliver non-trivial endogenous reversals when new borrowing is auto-correlated and debt is long-term. We assume that there is a unit impulse to new borrowing at time 0 that decays exponentially at rate $\rho \in [0, 1)$ so that new borrowing at time t is $B_t = \rho^t$. For the figure, we set $r = 5\%$, $\delta = 15\%$ and consider three alternative scenarios. We depict new borrowing as positive numbers (light blue bars) and debt service as negative numbers (beige bars).

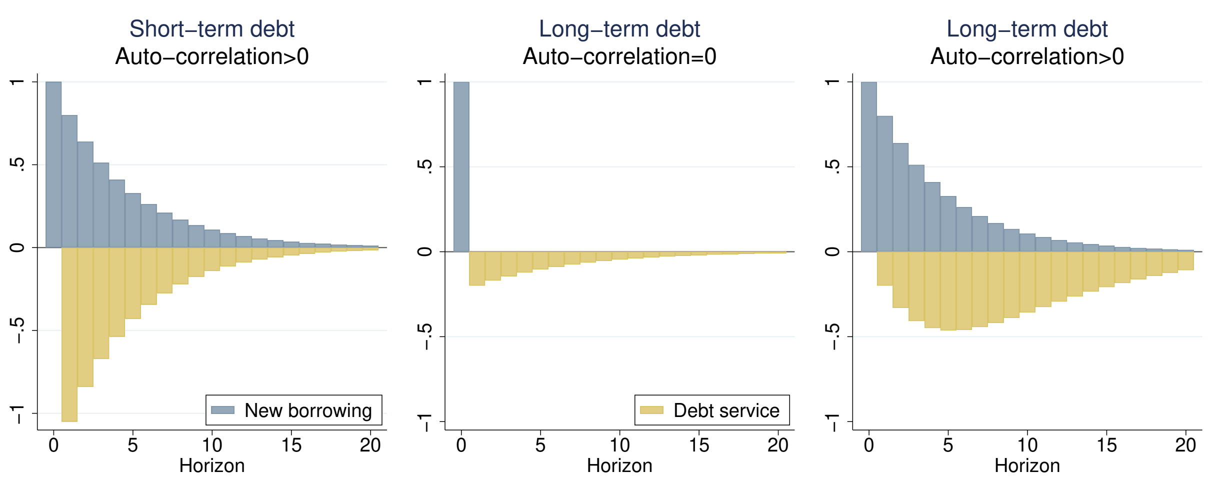

Figure 1: The evolution of new borrowing and debt service after a unit shock to new borrowing for varying levels of auto-correlation ρ and debt maturity δ. The simulations use equations (1) and (2) with $r = 5\%$ to trace out the effects on debt service and net cash flows. The first panel captures auto-correlated new borrowing with $\rho = 0.8$ and one-period debt so $\delta = 100\%$. The second panel captures no auto-correlation so $\rho = 0$ and long term debt with $\delta = 15\%$. The third panel captures both auto-correlated new borrowing with $\rho = 0.8$ and long-term debt with $\delta = 15\%$.

The first panel illustrates the dynamics following an impulse to new borrowing for the case of one-period debt contracts (full amortization, $\delta = 1$ each period) and auto-correlated new borrowing with a coefficient of correlation $\rho = 0.8$: new borrowing decays slowly after the initial unit impulse and debt service is simply the mirror image of new borrowing lagged by one period, so there is no interesting lead-lag relationship. The second panel depicts the case of long-term debt (amortization rate $\delta = 0.15$) but assumes there is no auto-correlation in new borrowing after the initial impulse ($\rho = 0$). In this case, the stock of debt peaks at $t = 1$, right after the impulse to new borrowing, and declines immediately after so there is also no interesting lead-lag relationship. In the last panel, debt is long-term ($\delta = 0.15$) and new borrowing is auto-correlated ($\rho = 0.8$). Only in this last case do we obtain a non-degenerate lead-lag relationship between the peak in new borrowing and the peak in debt service – here the lag is 5 periods. This case is empirically the most relevant.

In fact, we can also determine sharp analytic expressions for the lag between impulses in new borrowing and peaks in debt service in the described setup:

Lead-lag relationship *Following a unit impulse of new borrowing that decays at rate $\rho \neq 1 - \delta$ with $\rho, \delta \in [0, 1)$, debt service peaks at time*[5]

$$\hat{t} = \frac{\ln\left[\ln \rho / \ln(1-\delta)\right]}{\ln(1-\delta) - \ln \rho} - 1$$

(rounded to an integer). The lag between shocks to new borrowing and peaks in debt service is decreasing in the amortization rate and increasing in the auto-correlation of new borrowing.

Proof. See Appendix A.1. □

For the interested reader, Appendix A.2 proves that the lead-lag relationship holds not only for the special case of AR(1) processes covered in the observation above, but also for general hump-shaped processes of new borrowing.

3 Data and Measurement

The biggest obstacle to studying the workings of our propagation mechanism empirically is that amortizations, and therefore also debt service costs and new borrowing, are not directly recorded. In this section, we discuss how to measure these variables in the aggregate. We focus on the household sector for two reasons. First, data availability on debt maturities – which we need to infer amortizations – is considerably better than for the corporate sector. Second, it typically holds the largest share of long-term credit.

We also discuss other variables which we include in our analysis to avoid confounding effects from other channels than those associated with our propagation mechanism. All in all, we end up with an unbalanced panel of annual data for 16 countries. Our sample starts in 1980 and we have data for the flow measures until 2019. This allows us to estimate their real effects in a sample including 2020 as they enter these regressions with a lag of one.[6] The exact definitions, sources, and availability for all variables are listed in Appendix B.

3.1 New borrowing and debt service

We obtain expressions for new borrowing and debt service from our analytic framework. Adding the sub-index i to refer to the country in question, equation (1) tells us that new borrowing, $B_{i,t}$, equals the change in the stock of debt plus amortizations; and equation (2)

[5] In the special case $\rho = 1 - \delta$, we find $\hat{t} = -1/\ln \rho - 1$.

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

tells us that debt service, $S_{i,t}$, is the sum of interest payments and amortizations (Appendix A.3 considers the effect of write-downs on our measures).

Data on the total stock of debt are readily available across countries and time. We take the outstanding stock of debt in country i at time t, $D_{i,t}$, from the BIS database compiled by Dembiermont et al. (2013). This variable captures credit to the household sector from all sources, including bank credit, cross-border credit and credit from non-banks.

We construct time series for amortizations of household debt, since these are generally not recorded. We do so by modeling 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 also separately take account of interest-only mortgages, and within other household debt, we distinguish credit card debt, student loans and auto loans as separate categories.

We follow the methodology of Luckett (1980) and Dynan et al. (2003) to model repayments. This methodology is also used by the US Fed and the Bank of Canada to construct time series of aggregate debt service. For each category $l = 1, ..., L$ of household debt, we assume that the amortization rate, $\delta^l_{i,t}$, is given by the amortization rate of an installment loan with the average remaining maturity $m^l_{i,t}$ and the average interest rate paid $r^l_{i,t}$ on the outstanding stock of debt in that category:

$$\delta^l_{i,t} = \frac{r^l_{i,t}}{\left(1 + r^l_{i,t}\right)^{m^l_{i,t}} - 1} \tag{3}$$

A derivation of this formula is provided in Appendix A.4.

Equation (3) does not apply to interest-only mortgages as they are not amortised and credit card debt. Following Dynan et al. (2003), we set the amortization rate for credit card debt to the minimum required payment rate of 2.5%, i.e. $\delta^{credit\,card}_{i,t} = 0.025$, for that case.[7]

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.

$$amortizations_{i,t} = \sum_{l=1}^{L} \delta^l_{i,t} D^l_{i,t} \tag{4}$$

To compile time series for amortizations using equation (3) and (4), we collect data from a wide range of sources on the stock of debt, average interest rates and maturities for the different debt categories (see Tables B.3 and B.4 in Appendix B).[8]

Data on maturities are available for mortgages, which account for around 70% of household debt on average. But for many countries it is infrequently recorded. In these cases we linearly interpolate between consecutive observations and extend the initial (last) observation backward (forward) to obtain complete annual series. In most cases, we only have

[7] Dynan et al. (2003) base this assumption on the Senior Loan Officer Opinion Survey in the United States. Informal discussions with other central banks indicate that similar minimum repayments apply broadly internationally as well.

[8] Discrepancies can emerge between the sum of the individual debt components that we can collect and the total stock of debt. If so and to ensure consistency, we apply the shares of the individual debt components in their sum to the total stock of debt to genereate $D^l_{i,t}$.

information on the contractual maturity of new loans and calculate the average maturity of the outstanding stock of debt by carefully modeling the implied payment stream, as detailed in Appendix A.4. Contractual maturities of new mortgages are on average 25 years but range from 11 years in Finland in the 1980s to 45 years in Sweden most recently. Data on maturities for other household debt and student loans are 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 the United States.[9] We verify the robustness of our approach by comparing our time series with the only available long time series on amortizations, which is constructed from Australian micro data. Figure C.2 in Appendix B shows that, although the levels are somewhat lower, our series for new borrowing and debt service of mortgages in Australia match the dynamics of the time series constructed from micro data closely.[10]

For the ensuing empirical analysis, we normalize both new borrowing and debt service by nominal GDP obtained from the national accounts. We denote the resulting normalized variables by $b_{i,t} = B_{i,t}/Y_{i,t}$ and $s_{i,t} = S_{i,t}/Y_{i,t}$. We plot these series for all countries in our sample in Figure C.1, Appendix B.

When we study the real implications of new borrowing and debt service we primarily use real output growth, $\Delta y_{i,t}$, where $y_{i,t} = \ln(Y_{i,t}/P_{i,t})$ and $P_{i,t}$ is the GDP deflator. For robustness, we also analyze the effects on real consumption growth and the changes in unemployment growth.

3.2 Other variables

We use several different sets of variables to control for factors that may influence the propagation between new borrowing and debt service as well as the propagation to real outcomes beyond our main channel of interest. To ease the exposition, we organize these control variables in three expanding sets (Table 1). This also serves as a robustness exercise to ensure that our results are not driven by either under- or over-controlling. In all of our regression specifications we denote the relevant control variables by the vector $x_{i,t}$.

The smallest, or *parsimonious*, set of controls that we consider consider consists of the real 3-month money market rate and annual CPI inflation rate. Notably, these variables ensure that the debt service effects that we identify are not confounded with conventional real (or nominal) interest rate effects. Together with real GDP growth, this set of variables captures the information contained within the canonical equations of standard monetary models. We also add three dummy variables controlling for the Global Financial Crises

[9]Given the non-linearities inherent in equation (3), relying on average maturities and modeling broader loan categories matters for the derived repayments. As a robustness check, we replace our series with those published by the US Fed, the Bank of Canada and the BIS, which all rely on the same methodology and, in case of the BIS, look at household debt in an even less granular fashion. While the levels of debt service differ somewhat, the dynamics, and hence all econometric results, are largely unaffected. Drehmann et al. (2015) also use a simulation approach to show that modeling repayments using equation 3 versus aggregating repayments of individual loans affects the intercept but largely does not matter for the dynamics of debt service.

[10]The R^2 of regressing new mortgage borrowing (mortgage debt service) from Australian micro data on our measure of new mortgage borrowing (mortgage debt service) in Australia and a constant is 0.91 (0.90).

Control variables
Parsimonious:
real 3m money market rate, CPI inflation, crisis dummy (1 if banking crisis), global financial crisis dummy (1 in 2009), Covid-19 dummy (1 in 2020)
Baseline:
Parsimonious + real residential property price growth, term spread, lending spread on mortgages
Extended:
Baseline + unemployment growth, labour productivity growth, 1-year ahead GDP forecasts, change in the current account, change in real effective exchange rates, change in loan loss provisions
Other: Baseline + lending standards

Table 1: Control variables. Detailed definitions and sources are listed in Appendix B, Tables B.1–B.4.

in 2009, the onset of the Covid-19 pandemic in 2020, and the onsets of banking crises in individual countries.[11]

Our *baseline* set, which we use in most specifications, adds several financial factors to the parsimonious set that may influence new borrowing and debt service. For one, we add the term spread which is known to capture market expectations of the future economic outlook. We also include real residential property price growth and the lending spread on mortgages to control for changes in collateral and household borrowing limits. The inclusion of real residential property prices, in particular, also ensures that the new borrowing effects we later uncover do not simply capture standard wealth effects as a result of home equity withdrawals.

We also consider an *extended* set of controls that includes further variables that may impact our outcomes of interest. On the real side, we add unemployment to control for labor market influences and labor productivity growth as credit booms are more likely to end in crisis if productivity is low (Gorton and Ordoňez (2019)). We also add 1-year ahead GDP growth forecasts from Consensus Economics to control more directly for expected future activity. To control for changes in external demand and supply, as well as external competitiveness, we add changes in the current account (to GDP) and the real effective exchange rate.[12] Finally, we add the change in loan loss provisions to account for changes in credit quality.

