Debt Service:
The Painful Legacy of Credit Booms

Mathias Drehmann (BIS)
Mikael Juselius (Bank of Finland)
Anton Korinek (JHU and NBER)*

Preliminary – Please Do Not Distribute

December 15, 2016

Abstract

Credit booms generate a predictable increase in future debt service that depresses spending and economic growth for many years to come. The longer the maturity of debt contracts, the greater is the lag between the peak of the credit boom and the peak in debt service burden. We document this dynamic pattern for both household debt and total debt in a panel of 17 countries from 1980 to 2015. Our results also shed light on the mechanism behind several puzzling findings in the recent empirical literature on credit booms: high growth in credit predicts low output growth for a number of years in the future, deeper recessions, and a greater likelihood of financial crises. Explicitly accounting for debt service not only explains the channel behind the described findings but also generates stronger empirical relationships. We hope that our findings will be useful for future efforts to better model credit cyles.

1 Introduction

An influential recent literature has demonstrated that credit booms predict lower economic growth several years in the future, are associated with deeper recessions and increase the probability of future financial crisis.[1] These results are starkly at odds

*Contact information: Wyman 531, Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218. Phone: +1-240-575-0995. Email: akorinek@jhu.edu.

[1]For example, Mian et al. (2015) and Lombardi et al (2016) document that high growth in credit to the household sector is associated with low future output growth in the medium run. Claessens

with traditional macroeconomic models in which real and financial developments are independent of each other. Recognizing the importance of financial and real interactions, a strand of theoretical literature has highlighted the role of financial frictions for macroeconomic dynamics.[2] But these models are unable to explain the protracted effects of credit booms and, hence, why increases in debt imply medium-run predictability for output. Another nascent strand of theoretical literature focuses on the link between debt and aggregate demand problems, but likewise cannot account for the puzzling lead-lag relationship between credit and output.[3] This leaves a gap in our understanding of the mechanisms through which credit booms have long-lasting real effects.

The main contribution of this paper is to document that debt service is the missing link: the lasting real effects of credit booms are driven by the debt service obligations taken on during the boom. In the short run, new credit generates extra purchasing power for agents who are willing to spend it. However, when borrowers enter long-term debt contracts, they take on a predictable schedule of future interest and principal repayment obligations. As we show empirically, this generates a drag on future spending and depresses economic growth with a predictable lag.[4] Our paper thus documents the mechanism through which high credit growth predicts lower output in the medium run.

We develop a simple analytical framework that accounts for the dynamic interactions between a credit boom, new credit issuances and debt service. As a matter of pure accounting, a credit boom in which borrowers take on long-term debt with fixed amortization schedules leads to a predictable pattern in debt service and in the net cash flows between borrowers and lenders. We prove a number of results that hold under mild conditions: First, there is a lag between the peak in debt issuance and the peak of debt service that increases in the maturity of debt. The reason is that debt service is a function of the stock of debt outstanding, which continues to grow even after the peak in debt issuance. Second, net cash flows from lenders to borrowers reach their maximum before the peak in debt issuance and turn negative before the end of the credit boom since the cash flow from debt issuance is increasingly offset by rising debt service.

The data confirm the insights from the simple accounting framework. Using a panel of 17 countries from 1980 to 2015, we find that there is a robust and predictable lag between real credit growth and debt servicing. In particular, the data show that

et al. (2012) and Jorda et al. (2013) show that credit booms deepen recessions. There is by now a large literature showing that credit booms increase the likelihood of financial crisis and are useful early warning indicators for crises. See e.g. Borio and Lowe (2002), Borio and Drehmann (2009), Reinhart and Rogoff (2009) or Schularick and Taylor (2012).

[2]For example, Kiyotaki and Moore (1997), Bernanke, Gertler and Gilchrist (1999) and Iacoviello (2005) develop models with credit frictions that amplify shocks, but immediately after the initial impulse, shocks start to decay.

[3]For example, Farhi and Werning (2016) and Korinek and Simsek (2016) explore the aggregate demand effects of excessive household borrowing. Schmitt-Grohe and Uribe (2016) focus on the effects of external borrowing in open economies.

[4]We are agnostic as to whether the decline in growth is due to a decline in potential output or due to a shortage in demand that cannot be or simply is not offset by expansionary monetary policy.

peaks in real credit growth precede peaks in debt servicing by an average of 3 years. Furthermore, after the peak in the credit boom, when credit growth starts to slow down, the total stock of debt and, by implication, debt service, continues to rise and remains above average until year 7 after the peak of the credit boom.

Next we investigate the implications for the real economy and show that debt service obligations link credit booms to future low economic growth, deeper recessions, and higher crisis probabilities. In fact, keeping track of debt service obligations improves predictability along all these dimensions.

First, we document that accounting for debt service is important for capturing the link between credit and the real economy. In particular at short horizons, debt service has a strong negative impact on output. Disentangling the effects of new debt and debt servicing thus improves our predictive ability by a considerable margin. In particular, adding debt service increases the adjusted within R^2 for one-year ahead predictions by 12 percentage points from 24% to 36% compared to a model that only includes real debt growth. And the difference between R^2s of both models this similarly stark for a predictive horizon of three years ahead. The R^2 of the model that accounts for the debt service is 0.13 instead of close to 0 otherwise.

Second, debt service explains why there are negative medium-run effects of credit booms on output growth. This was recently found e.g. by Mian et al. (2016) in a cross-country panel, but without providing a mechanism for how credit booms lead to lower growth.[5] We corroborate their findings in our data, and show that the negative correlation between credit and future output growth is entirely due to projected increases in debt service that follow from the credit expansion.[6] And once we strip out the effects credit growth has on output via debt servicing, we find that the effect of credit growth is unambiguously positive .

Third, we show that the link between credit booms and deeper recessions, documented e.g. in Claessens et al. (2012) and Jorda et al. (2013), and Krishnamurthy and Muir (2016), can be related to the size of the increase in debt service resulting from the credit expansion. Moreover, we find that the negative effects of debt servicing tends to dominate the positive effects from new debt issuance over the cycle, in line with the findings in Cerra and Saxena (2008) who find that crises that follow credit booms are associated with permanent output losses.

Forth, we show that debt service is also the main channel through which credit growth affects the probability of financial crises (e.g. Borio and Lowe (2002), Reinhart and Rogoff (2009), Schularick and Taylor (2012), among others). In line with recent work (eg Drehmann and Juslius (2012) or Detken et al (2014)), we first show that adding debt servicing improves the forecasting ability of the benchmark financial crisis prediction models in this literature. Furthermore, the timing is in line with our accounting framework: debt servicing helps to improve the forecasts at shorter horizons

[5]Mian and Sufi (2009, 2010) also document a similar relationship in cross-sectional data from US counties.

