NBER WORKING PAPER SERIES

GOING WITH THE FLOWS:
NEW BORROWING, DEBT SERVICE AND THE TRANSMISSION OF CREDIT BOOMS

Mathias Drehmann
Mikael Juselius
Anton Korinek

Working Paper 24549
http://www.nber.org/papers/w24549

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
April 2018

We would like to thank Larry Ball, Claudio Borio, Stjin Claessens, Giovanni Dell'Ariccia, Jon Faust, Andreas Fuster, Oscar Jorda, Arvind Krishnamurthy, Atif Mian, Hyun Song Shin, Amir Sufi, Emil Verner as well as participants at the 2017 IEA World Congress, the 2017 NBER Summer Institute, the 2017 SED Meetings, the 2017 SITE Workshop on New Models of Financial Markets, the Drexel-PFED Conference on Credit Markets and the Macroeconomy, the Money, Macro and Finance Annual Conference 2017, the 2018 AEA Meetings, and seminars at the Fed Board, the IMF, the BIS, the Central Bank of Mexico, the Bank of Finland, Johns Hopkins and the University of Virginia for helpful comments and suggestions. Part of this research was performed when Korinek was a Research Fellow at the BIS. The views presented here are the authors’ and do not necessarily reflect those of the Bank for International Settlements, the Bank of Finland, or the National Bureau of Economic Research.

Going With the Flows: New Borrowing, Debt Service and the Transmission of Credit Booms
Mathias Drehmann, Mikael Juselius, and Anton Korinek
NBER Working Paper No. 24549
April 2018
JEL No. E17,E44,G01

ABSTRACT

Traditional economic models have had difficulty explaining the non-monotonic real effects of credit booms and, in particular, why they have predictable negative after-effects for up to a decade. We provide a systematic transmission mechanism by focusing on the flows of resources between borrowers and lenders, i.e. new borrowing and debt service. We construct the first cross-country dataset of these flows for a panel of household debt in 16 countries. We show that new borrowing increases economic activity but generates a pre-specified path of debt service that reduces future economic activity. The protracted response in debt service derives from two key analytic properties of credit booms: (i) new borrowing is auto-correlated and (ii) debt contracts are long term. We confirm these properties in the data and show that debt service peaks on average four years after credit booms and is associated with significantly lower output and higher crisis risk. Our results explain the transmission mechanism through which credit booms and busts generate non-monotonic and long-lasting aggregate demand effects and are, hence, crucial for macroeconomic stabilization policy.

Mathias Drehmann
Bank for International Settlements
Centralbahnplatz 2
CH-4002 Basel
Switzerland
Mathias.Drehmann@bis.org

Mikael Juselius
Bank of Finland
P.O. Box 160
FI-00101 Helsinki
Finland
Mikael.Juselius@bof.fi

Anton Korinek
Department of Economics
Johns Hopkins University
Wyman Park Building 531
3400 N. Charles Street
Baltimore, MD 21218
and NBER
akorinek@jhu.edu

1 Introduction

Macroeconomists have long been interested in the real effects of financial market developments (eg Bernanke, 1983). This interest has been renewed by the Great Financial Crisis of 2008/09, with a particular focus on the effects of household debt (eg Mian and Sufi, 2010; Mian et al, 2013; Jorda et al, 2011, 2013). However, the literature has been held back by the lack of systematic data on the aggregate *flows* of resources between borrowers and lenders. We identify these flows as a crucial part of the transmission mechanism from financial markets to real economic activity.

Flows from lenders to borrowers, in short new borrowing, are systematically associated with economic expansions, whereas flows in the reverse direction, in short debt service, are associated with economic contractions and increased crisis risk.[1] Given that credit expansions tend to be persistent and involve long-term debt, new borrowing implies a pre-specified future path of debt service, consisting of interest payments and amortizations. This generates a systematic lead-lag relationship between the two flow variables that lies at the heart of the transmission mechanism from credit booms to the real economy. Furthermore, it gives rise to substantial predictability.

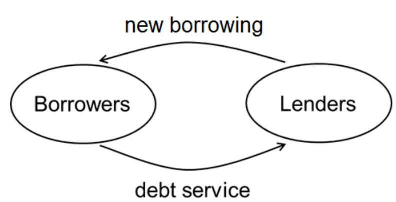

Figure 1: New borrowing and debt service

Our first contribution is to show that new borrowing implies a well-specified and systematic schedule of debt service in the future, using a simple analytic framework. In particular, we show that when new borrowing is auto-correlated and debt is long term – features that are present in the real world – two systematic lead-lag relationships between our flow variables emerge that may be quite long-lasting: First, debt service peaks at a well-specified interval after the peak in new borrowing. The lag increases both in the maturity of debt and the degree of auto-correlation of new borrowing. The reason is that debt service is a function of the stock of debt outstanding, which continues to grow even after the peak in new borrowing. Second, net cash flows from lenders to borrowers reach their maximum before the peak in new borrowing and turn negative before the end of the credit boom.

Our second contribution is to compile the first cross-country dataset of the aggregate flows of new borrowing and debt service of household debt for 16 countries from 1980 to 2015. This contrasts with previously available data on private debt that focus on stocks. We construct

[1] Although the focus of our paper is mainly empirical, we observe from the outset that these associations are consistent with models of financial market imperfections in which borrowers have higher marginal propensity to consume than lenders, as eg in Eggertsson and Krugman (2012), Farhi and Werning (2016), Korinek and Simsek (2016). By contrast, our observations are difficult to reconcile with models of rational agents in perfect financial markets in the context of household debt – in such models, new borrowing and debt service would be used to smooth household consumption and would therefore associated with economic expansions.

the flows by modeling the amortizations of up to six different household debt categories, such as mortgages, credit card debt, student loans and other household borrowing.[2] Using this new dataset, we provide empirical evidence on the lead-lag relationship between new borrowing and debt service. This relationship is already visible in the raw data, and confirmed in a formal impulse response analysis. Following an impulse to new borrowing, debt service shows a hump-shaped response that peaks after four to six years. In line with the predictions of the analytical framework, the lead-lag relationship is also more drawn-out for mortgages than for other household debt as they have longer maturities.

Our third contribution is to show that the aggregate flows between lenders and borrowers explain the real effects of credit booms and busts, both in the short and medium run. New household borrowing has a significant positive effect, and its counterpart, debt service, a significant negative effect on output growth in the near term. And once we control for the flow variables, we demonstrate that more traditional measures of credit booms, such as growth rates in the credit-to-GDP ratio, lose their explanatory power.

We show that these two flow effects together imply that the impulse response of output to new borrowing is non-monotonic over time. Initially, output growth increases. But it turns significantly negative in the medium run, at a horizon of five to seven years, as debt service builds up.[3] By developing and applying a novel decomposition method that extends the local projection method of Jorda (2005), we demonstrate that the delayed effects of debt service can, to a large extent, account for the negative medium run impact on output from credit growth. Other variables highlighted in the macro-finance literature, such as net-worth, have much less explanatory power for the transmission mechanism than debt service. Similarly, we find that debt service is the main channel through which new borrowing increases the probability of financial crises in the medium run.[4]

Taken together, our results provide a systematic transmission mechanism for the real effects of credit booms and busts.

These findings are robust to the inclusion of range of control variables as well as changes in sample and specification. Our baseline controls consists of variables that we expect to directly influence new borrowing and debt service, such as collateral values and interest rates. But results are similar when we only control for GDP growth or include a large set of additional variables such as credit spreads, net-worth, productivity, banking sector provisions and GDP forecasts. 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.

[2]We focus on household data since long-term debt contracts are most prevalent in this sector, especially for mortgages. But we also draw comparisons with the corporate sector at several points in the paper. Furthermore, we found similar results when using total non-financial debt in each country.

[3]The negative medium-run effect of increases in the stock of credit on growth are documented e.g. by Mian and Sufi (2014), Mian et al. (2013, 2017) and Lombardi et al. (2016). Claessens et al. (2012), Jorda et al. (2013), and Krishnamurthy and Muir (2017) document a link between credit booms and deep recessions. Brunnermeier et al. (2017) report a similar impulse-response pattern to credit shocks and attribute the medium-term output losses to monetary policy. Our paper contributes a more systematic transmission mechanism to this literature by showing that it is the flows of resources between borrowers and lenders that matter. Furthermore, employing our flow variables generates stronger empirical relationships.

[4]See e.g. Borio and Lowe (2002), Reinhart and Rogoff (2009), Schularick and Taylor (2012), and Drehmann and Juselius (2014), among others.

Our results are consistent with the view that credit supply shocks, as postulated e.g. by Mian et al. (2017) and Mian and Sufi (2018), lead to significant aggregate demand effects that are difficult to counteract by macroeconomic policymakers. Although we find that monetary policy systematically responds to credit booms and busts, it does not fully offset the effects of credit fluctuations on aggregate demand, even if we only focus on periods in which the economy was *not* in a liquidity trap.

The transmission mechanism from new borrowing to debt service and real economic activity that we document in this paper is of great relevance for developing realistic models and policies to deal with credit booms and busts. The flows of new borrowing and debt service enter budget constraints directly and thus encapsulate contemporaneous and future liquidity effects of credit relationships, as emphasized eg by Eberly and Krishnamurthy (2014).[5] Our results highlight an important trade-off when trying to stimulate the economy by encouraging the expansion of debt. New borrowing has positive effects in the short run, but as it will mechanically increase debt service in the future, these benefits must be weighed against the associated drag on growth in the medium run. Equally, this trade-off has potential implications for using monetary policy to lean against the wind as dampening a credit boom with higher policy rates may weaken growth in the short run but avoid higher debt service – and low output and higher crisis risk – in the medium run.[6] More broadly, our results show that policy needs to take into account contractual features that affect future debt service and, thus, have a predictable effect on economic activity.

The paper is structured as follows. In the ensuing section, we provide a simple analytic framework to illustrate the main channels at work. In Sections 3 and 4, we discuss the data and document the lead-lag relationship between new borrowing and debt service. In Section 5 we describe the transmission channel from new borrowing to debt service and, in turn, to economic activity and crisis risk. Section 7 concludes.

2 Analytic Lead-Lag Structure

This section lays out a simple analytic framework that clarifies the key mechanism underlying the lead-lag relationship between new borrowing, future debt service, and the net cash flows between borrowers and lenders. The framework highlights the key roles of auto-correlated new borrowing and long-term debt contracts, both of which are present in the data, in generating an interesting lead-lag structure.

Analytic framework Consider a borrower who borrows an amount B_t of long-term debt in period t. Assume, for simplicity, a constant amortization rate δ and fixed interest rate r. In the following period $t+1$, this contract implies a debt service of $(r+\delta)\,B_t$, consisting of

[5] From a statistical point of view, an additional benefit is that, once normalized by GDP, new borrowing and debt service do not show pronounced trends, in contrast to traditional credit-to-GDP aggregates. Hence, we do not need to apply detrending methods typically used in the literature.

[6] Juselius et al (2017) develop this theme further by introducing debt service and leverage into a standard reduced form model of the economy. They run counterfactual simulations and conclude that a monetary policy rule that takes debt service systematically into account during both good and bad times could dampen both financial and real cycles.

interest payments and amortization, and a remaining stock of debt outstanding of $(1-\delta) B_t$ at the end of the period, which is carried over to the next period. After k periods, a balance of $(1-\delta)^{k-1} B_t$ is left of the original amount borrowed, implying debt service obligations of $(r+\delta)(1-\delta)^{k-1} B_t$.

The total stock of debt outstanding at the end of period t, D_t, follows the law-of-motion

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

Hence, the stock of debt can be represented as a moving average of current and past 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,

$$\begin{aligned} S_t &= (\delta + r) D_{t-1} \\ &= \sum_{j=0}^{t-1} (\delta + r)(1-\delta)^{t-j-1} B_j \end{aligned} \tag{2}$$

The net cash flow from lenders to the borrowers in a given period t consists of the new borrowing B_t minus all the debt service obligations due in period t,

$$N_t = B_t - S_t = B_t - (\delta + r) D_{t-1} \tag{3}$$

Observe that the standard case of short-term debt corresponds to $\delta = 1$. In that case, the above formulas reduce to $D_t = B_t$, $S_t = (1+r) B_{t-1}$ and $N_t = B_t - (1+r) B_{t-1}$. In other words, with short-term debt, it is unnecessary to distinguish between new borrowing and the stock of debt carried into the next period.

Dynamic implications of a credit boom We now use these analytic relationships to trace out the implications of a boom in new borrowing for the lag structure between borrowing and debt service.

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 $B_{t^*} = \max_{t \in \{0,...T\}} \{B_t\}$ and 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 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 $t > T$.

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

Proposition 1 (**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.

The formal proof of the proposition is given in Appendix A.1 but the intuition 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.

Some of the results in the proposition are stated as weak inequalities due to the discrete time nature of our framework. Appendix A shows that in an equivalent continuous time framework all of the stated inequalities hold strictly.

Figure 2 illustrates our findings. We assume that new borrowing (light-blue bars) is given

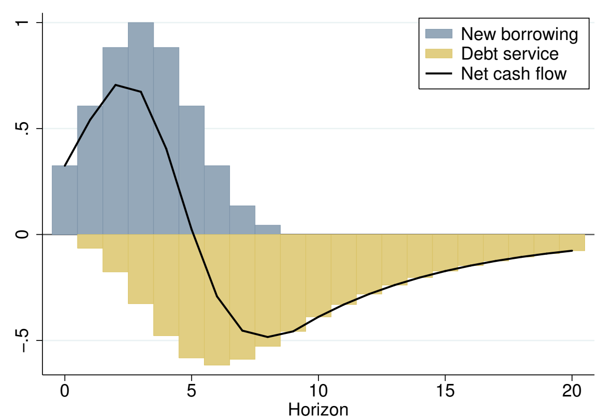

Figure 2: The evolution of new borrowing and debt service during a credit boom. The simulation assumes an exogenous boom in new borrowing and uses equations (1) and (2) to trace out the effects on debt service and net cash flows. Debt is long term with $\delta = 15\%$ and $r = 5\%$.

by an exogenous bell-shaped process that starts at $t = 0$ and lasts for 9 periods, with a peak at $t = 3$.[7] 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.

Analytic results for a unit impulse in new borrowing Although new borrowing in the data is typically a bell-shaped process during credit booms, it is useful to consider the special case of a unit impulse in new borrowing that decays exponentially. This process allows us to obtain analytic results for the timing of the peak in debt service. It also corresponds to the way that shocks are typically modeled in theoretical models.

Assume that there is a unit impulse to new borrowing at time 0 that decays exponentially at rate $\rho \in [0,1)$. As a result, new borrowing at time t is $B_t = \rho^t$. This process of new borrowing is a limit case of the class of credit boom processes covered by Proposition 1 with $t^* = 0$ and $T \to \infty$. The results of the proposition therefore still apply, but they can be sharpened by obtaining 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

$$
\begin{aligned}
D_t &= \sum_{s=0}^{t} (1-\delta)^{t-s} B_s = (1-\delta)^t \rho^0 + (1-\delta)^{t-1} \rho + \cdots + (1-\delta)^0 \rho^t \\
&= (1-\delta)^t \frac{1-\left(\frac{\rho}{1-\delta}\right)^{t+1}}{1-\frac{\rho}{1-\delta}} = \frac{(1-\delta)^{t+1} - \rho^{t+1}}{1-\delta-\rho}
\end{aligned} \tag{4}
$$

Proposition 2 (**Peak in debt service**). *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 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 $d\hat{t}/d\delta < 0$.[8]

As in the previous proposition, our discrete time setup implies that we can only obtain an interval $\left(\hat{t} \pm 1\right)$ for the peak. Appendix A.1 provides a proof and shows that an equivalent proposition for a continuous time version of our model delivers a precise value for $\hat{t}$.

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 $\rho = 0$:

[7] For illustration purposes, we set $r = 5\%$ and $\delta = 15\%$ in this simulation.