A variable that has been highlighted in the macro-finance literature is lending standards. Unfortunately, data on lending standards are not widely available, and if so, start generally only in the early to mid-2000s. Hence, we only consider it (together with baseline variables) as an additional robustness check in Appendix C, Figure C.6.

In Section 5, we contrast the information in the flow variables that we analyze – new borrowing and debt service – with that contained in other credit-cycle measures proposed in

[11] We use 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).

[12] We use changes rather than levels for the unemployment rate, the real effective exchange rate and the current account to GDP as these variables contain sizable low-frequency components.

the literature. For this exercise, we consider the 3-year change in the credit-to-GDP ratio, the change in the household net worth to GDP ratio, and the corporate credit spread.

4 Long-term debt propagation in the data

How do we find out if long-term debt propagation is indeed important for understanding debt dynamics and real activity in actual data? The defining feature of any propagation mechanism is that it allows us to make systematic predictions that are anchored in a sound economic mechanism. In our case, the long-term debt propagation mechanism predicts that starting from an (auto-correlated) increase in new borrowing (all else equal), debt servicing will initially rise, then peak, and finally slowly decline. Such a lead-lag relationship is already suggested by the raw data at the country level where debt service peaks on average two to three years after a peak in new borrowing (see Figure C.1, Appendix C) as well as the cross-correlogram of new borrowing and debt service of the overall panel (see Figure C.3, Appendix C).

In the following, we trace out the impact of a unit increase in new borrowing on future new borrowing and future debt service more formally, to check whether we can identify the proposed long-term debt propagation mechanism. This need not be the case *a priori*. For one, other propagation mechanisms may start to dominate as the forecast horizon increases. For example, interest rates may change as a result of the initial increase in new borrowing and thereby alter the predicted paths of new borrowing and debt service. Individual loans can be subject to early repayment, refinancing, or default and may therefore not behave as predicted by the accounting framework in Section 2. Moreover, if early repayment, refinancing, or default occur at a sufficient scale, the relationships described by the accounting framework in Section 2 may break down.

4.1 Debt propagation

In this section, we conduct a more formal empirical analysis of long-term debt propagation. Specifically, we introduce a decomposition method to separate out the effects of long-term debt propagation from local projections of both real and financial outcomes.

As in Section 2, we are interested in the predictable part of future financial flows coming from contractual debt commitments undertaken in the past.[13] The empirical challenge is to isolate this channel from other forces that may influence debt flows.

Suppose that the macroeconomic variables of country i at time $t + h$ are described by

[13]In order to study long-term debt propagation in the spirit of Section 2, it is necessary to start with the reduced-form shock consisting of a unit increase in new borrowing. Other questions of interest, such as the role of this propagation channel for the transmission of monetary policy shocks, require structural identification strategies. Those questions are separate from the focus of the current paper.

the following system of local projections based on information at time t:

$$b_{i,t+h} = \beta_{bb}^{(h)} b_{i,t} + \beta_{bs}^{(h)} s_{i,t} + \beta_{by}^{(h)} \Delta y_{i,t} + \beta_{bx}^{(h)\prime} x_{i,t} + \varepsilon_{b,i,t+h}^{(h)} \tag{5}$$

$$s_{i,t+h} = \beta_{sb}^{(h)} b_{i,t} + \beta_{ss}^{(h)} s_{i,t} + \beta_{sy}^{(h)} \Delta y_{i,t} + \beta_{sx}^{(h)\prime} x_{i,t} + \varepsilon_{s,i,t+h}^{(h)} \tag{6}$$

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

$$x_{i,t+h} = \beta_{xb}^{(h)} b_{i,t} + \beta_{xs}^{(h)} s_{i,t} + \beta_{xy}^{(h)} \Delta y_{i,t} + \beta_{xx}^{(h)\prime} x_{i,t} + \varepsilon_{x,i,t+h}^{(h)} \tag{8}$$

where as before $b_{i,t}$ is new borrowing, $s_{i,t}$ is debt service, $\Delta y_{i,t}$ is real GDP growth, $x_{i,t}$ is a vector of controls (Table 1), 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 $h > 1$.

Consider a unit increase in $b_{i,t}$ at time t, i.e., $\varepsilon_{b,i,t}^{(0)} = 1$, while keeping all other error terms at zero. 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, as in our earlier accounting framework. 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 all other systematic responses of variables in time periods between t and $t + h$. 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 $t + h$. If the described system follows a VAR structure, this can be seen by solving the system recursively forward.[14]

To isolate the response of debt service that occurs for predictable accounting reasons, we can recursively iterate forward equation (6) for $h = 1$ with $\beta_{sy}^{(1)} = 0$ and $\beta_{sx}^{(1)\prime} = 0$ and find that a unit increase in new borrowing at t ceteris paribus gives rise to contractual debt service at date $t+h$ of $\beta_{sb}^{(1)} \sum_{i=1}^{h} \left(\beta_{ss}^{(1)}\right)^{i-1}$. While this expression captures the essence of long-term debt propagation, it neither takes into account that new borrowing is highly autocorrelated nor that growing debt service plays a role in curtailing new borrowing empirically.[15] Hence, from an empirical standpoint, a more complete characterizations of the long-term debt propagation channels are obtained by recursively iterating on the system of the two variables

$$\tilde{b}_{i,t+h} = \beta_{bb}^{(1)} \tilde{b}_{i,t+h-1} + \beta_{bs}^{(1)} \tilde{s}_{t,t+h-1} \tag{9}$$

$$\tilde{s}_{i,t+h} = \beta_{sb}^{(1)} \tilde{b}_{i,t+h-1} + \beta_{ss}^{(1)} \tilde{s}_{t,t+h-1} \tag{10}$$

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

The identified long-term debt propagation channels are shown in Figure 2 (the associated regression results are shown in tables C.1 and C.2). New borrowing is highly persistent following the initial unit impulse (yellow bars). In line with the debt compounding framework, auto-correlated new borrowing results in a humped shaped impact on debt service (light

[14]See Marcellino et al. (2006) for a discussion on the difference between direct and recursive forecasts.

[15]Figure C.4 in Annex C show the estimated debt propagation channels following a unit increase in new borrowing if we do not account for feedback of debt service on new borrowing. Auto-correlation is much higher, which in turn implies a much more drawn out response in debt service. In the medium term horizon, there is also a large gap between the estimated debt propagation channels and the local projections.

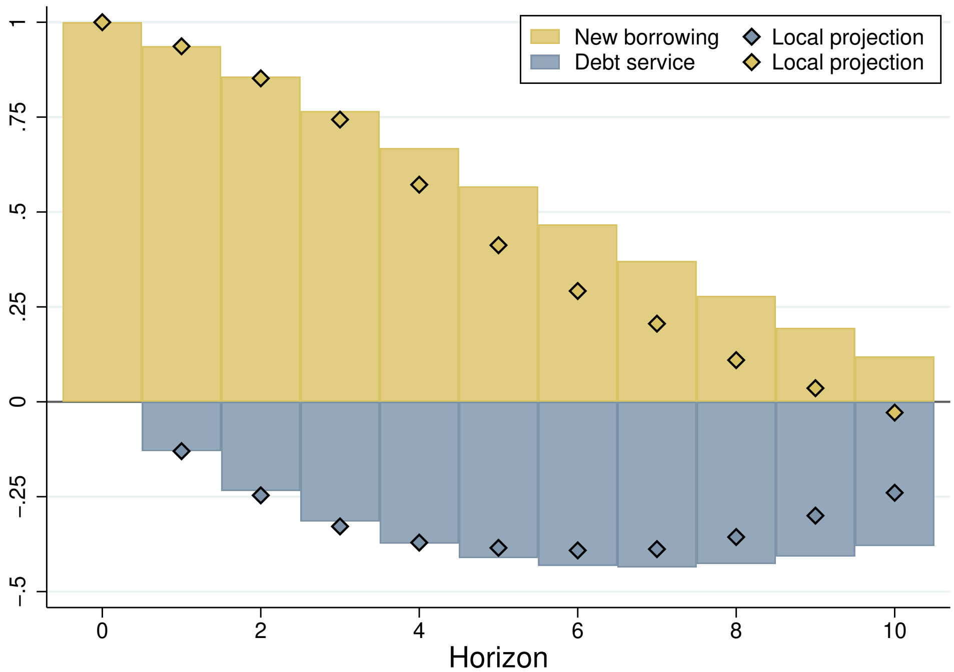

Figure 2: Long-term debt propagation after a unit increase in new borrowing at $t = 0$. Yellow and light blue bars show the new borrowing and debt service channels respectively (i.e. Equations (9) and (10)) using the baseline set of controls (Table 1). Diamonds show corresponding local projections for new borrowing and debt service from a unit increase in new borrowing at $t = 0$.

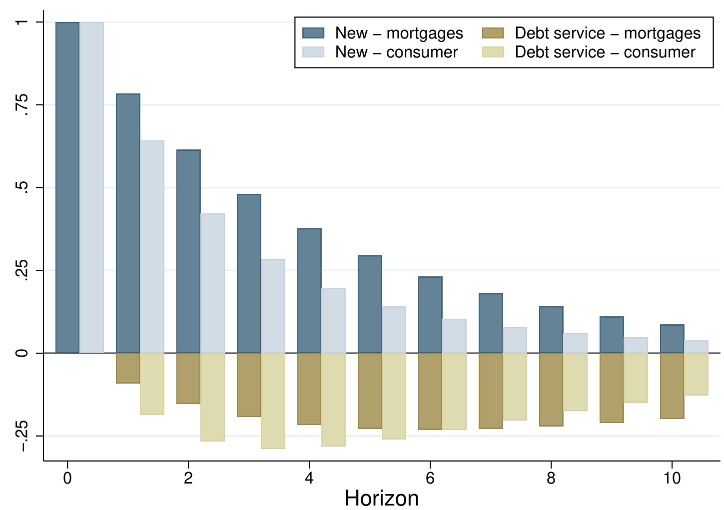

Figure 3: Long-term debt propagation of mortgage and consumer loan (Equations (9) and (10) using the baseline set of controls) The darker (lighter) blue and yellow bars show long-term debt propagation for mortgage (consumer) loans.

blue bars). The long-term debt propagation mechanism is quite drawn out. The impulse to new borrowing dies out after ten years and debt service peaks after seven years and remains relatively high in year ten.

The fit between the proposed debt propagation mechanism and the local projections (diamonds in Figure 2) is remarkable. The debt propagation channels of both new borrowing and debt service match the local projections nearly one-to-one for horizons up to five years. But even at longer horizons, the match is very close, especially for debt service. Hence, the highly stylized framework in Section 2 can capture the essential features of debt dynamics in the data to a surprisingly large degree.

4.1.1 Dependence on Loan Type

Separating household debt into mortgage and consumer loans further confirms the consistency of the debt compounding framework of Section 2 with the data. In particular, both the autocorrelation and maturity of mortgage borrowing are higher than for consumer debt. Hence, we should expect a more drawn out debt propagation mechanism for mortgages.

This is indeed what we find. Following a unit impulse of new borrowing, new mortgage borrowing shows high persistence with approximately 30% of the original impulse still remaining after 5 year (Figure 3). In the case of other household debt, in contrast, only one eighth of the original shocks remains after 5 years. In line with differences in the autocorrelation, debt service peaks after three years and then falls rapidly for household debt, compared to a much more drawn out response for mortgage debt with a peak after seven years.