[6]These findings complement 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.

leading up to a banking crisis, whereas credit growth or credit "gaps" are more helpful at longer horizons. We then document that the predictive ability of credit growth in the medium run is entirely due to the projected increase in debt service .

We confirm the validity of our findings by performing a number of robustness checks. We show that our results are not an artefact of the Great Recession and hold in several subsamples of the data. They also hold at the individual country level, although the small size of our sample leads to lower significance in that case. Controlling for a range of macroeconomic factors, including credit spreads, productivity or GDP forecasts as well as time fixed effects, does not alter the main results of the paper. We also show that the results are symmetric for positive and negative innovations to credit growth as debt service has a consistently negative impact and net new credit a consistently positive impact on output. Lastly, our results are robust to different empirical measures of debt service, including one where we only use interest payments that are directly observable from national accounts.

The paper is structured as follows. First, we lay out our simple accounting framework. We then discuss the data that are used and document the lead-lag relationship between new credit and debt service. Next we turn to the macroeconomic implications. After laying out our basic empirical strategy, Section **??** shows that debt service helps to explain the negative relationship between credit growth and output growth in the medium run. After conducting a battery of robustness checks, Section **??** relates our findings to the existing empirical literature on the medium-run effects of credit booms. Section 7 concludes.

2 Accounting for Debt Service

This section lays out a simple accounting framework to describe the cash-flow implications of long-term debt, which we argue captures the key force through which credit booms lead to delayed declines in output.

To keep matters simple and focus on the essential argument, consider a borrower who enters a long-term debt contract with face value d_t in period t with constant amortization rate δ and fixed interest rate r. In period $t+1$, this contract implies a debt service of $(r+\delta)\, d_t$, consisting of amortization and interest payments on the remaining stock of debt $(1-\delta)\, d_t$. Give this debt contract, k periods after issuance, a balance of $(1-\delta)^{k-1}\, d_t$ is left of the original debt amount, and the borrower is obliged to amortize a further fraction δ and pay interest r on the outstanding balance, implying debt service obligations $s_k(d_t)$ with

$$s_{t+k}\left(d_t\right) = \left(r+\delta\right)\left(1-\delta\right)^{k-1} d_t$$

If debt is taken on over multiple periods, we can keep track of the total sock of debt outstanding using a variable D_t that follows the law-of-motion

$$D_{t+1} = \left(1-\delta\right) D_t + d_t = \sum_{s=0}^{t} \left(1-\delta\right)^{t-s} d_s$$

and total debt service is given by all the debt service obligations from all past borrowing $(d_s)_{s=0}^{t-1}$ that are due in period t,

$$S_t = \sum_{s=0}^{t-1} s_t(d_s) = \sum_{s=0}^{t-1} (\delta + r)(1-\delta)^{t-s-1} d_s = (\delta + r) D_t$$

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

$$N_t = d_t - S_t = d_t - \sum_{s=0}^{t-1} (\delta + r)(1-\delta)^{t-s-1} d_s$$

We now use these accounting relationships to trace out the implications of a temporary credit boom for the lag structure between debt issuance and debt service. Consider an exogenous process of new debt issuance $\{d_t\}$ which involves $T > 2$ periods of positive new debt issuance $d_t > 0$ for $t \in \{1, ...T\}$ that is hump-shaped, i.e. there is a unique interior peak at a time $1 < t^* < T$ such that $d_{t^*} = \max_{t \in \{1,...T\}} \{d_t\}$ and debt issuance is increasing up until the peak $d_1 < d_2 < \cdots < d_{t^*}$ and decreasing after the peak $d_{t^*} > d_{t^*+1} > \cdots > d_T$. For expositional simplicity, we assume that all debt is contracted at a constant interest rate r and depreciation rate δ. Furthermore, we impose a mild condition on timing: the process of debt issuance 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 issuance so $d_t = 0$ for $t > T$.

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

Proposition 1 (**Lead-lag structure of new debt and debt service**). *(i) The peak in debt service $\hat{t}$ occurs after the peak in debt issuance t^*. The lag between the two peaks $t^* - \hat{t}$ is weakly decreasing in δ.*

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

Proof. (i) At the peak of debt issuance t^*, debt is still growing $\Delta D_{t^*+1} = D_{t^*+1} - D_{t^*} > 0$ if new issuance exceeds amortization, $d_{t^*} > \delta D_{t^*}$ at t^*. An upper bound on debt D_{t^*} is $t^* d_{t^*}$. Our analytic condition on timing implies that $\delta D_{t^*} \leq \delta t^* d_{t^*} < d_{t^*}$ so debt is still growing at the peak of new debt issuance and $\Delta D_{t^*+1} > 0$. 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^*.

At the peak $\hat{t}$ in the stock of debt for the original time series $\Delta D_{\hat{t}} > 0 > \Delta D_{\hat{t}+1}$. 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 debt issuance is exogenous, the lag $t^* - \hat{t}$ is decreasing in δ.

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

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

Some of the comparisons in the proposition involve weak inequalities due to the discrete time nature of our framework. In Appendix A, we show that if we move to a continuous time framework, all of the inequalities in an equivalent proposition are strict.

Figure (1) illustrates our findings in a simulation. The figure assumes an exogenous credit boom that lasts for several periods, indicated by the hump-shaped blue bars of new debt d_t in the first 9 periods with a peak at $t = 4$. The solid black line captures the resulting build-up in the stock of debt. We set $r = 7\%$ and $\delta = 15\%$ in our simulation. The red bars depict the resulting debt service obligations. As can be seen, debt service builds up with a lag of three years in our simulation – it continues to grow even when new debt issuance is already declining – because it depends on the total stock of debt, which is a moving average of new debt issuance.

In the bottom panel of the figure, we depict the net cash flow from lenders to borrowers, i.e. the difference between new debt issuance and debt service. The net cash flow peaks before the peak in new debt issuance and turns negative before the boom is over, consistent with the analytical findings in the proposition.

Our simple accounting framework suggest that debt service may account for the strong empirical finding that prolonged periods of high debt growth predict negative future output growth with a lag, i.e. that debt service may be *the painful legacy of credit booms.* Ultimately, though, this is an empirical question. We next turn to testing the predictions of our accounting framework in the data.

3 Data

We use annual data from 17 countries for which debt service data is available over the sample period from 1980 to 2015. Our main interest lies in debt service and new credit. We focus on the household sector, for which the literature has found strong negative effects from credit growth (e.g. Mian et al., 2015, or Jorda et al., 2015) and in which long-term debt contracts are most prevalent.[7] We use debt service data from

[7]We consider non-financial corporations and the total private non-financial sector (i.e. the sum of household debt and the debt of non-financial corporations) in a separate robustness section.