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

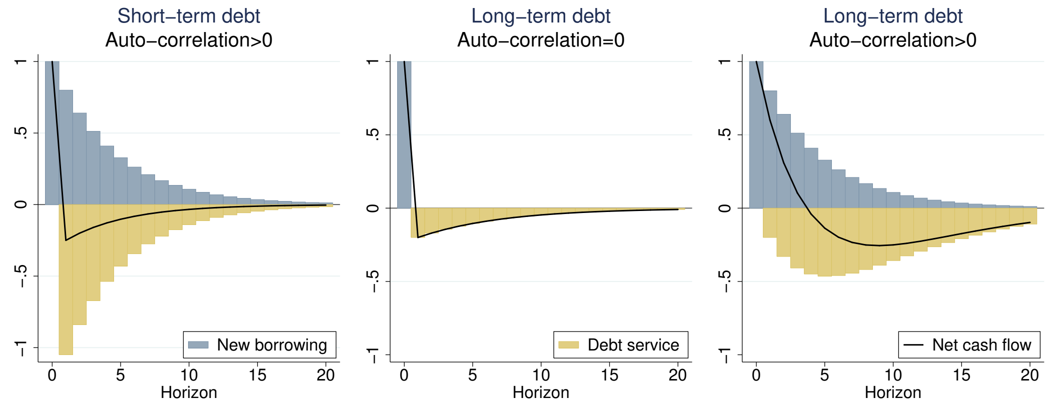

Figure 3: The evolution of new borrowing and debt service after a unit impulse to new borrowing The simulation uses equations (1) and (2) with $r = 5\%$ to derive debt service and net cash flows. If debt is short term $\delta = 100\%$. If it is long term $\delta = 15\%$. If new borrowing is autocorrelated,$\rho = 0.8$.

Corollary 3 (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 3 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 3). 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 $t = 1$.

The case with auto-correlation ($\rho > 0$) and long term debt ($\delta < 1$) is illustrated in the right-hand panel of Figure 3. In this case, we obtain a non-degenerate lag relationship between the peak in new borrowing and the peak in debt service, as described by the corollary. This case is rarely considered in theory papers but is empirically the most relevant.

In summary, our simple analytic framework thus suggests that it is the combined effects of auto-correlated new borrowing and long-term debt that account for the substantial lags between peaks in new borrowing and debt service. The key empirical issues that we address in the remainder of this paper is to document that this relationship holds in the data and to investigate to what extent the lagged response of debt service can account for delayed negative real effects of credit booms.

3 Data and Measurement

Our main variables of interest are the flows of new borrowing and debt service. This section discusses how we measure both variables in the aggregate, which variables we use to assess their real effects, and what controls we employ. We use an unbalanced panel of annual data for 16 countries from 1980 to 2015.[9] The exact definitions, sources, and availability for all variables are listed in Tables 2 and 5 in Appendix D.

We focus on the household sector for a number of reasons. First, this is the sector in which long debt maturities and auto-correlated new borrowing are most prevalent, giving rise to the most interesting lead-lag relationships. Second, in doing so, we also complement a literature that has demonstrated negative effects of household debt in the medium run (e.g. Jorda et al (2016) or Mian et al (2017)) and show that their results arise from the lead-lag relationship between new borrowing and debt service that we identify. Third, borrowing by the household sector is unlikely to result in productive investments that add to future output. Finally, data availability on debt maturities is considerably better in the household sector compared to the corporate sector. For comparison, we report a summary of results for the corporate sector in Appendix C. Our results are also largely unchanged when we consider total non-financial debt.

3.1 New borrowing and debt service

From our analytic framework we obtain expressions for new borrowing and debt service. 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) tells us that debt service, $S_{i,t}$, is the sum of interest payments and amortizations.

Data on debt stocks and interest payments 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. For interest payments we use total interest paid by households, $R_{i,t}$, from national accounts and obtain the average interest rate on the stock of debt $r_{i,t} = R_{i,t}/D_{i,t}$.[10]

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 relevant, we separately take account of interest-only mortgages. And as far as necessary and possible, we consider credit card debt, student loans and auto loans as separate categories within other household debt.

[9] 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.

[10] As in Drehmann et al (2015), we also include financial intermediation services indirectly measured (FISIM) from national accounts in our measure of $R_{i,t}$. FISIM is an estimate of the value of financial intermediation services provided by financial institutions which consumers pay as part of their borrowing costs. In the beginning of our sample, national accounts data on interest paid is not available for all countries. In that case, we proxy interest paid on the stock of debt by using an alternative interest rate such as the average interest rate on bank loans.

Except for credit card loans and interest-only mortgages, we follow the methodology of Lucket (1980) and Dynan et al (2003) to model repayments for each category $l = 1, ..., L$ of household debt, assuming 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:[11]

$$\delta^l_{i,t} = \frac{r^l_{i,t}}{\left(1 + r^l_{i,t}\right)^{m^l_{i,t}} - 1} \tag{5}$$

A derivation of this formula is provided in Appendix A.3. For credit card debt, we also follow Dynan et al. (2003) and assume $\delta^{credit-card} = 2.5\%$.[12] By definition, interest-only loans have no amortizations, ie $\delta^{interest-only} = 0$.

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, ie

$$amortizations_{i,t} = \sum_{l=1}^{L} \delta^l_{i,t} D^l_{i,t} \tag{6}$$

To compile time series for amortizations using equation (5) and (6), 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 Table 2 in Appendix D).[13]

Data on maturities is 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 information on the contractual maturity of new loans and use a formula derived in Appendix A.3 to approximate the average maturity of the outstanding stock of debt. Contractual maturities of new mortgages are on average 25 years but range from 11 years in Finland to 45 years in Sweden. 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 respectively student loans in line with data from the United States.

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 16, Appendix D.

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 17, Appendix D, shows that our series for new borrowing and debt service of

[11] This methodology is also used by the US Fed and the Bank of Canada to construct time series of aggregate debt service.

[12] 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.

[13] When no data on interest rates for sub-categories are available, we use $r_{i,t}$. We performed robustness checks for countries where all data are available to verify that this is a good approximation.

mortgages in Australia match the dynamics of the time series constructed from micro data closely.

3.2 Real variables and controls

Real variables We study the real implications of new borrowing and debt service by looking at two main variables: output growth and the incidence of banking crises. We denote the logarithm of real GDP from national accounts by $y_{i,t} = \ln(Y_{i,t}/P_{i,t})$ so that real output growth is $\Delta y_{i,t}$.

For crisis dates, we use the official ECB/ESRB EU crises database for the European countries in our sample (Lo Duca et al (2016)). For the remaining countries, we rely on Laeven and Valencia (2012) and extend their dataset using additional information from central banks as in Drehmann and Juselius (2014). We only consider crises that originated from domestic developments. We therefore exclude crises that the ECB/ESRB identified as imported from abroad as a result of cross-border contagion (Lo Duca et al (2016)). This leaves us with 18 crises, of which 8 are related to the Great Financial Crisis.

Controls In our regressions, we include several different control variables to account for factors that might be expected to influence the relationship between new borrowing and debt service as well as real outcomes. We use three different sets of controls throughout our analysis: (i) a minimal set consisting only of real GDP growth , (ii) a baseline set that, in addition to real GDP growth, consists of variables that we expect to directly influence new borrowing and debt service, and (iii) a set that extends the baseline set with variables that affect new borrowing and debt service as well as macroeconomic outcomes more generally. These three sets of controls ensure that our results are not driven by under- or over-controlling. They are summarized in Table 1.

Our minimal set (i) consists real GDP growth to capture the effects of past real developments on our flow variables and real outcomes. Since we normalized new borrowing and debt service by output, this set of controls also ensures that our results are not driven by the normalization.

The baseline set (ii) adds variables that may directly influence the persistence (autocorrelation) of new borrowing and the evolution of debt service. To capture the effects of credit limits on new borrowing, we include the growth rate in real residential property prices as a proxy for changes in collateral values, and the lending spread between the 3-month money market rate and the prime lending rate as a proxy for the cost of access to credit. We also include the (ex-post) real 3-month money market rate to capture the effect of the real interest rate level on future new borrowing. An additional benefit of the two interest-rate-based controls is that they ensure that the debt service effects that we identify do not result merely from interest rate effects. Since outstanding loans are only partially repriced in each period, we also control for the change in the average lending rate to identify movements in debt service that are due to new borrowing rather than changes in lending rates. Finally, we add one crisis dummy that takes the value of 1 in the year when a banking crisis starts, as well as a dummy that takes the value of 1 in 2009 with the onset of the global financial crisis, to capture potential non-linear effects associated with crisis events.

(i) Only GDP	(ii) Baseline	(iii) Additional controls
real GDP growth	real GDP growth	baseline controls
	3m money market rate	unemployment growth
	lending spread on mortgages	Δinflation
	Δ average interest rate on stock of debt	Δreal effective exchange rate
	growth in real residential property prices	Δcurrent account[1]
		productivity growth[1]
		1y ahead GDP forecast[1]
		term spread
		corporate credit spread[1]
		net worth
		Δ loan loss provisions[1]
	Dummies	
country fixed effects	country fixed effects	country fixed effects
	crisis dummy (1 if banking crisis starts)[1]	crisis dummy (1 if banking crisis starts)[1]
	global financial crisis (1 in 2009)[1]	global financial crisis (1 in 2009)[1]

Table 1: The set of controls for our different specifications. [1] Control is not included in the crisis regressions.

Our extended set of controls adds variables that capture changes in the macroeconomic environment more generally, and that may therefore affect the relationship between the flows of new borrowing and debt service, as well as their real effects. These additional macro variables are: the change in CPI inflation, the growth rate of unemployment, the change in the real effective exchange rate, the change in the current account, the growth rate in labor productivity,[14] and the term spread measured by the difference between the 10-year government bond and the three-month money market rate.[15] We include 1-year-ahead GDP growth forecasts from Consensus Economics to control for expected future activity. To control for other channels highlighted in the macro-finance literature that may affect credit markets and real activity, we add real household net worth, a corporate credit spread, and the change in loan loss provisions by banks.[16] Given the limited number of crisis, we cannot use the full set of additional controls in our crisis regressions as it would constrain the sample too much. The controls that are dropped are indicated in Table 1.

In all of our regression specifications we include a generic vector variable, $controls_{i,t}$, consisting of the variables in the relevant set of controls. Except for the crisis regressions, we also add one lag of each of the controls (the results remain largely the same with up to three lags). The only variables that we do not lag are the dummy variables, and GDP forecasts when the additional controls are used.

[14] Gorton and Ordonez (2016) find that shocks to productivity often start booms, and that booms are more likely to end in crisis if productivity is low.

[15] It is well know that CPI inflation, the unemployment rate and the real exchange rate contain sizable low-frequency components across countries. As this can bias their coefficients toward zero when used as regressors for a non-trending variable, such as real GDP growth, we use their growth rates rather than levels.

[16] Adding household net worth to our controls reduces the sample size considerably; this is the reason why we only include it in the additional controls and not the baseline controls.

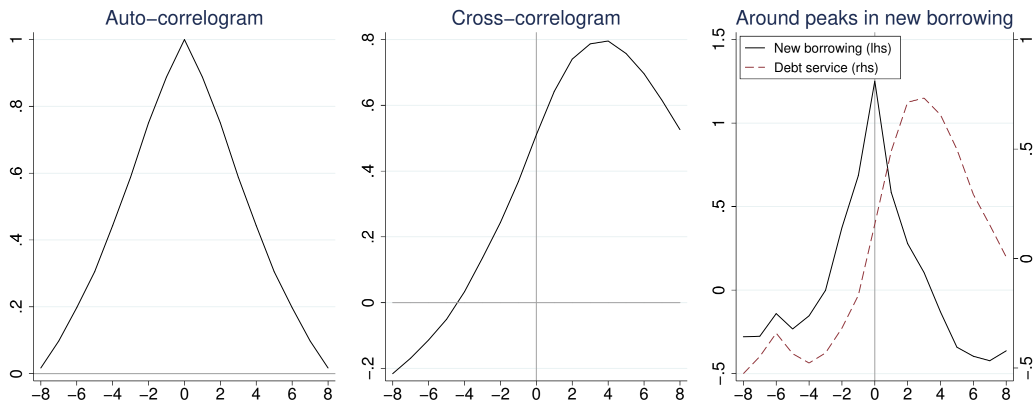

Figure 4: Auto-correlation of new borrowing (left-hand panel) and cross-correlation between new borrowing and debt service (center panel) for the household sector. For the right-hand panel, peaks in new borrowing are defined as local maxima in a 5-year window. We normalize new borrowing and debt service by country-specific averages.

4 New Borrowing and Debt Service

In this section we document that the basic relationships identified in the analytic framework are indeed present in the data: new borrowing is significantly auto-correlated, and there is a clear multi-year lead-lag relationship between new borrowing and debt service that depends on the maturity of the loan stock.

4.1 Patterns in the raw data

New borrowing is significantly autocorrelated, with a correlation coefficient ρ across consecutive periods of 0.88 as illustrated in the autocorrelogramme for new borrowing in the left-hand panel of Figure 4. The autocorrelation of new borrowing is positive for up to eight years.

New borrowing is also positively correlated with future debt service for an extended time period (middle panel) in line with the prediction of our analytic framework under highly autocorrelated new borrowing and long-term debt contracts. It leads debt service by several periods, with the peak correlation occurring after period 4. Proposition 2 of our analytic framework implies a similar lead-lag pattern with $\rho = .88$ and $\delta = 0.15$.

The right-hand panel of Figure 4 depicts the phase-shift between new borrowing and debt service by focusing on peaks. It reports the average evolution of the two variables around peaks in new borrowing across countries (defined as local maxima within a five-year window). The figure shows that debt service continues to rise when new borrowing already decreases. Peaks in new borrowing are followed by peaks in debt service on average three years later. Figure 16 in Appendix D documents that the lead-lag relationship is also present at the individual country level.

4.2 New borrowing and future debt service

To study the relationship between new borrowing and debt service in the data more systematically, we use local projections a la Jorda (2005) and control for other factors that may affect credit markets. In particular, we estimate for each horizon h projections for new borrowing, b, and debt service, s, with,

$$b_{i,t+h} = \mu_{b,i}^{h+1} + \beta_{bb}^{h+1} b_{i,t-1} + \beta_{bs}^{h+1} s_{i,t-1} + \beta_{bc}^{h+1\prime} controls_{i,t-1} + \varepsilon_{b,i,t+h}^{h} \tag{7}$$

$$s_{i,t+h} = \mu_{s,i}^{h+1} + \beta_{sb}^{h+1} b_{i,t-1} + \beta_{ss}^{h+1} s_{i,t-1} + \beta_{sc}^{h+1\prime} controls_{i,t-1} + \varepsilon_{s,i,t+h}^{h} \tag{8}$$

where $\mu_{j,i}^{h+1}$ is a country fixed effect, *controls* captures our control variables, and $\varepsilon_{j,i,t+h}^{h}$ is the projection residual for $j = \{b, s\}$. With this convention for the indices, the h successive β_{bb}^{h} and β_{sb}^{h} coefficients trace out the impulse response of future new borrowing and future debt service, respectively, to a unit increase in new borrowing at time t over h successive years (see Appendix B). Since we are primarily interested in the effects of a unit increase in new borrowing in this section, debt service can be seen as an additional control in (7) and (8).

There are two alternative ways to interpret our regression results:

Firstly, we can interpret the change in household credit as largely arising from from exogenous credit supply shocks, as e.g. forcefully argued by Mian and Sufi (2016). Under this interpretation, our regression results indicate how these exogenous shocks transmit from new borrowing to debt service and, as we show in Section 5, to the real economy, generating predictable reversals.[17]

Secondly and more broadly, we can interpret the unit change in household new borrowing as an initial condition, arising from an unknown combination of exogenous structural shocks. Under this interpretation, we cannot single out any specific structural shock as the source for the impulse responses, but this is not necessary from the perspective of the analytic framework. It still allows us to trace how elevated new borrowing affects debt service and ultimately correlates with real economic activity. This provides an empirical benchmark that a full theoretical characterization of debt and output dynamics needs to match.