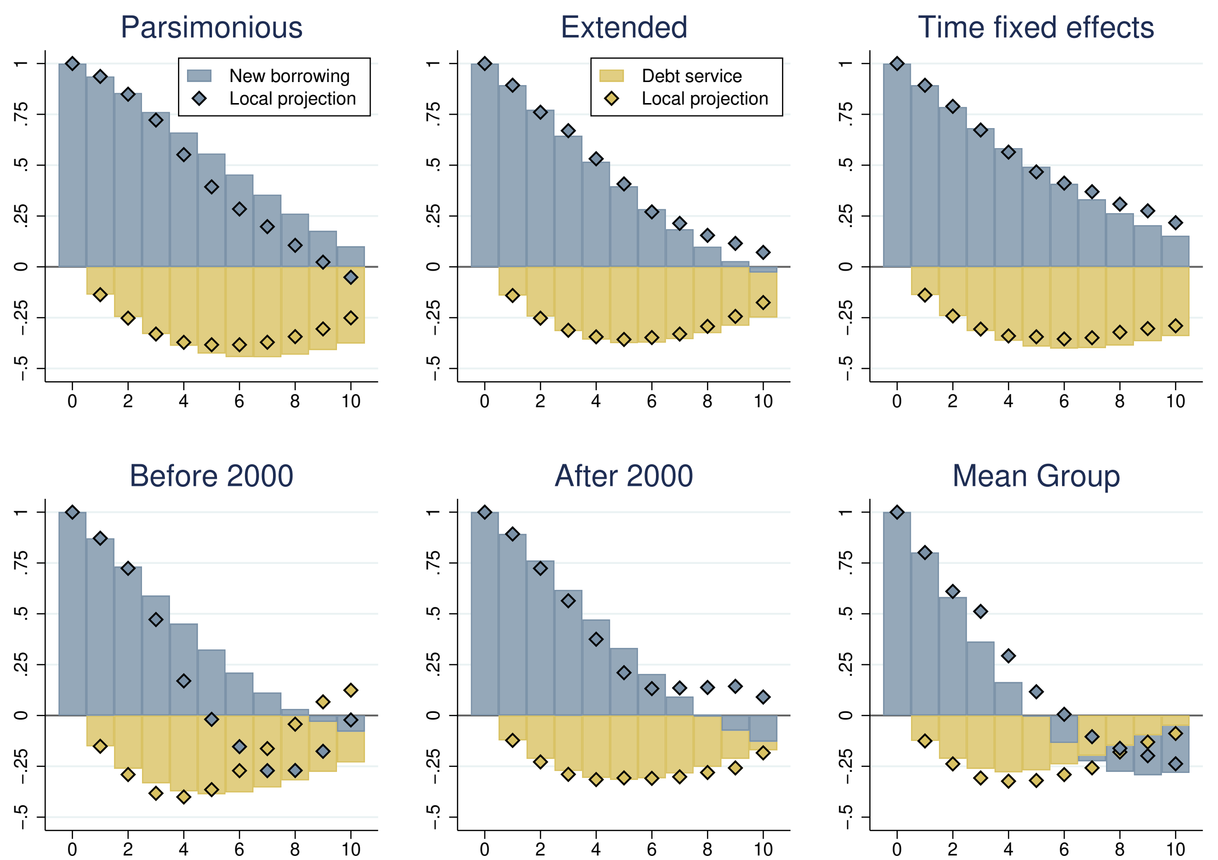

Figure 4: The robustness of long-term debt propagation under different specifications (Equations (9) and (10)). All specifications, except *Parsimonious* and *Extended*, use the baseline set of controls (see Table 1 for the different sets of controls). *Time fixed effects*: additionally controls for time fixed effects. *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. Diamonds show corresponding local projections for new borrowing and debt service from a unit increase in new borrowing at $t = 0$.

4.1.2 Robustness

The finding that long-term debt propagation can account for the bulk of systematic debt dynamics is very robust. For instance, one might worry that this result is sensitive to the specific set of controls included in the regressions. But this is not the case.

Independent of the set of controls, including when we add time-fixed effects, we find that the the proposed propagation mechanism is a very robust feature of the data. The estimated dynamics of the propagation change somewhat, though ((Figure 4 and also Figure C.5 that overlays the channels for better comparison). The persistence of new borrowing decreases marginally if we use the *extended* set of controls compared to using the *baseline* set, the *parsimonious* specification or the one with fixed-effects. This also reduces the lead-lag distance with respect to debt service.

The propagation mechanism is also not driven by the specific time periods or the country selection. This is evident when we consider pre- and post-2000 samples, or allow for full panel heterogeneity by using a mean-group estimator (Figure 4, lower panels). The most notable difference is that new borrowing is less auto-correlated when we allow for full panel heterogeneity, which in turn implies that debt service peaks earlier. While the alignment between the propagation mechanism and the local projections remains very close in the post-2000 sample or when we use the mean-group estimator, this is not the case for the pre-2000 sample. This seems to be mainly driven by less stable estimates for the local projections from horizons 5 to 10 years that arise from the shorter sample due to the unbalanced nature of our panel.

The propagation mechanism and the finding that it accounts for the bulk of systematic debt dynamics is also robust to other specifications (Figure C.6, Annex C). We try adding country-specific crisis dummies (taking the value one during a financial crises and two years after), controlling for lending standards[16], and splitting the sample according to the dominant form of loan repricing structure for mortgages in each country.[17] While some of these robustness checks affect the autocorrelation of new borrowing and thus the shape of the debt service channel, none of them alter the our key results.

4.2 Real effects

The importance of the long-term debt propagation channel ultimately rest on how well it helps us to predict real activity. For instance, if liquidity effects matter and borrowers have higher marginal propensities to consume than lenders, then new borrowing could increase consumption and output, whereas debt service could have the opposite effect all else equal. If such real effects are present in the data, they would not only provide a natural channel for real output persistence, but also predictable endogenous real reversals.

To examine the effects of long-term debt propagation from new borrowing and debt service, $\tilde{b}_{i,t+h}$ and $\tilde{s}_{i,t+h}$, on real output growth, we make use of their direct effects on 1-period ahead output growth (Equation (7) with $h = 1$) given by $\beta_{yb}^{(1)}$ and $\beta_{ys}^{(1)}$. Hence, the real effects are given by

$$\tilde{\Delta y}_{i,t+h} = \beta_{yb}^{(1)} \tilde{b}_{i,t+h-1} + \beta_{ys}^{(1)} \tilde{s}_{i,t+h-1} \tag{11}$$

which avoids the effects of other confounding influences on output.

The effects of new borrowing ($\beta_{yb}^{(1)}$) and debt service and ($\beta_{ys}^{(1)}$) are highly significant. In particular, new borrowing has a significantly positive effect on next periods output growth, while debt servicing has a significantly negative effect (Table 2). With the baseline controls, GDP growth significantly increases by approximately 12 basis points following a percentage point increase in new borrowing. A unit increase in debt service, on the other hand, decreases GDP growth by almost 19 basis points.[18] This result is novel and highlights the value

[16] As lending standards are only available for a limited sample, we can only consider horizons up to year 5.

[17] We investigate this by splitting the sample into countries where fixed-rate mortgages are dominant (approximately half of the countries) and countries where floating-rate mortgages are dominant. In each group, more than 75% of all mortgages belong to the dominant type (see Committee on the Global Financial System (2006) and European Central Bank (2000)) and the average contractual maturity is the same (25 years), in both.

[18] We cannot reject the null hypothesis that the two effects are equal but with opposite sign (p-value of 0.13). Hence, our results are consistent with the notion that the net cash flow between borrowers and lenders

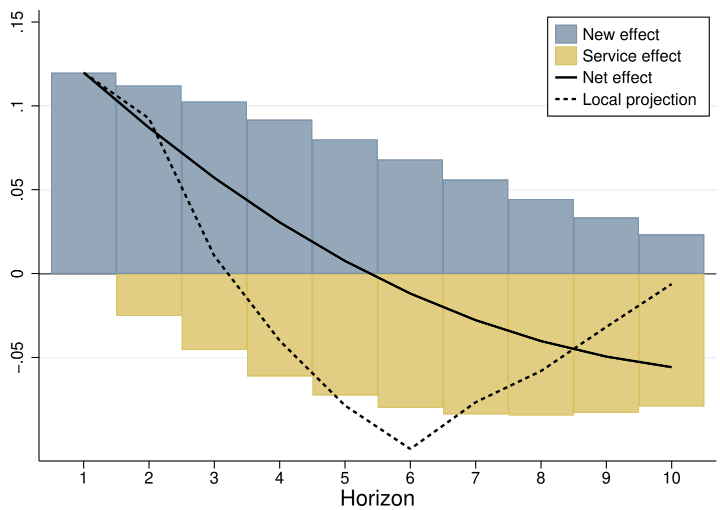

Figure 5: Real effects of long-term debt propagation. The new effect (blue bars) correspond to the first, and debt service effect (yellow bars) bars to the second right-hand term in (11), respectively, where $\tilde{b}_{i,t+h-1}$ and $\tilde{s}_{i,t+h-1}$ are derived from Equations (9) and (10)). The black line is the net effect of these two terms. The dotted line shows the local projections of real GDP growth from a unit increase in new borrowing at $t = 0$. The baseline set of controls is used.

added of keeping track of debt service in a world with long-term debt contracts. 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.

Over time long-term debt propagation gives rise to real reversals. This reflects the real effects of new borrowing and debt service and the non-trivial lead-lag relationship between new borrowing and debt service. Following a unit impulse of new borrowing, the real effects of new borrowing (Figure 5, light blue bars) dominate those of debt service (yellow bars) for the first five years, so that the net effect (solid black line) is positive. From then onward, the net effect turns negative as new borrowing dissipates and debt service lingers.

The effects are economically meaningful. New borrowing is on average 4.6 percentage points higher than normal at the peak of a credit boom (see Figure C.3). Such levels imply a 0.55 percentage point boost to economic output under the baseline specification. Debt service following these booms in new borrowing is on average 2 percentage points higher, depressing output by roughly 0.4 percentage points. However, these figures 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 percentage points above normal, generating a 6.7 percentage point increase in debt service. Moreover, given that both new borrowing and debt service are persistent variables, they have sizable effects on the business cycle over time. This suggests that long-term debt and auto-correlated new borrowing can serve as a powerful endogenous propagation mechanism for understanding the real dynamics surrounding credit booms.

is what matters for real activity.

	Dependent variable: *real GDP growth at* $t+1$						
	Baseline	Extended	Parsimonious	Before 2000	After 2000	Time effects	Mean Group
New borrowing	0.120^{***} (0.035)	0.058^{*} (0.029)	0.093^{***} (0.029)	0.136^{**} (0.053)	0.147^{**} (0.054)	0.042 (0.030)	0.133^{***} (0.049)
Debt service	-0.194^{***} (0.054)	-0.132^{***} (0.033)	-0.196^{***} (0.044)	-0.325^{***} (0.071)	-0.279^{***} (0.086)	-0.084^{*} (0.044)	-0.601^{***} (−0.092)
GDP growth	0.226^{***} (0.047)	0.050 (0.075)	0.261^{***} (0.041)	0.253^{***} (0.082)	0.078 (0.051)	0.380^{***} (0.059)	0.019 (0.043)
Controls:							
Parsimonious	✓	✓	✓	✓	✓	✓	✓
Baseline	✓	✓		✓	✓	✓	✓
Extended		✓					
Fixed effects:							
Country	✓	✓	✓	✓	✓	✓	✓
Time						✓	
N	620	495	628	284	336	620	620
R^2	0.605	0.672	0.580	0.469	0.712	0.729	NA

Table 2: Real effects of new borrowing and debt service. The tables reports estimates of the key coefficients of (7) for various specifications, samples and estimators. All specifications, except *Parsimonious* and *Extended*, use the baseline set of controls (see Table (1) for the different sets of controls). *Time 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. The numbers in parenthesis are standard deviations. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

How well do the real effects of long-term debt propagation (solid black line) line up with the known result in Mian et al. (2017) that credit booms depress output several years down the line? We will replicate the exact specification of Mian et al. (2017) in the next section. But as a first pass, Figure 5 compares the net effect of our propagation mechanism with the local projections of real GDP growth from a unit impulse to new borrowing (dotted line). In line with the mechanism, the local projection indicate that output grows initially and the falls medium run following an increase in new borrowing. For the first 2 to 3 years, the quantitative effects of the unconstrained local projection and the debt propagation are also very close. But the reversal occurs quicker in the case of the local projections as these turn negative after year three and reach a trough in year six. The corresponding numbers for long-term debt propagation are seven and 12 years (not fully shown).

4.2.1 Robustness

As illustrated in Table 2, the estimated real effects of new borrowing and debt service are robust. Independent of the specification we use, new borrowing has a positive and debt service a negative impact on GDP growth in the next period. The most notable changes occur when we add time fixed effects or allow for full panel heterogeneity. In the first case, the impact of new borrowing on GDP growth remains positive but is two thirds lower and not significant anymore. The effect of debt service is approximately halved even if it remains significant. This may be a sign that our other regressions are picking up some effects that are related to a global component with respect to credit developments across countries. On the other hand, when we use the Pesaran and Smith (1995) mean group estimator, the impact of debt service becomes much larger, suggesting that this flow variables may have differential effects on real activity across countries.

Given the robust propagation mechanism and the robust effect of new borrowing and debt service on GDP (Table 2), all specifications give rise to endogenous reversals. To visualise this, we overlay the net effect of different specifications in Figure C.7 in Annex C. Given the different sized coefficients, reversals are most muted when we add time fixed effects and most pronounced when we allow for full panel heterogeneity.

The effects of new borrowing and debt service – and thus also the long-term debt propagation mechanism – behave similarly when we consider unemployment and consumption growth in place of real GDP growth, control for lending standards or add crisis-specific dummies (Table C.3 in Annex C). Consumption growth increases significantly with higher new borrowing and decreases (significantly) with higher debt service. The effects on unemployment growth are reversed and new borrowing becomes insignificant. When we consider the different debt types, new borrowing drives up GDP growth in all cases, but the effects are weak and insignificant for consumer loans and fixed rated mortgages. The debt service effect, on the other hand, has a negative impact on GDP growth but is insignificant for flexible rate mortgages. This may indicate that in these cases monetary policy can offset the debt service effect as debt service costs can be quickly lowered by loosening monetary policy.

5 Predictive ability and alternative measures

The macro-financial literature has identified several alternative measures of the "credit cycle." We consider three variables. First, net worth, $(A_{it} - D_{it})/Y_{it} = nw_{it}$ where A_{it} denotes assets, which is a key driver of financial accelerator effects following the seminal work by Bernanke and Gertler (1989) and Bernanke et al. (1999). Second, credit spreads, spr_{it},[19] which have been shown to have predictive power for future business cycle fluctuations (e.g. Gilchrist and Zakrajsek (2012) and Krishnamurthy and Muir (2017)). Third, three-year credit-to-GDP growth, $\Delta_3(D_{it}/Y_{it}) = \Delta_3 d_{it}$, which has been shown as a predictor of financial crises and of future real activity (e.g. Jordà et al. (2013) and Mian et al. (2017)).