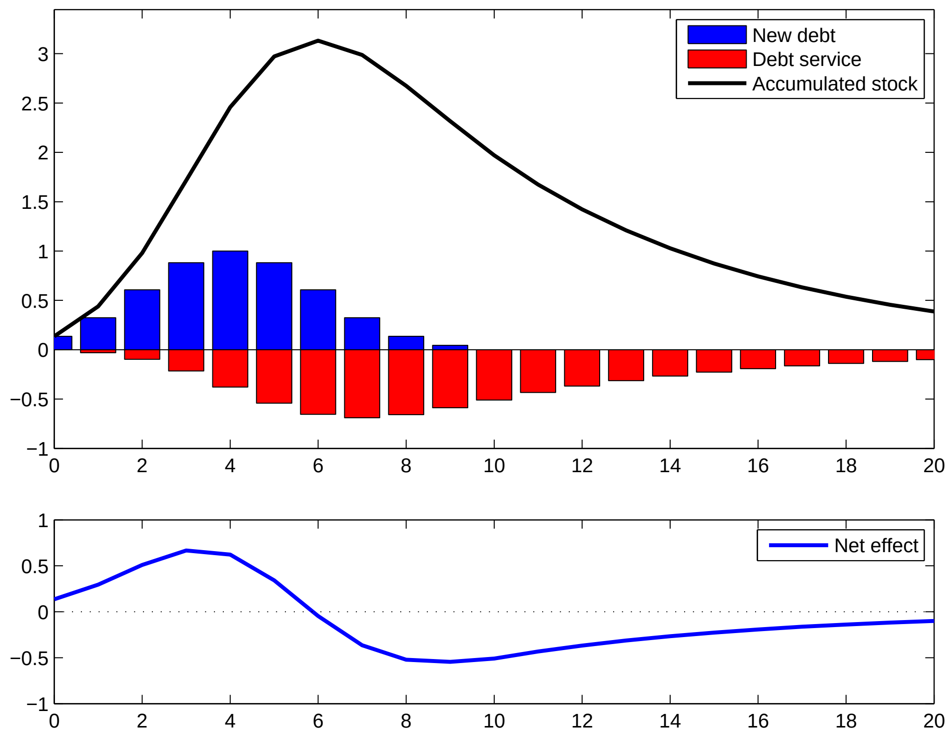

Figure 1: Sample dynamics of debt issuance and debt service.

the Bank for International Settlement (BIS) from 1999 onward compiled by Drehmann et al. (2015), and extend the time series backwards to 1980 or as far as possible.[8] We normalise debt service by income as in the BIS database. However, we undertake robustness checks normalising debt service by GDP.

Since new credit (net of refinancing) is generally not directly measured, we proxy it by the growth rate of real household sector debt, $\Delta d_{i,t}$, where $d_{i,t}$ is the logarithm of the household credit stock divided by the GDP price deflator for country i at time j. Our debt stock measure is taken from the BIS database compiled by Dembiermont et al (2013). These data capture credit to a specific sector from all sources, including bank credit, cross-border credit and credit from non-banks. In Figure 9 in the Appendix, we show credit growth and debt service for each country in the sample.

In our local projection regressions, we use several control variables to account for other factors than new credit and debt service that may drive macroeconomic dynamics. We include the real 3-month money market rate and two credit spreads: the credit spread and the term spread. The term spread captures the difference between the three month money market and 10-year government bond rate. The credit spread is constructed as the spread between the general corporate bond index and the weighted

[8] Appendix B.2 describes in detail how our time series on debt service are constructed and lists the coverage for each country. The results in Section **??** remain the same if we limit the panel only to publicly available data.

average of the five and 10 year government bond rates in each country, following Krishnamurthy and Muir (2016). We also include the change in labor productivity which may be important for explaining the dynamics of credit booms (Gorton and Ordonez (2016)). In addition, we control for inflation and the change in the average interest rates households pay on the stock of their debts. To avoid that we pick up the effects of financial crisis, we also insert a dummy that takes the value of one in the year of the crisis and 2 years thereafter.[9] In a robustness section, we also include consensus forecasts for GDP growth in the following year. The exact definitions, availability and sources for all variables are listed in Appendix (B.1).

4 Empirics of Debt Issuance and Debt Service

The main insights from the accounting framework are found in the raw data. A simple cross programme between real debt growth and debt service (left-hand panel, Figure **2),** shows that real debt growth leads debt servicing by some years as our accounting framework would suggest. In particular, the cross-correlation reaches a peak around 5 to 10 years. Note that the lead-lag relationship holds even though debt service in the data changes in response to interest rate changes whereas our accounting framework assumed, for simplicity, that interest rates remain constant.

The relationships identified by the accounting framework become even clearer, when we focus on the evolution around major peaks in real debt growth (right-hand panel, Figure **2)** . To identify peaks, we apply a simple dating algorithm as in Harding and Pagan (2002) to annual data. This identifies local maxima, subject to the constraint that the cycle is at least 2years long, and each phase lasts at a minimum one year. To focus on credit booms, we only take peaks in the 75th percentile of the distribution. And prior to taking the mean across countries and episodes, both variables are normalised by country specific averages and standard deviations.

The figure highlights two key insights from the accounting framework. First and in line with the cross-correlogram, real debt debt growth leads debt service. When we look at the median evolution around peaks in our sample, debt growth peaks four years ahead of debt service. But across countries and peaks, the lag ranges from a minimum of two to a maximum of seven years. Second, the figure shows clearly that the debt service continues to rise when real credit growth already starts to decrease. Note that these dynamics are also evident at the country level (see Figure 9 in the Appendix).

5 Debt Service and Output

5.1 Empirical Framework

We use local projections a la Jorda (2005) to assess the dynamic relationship between credit, debt service and output. In a first step, we establish the predictive power of new

[9] We use crisis data by Drehmann and Juselius (2014) that are based on amended data by Laeven and Valencia (2012).