The impulse responses to new borrowing confirm the impression from the patterns in the raw data. A unit increase in new borrowing takes more than six years to dissipate (Figure 5, Tables 6 and 7, Appendix D). And immediately after the shock, debt service begins to rise; it peaks after four to six years and remains significantly elevated even after eight years (right-hand panel).

The patterns remain the same irrespective of whether we use only real GDP growth as a control (orange line with circles), the baseline set of controls (black solid line), or the additional set of controls (green line with triangles). But the autocorrelation of new borrowing, and hence the persistence of the debt service response, increases as we successively

[17] There is significant evidence for this view: First, increases in household debt are largely independent of improved economic circumstances and, in fact, predict lower growth in the future. See Mian and Sufi (2016) for a more comprehensive discussion. (We follow the convention of using the word *prediction* to refer to within-sample impulse responses.)

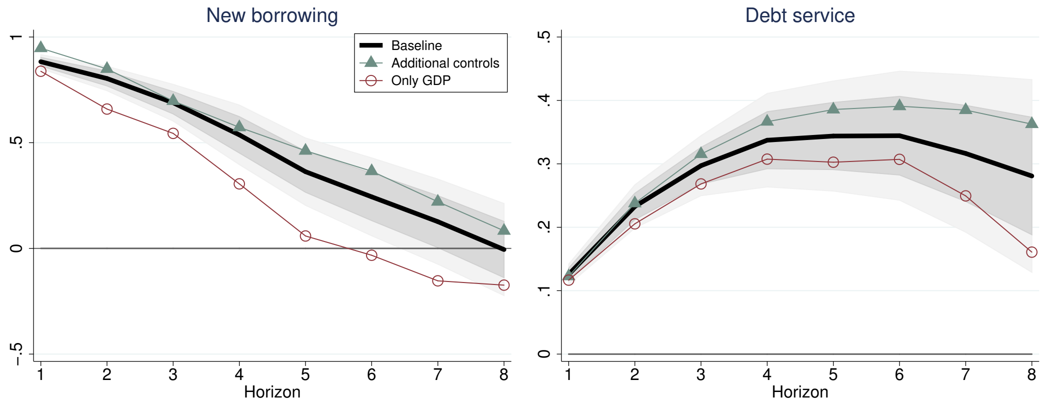

Figure 5: Impulse response of new borrowing and debt service to a unit increase in new household borrowing at t_0 using local projections (7) and (8) for horizons $h = 1$ to 8. The different specifications refer to our three sets of controls (see Table 1). Errors are clustered at the country level. The dark and light shaded areas show the 68% and 90% confidence intervals, respectively, around the baseline specification.

add more controls, especially at horizons five and beyond. Therefore forces captured by some of the controls, e.g. interest rates, have a systematic dampening effect that mitigates the lead-lag pattern between new borrowing and debt service in the raw data.

However, the presence of a lead-lag relationship is a very robust feature of the data, as the analytic framework suggests. Results from additional specifications and sample splits (Tables 6 and 7, Appendix D) show the same lead-lag pattern, for instance, in pre- and post-2000 samples, if we add time fixed effects, or allow for full panel heterogeneity by using the mean-group estimator.

4.2.1 Loan types and the lead-lag relationship

Our analytic framework predicts that the lead-lag relationship between new borrowing and debt service depends on the features of the underlying debt contracts. For instance, the distance between the peaks in new borrowing and debt service should increase with both the auto-correlation of new borrowing and the average maturity of the debt stock. More broadly, flexible interest rate loans may have a more compressed lead-lag pattern compared to fixed rate loans if monetary policy counteracts the real effects of transfers between borrowers and lenders.

The predictions regarding maturity are borne out in the data. To show this, we analyze mortgages and other household debt separately. Other debt consists mainly of consumer loans and credit card debt that have a shorter maturity than mortgages. In addition, the autocorrelation of new borrowing of mortgages is also higher than for other household debt (upper left-hand panel, Figure 6). Given these two factors, the lead-lag relationship is much more drawn out for mortgages than for other debt, as predicted by the analytic framework (upper right-hand panel, Figure 6, and Tables 6 and 7 in Appendix D). Following an impulse to new mortgage borrowing, mortgage debt service peaks after eight years.[18] In contrast,

[18]Extending the forecast horizon shows that the peak in the mortgage debt service after a unit impulse to

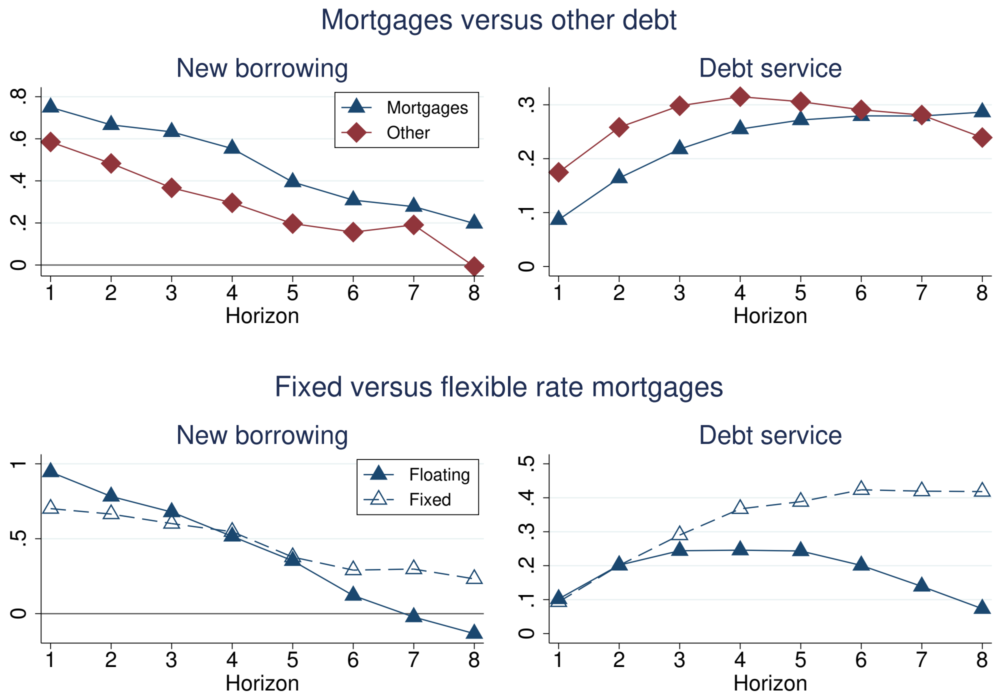

Figure 6: Impulse response of new borrowing and debt service for different loan types. The impulse is a unit increase in new household borrowing of the specific type at t_0 using local projections (7) and (8) for horizons $h = 1$ to 8 using our baseline controls (see Table 1).

debt service on other household debt peaks after four years.

Within mortgages, the type of mortgage also matters for the lead-lag relationship between new borrowing and debt service (lower panels, Figure 6 and Tables 6 and 7, Appendix D). We split the sample into countries with predominantly fixed versus floating-rate mortgages.[19] The average maturity of new mortgages is approximately 25 years in both samples. As illustrated in the left-hand panel, the autocorrelation of new mortgage borrowing is also broadly similar across both samples, in particular up to horizon five. However, mortgage debt service peaks much more quickly if mortgages are flexible rate. This suggests that monetary policy may be able to counteract high household debt service burdens more effectively in countries with floating-rate mortgages.

Comparisons with the corporate sector also provide support for the impact of maturities and autocorrelations on the lead-lag relationship that we identified in the analytic framework. Corporate debt has a shorter average remaining maturity of 13 years, and the autocorrelation of new borrowing across periods is 0.4 compared to 0.88 in the household sector. Together, this generates a shorter lead-lag relationship between new borrowing and debt service (Figure 14, Appendix C).

new borrowing is indeed after eight years.

[19] In each country of our sample, one mortgage type is dominant with a share of more than 75% (see CGFS (2006) and ECB (2009)). For our country classification see Table 5, Appendix D.

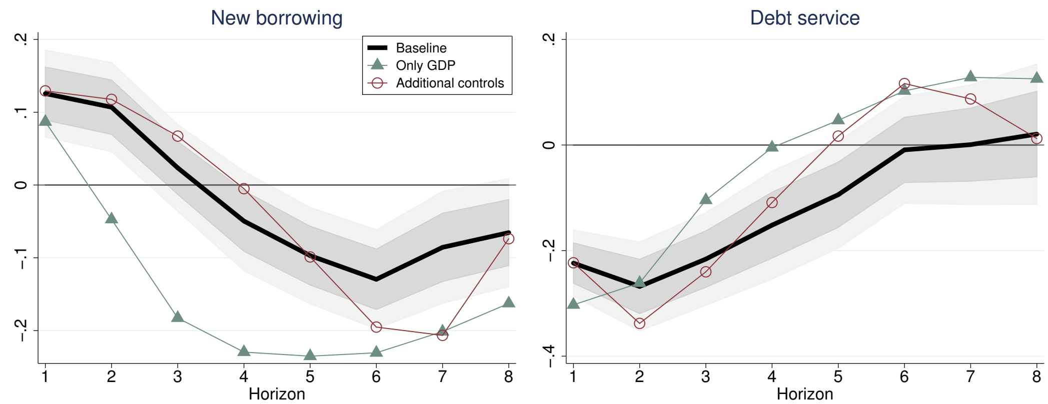

Figure 7: Impulse response of GDP growth to a unit increase in new household borrowing or household debt service at t_0 using local projections (9) for horizons $h = 1$ to 8. The different specifications refer to our three sets of controls (see Table 1). Errors are clustered at the country level. The dark and light shaded areas show the 68% and 90% confidence intervals, respectively, around the baseline specification.

5 New Borrowing, Debt Service and Real Activity

In this section, we document the effects of the flows of new borrowing and debt service on future real economic activity, and show that debt service represents the main transmission channel through which new borrowing affects subsequent output growth and the probability of crisis in the medium term.

5.1 Effects on output growth

To shed light on the link between new borrowing, b, debt service, s, and real output growth, Δy, we estimate local projections of the form

$$\Delta y_{i,t+h} = \mu_{y,i}^{h+1} + \beta_{yb}^{h+1} b_{i,t-1} + \beta_{ys}^{h+1} s_{i,t-1} + \beta_{yc}^{h+1,\prime} controls_{i,t-1} + \varepsilon_{y,i,t+h}^{h} \qquad (9)$$

for increasing values of h. The estimates of β_{yb}^{h} and β_{ys}^{h} for successive values of h trace out the impulse response of GDP growth to a unit increases in new borrowing and debt service, respectively.

New household borrowing initially boosts output but then predicts a slowdown in the medium run (Figure 7). In the baseline case, GDP growth significantly increases by around 10 basis points for the first two years following a percentage point increase in new borrowing, after which it declines and becomes around 10 basis points lower than normal in years 4 to 8 (Figure 7, left-hand panel). Since new borrowing rises on average between 5 to 10 percentage points above normal during credit booms, this implies eventual cumulative losses of 1.5 to 3 percentage points of GDP. The negative effects of new borrowing at medium horizons are in line with the output responses to a unit change in the credit-to-GDP ratio that has recently been documented in the literature (e.g. Mian et al. (2017)).

In contrast, the local projection of GDP growth to a unit increase in household debt service (right-hand panel) is large and significantly negative for the first five years.[20] It then becomes insignificant. On impact, a unit increase in debt service decreases GDP growth by more than 20 basis points. This is also large as peaks in debt service are on average between 2 to 6 percentage points above normal across countries. This result is novel and highlights the value added of debt service in the presence of long-term debt contracts for understanding debt dynamics and their impact on the real economy.

The estimated output effects of debt service are robust. In particular, the effect of debt service on next year's GDP growth is the same, whether we use the baseline specification or control for additional factors (Table 9, Appendix D). The effect are also stable in pre- and post-2000 samples. But allowing for country heterogeneity leads to an even bigger impact.

In contrast, the output effects of new household borrowing are more sensitive to the precise specification. For example, the impact of new borrowing is significantly more negative than in the other specifications when only lagged real GDP growth is used as a control (Figure 7). This difference is primarily due to the real money market rate and the crisis dummies. Hence, new borrowing appears to go together with real higher interest rates and higher crisis probabilities, which in turn lower output down the road. This seems natural, as increases in real interest rates reduce activity beyond their impact on new borrowing. Moreover, the connection between borrowing and the probability of a banking crisis is well documented in the literature and something we will explore in Section 5.4. Further robustness checks confirm the initial positive and then negative impact of new borrowing on output but show that magnitudes are somewhat sample- and specification-specific (Table 9, Appendix D)

The dynamics are similar for the corporate sector, although coefficient estimates are lower (see Figure 15 in Appendix C). This is in line with Mian et al (2017) who found little impact of corporate debt on GDP. The medium-term negative effect of new borrowing on GDP also occur earlier for the corporate sector (the maximum negative impact is in year 4) than for the household sector (year 6).

5.2 A novel method for decomposing local projections

So far, we have shown that new borrowing decreases output growth in the medium run. At the same time, new borrowing increases debt service over time and debt service, in turn, has a strong negative effect on output next year. This suggests that the negative effects of new borrowing may flow through debt service. To assess this formally, we decompose the impulse response function of new borrowing. We provide an intuitive description of our decomposition method in the following and develop a detailed formal description in Appendix B.

The local projections of new borrowing on GDP growth trace out an impulse response function. After the first round, this impulse response includes all factors that dynamically respond to the initial impulse to new borrowing and feed into GDP growth, including the effects of future debt service on GDP growth. Hence, they capture the "net effect" of an

[20] This finding complements micro level evidence in e.g. Olney (1999), Johnson and Li (2010), and Dynan (2012) who document negative effects from debt service burdens on household expenditure.

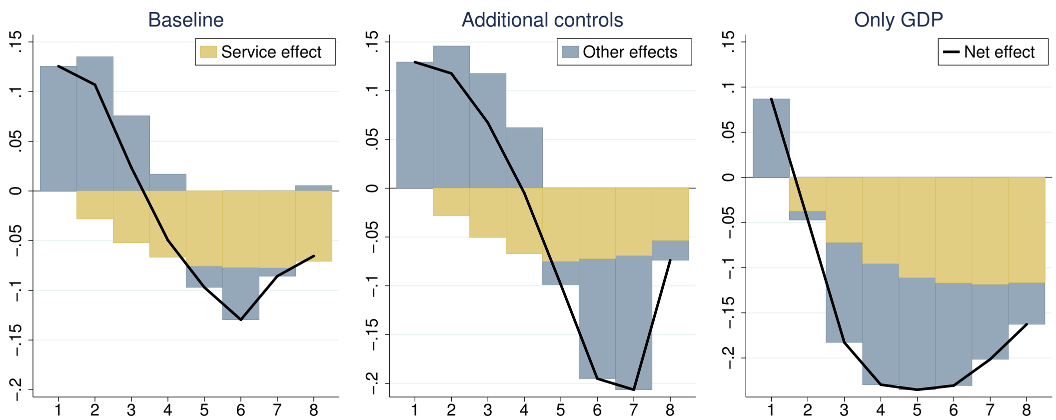

Figure 8: Decomposition of the net effect of new borrowing on future GDP growth (equation (10)) into the service effect (equation (11)) and the other effects (equation (12)) for horizons h=1 to 8. The different specifications refer to our three sets of controls (see Table 1).

impulse to new borrowing. From equation (9) the net effect at time $t+h$ is

$$\text{net effect}_h = \beta^h_{yb}. \tag{10}$$

The part of the net effect that goes via debt service can be calculated in two steps. First, for any prediction horizon $h > 1$, we know from estimating equation (8) the effect of new borrowing at time t on debt service at time $t+h-1$, ie β^{h-1}_{sb}. Second, we know from estimating equation (9) that the first-round effect of debt service at $t+h-1$ on output growth at $t+h$ is β^1_{ys}. Combining these estimates, we calculate the "debt service effect" as:

$$\text{debt service effect}_h = \beta^1_{ys}\beta^{h-1}_{sb} \tag{11}$$

and the effects of all remaining factors as

$$\text{other effects}_h = \beta^h_{yb} - \beta^1_{ys}\beta^{h-1}_{sb}. \tag{12}$$

The other effects will include, for example, any direct effects of new borrowing on output.