In this section, we compare the predictive performance of our flow measures relative to the three alternative credit cycle measures.[20] Rather than looking at h-period ahead real GDP growth as in (7), we follow the literature and look at *accumulated* real GDP growth (e.g. Jordà et al. (2013) or Krishnamurthy and Muir (2017)). In particular, we consider specifications of the following form:

$$y_{i,t+h} - y_{i,t} = \alpha_i^{(h)} + \beta_1^{(h)} \text{cycle\_measures}_{i,t} + \beta_2^{(h)} \text{baseline\_controls}_{i,t} + \varepsilon_{i,t+h}^{(h)} \qquad (12)$$

for $h = 1, ..., 6$, where the variable "cycle_measures" can be new borrowing and debt service, the three alternative financial cycle measures or combinations of these variables.

Both new borrowing and debt service have significant in-sample predictive power over accumulated real GDP growth (Table 3, Specification 1). Real GDP growth increases for two years following a unit increase in new borrowing. At its peak, real GDP is 0.2 percentage points higher. After year two, the positive effect gradually dissipates. The effect of a unit increase in debt service is even stronger. It significantly depresses cumulative output growth for up to six years (the effect becomes insignificant from year seven onward (not shown)). Real GDP is nearly 0.7 percentage points lower than on average at the trough in year 4 and only slowly starts to recover slowly thereafter.

Out of the three standard credit-related measures, only the 3-year change in the credit-to-GDP ratio has predictive information over cumulative real GDP growth (specifications 2-7). Net worth and the credit spread have no explanatory power, whether we look at these measures on their own or in combination with our flow based measures. In contrast, we find that an increase in the 3-year growth of the credit-to-GDP ratio significantly depresses cumulative GDP growth from year two onward (specification 2 and 5). This is the case even if we include the flow-based measures. But we show below that the negative additional effect from the 3-year change in credit-to-GDP is most likely related to the effect of corporate sector credit growth, which is not included in our flow measures of the household sector.

In-sample predictive ability does not necessarily imply good out-of-sample forecasting performance. Unfortunately out-of-sample forecasts typically only account for a small fraction of observed variation of outcomes in a panel setting, making it hard to find appropriate

[19] To construct the spread, we follow Krishnamurthy and Muir (2017). As the maturity of corporate bonds is not known, the spread is derived by regressing corporate bond yields on 5 and 10 government bond yields in each country.

[20] The literature has explored many other similar variables, such as the five-year growth rate or credit gaps derived as the difference between the credit to GDP ratio and its Hodrick-Prescott filtered trend with $\lambda = 400K$. Using such variants does not change our results to any significant degree.

Dependent variable: $y_{i,t+h} - y_{i,t}$						
	$h=1$	$h=2$	$h=3$	$h=4$	$h=5$	$h=6$
Specification 1: Baseline						
b_{it}	0.120^{***}	0.208^{**}	0.156	0.019	-0.135	-0.258
	(0.035)	(0.078)	(0.130)	(0.168)	(0.198)	(0.234)
s_{it}	-0.194^{***}	-0.446^{***}	-0.630^{***}	-0.689^{**}	-0.677^{**}	-0.673^{*}
	(0.054)	(0.135)	(0.200)	(0.248)	(0.288)	(0.317)
Specification 2: Only 3-year change in credit-to-GDP						
$\Delta_3 d_{it}$	-0.006	-0.035^{**}	-0.074^{***}	-0.100^{***}	-0.112^{**}	-0.113^{**}
	(0.006)	(0.015)	(0.023)	(0.032)	(0.039)	(0.048)
Specification 3: Only net worth						
nw_{it}	-0.001	-0.005	-0.014	-0.021	-0.026	-0.029
	(0.003)	(0.007)	(0.011)	(0.015)	(0.018)	(0.020)
Specification 4: Only corporate credit spread:						
spr_{it}	0.007	-0.291	-0.457	-0.612	-0.797	-0.800
	(0.102)	(0.185)	(0.312)	(0.468)	(0.604)	(0.717)
Specification 5: Baseline and 3-year change in credit-to-GDP						
b_{it}	0.174^{***}	0.408^{***}	0.466^{***}	0.358^{**}	0.134	-0.103
	(0.042)	(0.098)	(0.150)	(0.174)	(0.198)	(0.220)
s_{it}	-0.216^{***}	-0.526^{***}	-0.748^{***}	-0.821^{***}	-0.761^{**}	-0.693^{*}
	(0.055)	(0.136)	(0.202)	(0.253)	(0.306)	(0.343)
$\Delta_3 d_{it}$	-0.020^{***}	-0.065^{***}	-0.099^{***}	-0.108^{***}	-0.091^{**}	-0.062
	(0.006)	(0.015)	(0.023)	(0.031)	(0.040)	(0.047)
Specification 6: Baseline and net worth						
b_{it}	0.125^{***}	0.211^{**}	0.135	-0.006	-0.133	-0.213
	(0.037)	(0.078)	(0.133)	(0.167)	(0.195)	(0.224)
s_{it}	-0.206^{**}	-0.466^{**}	-0.581^{**}	-0.571^{*}	-0.478	-0.422
	(0.079)	(0.180)	(0.259)	(0.328)	(0.389)	(0.421)
nw_{it}	0.000	-0.001	-0.007	-0.012	-0.016	-0.019
	(0.003)	(0.006)	(0.011)	(0.014)	(0.016)	(0.019)
Specification 7: Baseline and corporate credit spread						
b_{it}	0.132^{**}	0.235^{**}	0.199	0.071	-0.074	-0.162
	(0.048)	(0.097)	(0.150)	(0.178)	(0.193)	(0.209)
s_{it}	-0.173^{**}	-0.373^{**}	-0.502^{**}	-0.494^{*}	-0.414	-0.396
	(0.060)	(0.141)	(0.211)	(0.273)	(0.331)	(0.379)
spr_{it}	0.057	-0.179	-0.314	-0.490	-0.726	-0.758
	(0.096)	(0.207)	(0.326)	(0.470)	(0.602)	(0.689)

Table 3: Predictive content of the flow variables and standard financial cycle measures for accumulated real GDP over different horizons. The specification corresponds to (12) using different cycle measures. In addition to new borrowing and debt service, the other cycle measures are: the three year change in the (private non-financial sector) credit- to-GDP ratio ($\Delta_3 d_{it}$) the corporate credit spread (spr_{it}), and net worth divided by GDP, (nw_{it}). *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

evaluation metrics. Nevertheless, good out-of-sample performance critically rests on parameter stability across sub-samples.

We indeed find that coefficients for new borrowing and debt service are stable. In particular, for new borrowing and debt service, we find statistically significant coefficients of very similar magnitudes as in Specification 1 in Table 3 for all horizons, h, when we re-estimate them starting from a sample that ends in 2000 and then successively expand the sample by adding a year (Figure C.8). Coefficients for the 3-year change in the credit-to-GDP ratio are also reasonable stable in magnitude. However, they only become significant once the Great Financial Crises is in the data.

It is interesting to compare our results with those of Mian et al. (2017) who decompose the 3-year change in the credit-to-GDP ratio into the components related to the household (indexed HH) and non-financial corporate (indexed NFC) sectors. We therefore first replicate the main results in Mian et al. (2017), Table II, in our sample, and then check how the results change when we add our flow measures. In particular, Mian et al. (2017) run regressions of the form:

$$\Delta_3 y_{i,t+k} = \alpha_i + \beta_{1,k}\Delta_3 d_{i,t}^{HH} + \beta_{2,k}\Delta_3 d_{i,t}^{NFC} + \upsilon_{i,t+k} \tag{13}$$

for $k = 0, 1, ..., 6$, where $\Delta_3 d_{i,t}^{X} = D_{i,t}^{X}/Y_{i,t} - D_{i,t-3}^{X}/Y_{i,t-3}$ for $X = \{HH, NFC\}$. We replicate these regressions and also run expanded versions of the form:

$$\Delta_3 y_{i,t+k} = \alpha_i + \beta_{1,k}\Delta_3 d_{i,t-1}^{HH} + \beta_{2,k}\Delta_3 d_{i,t-1}^{NFC} + \beta_{3,k} b_{i,t-1} + \beta_{4,k} s_{i,t-1} + \upsilon_{i,t+k} \tag{14}$$

where we have added new borrowing and debt service.

The results from estimating Equation (13) 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 4). 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 revert signs and become significantly positive by the end of the horizon.

When we add our flow measures, the household effects largely disappear (specifications 2, 4, 6, 8, 10, 12, and 14). Instead, new borrowing initially has a significant positive effect for $h = 0, 1, 2, 3$, which then turns negative for $h = 4, 5, 6$. Debt service has a strong negative effects for up to $h = 3$ and is insignificant thereafter. 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 4, 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 unsurprisingly, that there is some complementary information in corporate sector credit data. These effects are also similar to those associated with $\Delta_3 d_{it}$ in Specification 5 of Table 3, suggesting that the latter results may be driven by complementarities between sectoral credit aggregates.

Taken together, these results suggest that the propagation mechanism that we have highlighted can to a large extent account for the systematic predictive power over real economic

Dep.	$\Delta_3 y_{i,t}$		$\Delta_3 y_{i,t+1}$		$\Delta_3 y_{i,t+2}$		$\Delta_3 y_{i,t+3}$	
Spec.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta_3 d_{i,t}^{HH}$	$0.172^{\star\star}$ (0.073)	-0.107 (0.069)	$0.153^{\star}$ (0.077)	-0.085 (0.074)	0.058 (0.071)	-0.091 (0.073)	-0.065 (0.063)	-0.050 (0.072)
$\Delta_3 d_{i,t}^{NFC}$	$-0.110^{\star}$ (0.059)	-0.051 (0.044)	$-0.158^{\star\star}$ (0.061)	$-0.100^{\star\star}$ (0.045)	$-0.155^{\star\star\star}$ (0.049)	$-0.101^{\star\star}$ (0.036)	$-0.115^{\star\star\star}$ (0.036)	$-0.080^{\star\star}$ (0.030)
$b_{i,t}$		$0.814^{\star\star\star}$ (0.127)		$0.744^{\star\star\star}$ (0.161)		$0.492^{\star\star}$ (0.174)		0.029 (0.181)
$s_{i,t}$		$-0.965^{\star\star\star}$ (0.136)		$-1.042^{\star\star\star}$ (0.145)		$-0.965^{\star\star\star}$ (0.154)		$-0.637^{\star\star\star}$ (0.176)
FE	✓	✓	✓	✓	✓	✓	✓	✓
R^2	0.066	0.260	0.107	0.292	0.103	0.246	0.092	0.171
Obs.	584	570	568	568	552	552	536	536

Dep.	$\Delta_3 y_{i,t+4}$		$\Delta_3 y_{i,t+5}$		$\Delta_3 y_{i,t+6}$	
Spec.	(9)	(10)	(11)	(12)	(13)	(14)
$\Delta_3 d_{i,t}^{HH}$	$-0.186^{\star\star\star}$ (0.060)	-0.018 (0.066)	$-0.258^{\star\star\star}$ (0.062)	0.013 (0.064)	$-0.253^{\star\star\star}$ (0.070)	0.081 (0.064)
$\Delta_3 d_{i,t}^{NFC}$	-0.047 (0.030)	-0.030 (0.031)	0.027 (0.028)	0.031 (0.033)	$0.073^{\star\star}$ (0.027)	$0.068^{\star\star}$ (0.030)
$b_{i,t}$		$-0.381^{\star\star}$ (0.181)		$-0.630^{\star\star\star}$ (0.176)		$-0.763^{\star\star\star}$ (0.149)
$s_{i,t}$		-0.293 (0.206)		-0.050 (0.210)		0.126 (0.190)
FE	✓	✓	✓	✓	✓	✓
R^2	0.090	0.165	0.096	0.192	0.087	0.200
Obs.	520	520	504	504	488	488

Table 4: The flow variables and the main results form Mian et al. (2017), who differentiate between 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 (13) and (14) for $k = 0, ..., 6$. Reported R^2 values are from within-country variation. Standard errors in parentheses are clustered along the country dimension. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

outcomes reported in the past literature. As such, they 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), as fruitful avenues for capturing these effects.

6 Conclusions

This paper shows that it is crucial to focus on the financial flows between borrowers and lenders in order to understand how credit market developments propagate to the real economy. In particular, new borrowing is associated with higher economic growth. Its counterpart, debt service, accounts for much of the adverse real effects of credit, systematically linking past credit booms to predictable future slumps in economic activity. We lay out a simple analytic framework that describes how debt service can build up with a sizable lag if debt is long-term and new borrowing is auto-correlated, as it typically is in the data. We construct the first systematic cross-country data set of these flows for a panel of 16 countries from 1980 to 2019 and show that the lag between peaks in new borrowing and debt service is on average four years for the household sector. We also show that predicted future debt service accounts for the majority of the transmission mechanism from an impulse to household borrowing to predicted output losses in the medium run.