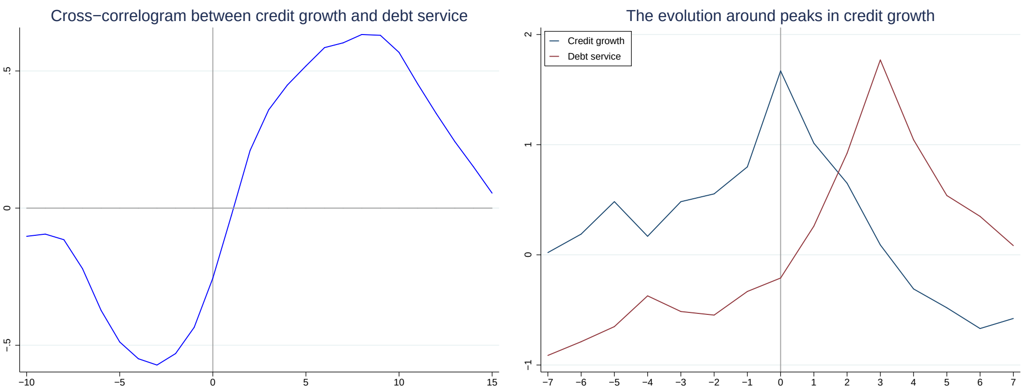

Figure 2: Before calculating the cross correlation or mapping the media evolutionof real credit growth and debt service around major peaks in real credit growth (time 0),both variables are normalised by country specific averages and standard deviations. Major peaks in credit growth are identified by a simple dating algorithm and the condition that real credit growth is in the 75th percentile of the distribution.

credit and debt service for future output growth.[10] In particular, we estimate versions of the general specification

$$\Delta y_{i,t+h} = \alpha^h_{0,i} + \alpha^h_{1,t} + \beta^h_1 s_{i,t} + \beta^h_2 \Delta d_{i,t} + controls + \varepsilon_{i,t+h} \tag{1}$$

where $y_{i,t}$ denotes the logarithm of annual real GDP for country i. Our estimates of β^h_1 and β^h_2 for successive values of h trace out the impulse response functions of GDP growth from unit changes in household debt service and credit growth, respectively.

A key question for our analysis is how credit booms feed into the real economy through new credit and debt servicing. To answer it we first consider the impulse response function of credit growth. This impulse response function embodies all factors that dynamically respond to the initial credit impulse and feed into the real economy, including debt servicing. Hence, we label it the "net_effect" of credit. From (1), we see that the net effect at time $t + h$ is

$$\text{net\_effect}_h = \beta^h_2. \tag{2}$$

To understand the net effect in relation to our accounting framework, we decompose it into the part that goes through debt servicing and the part that captures all other effects. We discuss the intuition behind this decomposition below and provide a formal derivation in the appendix..

The part of the net effect that goes via debt servicing – the debt service effect or "service_effect" for short – can be calculated in two steps. First, for any finite prediction horizon h we successively regress debt servicing at time $t + 1$, $t + 2$, ..., $t + h - 1$ on credit growth (and controls) at time t. The $h - 1$ estimated credit growth coefficients,

[10]We follow the convention of using "prediction" in reference to the within-sample impulse responses and "forecasting" for out-of-sample predictions.

$\beta^j_{\Delta d}$, from these regressions tell us how debt servicing consecutively changes due to a unit increase in credit growth at t. Second, we regress output growth at $t+h$ on debt servicing (and controls) at times $t+h-1, ..., t+1$ and collect the corresponding coefficients, $\beta^{h,j}_s$. These coefficients tell us how past debt servicing affects current output growth. We can now calculate the "service effect" by multiplying the predicted increases in debt servicing with their predicted effects on GDP growth:

$$\text{service\_effect}_h = \sum_{j=1}^{h-1} \beta^{h,j}_s \beta^j_{\Delta d}. \tag{3}$$

Finally, the impulse response of all remaining factors once we account for debt servicing – which we call "other_effects" – can be calculated as

$$\text{other\_effects}_h = \beta^h_2 - \sum_{j=1}^{h-1} \beta^{h,j}_s \beta^j_{\Delta d}. \tag{4}$$

According to our accounting framework in Section 2, the other_effects should primarily reflect the effects of new credit and, hence, if relevant at the aggregate level, we would expect them to be positive.

We present the empirical evidence in two steps. We first show that credit growth and debt service are useful for predicting future GDP growth and report the resulting impulse responses. Secondly, in line with the accounting framework in Section 2, we decompose the local projections of a unit increase in credit growth into the effects that go via debt servicing and the other effects. We conclude the section by conducting several robustness checks.

5.2 Credit growth, debt service and future output growth

Table 1 shows that both credit growth and debt servicing are useful for predicting future GDP growth. The effect of current credit growth on one-year ahead GDP growth, for instance, is positive and highly significant. This is in line with our accounting framework as new debt issuance should have positive effects provided that net-transfers from lenders to borrowers boost aggregate demand in general equilibrium. Adding credit growth increases the adjusted within-variation R^2 by 6 percentage points (model 1) compared to a model with just lags of GDP growth. When debt servicing is added to the model, R^2 increases by a further 12 percentage points. This variable has a significant and negative effect on GDP growth as predicted by our accounting framework and it does not materially alter the coefficient on credit growth.

The effects of credit growth and debt servicing are robust and do not qualitatively change if we, for example, only use data until 2000 (model 4), add several macro variables (model 5), and add time fixed effects (model 6). With time fixed effects, the magnitude of the credit growth and debt service effects become smaller suggesting that there are sizable global components in credit, as recently evidenced in Mian et al (2016).

	(1) Only $\Delta d_{i,t}$	(2) $\Delta d_{i,t}$ and $s_{i,t}$	(4) Pre 2000	(5) Macro	(6) Year FE
	Dependent variable is: $\Delta y_{i,t+1}$				
$\Delta d_{i,t}$	0.14^{***}	0.12^{***}	0.08^{***}	0.12^{***}	0.03
	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)
$s_{i,t}$		-4.71^{***}	-5.35^{***}	-3.19^{**}	-2.11^{***}
		(0.78)	(0.95)	(1.09)	(0.49)
N	455	455	188	337	455
adj. R^2	0.24	0.36	0.45	0.51	0.70
	Dependent variable is: $\Delta y_{i,t+3}$				
$\Delta d_{i,t}$	-0.02	-0.04	-0.01	-0.04	0.00
	(0.05)	(0.05)	(0.06)	(0.03)	(0.04)
$s_{i,t}$		-4.89^{***}	-5.97^{***}	-3.92^{**}	-2.58^{**}
		(0.86)	(1.79)	(1.40)	(0.91)
N	421	421	159	313	421
adj. R^2	-0.00	0.13	0.17	0.14	0.63
	Dependent variable is: $\Delta y_{i,t+5}$				
$\Delta d_{i,t}$	-0.09^{*}	-0.10^{*}	-0.08^{*}	-0.07^{*}	-0.04
	(0.05)	(0.05)	(0.04)	(0.04)	(0.03)
$s_{i,t}$		-2.80^{***}	1.73	-1.88	-1.93^{**}
		(0.80)	(1.97)	(1.15)	(0.84)
N	387	387	133	288	387
adj. R^2	0.02	0.06	0.17	0.09	0.61
Country FE	✓	✓	✓	✓	✓
lags of $\Delta y_{i,t}$	✓	✓	✓	✓	✓
Controls				✓	
Time FE					✓