5.3 Decomposing the effect of borrowing on future output

The decomposition shows that increasing debt service can, to a large degree, account for the delayed slowdown in GDP growth following an initial increase in new household borrowing. Figure 8, left-hand panel, reports the net effect (black line), the debt service effect (beige bars) and other effects (light-blue bars) given the baseline specification up to 8 years after an impulse to new borrowing.

The dynamics of these effects largely follow the patterns predicted by our analytic framework (Figure 2). The black line is the net effect – or in terms of the analytic framework the effect of net cash flows. It equals β^h_{yb} and thus is simply the impulse respone of GDP growth to new borrowing in t_0 (Figure 7). It turns negative (period 4 in the baseline specification) between the peak of new borrowing (period 1) and the peak in debt service (period 6, Figure 5) as the analytic framework predicts.

The service effect is always negative and accounts to a large extent for the negative medium run impact of an impulse to new borrowing. Other effects are generally positive and decline over time. This is broadly in line with what one would expect from new borrowing and the fact that it is autocorrelated. The only exception occurs in years 5 and 6 where the other effects are visibly negative.

The estimated service effect is very robust across specifications, in contrast to the net effect and hence the other effects. The middle and right-hand panels shows the decomposition for the additional and minimal sets of controls, respectively. Differences between the service effect across the three specifications only become noticeable from horizon 6 onward. In contrast, both the net effect and the other effects are less stable across the specifications. For instance, the negative other effects at horizons 6 and 7 become larger when the additional controls are used. The main reason is that this set of controls is only available for a shorter, more recent, sample that places more emphasis on the global financial crisis.[21] The other effects become consistently more negative when only GDP growth is used as a control for the same reasons as in Section 5.1.

The negative other effects between years five and seven are interesting more generally, as they may partly reflect non-linearities associated with financial crises. For instance, if we dummy out crises fully, the negative other effects disappear completely (Figure 18, Appendix D). Equally, if we condition the impulse responses on periods where the output gap is initially negative, the negative other effects also disappears. In contrast, if we condition on positive output gaps, the negative other effects become larger. These observations point to potential asymmetric effects related to financial crises, which we analyze in the next section.

The decomposition is also robust across several alternative specifications and samples (Figure 18, Appendix D). For instance, controlling for lending standards has no impact. And the overall pattern does not change much if we split the sample around year 2000, suggesting that the results are not exclusively related to the Great Recession and the boom that preceded it. The effects become larger when we allow for heterogeneity in the panel using the mean group estimator (Pesaran and Smith (1995)). The pattern is also the same if we use consumption rather than real output as the left hand variable. Interestingly, in this case the estimated decomposition looks virtually identical to our analytical simulation in the right-hand panel of Figure 3.

So far we have used our decomposition method to show that debt service explains the majority of the medium-run effects of new borrowing. We can use the same method to demonstrate that other variables do not play an important role in the medium-run transmission of new borrowing to output, as shown in Figure 9. First, we apply our decomposition method to new borrowing itself (upper left-hand panel). As would be expected in the presence of autocorrelated new borrowing, and given the first-round positive impact of new borrowing on growth, the *direct effect* of new borrowing is (nearly) always positive.

Other variables that are commonly viewed as playing a systematic adverse role in the transmission of credit booms have much less explanatory power than debt service.[22] Property

[21] This is confirmed by Table 8 in Appendix D, where we show the local projection of a unit impulse to new borrowing using the baseline controls but constraining the sample to the periods when all additional controls are available.

[22] We also looked at the impact of provisions, which shows the expected dynamics, ie bank provisions for bad loans go up following a impulse to new borrowing, and this affects output negatively. But the overall

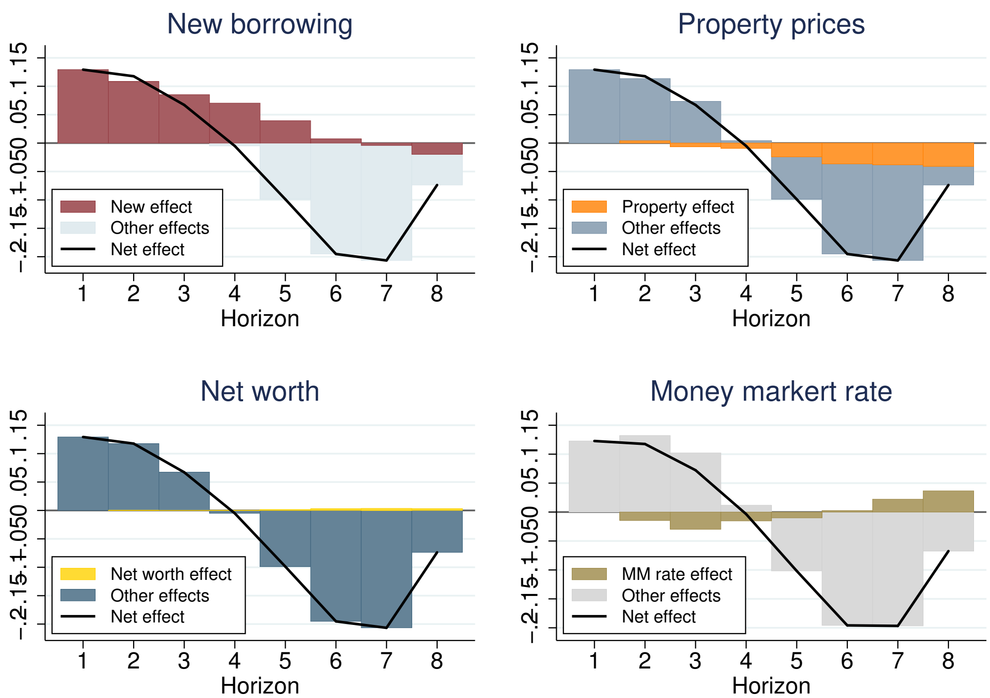

Figure 9: Decomposition of the net effect of new borrowing on future GDP growth into the direct effect of new borrowing, the property price effect, the net worth effect and the money market rate effect respectively in line with the decomposition framework applied to these variables. All specifications control for "additional controls".

prices, which capture the value of collateral in leverage dynamics, do seem to explain some of the negative output effects following an impulse to new borrowing, but much less so than the debt service effect (bottom left-hand panel). The role of the household net-worth channel seems very small in the decomposition (bottom right-hand panel), although this is likely driven by the fact that the stock of assets in financial accounts is not marked to market. In summary, debt service plays by far the most important role in the transmission of impulses of new borrowing to medium-run output growth.

Last, while our results imply that monetary policy does not fully offset the flow effects, the evidence nevertheless suggest that it does so partially. This can be seen by tracking the effect that go through the money market rate (bottom right-hand panel). Following an impulse to new borrowing, this effect is initially negative, offsetting some of the positive effects of the credit expansion. Conversely, once debt service peaks, the effects turn positive, countering some of the negative debt service effects.

5.4 Effects on the probability of crises

There is a growing empirical literature on the link between credit booms and financial crises (e.g. Borio and Lowe (2002), Reinhart and Rogoff (2009) or Schularick and Taylor (2012)) that finds strikingly similar lead-lag relationships to the ones that we report for new borrowing and output growth. For instance, a large increase in the debt-to-GDP ratio above a long run trend substantially increases the probability of a banking crisis. The results in the previous section also indicated that some of the negative output effects of new borrowing are related to the incidence of financial crisis. In this section, we therefore investigate the extent to which projected future debt service, resulting from a debt impulse, can account for the increase in crisis probability.[23] This is natural because it is the debt service, not borrowing in itself, that risks triggering defaults and ultimately financial crises.

To study the effects of new borrowing and debt service on the probability of banking crises, we adapt our previous empirical framework to binary response models. We take the crisis indicator at $t+h$ as the outcome variable and use it to model the probability of a crisis conditional on new borrowing, debt service and our baseline control variables in a panel logit framework with country fixed effects.[24]

The local projections show that both new borrowing and debt service increase the probability of a crisis, but the effect of debt service is immediate whereas the effect of new borrowing takes time to fully materialize (Figure 10). New borrowing (left panel) does seem to affect the likelihood of crisis in the following year, but the strongest and most significant effects are in year 3. By contrast, a unit increase in debt service (right panel) has its largest effect on the crisis probability in first year after which it declines slowly and becomes

impact of this channel is very small.

[23] A few recent studies that look at debt service in this context find that it is an excellent early warning indicator, particularly at shorter forecasting horizons (e.g. Drehmann and Juselius (2014), Detken et al (2014)).

[24] Given country fixed effects, countries that do not have a crisis drop out of the sample. To avoid post-crisis bias (Bussiere and Fratzscher (2006)), we drop the years between the beginning and the official end of crisis management actions as identified by Lo Duca et al (2016) for the European countries or Laeven and Valencia (2012). In case of no information, we dropped the first two years after the outbreak of the crisis.

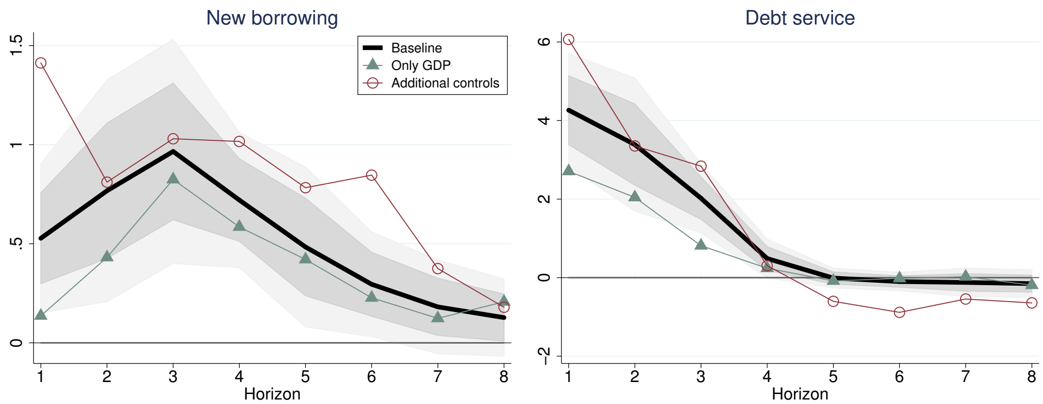

Figure 10: The impact of new borrowing and debt service on the probability of crises as measured by the respective coefficients in local projections for horizons $h = 1$ to 8. We estimate a panel logit with country fixed effects and controls. The different specifications refer to our three sets of controls (see Table 1). The dark and light shaded areas show the 68% and 90% confidence intervals, respectively, around the baseline specification.

insignificant after four years. The results become stronger when we add more controls, indicating that the control variables generally counteract the effects of our flow variables on crisis probabilities.

5.5 Decomposing the effect of debt on the crisis probability

As before, our results suggest that debt service is the main transmission channel through which a credit boom leads to a higher probability of a crisis in the future. This is formally confirmed in Figure 11, which decomposes the local projections from a unit increase in debt on the crisis probability into the service effect and other effects, in a similar manner as in Section 5.3: debt service always has a sizable positive effect on the crisis probability. And after year one (when debt service effect is zero by construction), it explains most of the positive effects of new borrowing. Interestingly, after year three, other effects become increasingly negative, offsetting some of the positive effects of debt servicing and thereby reducing the net effect. The dynamics of these effects are robust with respect to the different sets of control variables.

6 Comparison With Alternative Measures of Credit Booms

This section compares how our measures of the flows of resources between borrowers and lenders – new borrowing and debt service normalized by GDP – compare to other indicators of credit booms that have traditionally been used in the empirical macro-finance literature.

Conceptual differences Our flows-based measures directly enter budget constraints and thus encapsulate contemporaneous and future liquidity effects of credit relationships, as

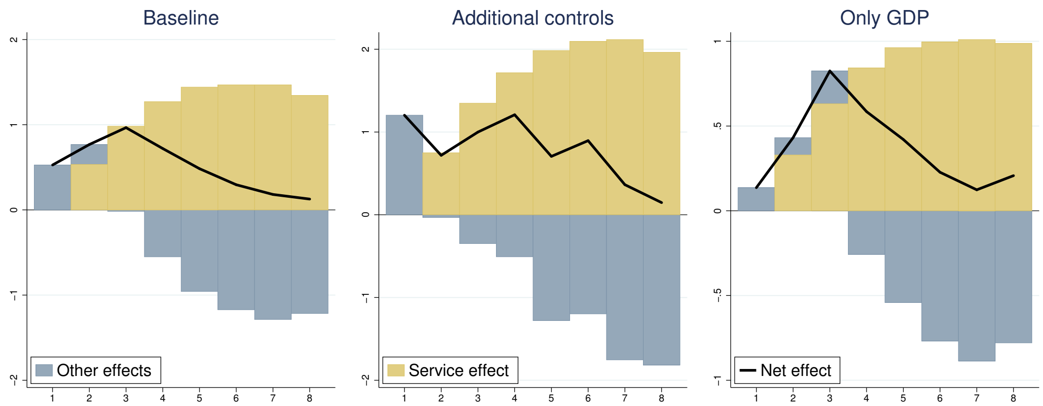

Figure 11: Decomposition of the net effect of new borrowing on the future likelihood of crises into the service effect and the other effects for horizons h=1 to 8. The different specifications refer to our three sets of controls (see Table 1).

emphasized eg by Eberly and Krishnamurthy (2014). Traditional measures, on the other hand, relate to credit stocks. Changes in the stock of credit partly depend on the flows but not the flow of interest payments, as we emphasized in equation (1) in our analytic framework. Furthermore, they commingle the flow of new borrowing with the flow of amortizations. Since these two flows are in opposite directions (ie from lenders to borrowers and from borrowers to lenders, respectively), they will partly offset each other, with unclear effects on regression results.

A second difference is that credit-to-GDP ratios have been growing for decades in most countries. Researchers have therefore either detrended (e.g. Drehmann et al (2011)) or differenced credit-to-GDP ratios (e.g. Schularick and Taylor (2012)) in empirical work linking credit booms to real developments. Such detrending reduces the informational content inherent in the variables and makes it more difficult to economically interpret the estimated relationships. Calculating debt service, by contrast, can be seen as an economically meaningful way of detrending the credit-to-GDP ratio, since low-frequency changes in the terms of credit over the past four decades, such as declines in nominal interest rates, have roughly offset the upward trends in credit-to-GDP ratios so that both new borrowing and debt service normalized by GDP are stationary.[25]

Empirical comparison Whether stock or flow concepts have more explanatory power for real variables is ultimately an empirical question. To assess this, we run a horse race between the two.

The existing literature on the real effects of credit booms has successfully employed multi-year growth rates in the stock of credit, normalized by GDP, and has uncovered that these measures predict real outcomes. For example, Mian et al (2017) assess the impact of the three-year growth rate of this measure on future GDP, or Taylor and Schularick (2012)

[25] Technically speaking there is a cointegrating relationship between credit-to-GDP ratios and interest rates (Juselius and Drehmann (2015)).

assess the impact of the five-year growth rate on the likelihood of crises.[26] To relate growth rates in the stock of credit to our flow measures, we refer back to the analytic framework that we developed in Section 2. As we observed there, the annual change in the stock of credit is a proxy for the flow of new borrowing, since it equals new borrowing minus amortizations. Similarly, the multi-year growth rates in the stock of credit are a moving sum of this flow variable and therefore proxy for the flow of debt service at intermediate horizons.[27]

To compare the empirical performance of our flow measures and of multi-year growth rates in the stock of credit in predicting real outcomes, we observe that the local projection of the n-year growth rate in credit on, say, real GDP, is a convolution of the local projections of one-year growth rates at different horizons. For this reason, we compare the predictive performance of new borrowing and the one-year growth rate in the stock of credit normalized by GDP, $\Delta cy_{i,t}$, in the following. In Appendix D we show that our flow-based measures also outperform the three- and five-year growth rates in credit stocks (Figures 19 and 20).