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 the credit market features that account for the lag structure of debt service in the data. In particular, doing justice to the data requires auto-correlated new borrowing and long-term debt. Theoretical contributions along these lines can be found in Garriga et al. (2017, 2021) and Gelain et al. (2017). Furthermore, the strong and systematic pattern in output that is generated by flows from lenders to borrowers and vice versa begs explanation. This pattern is consistent with models in which lenders and borrowers have different marginal propensities to consume and borrowers are financially constrained so the negative demand effects of high debt service cannot be offset by additional borrowing. Monetary policy cannot easily counter the resulting aggregate demand effects when it is constrained by the zero lower bound (e.g. Eggertsson and Krugman (2012), Korinek and Simsek (2016) and Guerrieri and Lorenzoni (2017)). However, our paper also finds strong negative output effects of debt service that seem not to have been offset by monetary policy during normal times. This raises the question of whether monetary policymakers were unable to counter the aggregate demand effects of debt service due to some other constraint, or whether they did not do so because they failed to fully account for this channel.

The systematic transmission channel whereby credit expansions have long-lasting adverse real effects also highlights an important policy trade-off. Our empirical results show that the flows of new borrowing have positive effects but debt service has negative effects on the real economy. But new borrowing necessarily generates future debt service. Hence, any policy that affects the economy by influencing the process of credit generation, for example monetary policy, has to trade off current output concerns with future debt service obligations. We hope that our findings will be useful for future efforts to model financial cycles and guide policy making.

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A Proofs and additional results

A.1 Analytic results for a AR(1) process of new borrowing

Assume that there is a unit impulse to new borrowing at time 0 that decays exponentially at rate $\rho \in [0,1)$ so that new borrowing at time t is $B_t = \rho^t$. For this case, we can obtain sharp analytic expressions for the timing of the peak in debt service. The debt stock resulting from a unit impulse in new borrowing is a moving average given by the geometric sum

$$\begin{aligned} D_t &= \sum_{s=0}^{t} (1-\delta)^{t-s} B_s = (1-\delta)^t \rho^0 + (1-\delta)^{t-1} \rho + \cdots + (1-\delta)^0 \rho^t \\ &= (1-\delta)^t \frac{1-\left(\frac{\rho}{1-\delta}\right)^{t+1}}{1-\frac{\rho}{1-\delta}} = \frac{(1-\delta)^{t+1} - \rho^{t+1}}{1-\delta-\rho} \end{aligned} \tag{A.1}$$

Proposition 1 (**Peak in debt service**). *Following a unit impulse of new borrowing that decays at rate $\rho \neq 1-\delta$ with $\rho \in [0,1)$ and $\delta \in (0,1]$, debt service peaks at an integer time index in the interval $\left(\hat{t} \pm 1\right)$ where*

$$\hat{t} = \frac{\ln\left[\ln \rho / \ln(1-\delta)\right]}{\ln(1-\delta) - \ln \rho} - 1$$

which satisfies $d\hat{t}/d\rho > 0$ and $d\hat{t}/d\delta < 0$.[21]

Proof. The peak in debt service coincides with the peak in debt. Although equation (A.1) is derived for integer values of t, it defines a continuous function of t with a maximum that is interior to the interval $[0,\infty)$. Maximizing the expression with respect to t yields the first-order condition

$$\ln(1-\delta) \cdot \left[1 - \left(\frac{\rho}{1-\delta}\right)^{t+1}\right] = \left(\frac{\rho}{1-\delta}\right)^{t+1} \ln\left(\frac{\rho}{1-\delta}\right)$$

which readily simplifies to the expression for $\hat{t}$ reported in the proposition. By definition, the maximum of the continuous function is within ± 1 of the integer of the function. The sign of $d\hat{t}/d\rho$ equals the sign of the expression $\frac{\ln(1-\delta)}{\ln \rho} - 1 - \ln\left[\frac{\ln(1-\delta)}{\ln \rho}\right]$. Define $x = \frac{\ln(1-\delta)}{\ln \rho} > 0$ and observe that the function $f(x) = x - 1 - \ln x$ is strictly positive for $x \neq 1$. □

Intuitively, the proposition captures that a higher amortization rate δ leads to an earlier peak in debt service since debt is paid off more quickly. Similarly, higher auto-correlation, ρ, leads to a later peak in debt service since borrowers continue to accumulate debt for a longer period.

To showcase that both long-term debt ($\delta < 1$) and auto-correlated new borrowing ($\rho > 0$) are necessary to obtain an interesting and non-degenerate lead-lag structure, it is useful to consider the two extremes $\delta = 1$ and $\rho = 0$:

[21] In the special case $\rho = 1-\delta$, the geometric sum for D_t is given by $\rho^t (t+1)$, which is maximized at $\hat{t} = -1/\ln \rho - 1$.

Corollary 2 (Necessity of both auto-correlation and long-term debt). *If either $\delta = 1$ or $\rho = 0$, the lag between an impulse to new borrowing and the peak in debt service becomes degenerate and collapses to $\hat{t} = 1$.*

The case $\delta = 1$ captures one-period debt contracts as is typically considered in theory models (see the left-hand panel of Figure 1, page 5, for an illustrative example). New borrowing is still autocorrelated and continues to be given by $B_t = \rho^t$ – after the initial unit impulse at $t = 0$, it decays slowly. Debt service is given by $S_t = (1 + r)\rho^{t-1}$ for $t \geq 1$, and is simply the mirror image of new borrowing lagged by one period. Intuitively, since any new borrowing is immediately paid off in the following period, there is no interesting lead-lag relationship between new borrowing and debt service. Given that new borrowing peaks at $t = 0$, debt service peaks at $t = 1$.

The case $\rho = 0$ captures a unit impulse to new borrowing without auto-correlation (center panel, Figure 1). In that case, no new borrowing occurs after the initial impulse. Hence, the stock of debt peaks at $t = 1$, i.e. in the period right after the impulse to new borrowing, and is declining immediately after. Debt service, given by $S_t = (r + \delta)(1 - \delta)^{t-1}$ for $t \geq 1$, follows the same pattern and also peaks at $t = 1$.

So far, our discrete time setup implied that we could only obtain an interval $\left(\hat{t} \pm 1\right)$ for the peak. In the following, we show an equivalent continuous time version of Proposition 1 in which we can obtain a precise value for $\hat{t}$.

Proposition 1 in continuous time In continuous time, we consider the same exponentially declining process of new borrowing $B_t = \rho^t = e^{-\eta t}$ as in the discrete version of Proposition 1, where $\eta = -\ln \rho$. The statement that is the equivalent of Proposition 1 in continuous time and its proof are as follows:

Following a unit impulse of new borrowing that decays at rate $\eta \neq \delta$ with $\eta, \delta \in (0, 1)$, debt service peaks at

$$\hat{t} = \frac{\ln \eta - \ln \delta}{\eta - \delta}$$

which satisfies $d\hat{t}/d\eta < 0$ and $d\hat{t}/d\delta < 0$.[22]

(We can now determine the exact peak instead of providing an interval that contains the peak in debt service, as in the discrete-time case.)

Proof. We substitute this process into the law of motion (A.2) and (for $\eta \neq \delta$) solve the resulting differential equation to find

$$\begin{aligned} D_t &= \int_{s=0}^{t} e^{-(t-s)\delta} e^{-\eta s} ds = e^{-t\delta} \int_{s=0}^{t} e^{s(\delta-\eta)} ds \\ &= e^{-t\delta} \left[\frac{e^{s(\delta-\eta)}}{\delta - \eta} \right]_{s=0}^{t} = e^{-t\delta} \left[\frac{e^{t(\delta-\eta)} - 1}{\delta - \eta} \right] = \frac{e^{-\eta t} - e^{-\delta t}}{\delta - \eta} \end{aligned}$$

[22] In the case $\eta = \delta$, the solution is $D_t = e^{-\eta t} t$ which is maximized at $\hat{t} = 1/\eta$.

The maximum of debt service, coinciding with the maximum in the debt stock, is given by the first-order condition to $\max_t D_t$, or equivalently,

$$\eta e^{-\eta t} = \delta e^{-t\delta}$$
$$\text{which can be solved for } \hat{t} = \frac{\ln \eta - \ln \delta}{\eta - \delta}$$

which satisfies

$$\frac{d\hat{t}}{d\eta} = \frac{\frac{\eta-\delta}{\eta} - \ln \eta + \ln \delta}{(\eta - \delta)^2} = \frac{1 - \frac{\delta}{\eta} + \ln \frac{\delta}{\eta}}{(\eta - \delta)^2} < 0$$
$$\frac{d\hat{t}}{d\delta} = \frac{-\frac{\eta-\delta}{\delta} + \ln \eta - \ln \delta}{(\eta - \delta)^2} = \frac{1 - \frac{\eta}{\delta} + \ln \frac{\eta}{\delta}}{(\eta - \delta)^2} < 0$$

The inequalities follow since the function $f(x) = 1 - x + \ln x$ satisfies $f(x) < 0 \, \forall x \neq 1$. Since $sign\left(d\hat{t}/d\rho\right) = -sign\left(d\hat{t}/d\eta\right)$, the signs are the same as in the discrete time case. □

A.2 Analytic results for the general process of borrowing

More generally, consider an exogenous process of new borrowing $\{B_t\}$, which involves positive new borrowing $B_t > 0$ for a finite number of periods $t \in \{0, ...T\}$ with $T \geq 0$ and is hump-shaped, i.e. there is a unique interior peak at a time $0 \leq t^* \leq T$ such that $B_{t^*} = \max_{t \in \{0,...T\}} \{B_t\}$, where borrowing is increasing up until the peak $B_0 < B_1 < \cdots < B_{t^*}$ and decreasing after the peak $B_{t^*} > B_{t^*+1} > \cdots > B_T$. For expositional simplicity, we maintain

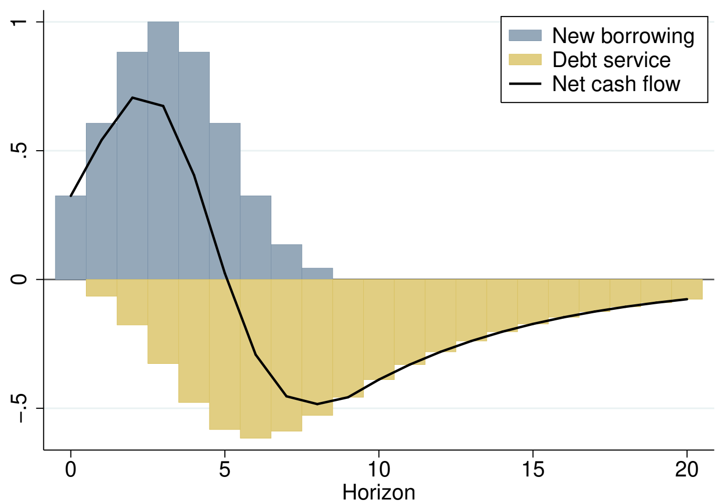

Figure A.1: The evolution of new borrowing and debt service during a credit boom. The simulation assumes an exogenous boom in new borrowing and uses equations (1) and (2) to trace out the effects on debt service and net cash flows. Debt is long term with $\delta = 15\%$ and $r = 5\%$.

the assumptions of constant interest and amortization rates. Furthermore, we impose a mild condition on timing: the process of new borrowing up until the peak t^* cannot be too drawn out over time, captured by the analytic condition $(\delta + r)\, t^* < 1$. After T, we assume no further borrowing so $B_t = 0$ for $t > T$. An example is given by the positive light blue bars in Figure A.1.

Given these assumptions, we find the following relationships between new borrowing and debt service:

Proposition 3 (**Lead-lag structure of new borrowing and debt service**). *(i) The peak in debt service $\hat{t}$ occurs after the peak in new borrowing t^*. The lag between the two peaks $t^* - \hat{t}$ is weakly decreasing in the amortization rate δ.*

(ii) The net cash flow from lenders to borrowers peaks weakly before the peak in new borrowing and turns negative after the peak in new borrowing but weakly before the end of the credit boom.

Proof. (i) At the peak of new borrowing t^*, debt is still growing, $\Delta D_{t^*} = -\delta D_{t^*-1} + B_{t^*} > 0$, if new borrowing exceeds amortization, $B_{t^*} > \delta D_{t^*-1}$, at t^*. An upper bound on debt D_{t^*-1} is $t^* B_{t^*}$. Our analytic condition on timing implies that $\delta D_{t^*-1} < \delta t^* B_{t^*} < B_{t^*}$ so debt is still growing at the peak of new borrowing and $\Delta D_{t^*} > 0$. Debt service is a linear transformation of the stock of debt outstanding $S_t = (\delta + r)\, D_{t-1}$ and therefore peaks after t^*.