Table 1: New credit and the debt service burden helps to predict future GDP growth. Notes:. All models include country fixed effects and $\Delta y_{i,t}$, $\Delta y_{i,t-1}$ and $\Delta y_{i,t-1}$. Control variables in Model (5): real money market rates, credit spread, term spread, change in inflation, change in the average nominal interest rate on the stock of debt, change in labor productivity and a dummy variable that takes the value 1 two years after financial crises. Standard errors in parenthesis are clustered along the country dimension. Adj. R^2 refers to the within variation coefficient of determination

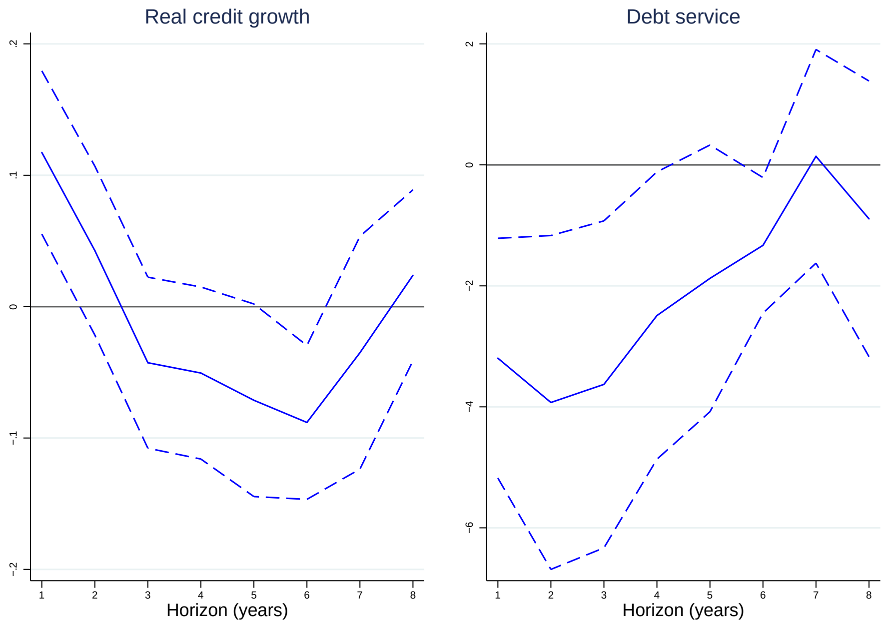

Figure 3: The negative growth effects transmit quickly for debt servicing and slowly for debt-to-GDP growth. Notes: The figure shows the implied local projections (solid lines) and standard errors (dotted lines) for unit changes in $\Delta_3 d_{i,t}$ and $ds_{i,t}$, respectively, from Model (5) in Table 1.

To not oversaturate the model, we will use model 5 as our baseline specification going forward. This controls for several important macroeconomic factors, in particular credit spreads that have been found to be important predictors for future GDP (Gilchrist and Zakrajsek (2012) or Krishnamurthy and Muir (2016)). We also include the level of real money market rates, the term spread, the change in inflation, the change in the average interest rate households pay on the stock of debt, the change in labor productivity and dummy variable takes the value of one during and two years after financial crises.

Table 1 also shows that the impulse response to credit growth is positive at short horizons, but becomes increasingly negative as the horizon gets longer. In contrast, the impulse responses to debt servicing is negative but decreasing in absolute magnitude at all horizons. This pattern is confirmed in Figure 3 which shows the impulse responses from model (5) in Table 1 up to a eight year horizon. The effect of credit growth turns negative after three years and its trough occurs in year six. The effect of debt servicing is negative at all horizon but disappears after approximately six years.

The negative effects of credit growth at medium horizons are fully in line with the findings in Mian et al (2015). And given our accounting framework, they raise the question whether they are due to rising debt service levels or something else. We study this issue next.

5.3 Identifying the channel from credit to future output

Increasing debt service payments can, to a large degree, account for the negative impulse responses to credit growth at long horizons. The other effects of credit growth, after accounting for debt servicing, are positive.

To build intuition for these results, Table 2 reports the details of the decompositions in equations (2) to (4) for the 5-year prediction. In column (1) of the table, we see that a unit increase in household credit growth at t is expected to reduce output growth by -0.069 percentage points five years later. How much of this is due to projected increases in debt servicing? The change in credit increases debt servicing one-for-one in t and then positively in all consecutive periods (columns 2-5). The joint debt service effect is obtained by summing the projected increases in debt servicing with their corresponding estimated effects on output in column (6). The outcome is reported in column (7) and suggests that the intermediary effect from debt servicing is -0.079 which is larger in absolute magnitude than the entire projected net effect. This also implies that the other effects, once debt servicing has been accounted for, are positive and equal to 0.01 (column 8). Finally, the directly estimated "other_effects" from Equation 4 is 0.008 (column 9) and, hence, broadly consistent with the results from our decomposition.

Figure 4 reveals that the estimated effects from new debt, debt service and net cash flows closely follow the predicted patterns from our accounting framework (Figure 1) for all horizons. Following an increase in real credit growth at t_0,"other_effects" are always positive but they decline over time. This is in line with what one would expect from new credit and the fact that credit growth is autocorrelated. On the other hand, the effects of debt servicing are always negative and increase until they reach their peak in year four. The net effect - or net cash flow in our accounting framework - turns negative in the third year. This is between the peak in credit growth and the peak in debt service as our accounting framework suggests. Equally in line with the accounting framework, the minimum of net cash flows is after the peak and debt service and we estimate this to occur in year 6.. Interestingly, at the end of our longer forecasting horizon we see some signs of new debt picking up again, possibly signaling some inherent cyclicality.

5.4 Robustness

The estimated debt service component and other components of the decomposition in Figure 4 are fairly robust. Figure 5 compares these components (dotted lines) to those obtained from several alternative specifications and samples (lines with triangles).

Variations to the set of control variables do not change the results qualitatively, but can have quantitative effects. For instance, adding one-year ahead GDP forecasts to the model reduces the magnitude of the net effect and the other effects in the first year, but leaves the debt service effect intact. This indicates that the forecasts account for credit growth to some extent, but not for debt servicing. Hence, debt servicing likely contributes new (orthogonal) information that may improve forecasting performance. Adding time fixed effects reduces all estimated effects by roughly half, even though they