Our horse race uses the specification

$$\Delta y_{i,t+h} = \mu_{y,i}^{h+1} + \beta_{ycy}^{h+1} \Delta cy_{i,t-1} + \beta_{yb}^{h+1} b_{i,t-1} + \beta_{ys}^{h+1} s_{i,t-1} + \beta_{yc}^{h+1,\prime} controls_{i,t-1} + \varepsilon_{y,i,t+h}^{h} \quad (13)$$

for horizons $h = 1, ..., 8$, where $controls_{i,t-1}$ consists of the baseline control variables. We consider four cases: (i) $\beta_{yb}^{h+1} = 0$ and $\beta_{ys}^{h+1} = 0$, (ii) $\beta_{ys}^{h+1} = 0$, (iii) $\beta_{yb}^{h+1} = 0$, and (iv) no restrictions. The first case allows us to study the local projection to credit-to-GDP growth in isolation. The second case runs a horse race with respect to new borrowing and will, by construction, reveal if our measure provides useful additional information for predicting GDP growth. The third case runs a horse race with respect to debt service. If credit-to-GDP growth is a sufficiently close proxy for new borrowing, this should give a similar pattern to that in Figure 7. The fourth case runs a horse race between all three variables. We also do the same from the perspective of new borrowing and debt service, ie we first consider them individually, then add the other two variables in turn, and finally combine all three variables.

The left-hand panel of Figure 12 shows the different local projections to an impulse to credit-to-GDP growth for the different specifications, whereas the middle and right-hand panels show the corresponding projections from impulses to new borrowing and debt service. We use large solid diamonds to indicate significance at the 1% level, medium solid diamonds to indicate significance at the 5% level, and medium hollow diamonds indicate significance at the 10% level, respectively.

[26] The early warning indicator literature has also used the credit-to-GDP gap as suggested by Basel III for the countercyclical capital buffer. We also ran horse races with this variable and results are similar to the multi-year growth rates in the credit-to-GDP ratio reported here.

[27] Technically speaking, the n-year *growth rate* in the stock of credit comes arbitrarily close to the stock of credit as $n \to \infty$. However, as n grows too large, the non-stationary components of the stock of credit begin to dominate, which reduces its usefulness and predictive relevance at cyclical frequencies. This is why growth rates over intermediate horizons, e.g. three- to five-year growth rates in the stock of credit normalized by GDP, appear the most useful predictors of real outcome. By contrast, the flow of debt service is constructed by multiplying the stock of credit with the sum of the interest and amortization rates and is a stationary variable, since the trends in interest and amortization rates roughly offset the trends in credit-to-GDP. As we will see in the following paragraph, this additional information makes debt service an even better predictor of real outcomes than growth rates in credit-to-GDP.

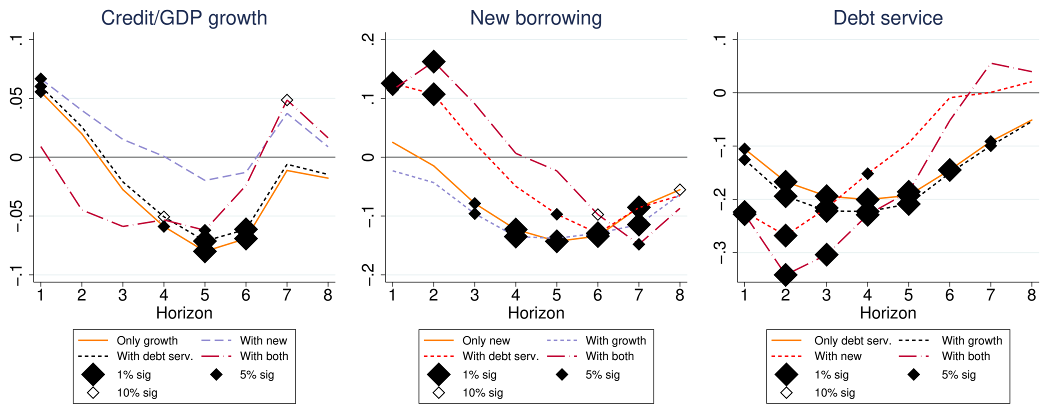

Figure 12: Impulse response of GDP growth to a unit increase in new borrowing, debt service or the growth rate in household credit to GDP at t_0 for horizons $h = 1$ to 8 for different specifications. All projections control for the baseline controls. Diamonds indicate significance levels (large solid / medium solid / medium hollow diamonds indicate significance at the 1% / 5% and 10% respectively).

The horse races show that new borrowing, in particular, outperforms credit-to-GDP growth in predicting real GDP. While the local projection to a unit increase in credit-to-GDP growth performs well on its own (left-hand panel, solid orange line), it looses its significance completely once we include new borrowing in the specification (blue dashed line). This suggest that new borrowing is a more relevant concept to explain real outcomes such as GDP growth. Put differently, properly measuring the flow of resources from lenders to borrowers by subtracting amortizations from the change in the stock of credit is more useful in predicting real variables. If we instead include contemporaneous debt service, the local projection to credit-to-GDP growth is almost the same as it is in isolation, as expected. Finally, when all three variables are added jointly, the projection to credit-to-GDP growth changes form and becomes largely insignificant (maroon dash-dotted line).

In contrast, the local projections to unit increases in new borrowing and debt service remain significant and fairly stable across specifications. In particular, they hardly change when we add credit-to-GDP growth to the model. The only big change occurs when we include both new borrowing and debt service in the model, in which case the local projections have larger effects and are more significant. This highlights the importance of distinguishing between flows from lenders to borrowers and from borrowers to lenders to maximize predictive performance.

New borrowing and debt service are also superior indicators to predict crises (Figure 13). Credit-to-GDP growth performs reasonably well as long as new borrowing is not included. But as soon as we add new borrowing, credit-to-GDP growth looses its significance (and even changes sign). The coefficients on new borrowing and debt service, on the other hand, are stable over the different horizons. This stability is also reflected in their high signaling quality, as measured by the area under the ROC curve (AUC) (see Figure 21 in Appendix). New borrowing and debt service, in particular, are very strong indicators at short horizons, with AUC values of above 0.9. In contrast, the signaling quality of credit-to-GDP is considerably lower.

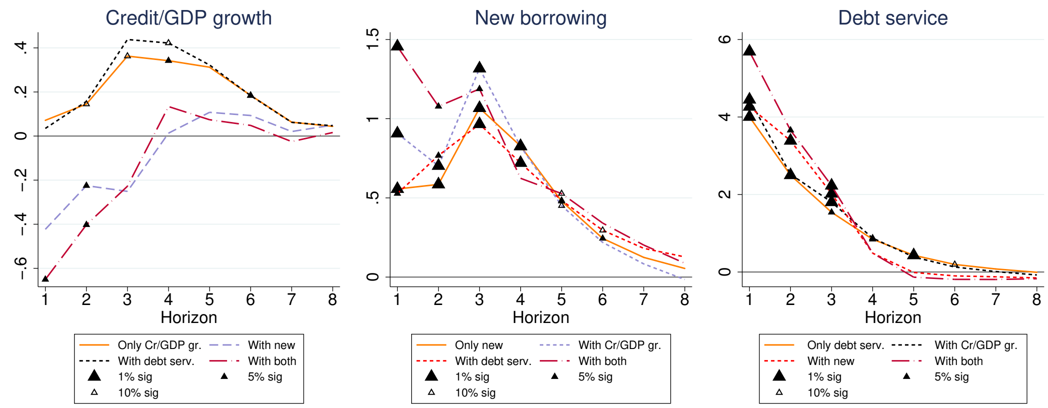

Figure 13: The impact of new borrowing, debt service and credit-to-GDP growth on the probability of crises as measured by the respective coefficients in local projections for horizons $h = 1$ to 8 using different specifications. We estimate a panel logit with country fixed effects and always add the baseline controls. Diamonds indicate significance levels (large solid / medium solid / medium hollow diamonds indicate significance at the 1% / 5% and 10% respectively).

7 Conclusions

This paper shows that the flows of resources between borrower and lenders are crucial for understanding how credit market developments affect 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 2015 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 and increases in crisis probability 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.[28] Furthermore, the strong and systematic pattern in output and crisis probabilities that is generated

[28] Garriga et al (2017) and Gelain et al (2018) have recently incorporated long-term debt in quantitative models of credit fluctuations.

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.[29] 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. We leave this for future research.

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.

[29] For models that explain the real effects of the financial crisis of 2008/09 through this prism, see e.g. Eggertsson and Krugman (2013), Korinek and Simsek (2016) and Guerrieri and Lorenzoni (2017).

Bibliography

Bernanke, B S (1983): "Non-monetary effects of the financial crisis in the propagation of the Great Depression", *American Economic Review* 73(3), pp. 257-276.

Borio, C and P Lowe (2002): "Assessing the risk of banking crises", *BIS Quarterly Review*, December, pp 43-54.

Brunnermeier, M, D Palia, K A Sastry, and C A Sims (2017), "Feedbacks: financial markets and economic activity", mimeo.

Bussiere, M, and M Fratzscher (2006): "Towards a new early warning system of financial crises", *Journal of International Money and Finance* 25(6), pp 953-973.

Claessens, S, M A Kose and M E Terrones (2012): "How do business and financial cycles interact?", *IMF Working Paper* 11/88.

Committee on the Global Financial System (CGFS) (2006): Housing finance in the global financial market.

Dembiermont, C, M Drehmann, and S Muksakunratana (2013): "How much does the private sector really borrow - a new database for total credit to the private non-financial sector", *BIS Quarterly Review*, March, pp 65-81.

Detken, C, O Weeken, L Alessi, D Bonfim, M M Boucinha, C Castro, . . . P Welz (2014): "Operationalising the countercyclical capital buffer: Indicator selection, threshold identification and calibration options", European Systemic Risk Board, Occasional Paper 5.

Drehmann, M, C Borio, and K Tsatsaronis (2011): "Anchoring countercyclical capital buffers: The role of credit aggregates", *International Journal of Central Banking* 7(4), pp 189-240.

Drehmann, M, A Ilnes, M Juselius, and M Santos (2015): "How much income is used for debt payments? A new database for debt service ratios", *BIS Quarterly Review*, March, pp 89-103.

Drehmann M, M Juselius (2014): "Evaluating early warning indicators of banking crises: Satisfying policy requirements", *International Journal of Forecasting* 30(3), pp 759-780.

Dynan, K (2012): "Is a household debt overhang holding back consumption?", *Brookings Papers on Economic Activity*, pp 299-344.

Dynan, K, K Johnson and K Pence (2003): "Recent changes to a measure of U.S. household debt service", *Federal Reserve Bulletin* 89(10), pp 417-426.

Eggertsson, G B and P Krugman (2012): "Debt, deleveraging, and the liquidity trap: A

Fisher-Minsky-Koo approach", *Quarterly Journal of Economics* 127(3), pp 1469-1513.

Eberly, J and A Krishnamurthy (2014): "Efficient credit policies in a housing debt crisis", *Brookings Papers on Economic Activity* Fall 2014, pp 73-146.

European Central Bank (ECB) (2009): "Housing fiance in the euro area", Occasional Paper Series, no 101.

Farhi, E and I Werning (2016): "A theory of macroprudential policies in the presence of nominal rigidities", *Econometrica* 84(5), pp 1645-1704.

Garriga C, F E Kydland, and R Sustek (2017), "Mortgages and monetary policy," *Review of Financial Studies* 30(10), pp 3337-3375.

Gelain, P, K J Lansing and G J Natvik (2018), "Leaning against the credit cycle," , forthcoming, *Journal of the European Economic Association.*

Gorton, G, and G Ordonez (2016): "Good booms, bad booms", NBER Working Paper, 22008.

Guerrieri, V, and G Lorenzoni (2017): "Credit crises, precautionary savings, and the liquidity trap", *Quarterly Journal of Economics* 132(2), pp 1427-1467.

Johnson, K W and G Li (2010): "The debt-payment-to-income ratio as an indicator of borrowing constraints: Evidence from two household surveys", *Journal of Money, Credit, and Banking* 42(7), pp 1373-1390.

Jorda, O (2005): "Estimation and inference of impulse responses by local projections", *American Economic Review*, 95(1), pp 161-182.

Jorda, O, M Schularick and A M Taylor (2011): "Financial crises, credit booms, and external imbalances: 140 years of lessons", *IMF Economic Review* 59(2), pp 340-378.

Jorda, O, M Schularick and A M Taylor (2013): "When credit bites back", *Journal of Money, Credit, and Banking* 45(2), pp 3-28.

Jorda, O, M Schularick, and A M Taylor (2016): "The great mortgaging: housing finance, crises and business cycles", *Economic Policy* (85),pp 107-140.

Juselius, M, C Borio, P Disyatat, and M Drehmann (2017): "Monetary policy, the financial cycle and ultra-low interest rates", *International Journal of Central Banking*, 13(3), pp 55-89.

Juselius, M, and M Drehmann (2015): "Leverage dynamics and the real burden of debt", BIS Working Paper 501.

Korinek, A and A Simsek (2016): "Liquidity trap and excessive leverage", *American Economic Review* 106(3), pp 699-738.

Krishnamurthy A and T Muir (2017): “How credit cycles across a financial crisis,” NBER Working Paper 23850.

Laeven, L, and F Valencia (2012): "Systemic banking crises database: An update", IMF Working Paper 12/163.

Lo Duca, M, A Koban, M Basten, E Bengtsson, B Klaus, P Kusmierczyk, . . . T Peltonen (2016): "A new database for financial crises in European countries, ECB/ESRB EU crises database", European Systemic Risk Board, Occasional Paper 13.

Lombardi, M, M Mohanty, and I Shim (2016): "The real effects of household debt in the short and long run", BIS Working Paper 607.

Luckett, C (1980): "Recent financial behaviour of households", *Federal Reserve Bulletin*, 66, pp 473-443.

Mian, A, K Rao, and A Sufi (2013): "Household balance sheets, consumption, and the economic slump", *Quarterly Journal of Economics* 128(4), pp 1687-1726.

Mian, A, and A Sufi (2010): "Household leverage and the recession of 2007-09", *IMF Economic Review* 58(1), pp 74-117.

Mian, A, and A Sufi (2014): "House of debt: How they (and you) caused the Great Recession, and how we can prevent it from happening again", *University of Chicago Press*

Mian, A, and A Sufi (2016): "Household debt and defaults from 2000 to 2010: the credit supply view," mimeo.

Mian, A, and A Sufi (2018): "Finance and business cycles: the credit-driven household demand channel," NBER Working Paper 24322.

Mian, A, A Sufi and E Verner (2017): “Household debt and business cycles worldwide,” *Quarterly Journal of Economics* 132(4), pp 1755-1817.

Olney, M L (1999): "Avoiding default: The role of credit in the consumption collapse of 1930", *Quarterly Journal of Economics* 114(1), pp 319-335.

Pesaran, M H, and R Smith (1995): "Estimating long-run relationships from dynamic heterogeneous panels", *Journal of Econometrics*, 68(1), pp 79-113.

Reinhart, C M and K S Rogoff (2009). *This time is different: Eight centuries of financial folly.* Princeton University Press.

Schmitt-Grohé, S and M Uribe (2016). "Downward nominal wage rigidity, currency pegs, and involuntary unemployment," *Journal of Political Economy* 124, pp 1466-1514.

Schularick, M and A M Taylor (2012): "Credit booms gone bust: monetary policy, leverage cycles, and financial crises, 1870-2008", *American Economic Review* 102(2), pp 1029-1061.