At the peak $\hat{t}$ in the stock of debt, we find $\Delta D_{\hat{t}} > 0 > \Delta D_{\hat{t}+1}$. If we consider a higher amortization rate $\tilde{\delta} > \delta$, the resulting time series for the stock of debt $\tilde{D}_t$ features $\Delta \tilde{D}_{\hat{t}} < \Delta D_{\hat{t}}$, which turns negative weakly before $\hat{t}$. Since the peak in new borrowing $t^*$is exogenous, the lag $t^* - \hat{t}$ is decreasing in δ.

(ii) The change in the net cash flow at the peak of new borrowing issuance t^* is given by $\Delta N_{t^*+1} = \Delta B_{t^*+1} - \Delta S_{t^*+1}$. At t^*, we find that $\Delta B_{t^*+1} < 0$ by the definition of the peak in new borrowing, and the second term is negative since, per point (i), $\Delta D_{t^*} > 0$ and $S_{t^*+1} = (r + \delta)\, D_{t^*}$. This implies that net cash flow is declining at t^* or earlier.

Our condition on the timing of new borrowing implies $(\delta + r)\, D_{t^*-1} < (\delta + r)\, t^* B_{t^*} < B_{t^*}$. As a result, we find $N_{t^*} > 0$ so net cash flow is still positive at the peak in new borrowing. Furthermore, after the the credit boom at time $T+1$, we observe that $N_{T+1} = -(\delta + r)\, D_T < 0$. Taken together, $N_{t^*} > 0 > N_{T+1}$, proving point (ii) of the proposition. □

The intuition for these results is straightforward. For part (i) of the proposition, observe that debt service is a function of the stock of debt, or technically speaking, debt service is a moving average of new borrowing. When new borrowing peaks, the stock of debt and thus debt service is still increasing, since new borrowing is still positive and existing debt depreciates at the comparatively low rate of δ. After the peak in new borrowing, a lower amortization rate pushes back the time when debt service outweighs the positive (but declining) effects of new borrowing, which moves the peak in debt service further away from the peak in new borrowing.

For part (ii) of the proposition, observe that at the peak of new borrowing, where the growth rate of new borrowing is zero, debt service is still increasing. This implies that the the difference between the two, i.e. the net cash flow from lenders to borrowers, is decreasing and must have already peaked. At some point, the net cash flow turns negative since debt service becomes greater than new borrowing. As long as the credit boom is not too drawn out, this happens after the peak in new borrowing. Furthermore, it happens before the end of the credit boom – once the boom is over and there is no more new borrowing, the net cash flow consists entirely of debt service and must be negative.

Figure A.1 illustrates our findings. We assume $r = 5\%$, $\delta = 15\%$, and that new borrowing (light blue bars) is given by an exogenous bell-shaped process that starts at $t = 0$ and lasts for 9 periods, with a peak at $t = 3$. The beige bars depict the resulting debt service obligations, which continue to grow even when new borrowing is already declining. The black line depicts the net cash flow from lenders to borrowers, i.e. the difference between new borrowing and debt service. In line with Proposition 1, the net cash flow peaks before the peak in new borrowing and turns negative before the boom is over.

Some of the results in Proposition are stated as weak inequalities due to the discrete time nature of our framework. In the following, we show that all of the stated inequalities hold strictly in a continuous time framework:

Proposition 3 in continuous time The results of Proposition 3 on the lag structure between new borrowing, debt service, and net cash flows can be proven with strict inequalities when we move to a continuous time framework.

Consider an exogenous hump-shaped process of new borrowing over a continuous interval $[0, T]$ that satisfies $B_0 = B_T = 0$ and $B_t > 0$ in between, i.e. for $t \in (0, T)$. The process is continuous and differentiable over the interval $[0, T)$ with a single maximum at t^* so that $\dot{B} > 0$ for $t \in [0, t^*)$ and $\dot{B} < 0$ for $t \in (t^*, T)$, i.e. new borrowing is increasing up to its peak and decreasing after the peak. Furthermore, assume that the process of new borrowing until the peak t^* is reached is not too drawn out over time, captured by the analytic condition $(\delta + r)\, t^* < 1$. After T, we assume no further issuance so $B_t = 0$ for $t > T$.

Given these assumptions, total debt outstanding grows at rate

$$\dot{D}_t = B_t - \delta D_t \tag{A.2}$$

The two statements that are the equivalent of Proposition 3 in continuous time and their respective proofs are as follows (with the modifications due to the continuous time setup emphasized in bold):

(i) The peak in debt service $\hat{t}$ occurs after the peak in new borrowing t^*. The lag between the two peaks $t^* - \hat{t}$ is ***strictly*** *decreasing in δ.*

Proof. At the peak of new borrowing t^*, debt is still growing $\dot{D}_t > 0$ if borrowing exceeds amortization, $B_t > \delta D_t$. An upper bound on debt D_{t^*} is $t^* B_{t^*}$. Our analytic condition on timing implies that $\delta D_{t^*} < \delta t^* B_{t^*} < B_{t^*}$ so debt is still growing at the peak of new borrowing and $\dot{D}_{t^*} > 0$. Debt service is a linear transformation of the stock of debt outstanding $S_t = (\delta + r)\, D_t$ and is therefore also still growing at t^* when debt issuance is starting to decline.

Let us denote the peak of debt service by $\hat{t} > t^*$, which is when the stock of debt peaks so $\dot{D}_{\hat{t}} = 0$. We observe that $\hat{t} < T$, i.e. the stock of debt and debt service peak before the process of new borrowing is over at T, since $\dot{D}_T = -\delta D_T < 0$. In summary, $\hat{t} \in (t^*, T)$. Since $d\dot{D}_{\hat{t}}/d\delta = -D_{\hat{t}} < 0$, a higher amortization rate δ strictly reduces the time index $\hat{t}$ at which debt and debt service peak. As t^* is given exogenously, this implies that the lag between the two peaks $t^* - \hat{t}$ is strictly decreasing in δ, proving the last part of the statement in (i). □

(ii) The net cash flow from lenders to borrowers peaks ***strictly*** *before the peak in new borrowing and turns negative after the peak in new borrowing but* ***strictly*** *before the end of the credit boom. Net cash flow reaches its minimum after the peak in debt service.*

Proof. Net cash flows in our setting here are given by $N_t = B_t - (\delta + r) D_t$ with derivative

$$\dot{N}_t = \dot{B}_t - (\delta + r) \dot{D}_t \tag{A.3}$$

At the peak of new borrowing t^*, we find that $\dot{N}_{t^*} < 0$ because the first term $\dot{B}_{t^*} = 0$ by the definition of the peak, and the second term is negative since we have just shown that $\dot{D}_{t^*} > 0$. This implies that net cash flow is already declining at t^* when new borrowing reaches its peak, proving the first part of the statement.

Our condition on the timing of new borrowing implies $(\delta + r) D_{t^*} < (\delta + r) t^* B_{t^*} < B_{t^*}$. This implies that $N_{t^*} > 0$ so net cash flow will turn negative *after* the peak in new borrowing. Furthermore, at the end of the credit boom, we observe that $N_T = -(\delta + r) D_T < 0$. Taken together, $N_{t^*} > 0 > N_T$, and by continuity of N_t there must be a value $t^* < t < T$ such that $N_t = 0$, proving the second part of the statement

Finally, we observe that net cash flow is still declining when the level of debt and debt service peak at $\hat{t}$ since

$$\dot{N}_{\hat{t}} = \dot{B}_{\hat{t}} - (\delta + r) \dot{D}_{\hat{t}} = \dot{B}_{\hat{t}} - 0 < 0$$

This proves the last part of the statement. □

A.3 Accounting for write-downs and default

If we account explicitly for write-downs and default, the laws-of-motion in our analytic framework are modified in two ways.

Missed payments First, borrowers may default on the flow of debt service by missing an amount M_t of the debt service payments that they owe. This implies an actual flow of debt service payments

$$S_t = (\delta + r) D_{t-1} - M_t \tag{A.4}$$

We assume that missed payments M_t are added to the stock of debt and are, for simplicity, compounded at the same interest rate r.

Write-downs Secondly, lenders may write down an amount W_t of the stock of debt. As a result, the modified law of motion for debt is

$$D_t = (1 - \delta) D_{t-1} - W_t + B_t + M_t \tag{A.5}$$

and the net cash flow from lenders to the borrowers in a given period t satisfies

$$N_t = B_t - S_t = B_t - (\delta + r) D_{t-1} + M_t \tag{A.6}$$

Mapping to the data Our measurement of new borrowing and debt service is affected as follows:

The data series on the stock of debt fully accounts for the implications of both write-downs and missed payments, captured by the two new terms in equation (A.5). To obtain a times series of new borrowing that accounts for these effects, we thus have to add back write-downs and subtract missed payments,

$$B_t = \Delta D_t + \delta D_{t-1} + W_t - M_t$$

The time series for debt service owed that we constructed in Section 3 is based on actual interest paid (which *excludes* missed interest obligations) and estimated amortizations owed (which *include* missed amortizations). If we assume that borrowers miss interest and amortization in equal proportion m, then missed payments are described by

$$M_t = m\left(\delta D_{t-1} + rD_{t-1}\right) \tag{A.7}$$

Actual interest payments are then given by the expression

$$R_t = (1-m)\, rD_{t-1} \tag{A.8}$$

If D_{t-1}, M_t and R_t are observable in the data and we use our usual imputation procedure for amortization δ, we can eliminate r and solve the two equations (A.7) and (A.8) for m. This allows us to obtain both debt service obligations $\delta D_{t-1} + R_t / (1-m)$ as well as actual debt service flows $S_t = (1-m)\,\delta D_{t-1} + R_t$.

A.4 Debt service on installment loans

Consider a debt in the 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

$$S = \frac{rD}{1-(1+r)^{-m}} \tag{A.9}$$

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 (A.9), the amortization rate can be expressed as

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

Notice that we find that

$$\frac{d\delta}{dr} = \frac{(1+r)^m - 1 - rm\,(1+r)^{m-1}}{\left[(1+r)^m - 1\right]^2} = \frac{(1+r)^{m-1}\left[1 - r\,(m-1)\right] - 1}{\left[(1+r)^m - 1\right]^2} < 0$$

where the sign of the numerator of the expression follows since $(1+x)^m(1-mx) < 1$ for any $x, m > 0$.

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 simplyfuing 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 (A.9) over the following m periods. At any given time, there are m generations that we may index $k = 1...m$ that are each 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 households is then simply given by

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

B Data and sources

Variable	Description	Source
Credit ($d_{i,t}$)	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	3-month money market rate minus the CPI inflation rate.	Datastream
Lending spread	Prime lending rate minus 3-month money market rate.	Macrobond
Term spread	10 year government bond yield minus 3-month money market rate.	Global Financial Data
Corporate credit spread	Spread between lending spread and a corporate credit spread. As Krishnamurthy and Muir (2017) 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
Real exchange rate	Real effective exchange rate.	BIS
Property price	Residential property price deflated by the CPI.	BIS
Unemployment	Unemployment rate.	Global Financial Data, OECD, central banks
Labor productivity	Labor productivity.	OECD, FRED, World Bank
Inflation rate	First difference of the logarithm of the CPI.	National sources.
Current account	Current account balance as a percentage of GDP.	OECD.
Future output growth	1-year ahead Consensus Forecasts for GDP growth.	Consensus Forecasts
Net worth	Total assets - total liabilities of the household sector.	National Accounts
Provisions	Aggregate provisions of the national banking sector.	Bankscope, OECD, Pesola (2011)
Lending standards	Bank lending standards.	Central banks

Table B.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.

	$b_{i,t}$	$s_{i,t}$	$y_{i,t}$	Short rate	Term spread	Lend. spread	Credit spread	Prop. pr.	Unempl.	GDP forec.	Net worth	Prov.	Lend. std	Other macro[1]	Mortg. type[2]
AU	1980	1980	1980	1986	1986	1986	1983	1980	1980	1990	1989	1991		1980	float
BE	1980	1980	1980	1980	1980	1981	1980	1980	1980	1989	1999	1981	2003	1980	fix
CA	1980	1980	1980	1980	1980	1980	1983	1980	1980	1989	1990	1988	1999	1980	fix
DE	1980	1980	1980	1980	1980	1980	1988	1980	1980	1989	1999	1980	2003	1980	fix
DK	1994	1994	1980	1980	1980	1980	1994	1980	1980	1989	1998	1980		1980	fix
ES	1980	1980	1980	1980	1980	1980	1980	1980	1980	1989	1999	1980	2003	1980	float
FI	1980	1980	1980	1980	1987	1980		1980	1980	1989	1997	1980		1980	float
FR	1980	1980	1980	1980	1980	1980	1980	1980	1982	1989	1999	1988	2003	1980	fix
GB	1980	1980	1980	1980	1980	1980	1980	1980	1980	1989	1999	1987	2006	1980	float
IT	1980	1980	1980	1980	1980	1982	1980	1980	1983	1989	1995	1984	2003	1980	float
JP	1980	1980	1980	1980	1980	1980	1980	1980	1980	1989	1994	1989	2000	1980	fix
NL	1990	1990	1980	1980	1980	1980	1980	1980	1980	1989	2010	1980	2003	1980	fix
NO	1980	1980	1980	1980	1980	1980		1980	1980	1989	1995	1980		1980	float
PT	1980	1980	1980	1983	1983	1983		1988	1983	1989	1999		2003	1980	float
SE	1980	1980	1980	1980	1980	1980	1984	1980	1980	1989	1999	1981		1980	float
US	1980	1980	1980	1980	1980	1980	1980	1980	1980	1989	1980	1980	1990	1980	fix

Table B.2: Data sample and whether mortgages are predominantly fixed or floating rate. For abbreviations see Table B.1. [1]Real effective exchange rate, current account, and productivity. [2]Mortgage systems are classified based on CGFS (2006): "Housing finance in the global financial market", *CGFS Paper*, no 26; ECB (2009): "Housing fiance in the euro area", *Occasional Paper Series*, no 101; and information from national central banks.