	(1) $\Delta y_{i,t+5}$	(2) $s_{i,t+1}$	(3) $s_{i,t+2}$	(4) $s_{i,t+3}$	(5) $s_{i,t+4}$	(6) $\Delta y_{i,t+5}$	(7) service_effect	(8) net_effect	(9) $\Delta y_{i,t+5}$
$\Delta d_{i,t}$	-0.069^{*} (0.036)	0.008^{***} (0.001)	0.012^{***} (0.002)	0.015^{***} (0.003)	0.016^{***} (0.003)		-0.079	0.010	0.008 (0.036)
$s_{i,t+4}$						-1.432 (3.458)			-1.544 (3.614)
$s_{i,t+3}$						-7.288^{*} (3.648)			-7.251^{*} (3.708)
$s_{i,t+2}$						5.743^{**} (2.587)			5.780^{**} (2.531)
$s_{i,t+1}$						-2.128 (2.985)			-2.417 (3.041)
$s_{i,t}$		0.945^{***} (0.017)	0.841^{***} (0.044)	0.713^{***} (0.067)	0.581^{***} (0.105)	1.318 (1.277)			1.605 (1.924)
Country FE	✓	✓	✓	✓	✓	✓			✓
Lagged GDP	✓	✓	✓	✓	✓	✓			✓
Controls	✓	✓	✓	✓	✓	✓			✓

Table 2: Decomposition of the local projection at $t+4$ from a unit change in 3-year debt to GDP growth. Notes: 'Equation:' refers to the relevant equation in Section 5. Adj. R^2 refers to the within variation coefficient of determination. All models include country fixed effects, $\Delta y_{i,t}$, $\Delta y_{i,t-1}$ and $\Delta y_{i,t-1}$, real money market rates, credit spread, term spread, change in inflation, change in the average nominal interest rate on the stock of debt, change in labor productivity, a dummy variable that takes the value 1 two years after financial crises . Standard errors in parenthesis are clustered along the country dimension.

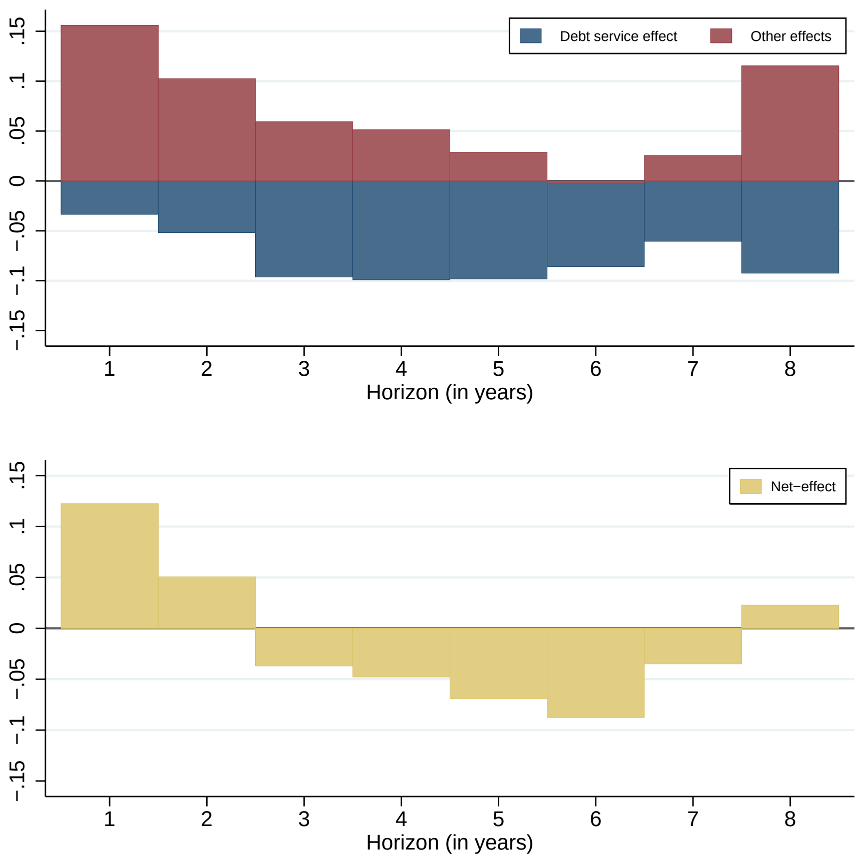

Figure 4: Empirical counterparts of new debt, debt service, and net cash flow. The upper panel shows (??), (3) over different horizons starting from a unit increase in 1-year debt-to-GDP growth. The lower panel shows the net effect as estimate in (2).