A Proofs and Additional Results

A.1 Lag Structure Between New Borrowing, Net Cash Flows, and Debt Service

Proof of Proposition 1 (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.

Proposition 1 in continuous time The results of Proposition 1 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

$$\dot{D}_t = B_t - \delta D_t \tag{14}$$

The two statements that are the equivalent of Proposition 1 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

$$\dot{N}_t = \dot{B}_t - (\delta + r) \dot{D}_t \tag{15}$$

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. □

Proof of Proposition 2 The peak in debt service coincides with the peak in debt. Although equation (4) 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 reported in the proposition,

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

By definition, the maximum of the continuous function is within ± 1 of the integer 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 $x \neq 1$.

Proposition 2 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 2, where $\eta = -\ln\rho$. The statement that is the equivalent of Proposition 2 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 $d\hat{t}/d\delta < 0$.[30]

(The difference from the discrete-time case is that we can determine the exact peak instead of providing an interval that contains the peak in debt service.)

Proof. We substitute this process into the law of motion (14) and (for $\eta \neq \delta$) solve the resulting differential equation to find

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

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

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

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 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.

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

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

$$S_t = (\delta + r)\, D_{t-1} - M_t \tag{16}$$

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

$$D_t = (1 - \delta)\, D_{t-1} - W_t + B_t + M_t \tag{17}$$

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

$$N_t = B_t - S_t = B_t - (\delta + r)\, D_{t-1} + M_t \tag{18}$$

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 (17). 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

$$M_t = m\, (\delta D_{t-1} + r D_{t-1}) \tag{19}$$

Actual interest payments are then given by the expression

$$R_t = (1 - m)\, r D_{t-1} \tag{20}$$

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 (19) and (20) 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.3 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

$$S = \frac{rD}{1-(1+r)^{-m}} \tag{21}$$

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 (21), 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 consider the steady-state of 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 (21) above 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 steady state 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 Decomposing Impulse Response Functions

This appendix explains our econometric methodology for decomposing the impulse responses of new borrowing. We first explain our decomposition using a linear local projection with one auto-regressive term that can easily be compared to a VAR(1) benchmark. We also describe how it can be applied in our specific setting to decompose the effects of new borrowing on real variables. We then present the methodology for a more general auto-regressive structure.

Econometric setup Let z_t be a $n \times 1$ random vector with $n \geq 3$ partitioned into four elements $z_t = (z_{1,t},\, z_{2,t},\, z_{3,t},\, z'_{4,t})'$, where for convenience the three first elements are scalars and the last element, z_{4t}, is a vector (possibly the empty vector, if $n = 3$). Suppose that we are primarily interested in knowing how $z_{2,t+h}$ responds to a shock to $z_{1,t}$. Moreover, we also want to know how much of this impulse response is due to the fact that $z_{3,t}, ..., z_{3,t+h-1}$ changes in response to the original shock to $z_{1,t}$.

In the specific context of Section 5, for example, the first element is new borrowing, i.e. $z_{1,t} = b_{i,t}$, the second element is output growth, i.e. $z_{2,t} = \Delta y_{i,t}$, the third element is debt service, i.e. $z_{3,t} = s_{i,t}$, and the fourth element is a vector of controls, i.e. $z_{4,t} = controls_{i,t}$.

To express the impulse response and its decomposition, we need to specify a process for z_t. For ease of exposition, we first consider the linear local projection of z_{t+h} on the space generated by z_{t-1}, which is given by

$$z_{t+h} = \mu_{h+1} + A_{h+1} z_{t-1} + \upsilon_{h,t+h} \tag{22}$$

where μ_{h+1} is a vector of constants, A_{h+1} is an $n \times n$ matrix of coefficients, and $\upsilon_{h,t+h}$ is an error term. The error term is a h^{th} order moving average of a set of reduced form *i.i.d.* disturbances, ν_t, arriving in each time period from t to $t + h$ (see Jorda (2005)). For $h = 0$, specifically, we have $\upsilon_{0,t} = \nu_t$. Using the index $h + 1$ on the parameters of (22) is convenient for expressing the impulse response at $t + h$, as will become clear shortly.

Impulse response Let d_i be a shock to the i^{th} element of vector z_t, technically defined as a linear combination of the reduced form disturbances, ν_t. The simplest example is a unit shock $d_1 = (1,\, 0,\, 0,\, 0)'$.[31] The impulse response of z_{t+h} from d_i, denoted $IR(z_{t+h},\, d_i)$, can be defined as

$$IR(z_{t+h},\, d_i) = E(z_{t+h} \mid \nu_t = d_i;\, Z_t) - E(z_{t+h} \mid \nu_t = 0;\, Z_t) \tag{23}$$

for $h = 0,\, 1, ...,$ where $E(\cdot \mid \cdot)$ denotes the expectation from the best mean squared error predictor and $Z_t = (z_{t-1},\, z_{t-2}...)'$ represents past information that is known at time t.

To calculate the impulse response (23) based on the process defined in (22), note that $E(z_{t+h} \mid Z_t) = E(E(z_{t+h} \mid z_t) \mid Z_t)$ by the law of iterated expectations. The expectation $E(z_{t+h} \mid z_t)$ can be found by leading the time index in (22) by one period and considering the forecast $h - 1$ periods ahead. This gives $E(z_{t+h} \mid z_t) = \hat{\mu}_h + \hat{A}_h z_t$ where the hat denotes the estimated value from the predictor. Moreover, from (22) with $h = 0$ we find that

[31] More generally, d_i could refer for example to a column of the inverse lower triangular matrix that is used in a Cholesky decomposition, if shocks are identified by a Wold-causal order of z_t when $h = 0$.

$z_t = \mu_1 + A_1 z_{t-1} + d_i$ when $\upsilon_{0,t} = \nu_t = d_i$ and $z_t = \mu_1 + A_1 z_{t-1}$ when $\nu_t = 0$. Combining these results we get

$$\begin{aligned} IR(z_{t+h},\, d_i) &= E\left(E(z_{t+h} \mid z_t) \mid \nu_t = d_i;\, Z_t\right) - E\left(E(z_{t+h} \mid z_t) \mid \nu_t = 0;\, Z_t\right) \\ &= \left(\mu_h + \hat{A}_h\left(\mu_1 + A_1 z_{t-1} + d_i\right)\right) - \left(\mu_h + \hat{A}_h\left(\mu_1 + A_1 z_{t-1}\right)\right) \\ &= \hat{A}_h d_i \end{aligned} \tag{24}$$

with the normalization $\hat{A}_0 = I$. The impulse response in (24) is our first object of interest. With $z_t = (b_{i,t},\, \Delta y_{i,t},\, s_{i,t},\, controls'_{i,t})'$ and $d_1 = (1,\, 0,\, 0,\, 0')'$, the expression (10) in the main text corresponds to $IR(\Delta y_{i,t+h},\, d_1)$.

Decomposition Next we decompose how a shock d_1 to $z_{1,t}$ at time t propagates through the system (22) to affect $z_{2,t+h}$ at horizons $h \geq 0$. Specifically, we ask how much of the impulse response of $z_{2,t+h}$ runs through the predictable effects of the shock on the realizations of $z_{3,t}, \ldots, z_{3,t+h-1}$. (In the application in Section 5, this corresponds to asking how much of the effect of a credit impulse at time t on output y_{t+h} occurs via debt service $s_{t+1}, \ldots, s_{t+h-1}$.) For this purpose, rewrite the prediction of equation (22) as

$$\begin{aligned} \hat{z}_{t+h|t-1} &= \hat{\mu}_{h+1} + \hat{A}_{h+1} z_{t-1} \\ &= \hat{\mu}_{h+1} + \hat{A}_1 \hat{A}_h z_{t-1} + \left(\hat{A}_{h+1} - \hat{A}_1 \hat{A}_h\right) z_{t-1} \\ &\approx \hat{\mu}_{h+1} + \hat{A}_1 \hat{A}_h z_{t-1} \end{aligned} \tag{25}$$

where $\hat{z}_{t+h|t-1}$ is shorthand for $E(z_{t+h} \mid Z_{t-1})$. The critical step in this derivation is the approximation in equation (25). This step is valid as long as $\hat{A}_{h+1} \approx \hat{A}_1 \hat{A}_h$. The equation holds exactly if the true data generating process (DGP) for z_t is a vector auto-regression (VAR), since $\hat{A}_{h+1} = (\hat{A}_1)^{h+1}$ in that case. In the more general case where the true DGP is not a VAR we are still likely to have $\hat{A}_{h+1} \approx \hat{A}_1 \hat{A}_1^h$ because the local projection and the VAR are the same at $h = 0$ and the approximation error in $\hat{A}_1 \hat{A}_1^h$ does not compound with h.

The approximation in (25) allows us to separate between first round and higher round effects in the impulse responses. Using (24) together with (25) we get

$$\begin{aligned} IR(z_{t+h},\, d_i) &= \hat{A}_h d_i \\ &\approx \hat{A}_1 \hat{A}_{h-1} d_i \\ &= \hat{A}_1 IR(z_{t+h-1},\, d_i) \\ &= IR\left(z_{t+h},\, IR(z_{t+h-1},\, d_i)\right) \end{aligned} \tag{26}$$

This captures that the impulse response of a shock d_i at horizon $h > 1$ is approximately equal to the first round effects of the expected position of the system $h - 1$ periods ahead.

In Section 5, our interest lies in the response of the 2^{nd} element of the vector z_{t+h} (output y_{t+h}) to a shock d_1 (i.e. to new borrowing). Focusing only on this first element and separating the vector $z_{t+h-1} = (z_{1,t+h-1},\, z_{2,t+h-1}, \ldots,\, z_{n,t+h-1}) = (z_{i,t+h-1})_{i=1}^n$ into its n individual scalar components and similar for the impulse response $IR(z_{t+h-1},\, d_1) = (IR(z_{i,t+h-1},\, d_1))_{i=1}^n$, equation (26) can be written as

$$\begin{aligned} IR(z_{2,t+h},\, d_1) \approx & IR\left(z_{2,t+h},\, IR(z_{t+h-1},\, d_1)\right) \\ = & IR\left(z_{2,t+h},\, (IR(z_{i,t+h-1},\, d_1))_{i=1}^n\right) \\ = & \underbrace{IR\left(z_{2,t+h},\, IR(z_{3,t+h-1},\, d_1)\right)}_{\text{service\_effect}} + \underbrace{IR\left(z_{2,t+h},\, (IR(z_{i,t+h-1},\, d_1))_{i\neq 3}\right)}_{\text{other\_effects}} \end{aligned}$$

Given our specification (22), we can denote these two terms in matrix notation as

$$\text{service\_effect} = IR\left(z_{2,t+h},\, IR(z_{3,t+h-1},\, d_1)\right) = \hat{A}_{23,1}\hat{A}_{3\cdot,h-1}d_1 \tag{27}$$

where $\hat{A}_{ij,h}$ denotes the ij^{th} element of $\hat{A}_h$ and $\hat{A}_{i\cdot,h}$ denotes its i^{th} row. The part of the impulse response that is due to all other factors is given by

$$\text{other\_effects} = IR\left(z_{2,t+h},\, (IR(z_{i,t+h-1},\, d_1))_{i\neq 3}\right) = \left(\hat{A}_{2\cdot,h} - \hat{A}_{23,1}\hat{A}_{3\cdot,h-1}\right) d_1. \tag{28}$$

With $z_t = (b_{i,t},\, \Delta y_{i,t},\, s_{i,t},\, controls'_{i,t})'$ and $d_1 = (1,\, 0,\, 0,\, 0')'$, Equations (27) and (28) reduce to (11) and (12) in the main text.

General case It is easy to generalize these calculations to a p^{th} order local projection of the form

$$z_{t+h} = \mu_{h+1} + A_{h+1,1}z_{t-1} + ... + A_{h+1,p}z_{t-p} + \upsilon_{h,t+h} \tag{29}$$

Again we can rewrite the prediction of (29) in terms of its projected first-order effects as

$$\begin{aligned} \hat{z}_{t+h} &= \hat{\mu}_{h+1} + \hat{A}_{h+1,1}z_{t-1} + ... + \hat{A}_{h+1,p}z_{t-p} \\ &= \hat{\mu}_{h+1} + \hat{A}_{1,1}\left(\hat{A}_{h,1}z_{t-1} + ... + \hat{A}_{h,p}z_{t-p}\right) + ... \\ &\quad + \hat{A}_{1,p}\left(\hat{A}_{h-p,1}z_{t-1} + ... + \hat{A}_{h-p,p}z_{t-p}\right) \\ &\quad + \left(\hat{A}_{h+1,1} - \hat{A}_{1,1}\hat{A}_{h,1} - ... - \hat{A}_{1,p}\hat{A}_{h-p,1}\right) z_{t-1} + ... \\ &\quad + \left(\hat{A}_{h+1,p} - \hat{A}_{1,1}\hat{A}_{h,p} - ... - \hat{A}_{1,p}\hat{A}_{h-p,p}\right) z_{t-p} \\ &\approx \hat{\mu}_{h+1} + \left(\hat{A}_{1,1}\hat{A}_{h,1} + ... + \hat{A}_{1,p}\hat{A}_{h-p,1}\right) z_{t-1} + ... \\ &\quad + \left(\hat{A}_{1,1}\hat{A}_{h,p} + ... + \hat{A}_{1,p}\hat{A}_{h-p,p}\right) z_{t-p} \end{aligned} \tag{30}$$

with the normalization $\hat{A}_{1-j,j} = I$ and $\hat{A}_{1-j,k} = 0$ for $j \geq 1$ and $1 \leq k \neq j$, as well as, $\mu_{-j} = 0$ for $j \geq 0$. The expression on the last line is valid if $\hat{A}_{h+1,j} \approx \hat{A}_{1,1}\hat{A}_{h,j} + ... + \hat{A}_{1,p}\hat{A}_{h-p,j}$, for $j = 1, ..., p$. As before, it will be zero if the true underlying DGP for z_t is a VAR. To see this, note that z_t can be written in companion form as

$$w_t = \mu + Aw_{t-1} + \upsilon_t$$

under the VAR assumption, where

$$w_t = \begin{bmatrix} z_t \\ \vdots \\ z_{t-p} \end{bmatrix},$$

$$A = \begin{bmatrix} A_{1,1} & A_{1,2} & \cdots & A_{1,p-1} & A_{1,p} \\ I & 0 & \cdots & 0 & 0 \\ 0 & I & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & I & 0 \end{bmatrix},$$

$$\upsilon_t = \begin{bmatrix} \nu_t \\ 0 \\ \vdots \\ 0 \end{bmatrix}.$$

Let

$$A^{h+1} = \begin{bmatrix} A_{1,1}^{(h+1)} & \cdots & A_{1,p}^{(h+1)} \\ \vdots & \ddots & \vdots \\ A_{p,1}^{(h+1)} & \cdots & A_{p,p}^{(h+1)} \end{bmatrix}$$

From Jorda (2005) we know that $A_{1,k}^{(h+1)} = A_{h+1,k}$ for all $h \geq 0$ and $k = 1, ..., p$. But given the definition of w_t this also implies

$$A^{h+1} = \begin{bmatrix} A_{h+1,1} & A_{h+1,2} & \cdots & A_{h+1,p} \\ A_{h,1} & A_{h,2} & \cdots & A_{h,p} \\ \vdots & \vdots & \ddots & \vdots \\ A_{h+1-p,1} & A_{h+1-p,2} & \cdots & A_{h+1-p,p} \end{bmatrix}$$

with the normalizations $A_{h+1-j,j-h} = I$ and $A_{h+1-j,k-h} = 0$ for $j \geq h+1$ and $0 < k \neq j$. But then the assumed VAR structure also implies that

$$\begin{aligned} A_{1,j}^{(h+1)} &= A_{1\cdot}A_{\cdot j}^{(h)} \\ &= A_{1,1}A_{1,j}^{(h)} + ... + A_{1,p}A_{p,j}^{(h)} \\ &= A_{1,1}A_{h,j} + ... + A_{1,p}A_{h-p,j} \end{aligned}$$

which shows the proposition.