	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 B.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		**Mortgage maturities**
	Total	**Sub-components**	**Total 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 B.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.

C Additional results

	Dependent variable: *new borrowing at* $t+1$						
	Baseline	Extended	Parsimonious	Before 2000	After 2000	Time effects	Mean Group
New borrowing	0.936*** (0.022)	0.893*** (0.022)	0.937*** (0.018)	0.872*** (0.081)	0.893*** (0.029)	0.893*** (0.024)	0.802*** (0.056)
Debt service	−0.156*** (0.053)	−0.185*** (0.034)	−0.159*** (0.039)	−0.186 (0.141)	−0.291*** (0.072)	−0.081* (0.039)	−0.486*** (0.101)
GDP growth	0.025 (0.022)	−0.046 (0.053)	0.034 (0.030)	0.128 (0.072)	−0.156*** (0.049)	0.144** (0.049)	−0.120** (0.055)
Controls:							
Parsimonious	✓	✓	✓	✓	✓	✓	✓
Baseline	✓	✓		✓	✓	✓	✓
E		✓					
Fixed effects:							
Country	✓	✓	✓	✓	✓	✓	✓
Time						✓	
N	606	481	614	284	322	606	606
R^2	0.818	0.857	0.819	0.689	0.792	0.848	NA

Table C.1: Internal debt propagation of new borrowing. The tables reports estimates of the key coefficients of (5) for various specifications, samples and estimators. The numbers in parenthesis are standard deviations. The last column uses the Pesaran and Smith (1995) Mean Group Estimator. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

	Dependent variable: *debt service ratio at* $t+1$						
	Baseline	Extended	Parsimonious	Before 2000	After 2000	Time effects	Mean Group
New borrowing	0.130^{***} (0.010)	0.141^{***} (0.013)	0.137^{***} (0.011)	0.151^{***} (0.030)	0.123^{***} (0.020)	0.139^{***} (0.010)	0.125^{***} (0.012)
Debt service	0.869^{***} (0.015)	0.845^{***} (0.013)	0.862^{***} (0.015)	0.852^{***} (0.028)	0.845^{***} (0.023)	0.852^{***} (0.016)	0.892^{***} (0.018)
GDP growth	0.011 (0.013)	0.023 (0.019)	0.024^{*} (0.012)	0.034 (0.024)	0.003 (0.015)	−0.003 (0.021)	0.048^{***} (0.011)
Controls:							
Parsimonious	✓	✓	✓	✓	✓	✓	✓
Baseline	✓	✓		✓	✓	✓	✓
E		✓					
Fixed effects:							
Country	✓	✓	✓	✓	✓	✓	✓
Time						✓	
N	606	481	614	284	322	606	606
R^2	0.968	0.972	0.968	0.935	0.946	0.972	NA

Table C.2: Internal debt propagation of debt service. The tables reports estimates of the key coefficients of (6) for various specifications, samples and estimators. The numbers in parenthesis are standard deviations. The last column uses the Pesaran and Smith (1995) Mean Group Estimator. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

Dependent ($t+1$):	Unemp.	Cons.	GDP gr.	GDP gr.	GDP gr.	GDP gr.	GDP gr.	GDP gr.
Extra controls:	–	–	Lend. st.	Ind. crises	–	–		
Misc.:	–	–	–	–	Mortg. flows	Cons. flows	Fixed rate	Flex rate
New borrowing	−0.132 (0.240)	0.108*** (0.019)	0.141** (0.062)	0.115*** (0.033)	0.116*** (0.027)	0.109 (0.088)	0.028 (0.059)	0.149*** (0.032)
Debt service	0.765** (0.323)	−0.242*** (0.051)	−0.352*** (0.089)	−0.153*** (0.051)	−0.162** (0.062)	−0.226** (0.079)	−0.117** (0.043)	−0.208 (−0.137)
GDP growth	−0.851* (0.450)	0.020 (0.046)	−0.051 (0.060)	0.174*** (0.055)	0.227*** (0.047)	0.227*** (0.047)	0.065 (0.036)	0.292*** (0.068)
Controls:								
Parsimonious	✓	✓	✓	✓	✓	✓	✓	✓
Baseline	✓	✓	✓	✓	✓	✓	✓	✓
Fixed effects:								
Country	✓	✓	✓	✓	✓	✓	✓	✓
N	606	589	244	620	620	620	319	301
R^2	0.533	0.639	0.767	0.635	0.604	0.604	0.633	0.630

Table C.3: Real effects of new borrowing and debt service for different specifications. The tables reports estimates of the key coefficients of (7) for various specifications, samples and estimators. The first two specifications use the unemployment and consumption growth, respectively, in place of GDP growth as explanatory variables. In these cases, the lagged dependent variable is added as an additional control. The third specification controls for lending standards. The fourth specification blocks out observations related to financial crises in individual countries. The fifth and sixth specifications substitute the two household flows with the corresponding flows related to mortgage and consumption borrowing, respectively. The last two specifications split the sample into countries where the majority of loan contracts are either fixed or flexible price, respectively. The numbers in parenthesis are standard deviations. *,**,*** indicate significance at the 0.1, 0.05, 0.01 levels, respectively.

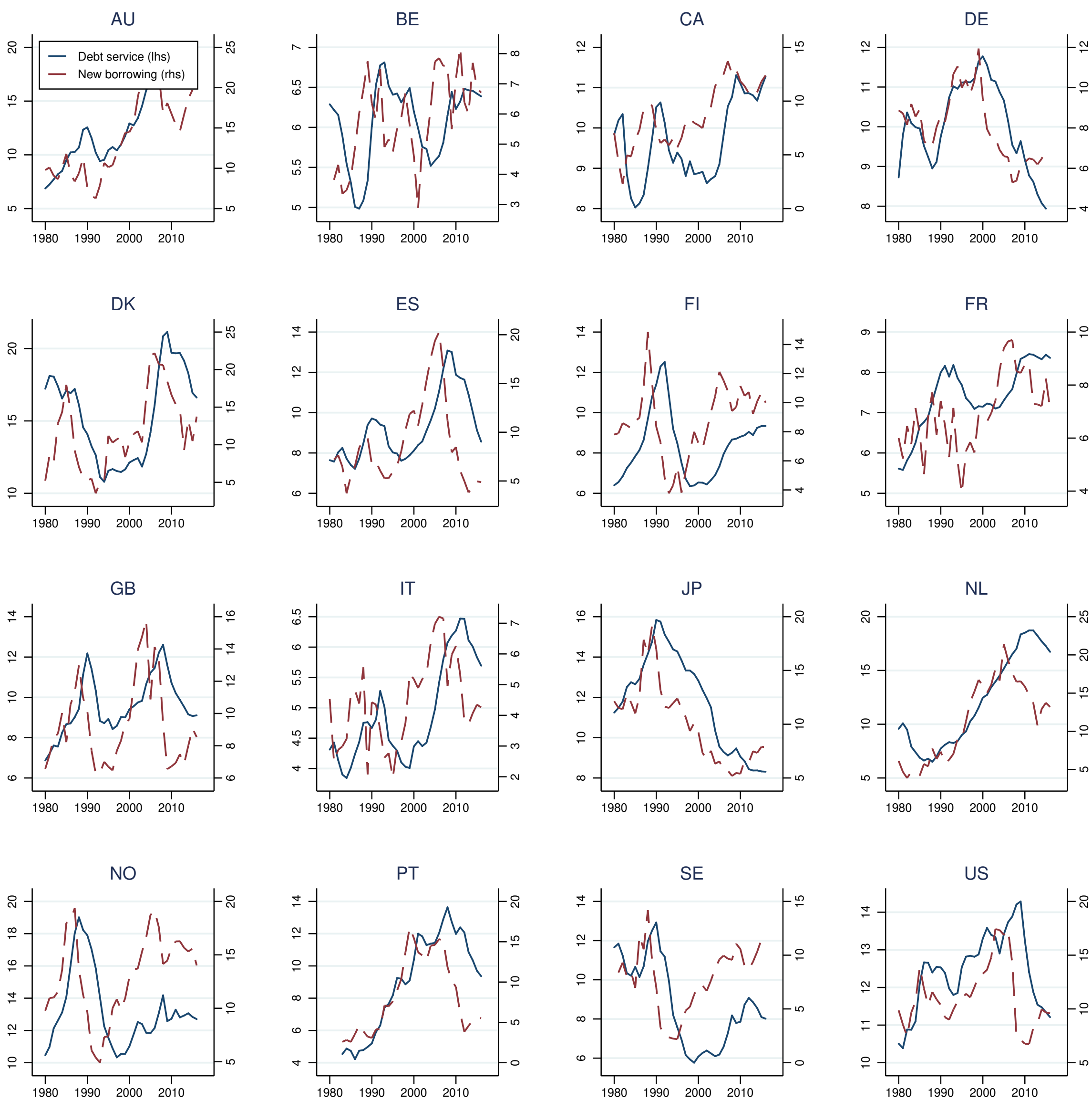

Figure C.1: New borrowing and debt service for the household sector in different countries.

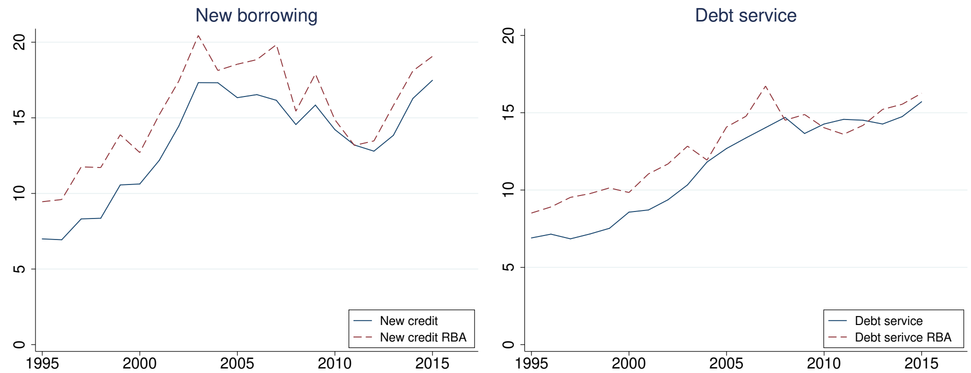

Figure C.2: Comparison of our measures of new borrowing and debt service for Australian mortgages with data from the Reserve Bank of Australia. The Reserve Bank of Australia reports data on the stock of mortgages outstanding, newly issued mortgages, refinanced mortgages and mortgage interest payments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

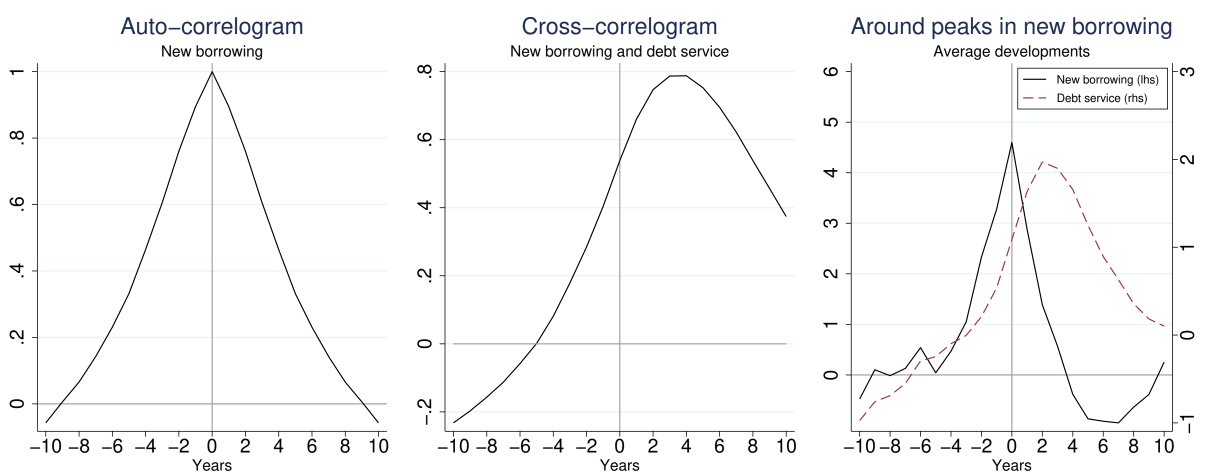

Figure C.3: Raw patterns between household sector new borrowing and debt service. The left-hand panel shows the auto-correlation profile of new borrowing and the central panel shows the cross-correlation between new borrowing and debt service. The right-hand panel shows the average evolution of the two 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.