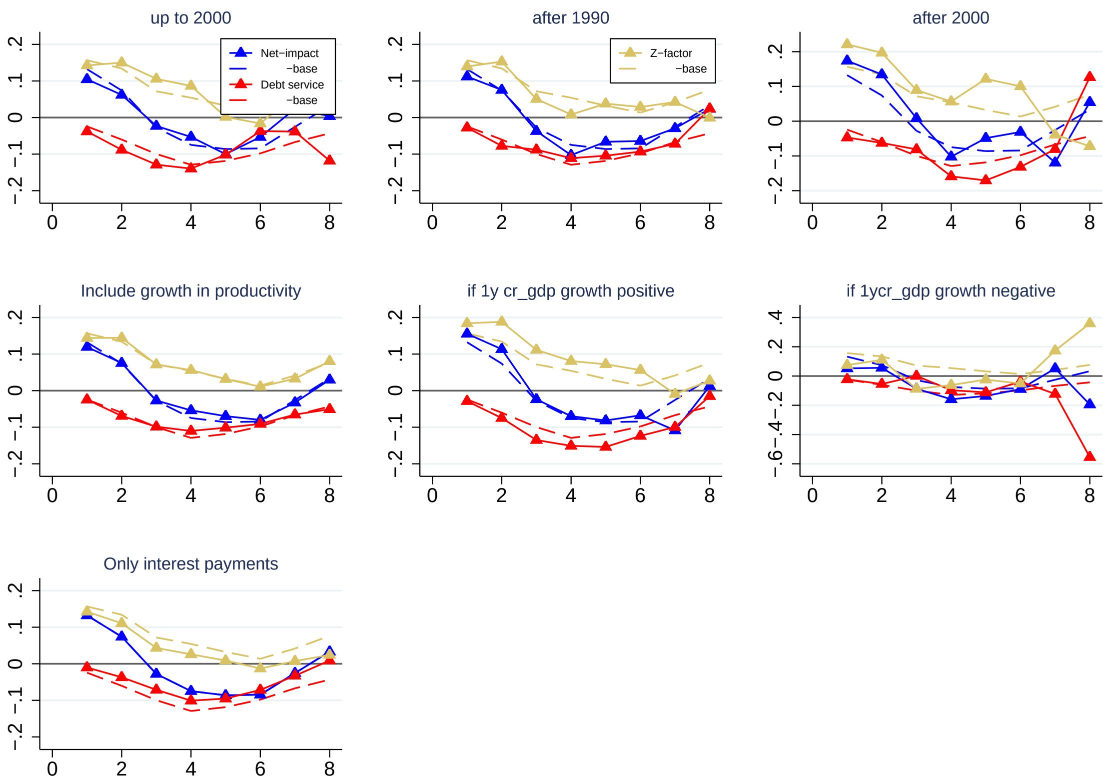

Figure 5: The debt service effect, other effects and net effect for different specifications. Lines with diamonds show the results for the different robustness checks, whereas dotted lines results for the baseline specification. As in the baseline specification, we always include $\Delta y_t, \Delta y_{t-1}, \Delta y_{t-2}$, real money market rates, credit spread, term spread, change in inflation, change in the average nominal interest rate on the stock of debt, change in labor productivity, a dummy variable that takes the value 1 two years after financial crises and country fixed effects. All control variables are indexed at t. "With GDP forecasts at $t+1$" adds the forecast for next year's GDP at t . "Time fixed effects" controls for year fixed effects. In "Only DSR hor -1", we only account for the impact of the change in credit growth on s_{h-1} and then the impac of s_{h-1} on $y_h$instead of including all $s_{t+1}...s_{h-1}$ in the models. For ""Before 2000" and "After 2000" we use samples that end or begin in the respective year. "Deb growth $>$ 0" and "Debt grrowth$<$ 0" look at samples when debt growth at t was either positive or negative. In the case of negative debt growth, we exclude the macro factors as controls except the lags of GDP growth to increase the sample size. The exclusion of macro controls in the full sample does not alter the results significantly. In "Only interest payments" we replace our standard measure of household debt service by interest payments on the stock of household debt divided by household income. In "Debt service normalised by GDP" we normalise household debt service by GDP instead of household income.

remain significant. This suggests that there may be a significant global component to the household credit cycle in line with the findings in Mian at al. (2016).

The results are neither generated by the Great Recession nor the boom that preceded it. For example the results are very similar in pre-2000 samples. If anything, the debt service effect is even stronger in this period. However, the negative debt service effect is more dragged out in the post-2000 sample compared to the pre-2000 sample. This may partly be due to the depth and length of the Great Recession, but it may also reflect the inability of central banks to lower rates much beyond the zero lower bound (e.g. Korinek and Simsek, 2016).

Results hold even at the country level. This is despite the fact that we have at most 35 years of data for an individual country. Given the limited sample size, we therefore exclude all macro controlls except the lags in GDP growth and only consider countries with at least 30 years of household debt service data. Figure 10 and 11 in Appendix C show that for all countries, credit growth has an initial beneficial impact on output growth and, with the exception of Japan, the debt servicing effect is always negative. But the size and dynamics of the net effects change. This suggests that the underlying mechanism that high credit growth feeds into future debt service which in turn depresses output is robust, but that the speed and size of transmission depends on country specific factors, presumably reflecting differences in the structure of mortgage markets for instance.

The results are also robust if we estimate the debt service and other effects from the impact of credit growth on debt service at horizon $h-1$, and its impacts on output growth at h. The results are virtually identical in comparison to the baseline where we take all future debt service (up to $h-1$) and their respective effect on GDP into account.

We also investigate the symmetry of the different effects by splitting the sample into periods where credit-to-GDP ratios were growing and periods where they were declining. The latter sample contains vastly fewer observations compared to the former. We therefore exclude all macro controls, except the lags of GDP growth for this regression, but this does not alter the full sample results significantly. Given several of these periods are at the end of the sample, we also consider only a prediction horizon of five years. Despite the differences in the samples and initial conditions, the results are qualitatively very well aligned.

Finally, the results do not depend on the exact debt service measure that we use. For instance, using only interest payments $r_{i,t}d_{i,t}$ – which captures all debt service variables of the form $(\delta_i + r_{i,t})\, d_{i,t}$ – results in very similar patterns as before. Also, normalizing the household debt servicing by GDP rather than household income has virtually no effects on the results.

It is particularly interesting to ask if the debt service effect that we uncover can account for the findings in a closely related paper by Mian et al. (2016), that credit-booms – defined by three-year growth in the credit-to-GDP ratio – can predict subsequent slowdowns in GDP growth. To make this comparison, we only need to replace real credit growth, $\Delta d_{i,t}$, with the three-year growth rate in credit-to-GDP, $\Delta_3\,(d_{i,t} - y_{i,t})$ in (1),

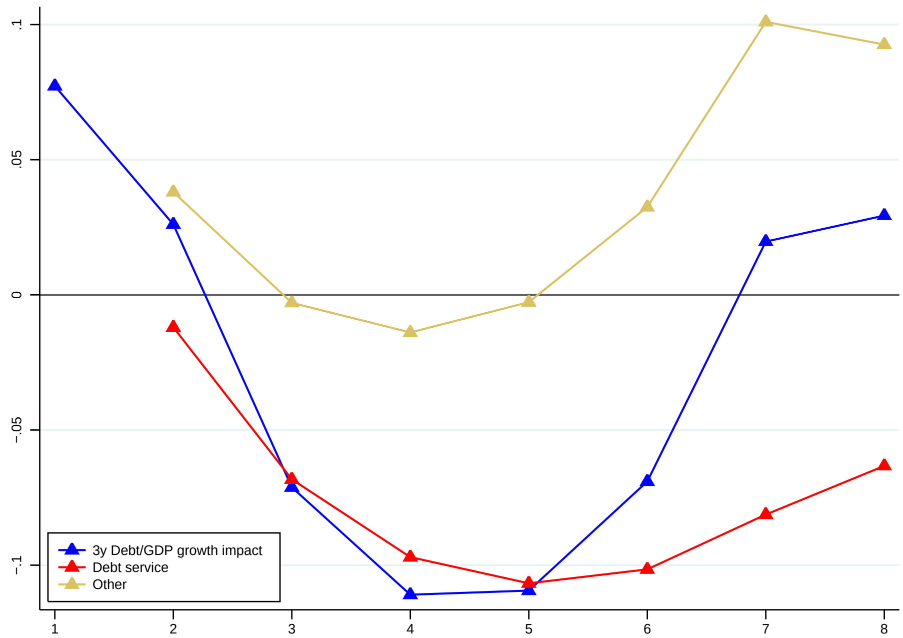

Figure 6: Decomposition of the local projections at various horizons and values of k in $\Delta_k d_{i,t}$.

(2), and (3). In Table 3 of Appendix C we show that the results in Mian et al. (2016) also hold in our sample and, moreover, that including the debt service variable to the model improves its fit.

We find that debt servicing can almost fully account for the predicted negative effects on future GDP growth from a unit increase in the three-year growth rate in credit-to-GDP. This is apparent from Figure 6 which plots the MSV impulse response function (blue line) decomposed into the service_effect (red line) and the other_effects (yellow line). The debt service effect is negative and larger or equal in absolute value compared to the MSV impulse response function. Hence, the other effects are consistently positive or close to zero. Interestingly, the MSV impulse responses and the other effects are positive in the initial periods, before the effects of increased debt servicing kicks in.