Using (23) together with (30) gives

$$\begin{aligned} IR(z_{t+h},\, d_i) &= \hat{A}_{h,1}d_i \\ &\approx \hat{A}_{1,1}\hat{A}_{h-1,1}d_i + ... + \hat{A}_{1,p}\hat{A}_{h-1-p,1}d_i \\ &= \hat{A}_{1,1}IR(z_{t+h-1},\, d_i) + ... + \hat{A}_{1,p}IR(z_{t+h-1-p},\, d_i) \\ & \quad IR\left(z_{t+h},\, IR(z_{t+h-1},\, d_i), ...,\, IR(z_{t+h-1-p},\, d_i)\right) \end{aligned} \tag{31}$$

which concludes our decomposition in the p^{th} order case.

C Results for the Corporate Sector

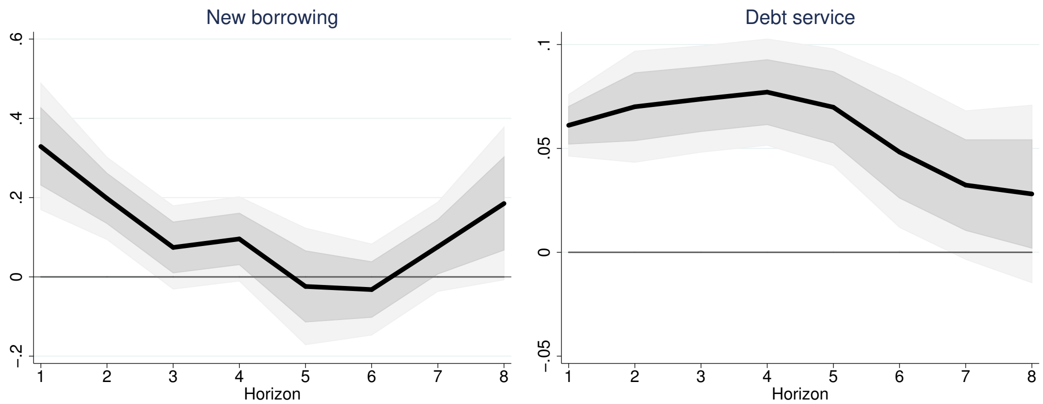

Figure 14: Impulse response of new borrowing and debt service to a unit increase in new corporate borrowing at t_0 using local projections (7) and (8) for horizons $h = 1$ to 8. The specification includes our baseline controls (see Section (3.2)). Errors are clustered at the country level. Dotted line are the 95% confidence bands.

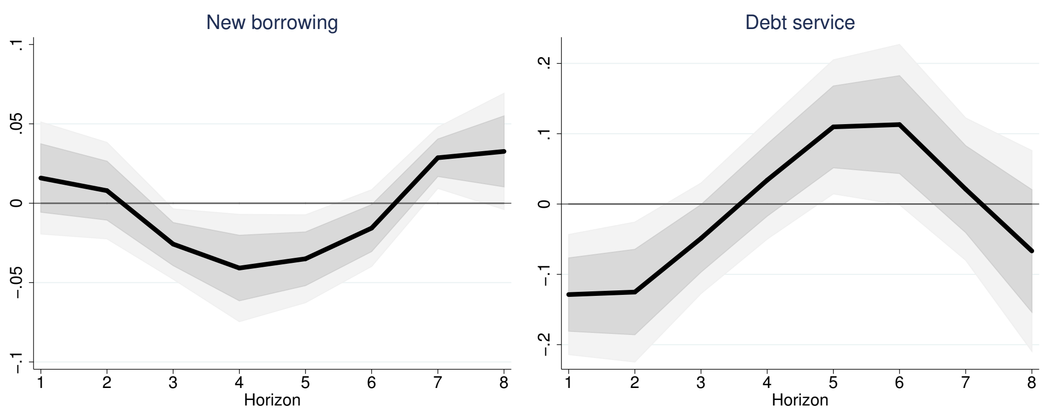

Figure 15: Impulse response of GDP growth after a unit increase in new corporate borrowing or corporate debt service at t_0 using local projections (9) for horizons $h = 1$ to 8 with our baseline controls (see Section (3.2)). Errors are clustered at the country level. Dotted line are the 95% confidence bands.

D Additional Tables and Graphs

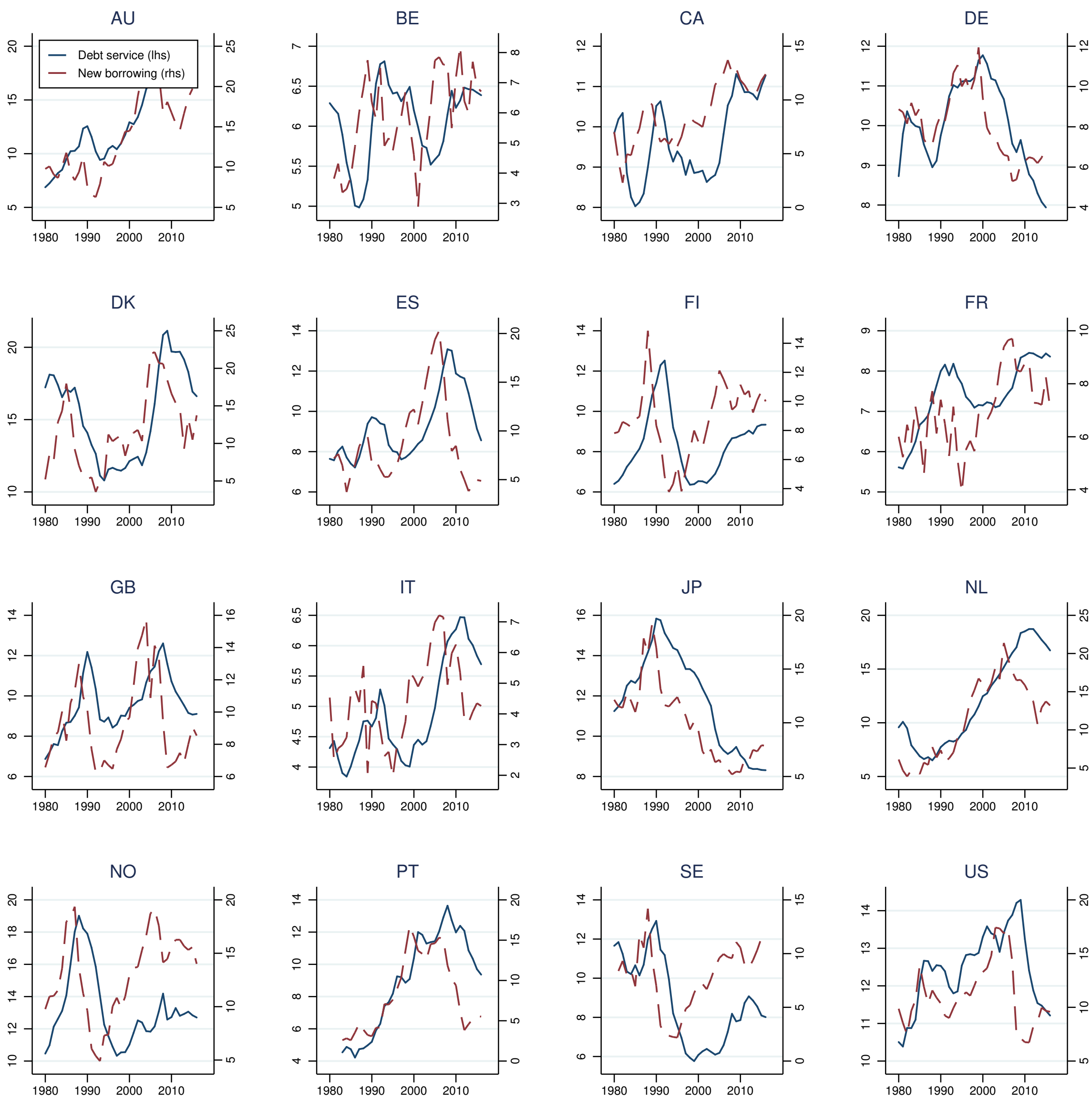

Figure 16: New borrowing and debt service for the household sector in different countries.

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
Interest rate on the stock of debt ($r_{i,t}$)	Interest payments and financial intermediation services indirectly measured (FISIM) divided by debt stock; all for the household sector. Where not available, backdated by alternative interest rates such as the average interest rates on bank loans to households.	National Accounts, central banks
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 (Fx)	Real effective exchange rate.	BIS
Property price	Residential property price deflated by the CPI.	BIS
Unemployment (Unempl.)	Unemployment rate.	Global Financial Data, OECD, central banks
Labor productivity (product.)	Labor productivity.	OECD, FRED, World Bank
Inflation rate (infl.)	First difference of the logarithm of the CPI.	National sources.
Current account (CA)	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 (prov.)	Aggregate provisions of the national banking sector.	Bankscope, OECD, Pesola (2011)
Lending standards	Bank lending standards.	Central banks

Table 2: 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.

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 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; 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", supplementary material for CGFS (2006); Ölcer, 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 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.

	new borrow. debt service	$y_{i,t}$	$r_{i,t}$	Short rate	Term spread	Lend. spread	Credit spread	Fx/infl./ CA/product.	Prop. pr.	Unempl.	GDP forec.	Net worth	Prov.	Lend. std	Mortgages
AU	1980	1980	1980	1986	1986	1986	1983	1980	1980	1980	1990	1989	1991		float
BE	1980	1980	1980	1980	1980	1981	1980	1980	1980	1980	1989	1999	1981	2003	fix
CA	1980	1980	1980	1980	1980	1980	1983	1980	1980	1980	1989	1990	1988	1999	fix
DE	1980	1980	1980	1980	1980	1980	1988	1980	1980	1980	1989	1999	1980	2003	fix
DK	1994	1980	1994	1980	1980	1980	1994	1980	1980	1980	1989	1998	1980		fix
ES	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1989	1999	1980	2003	float
FI	1980	1980	1980	1980	1987	1980		1980	1980	1980	1989	1997	1980		float
FR	1980	1980	1980	1980	1980	1980	1980	1980	1980	1982	1989	1999	1988	2003	fix
GB	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1989	1999	1987	2006	float
IT	1980	1980	1980	1980	1980	1982	1980	1980	1980	1983	1989	1995	1984	2003	float
JP	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1989	1994	1989	2000	fix
NL	1990	1980	1990	1980	1980	1980	1980	1980	1980	1980	1989	2010	1980	2003	fix
NO	1980	1980	1980	1980	1980	1980		1980	1980	1980	1989	1995	1980		float
PT	1980	1980	1983	1983	1983	1983		1980	1988	1983	1989	1999		2003	float
SE	1980	1980	1980	1980	1980	1980	1984	1980	1980	1980	1989	1999	1981		float
US	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1989	1980	1980	1990	fix

Table 5: Data sample and whether mortgages are predominantly fixed or floating rate. For abbreviations see Table 2. Mortgage systems are classified based on CGFS (2006), ECB (2009) and information from national central banks.

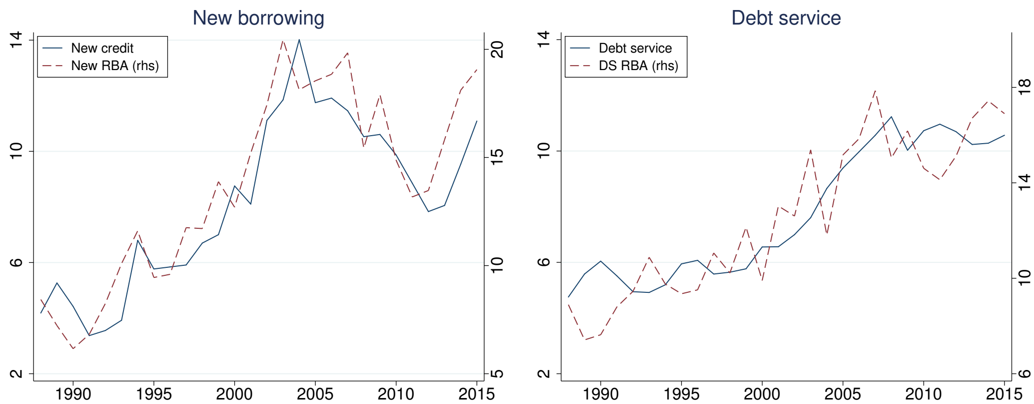

Figure 17: Comparison of our measures of new borrowing and debt service for Australian mortgages with alternative measures from the Reserve Bank of Australia. The Reserve Bank of Australia (2016) reports data on the stock of mortgages outstanding and newly issued mortgages and refinanced mortgages. From these series, we calculate new borrowing as all newly issued mortgages minus refinanced mortgages, and amortizations as the change in the stock of debt minus new borrowing.

Local projections on new borrowing from a unit impulse to new borrowing								
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$	$t+7$	$t+8$
Only GDP	0.947***	0.849***	0.697***	0.573***	0.462***	0.365***	0.221**	0.083
Base	0.883***	0.804***	0.689***	0.537***	0.363***	0.244**	0.127	−0.005
Additional	0.838***	0.659***	0.544***	0.305**	0.059	−0.032	−0.153	−0.174
Base res.	0.859***	0.703***	0.608***	0.415***	0.229**	0.112	−0.038	−0.296*
Time FE	0.846***	0.772***	0.652***	0.574***	0.478***	0.452***	0.338***	0.224*
Before 2000	0.776***	0.638***	0.397***	0.126	−0.020	−0.085	−0.198**	−0.244**
After 2000	0.814***	0.687***	0.540***	0.406***	0.198*	0.176**	0.086	0.057
Mean group	0.767***	0.617***	0.467***	0.213**	0.008	−0.074	0.019	−0.300**
Mortgages	0.770***	0.687***	0.647***	0.561***	0.394***	0.291**	0.247	0.157
Other loans	0.614***	0.511***	0.391***	0.310**	0.208	0.151	0.175	−0.022
Fixed rate	0.701***	0.665***	0.601***	0.547**	0.378	0.291	0.298	0.232
Flex rate	0.945***	0.782***	0.678***	0.516**	0.353*	0.121	−0.023	−0.133

Table 6: Local projections of new borrowing from a unit impulse to new borrowing (β_{bb}^{t+h} from eq. (7)). "Only GDP", "Base" and "Additional" refers to the three sets of controls (see Table 1). "Base res." uses the baseline controls but only considers observations when all other additional controls are available. "Time FE" adds time fixed effects to the baseline controls. "Before 2000" ("After 2000") uses data before 2000 (from 2000 onward). "Mean group" allows for full cross-country heterogeneity (Peseran and Smith (1995)). "Mortgages" ("Other loans") only assesses mortgages (other household debt). "Fixed rate" ("Flex rate") only assesses mortgages and splits the sample into countries with predominantly fixed rate (flexible rate) mortgages.***/**/* indicates significance at the 1 / 5 / 10 percent level.