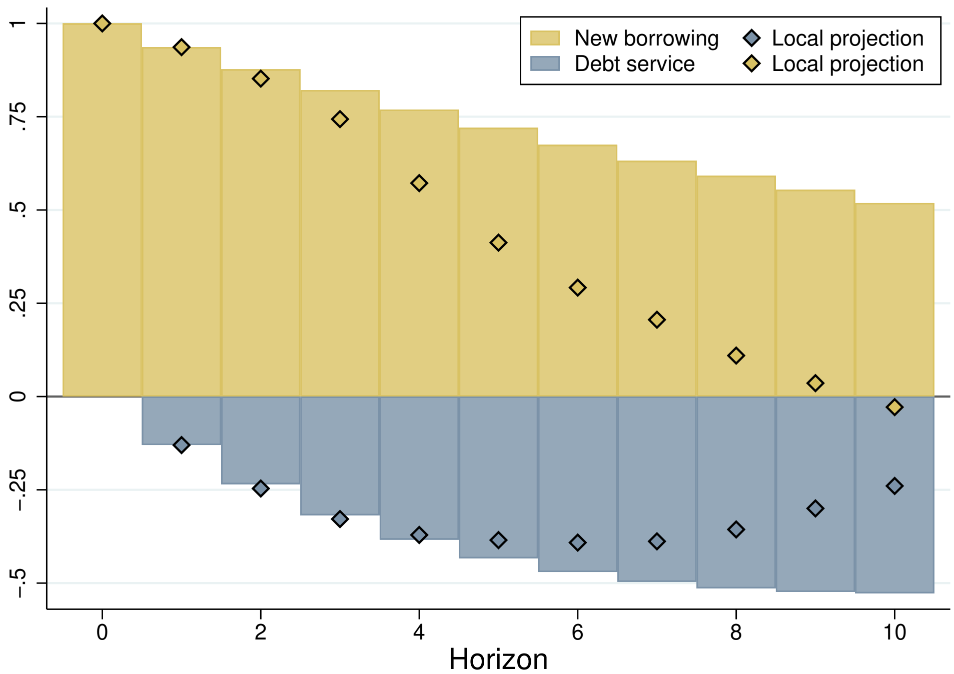

Figure C.4: Long-term debt propagation after a unit increase in new borrowing at $t = 0$ without feedback from debt service to new borrowing. Yellow and light blue bars show the new borrowing and debt service channels respectively (Equations (9) and (10)) and setting $\beta_{bs}^{(1)} = 0$. The baseline set of controls (Table 1) are used. Diamonds show corresponding local projections for new borrowing and debt service from a unit increase in new borrowing at $t = 0$.

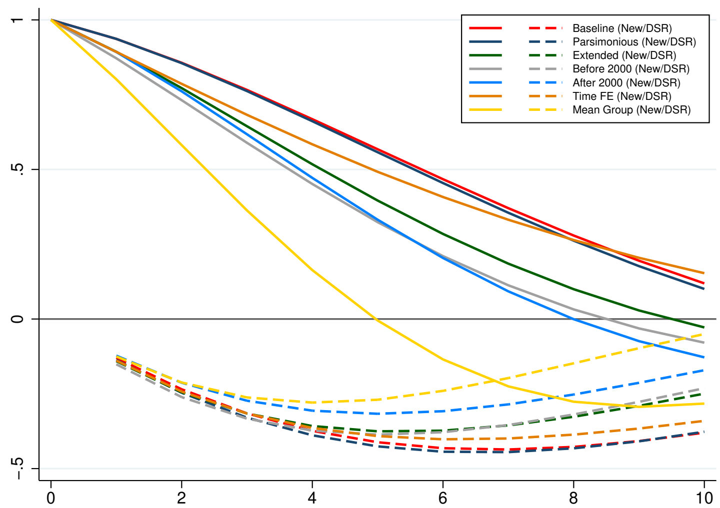

Figure C.5: Long-term debt propagation for different specifications. The sold/dashed lines show long-term debt propagation channels for new borrowing/debt service (Equations (9) and (10)). *Parsimonious* and *Extended*: parsimonious, respectively extended set of controls (see Table 1). All other specifications use the baseline controls. *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.

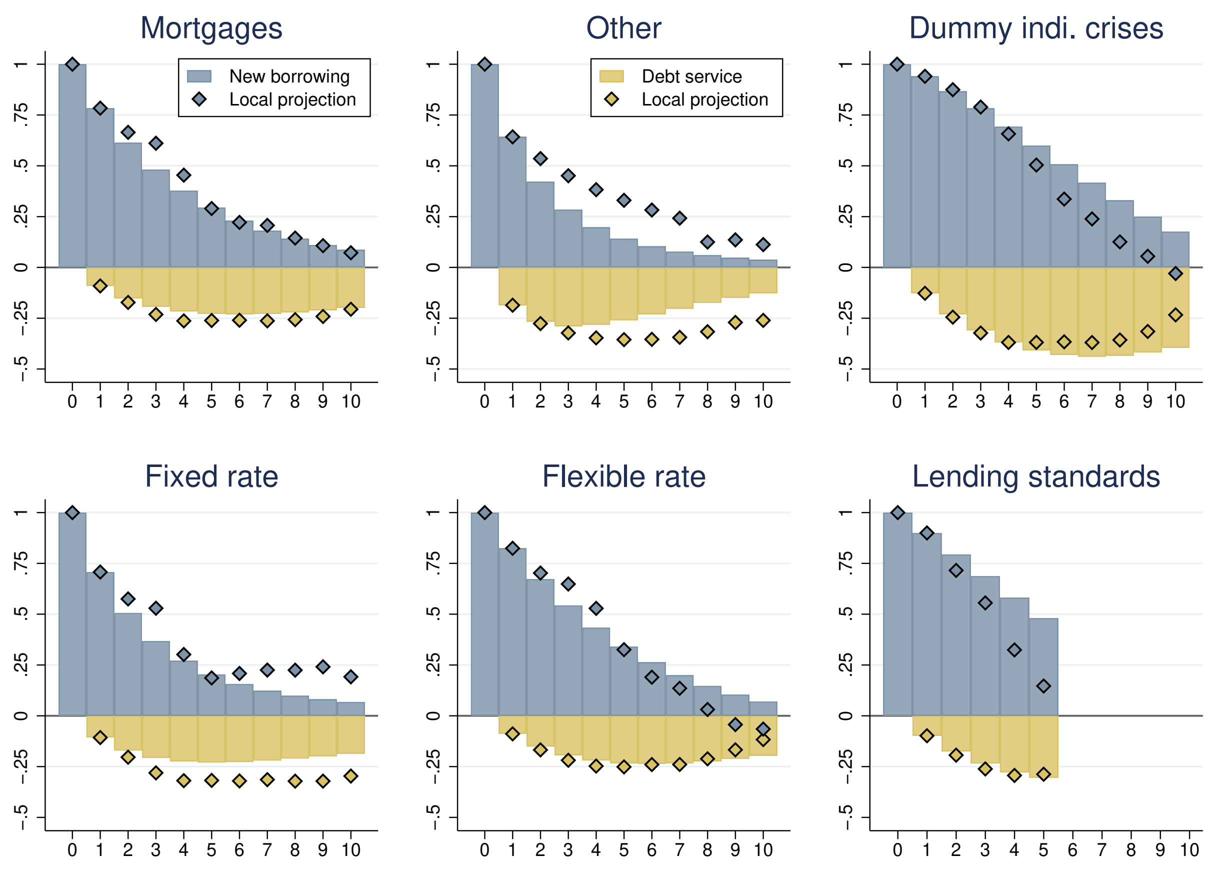

Figure C.6: The robustness of the long-term debt propagation with respect to different specification ((Equations (9) and (10)). *Mortages* and *Other*: mortgage and consumer loans respectively. *Fixed rate* and *flexible rate*: only countries with fixed and flexible rate mortgages. *Dummy indi. countries*: crises specific dummies are included instead of one general crisis dummy. *Lending standards*: adds lending standards as an additional control. Diamonds show orresponding local projections for new borrwing and debt service from a unit increase in new borrowing at $t = 0$. All specifications use the baseline set of controls.

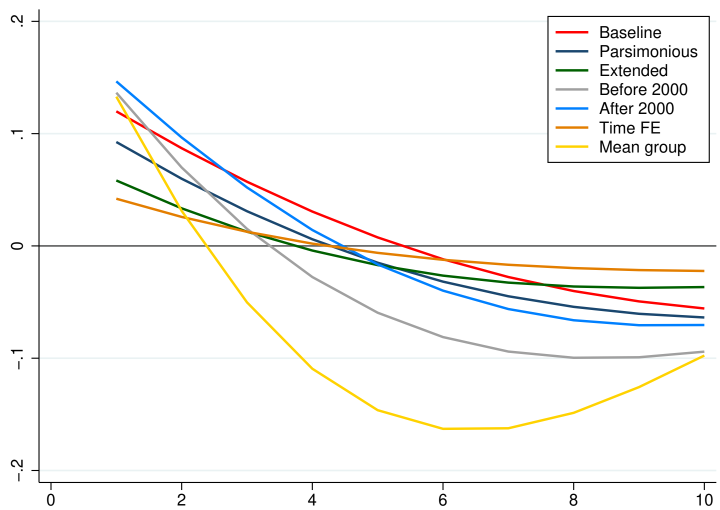

Figure C.7: The net-effect of a unit increase in new borrowing at $t = 0$ on GDP growth ahead under different specifications.*Parsimonious* and *Extended*: parsimonious, respectively extended set of controls (see Table 1). All other specifications use the baseline controls. *Time fixed effects* adds 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.

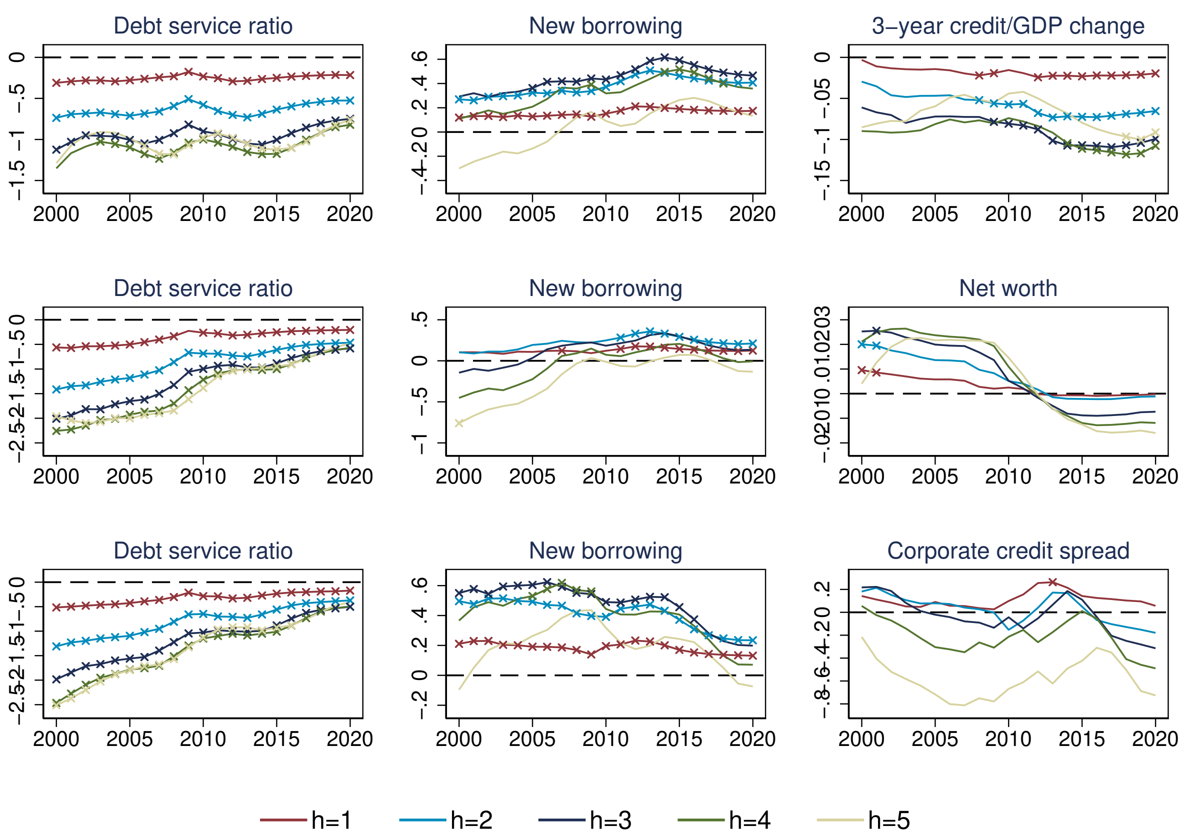

Figure C.8: Recursive estimates of the coefficients in (12) for three different specifications. Specifications always include new borrowing and debt service and one alternative credit cycle measure. Significant coefficient estimates at the 5% level are marked by "x".

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