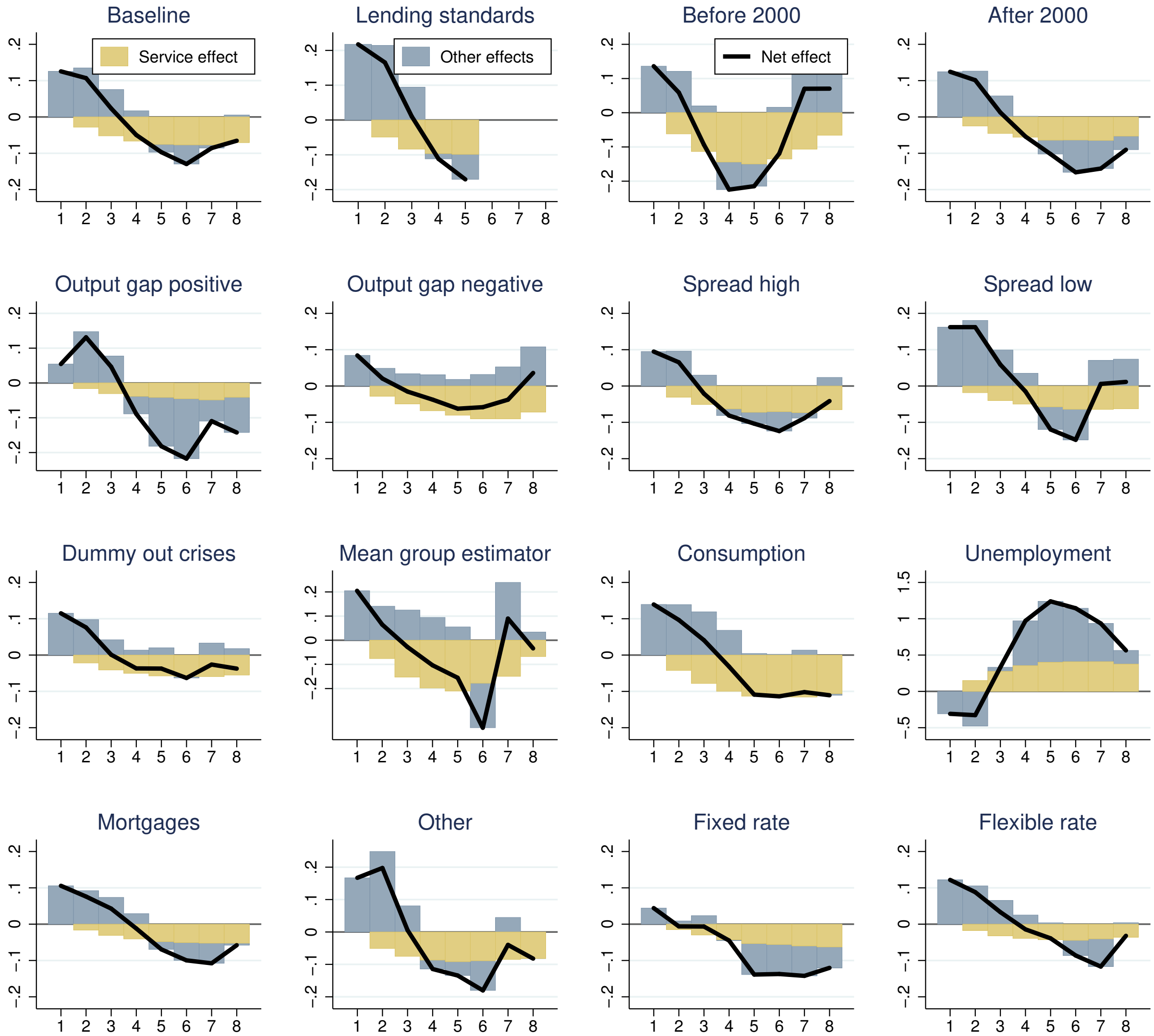

Figure 18: Decomposition of the net effect of new borrowing on future GDP growth (equation (10)) into the service effect (equation (11)) and the other effects (equation (12)) for horizons h=1 to 8. We always include the baseline controls (see Table 1). "Lending standards" controls for lending standards. Given limited observations we only forecast up to horizon 5. "Before 2000" (after 2000) uses data before 2000 (from 2000 onward). "Output gap positive" (negative) and "spread high" (low) considers data when the output gap was positive (negative), respectively credit spreads were above (below) country specific means, in the initial period. "Dummy out crises" adds country and crisis specific dummies that are 1 at the start of a crisis. "Mean group estimator" allows for full cross-country heterogeneity (Peseran and Smith (1995)). In "Consumption" ("Unemployment") we decompose the net effect of new borrowing on future consumption (unemployment) growth. "Mortgages" ("Other") decomposes the net effect of new mortgage (other household debt) borrowing. "Fixed rate" ("Flexible rate") decomposes the net effect of new mortgage borrowing splitting the sample into countries with predominantly fixed rate (flexible rate) mortgages.

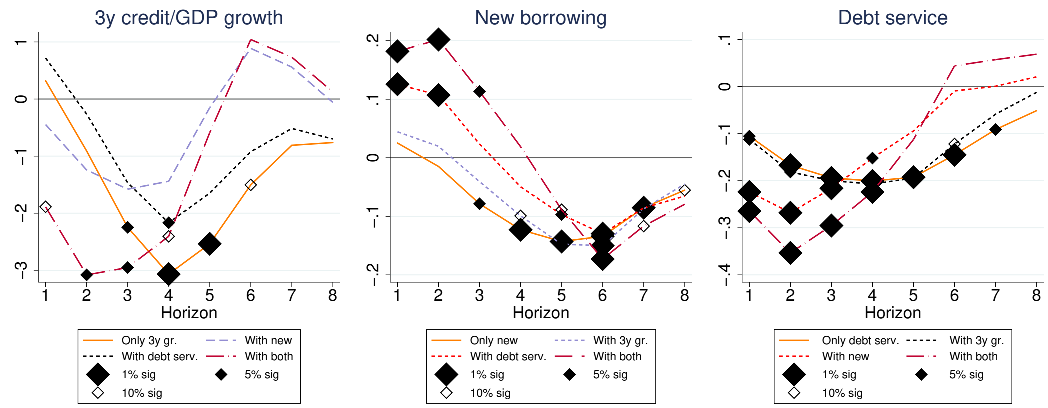

Figure 19: Impulse response of GDP growth to a unit increase in new borrowing, debt service or the three year growth rate in household credit to GDP for different specifications. All projections control for the baseline controls. Diamonds indicate significance levels (large solid / medium solid / medium hollow diamonds indicate significance at the 1% / 5% and 10% respectively).

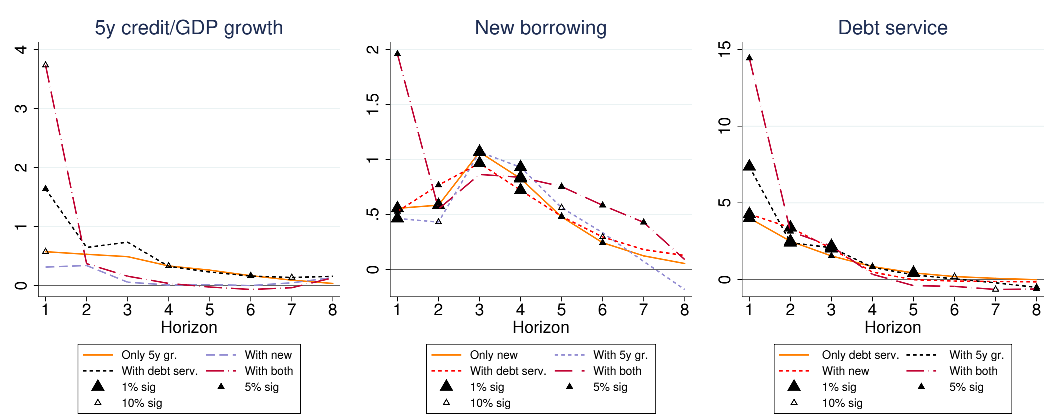

Figure 20: The impact of new borrowing, debt service and five year credit-to-GDP growth on the probability of crises as measured by the respective coefficients in local projections for horizons $h = 1$ to 8 using different specifications. We estimate a panel logit with country fixed effects and always add the baseline controls. Diamonds indicate significance levels (large solid / medium solid / medium hollow diamonds indicate significance at the 1% / 5% and 10% respectively).

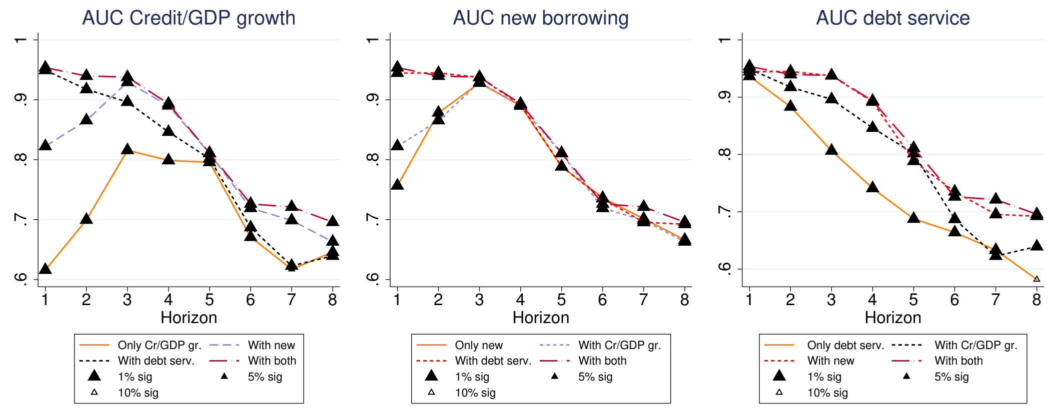

Figure 21: The area under the ROC curve (AUC) as a measure of signaling quality for the crisis prediction models including new borrowing, debt service and and credit-to-GDP growth individually or combined for $h = 1$ to 8. using different specifications. We estimate a panel logit with country fixed effects and but *no* other controls. Diamonds indicate significance levels (large solid / medium solid / medium hollow diamonds indicate significance at the 1% / 5% and 10% respectively).

Local projections on debt service from a unit impulse to new borrowing								
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$	$t+7$	$t+8$
Only GDP	0.123***	0.238***	0.315***	0.366***	0.386***	0.391***	0.385***	0.363***
Base	0.126***	0.233***	0.297***	0.337***	0.344***	0.344***	0.316***	0.281***
Additional	0.117***	0.205***	0.268***	0.307***	0.303***	0.307***	0.249***	0.161
Base res.	0.111***	0.197***	0.255***	0.291***	0.297***	0.303***	0.258***	0.190**
Time FE	0.131***	0.227***	0.283***	0.325***	0.338***	0.365***	0.356***	0.331***
Before 2000	0.173***	0.317***	0.403***	0.419***	0.378***	0.298***	0.184**	0.085
After 2000	0.110***	0.200***	0.246***	0.281***	0.280***	0.284***	0.232***	0.206***
Mean group	0.105***	0.210***	0.273***	0.290***	0.245***	0.206***	0.093*	0.002
Mortgages	0.089***	0.168***	0.222***	0.261***	0.272***	0.279***	0.279***	0.286***
Other loans	0.177***	0.266***	0.308***	0.325***	0.315***	0.295***	0.239***	0.228**
Fixed rate	0.093***	0.201***	0.290***	0.367***	0.389***	0.423***	0.420***	0.418**
Flex rate	0.102***	0.202***	0.244***	0.246**	0.243**	0.201*	0.139	0.073

Table 7: Local projections of debt service from a unit impulse to new borrowing (β_{sb}^{t+h} from eq. (8)). See Table 6 for description of labels.

Local projections of real GDP growth from a unit impulse to new borrowing								
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$	$t+7$	$t+8$
Only GDP	0.087**	−0.047	−0.183***	−0.230***	−0.235***	−0.231***	−0.201***	−0.163***
Base	0.126***	0.107**	0.024	−0.050	−0.097**	−0.130***	−0.086*	−0.065
Additional	0.129***	0.118**	0.067	0.067	−0.005	−0.099*	−0.195**	−0.207**
Base res.	0.151***	0.121**	0.050	−0.002	−0.060	−0.128**	−0.162***	−0.141***
time FE	0.061*	0.048	−0.011	−0.071	−0.071*	−0.056	−0.018	−0.001
before 2000	0.136*	0.059	−0.093	−0.225***	−0.215***	−0.119***	0.070	0.070
after 2000	0.124**	0.101	0.012	−0.054	−0.102**	−0.152**	−0.142*	−0.090
Mean group	0.205***	0.065*	−0.027	−0.104	−0.155***	−0.362***	0.090	−0.034
Mortgages	0.106***	0.076**	0.043	−0.012	−0.070*	−0.100**	−0.108	−0.058
Other loans	0.167	0.197	0.005	−0.114	−0.134	−0.180**	−0.040	−0.082
Fixed rate	0.044	−0.006	−0.006	−0.006	−0.045	−0.139**	−0.137*	−0.142*
Flex rate	0.122**	0.088	0.033	0.033	−0.014	−0.039	−0.086	−0.117

Table 8: Local projections of real GDP growth from a unit impulse to new borrowing (β_{yb}^{t+h} from eq. (9)). See Table 6 for description of labels.

Local projections of real GDP growth from a unit impulse to debt service								
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$	$t+7$	$t+8$
Only GDP	−0.303***	−0.261***	−0.104	−0.005	0.047	0.103*	0.128*	0.125
Base	−0.224***	−0.268***	−0.216***	−0.152**	−0.094	−0.009	0.001	0.021
Additional	−0.223***	−0.338***	−0.240*	−0.109	0.017	0.116	0.087	0.012
Base res.	−0.309***	−0.340***	−0.274**	−0.215*	−0.123	−0.013	0.102**	0.097
time FE	−0.126***	−0.163***	−0.129**	−0.060	−0.043	−0.017	−0.031	−0.043
before 2000	−0.357***	−0.417**	−0.303**	−0.051	0.119	0.108	0.061	0.015
after 2000	−0.227**	−0.256**	−0.195	−0.116	−0.037	0.063	0.071	0.021
Mean group	−0.725***	−0.814***	−0.739***	−0.423***	−0.240	−0.034	0.192	−0.249
Mortgages	−0.187***	−0.195**	−0.179**	−0.133	−0.095	−0.036	0.058	0.062
Other loans	−0.291***	−0.412***	−0.277***	−0.168*	−0.091	0.035	−0.069	−0.013
Fixed rate	−0.155**	−0.157	−0.177	−0.156	−0.063	−0.099	−0.074	0.005
Flex rate	−0.217**	−0.208*	−0.150	−0.118	−0.148	−0.059	0.098	0.050

Table 9: Local projections of real GDP growth from a unit impulse to debt service (β_{ys}^{t+h} from 9). See Table 6 for description of labels.

Local projections of financial crisis probability								
	Impulse to new borrowing							
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$	$t+7$	$t+8$
No controls	0.198	0.484***	0.860***	0.624***	0.419**	0.223*	0.160	0.193***
Only GDP	0.136	0.431***	0.825***	0.585***	0.421**	0.227*	0.124	0.207***
Base	0.528**	0.781**	0.966***	0.721***	0.484**	0.296*	0.182	0.127
Additional	1.203*	0.811**	0.999***	1.209***	0.706***	0.896**	0.364***	0.147
Base res.	0.931*	0.540	0.695*	0.934**	1.624***	0.554	0.251	0.037
OLS	0.006	0.005	0.017***	0.014***	0.016**	0.010*	0.005	0.003
	Impulse to debt service							
	$t+1$	$t+2$	$t+3$	$t+4$	$t+5$	$t+6$	$t+7$	$t+8$
No controls	2.212***	1.452***	0.494	0.045	−0.076	−0.005	−0.063	−0.237
Only GDP	2.709***	2.044**	0.814***	0.239	−0.083	−0.019	0.024	−0.191
Base	4.265***	3.037***	2.022***	0.487	−0.011	−0.100	−0.123	−0.152
Additional	4.265***	3.353**	2.672***	0.425	−0.517	−0.885**	−0.479**	−0.696***
Base res.	4.675***	3.075**	1.710***	0.977**	−1.356*	−0.434	−0.181	−0.526
OLS	0.023***	0.022**	0.007	0.008	−0.002	−0.002	−0.002	−0.003

Table 10: The impact of new borrowing and debt service on the probability of crises as measured by the respective coefficients in local projections for horizons $h = 1$ to 8. We estimate a panel logit with country fixed effects and controls. "Only GDP", "Base" and "Additional" refers to the three sets of controls (see Table 1). "No controls" employs no controls except new borrowing and debt service. "Base res." uses the baseline controls but only considers observations when all other additional controls are available. "OLS" uses a simple panel OLS approach instead of a panel logit model. ***/**/* indicates significance at the 1 / 5 / 10 percent level.