Using a three-year growth rate in debt-to-GDP ratio as a proxy for credit-booms makes it difficult to spot potential positive effects from credit extension. For instance, MSV pick this growth rate because it is the average duration of a credit boom in their data. Hence, after three years of positive credit-to-GDP growth we should expect new lending to decline. But this implies that the impulse responses will primarily reflect the painful debt servicing legacy of the boom, but not potential beneficial effects of new credit during the boom. That credit growth has positive effects on output at short horizons is indeed apparent from Figure 4. Taken together, these patterns seem more consistent with systematic over-borrowing rather than reductions in the quality of the loan portfolio, *per se*.

6 Debt service and the probability of crisis

There is clear evidence that credit booms increase risks of financial crises (eg Borio and Drehmann (2009), Reinhart and Rogoff (2009) or Schularick and Taylor (2012)). The literature has also shown that debt service is a useful early warning indicator (eg Drehmann and Juselius (2013), Detken et al (2014)). The predictive performance of debt service is particularly high for short horizons, whereas credit-related variables perform best in the medium run (Drehmann and Juselius, 2013) as the accounting framework would suggest. Given the previous result, we therefore investigate how much debt service helps to explain the effects of credit growth on the predictability of crisis.

To do this, we adapt our previous empirical framework to binary response models. In the first step, we re-estimate equation (1). But instead of having output growth at horizon $t+h$ as a left-hand side variable, we use a crisis indicator C_{t+h} that takes the value of 1 in a year of a financial crisis and 0 otherwise. To avoid post-crisis bias, we drop the first two years after a financial crisis (Bussiere and Fratzscher, 2006). We use a panel logit framework with country fixed effects. As a robustness check, we also use simple OLS with panel fixed effects. Given that our sample includes only 17 crises, we exclude macro factors.

To estimate the effect of credit growth on crisis likelihood that goes through debt service, we first regress the crisis indicator on debt service at $t+1$ to $t+h-1$. We then use our previous results relating debt servicing at time $t+1$, $t+2, ..., t+h-1$ to credit growth at time t. The coefficients of both models and the initial conditions at time t allow us to derive implied crisis probablities.

We assess the predictive performance of our models by reporting the Area Under the ROC Curve (AUC).[11] This statistic provides a full mapping between type I and type II errors that a binary response model generates across all possible thresholds that could be chosen for signalling a crisis. The ideal model defines a unique threshold above which the crisis would arrive with certainty and below which there would be no false alarms, giving rise to an AUC = 1. For a useless crisis indicator, on the other hand, the likelihood of a crisis arriving or not is the same for all thresholds so AUC = 0.5. Indicators that provides some useful information but also false alarms lie in between these two extremes. As such, the area under the curve (AUC) is a convenient and interpretable summary measure of the signalling quality of a binary signal. AUCs can be estimated using parametric and non-parametric estimators, and confidence bands and Wald statistics for comparing the AUCs of two signals can easily be computed (see e.g. Janes et al., 2009, and Pepe et al., 2009).

Figure 7 highlights that both credit growth and debt service are useful for predicting crises. Given that we use in-sample predictions, the country fixed effects mechanically have some forecast performance (light green line). However, both credit growth and

[11] Going back to World War II, the receiver operating characteristic (ROC) curve has a long tradition in the sciences (see e.g. Swets and Picket, 1982). Its applications to economics are more recent. See e.g. Cohen et al (2009), Gorr and Schneider (2011), Berge and Jorda (2011) and Jorda et al (2011).

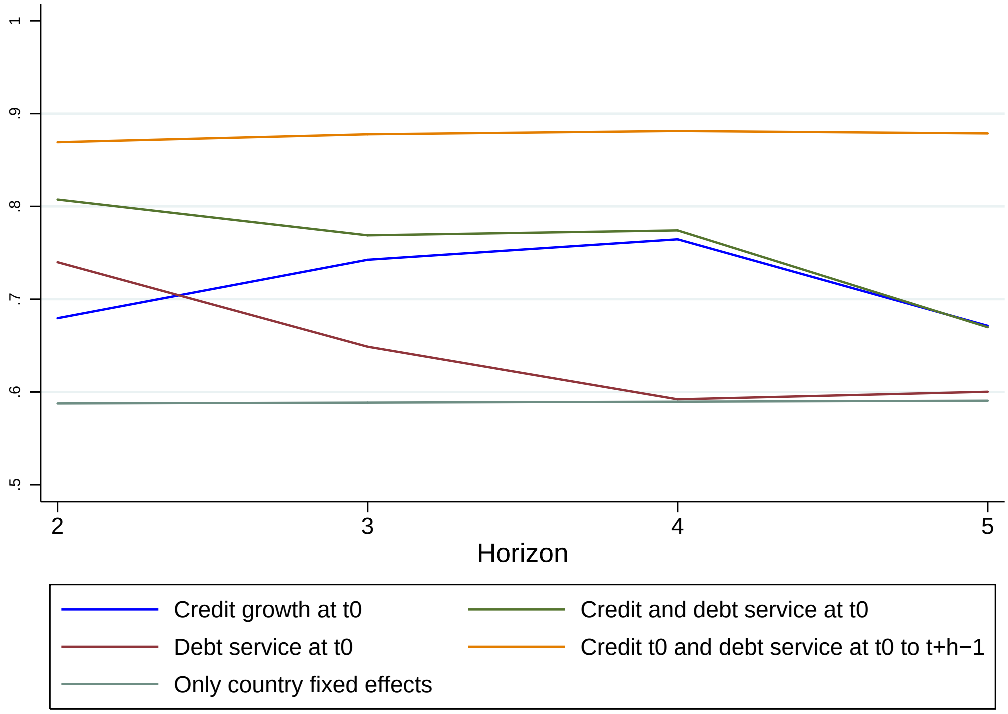

Figure 7: AUC for different models

debt service add significantly to it. In particular, debt service is more useful for shorter horizons (brown line), while credit growth performs best for predicting crisis 3 to 4 years in advance (blue line). Clearly, combining both indicators enhances the forecast performance even more, in particular if not only variables at time t (green line) but also debt service at time $t+1$ up to $t+h-1$ (orange line) are taken into account.[12]

As for the effects on output, debt service is also the painful legacy of credit booms when it comes to crisis prediction. This is evident from Figure 8. The blue line shows the AUC of the model with only Δd_t and its 95% confidence intervals for horizons from to up to 5 years. The red line is the AUC of the crisis probability implied by the effects of credit growth that goes through debt service. As can be seen, from horizon 3 onward, the AUC of the probability implied by the effects of credit growth on debt service is nearly the same as the AUC of the model with only credit growth. And the effects are not statistically significantly different.

[12]This is in line with Drehmann and Juselius (2013) who showed that combining credit and debt service in early-warning-indicator models generates AUCs of more than 90% for horizons up to 3 years.

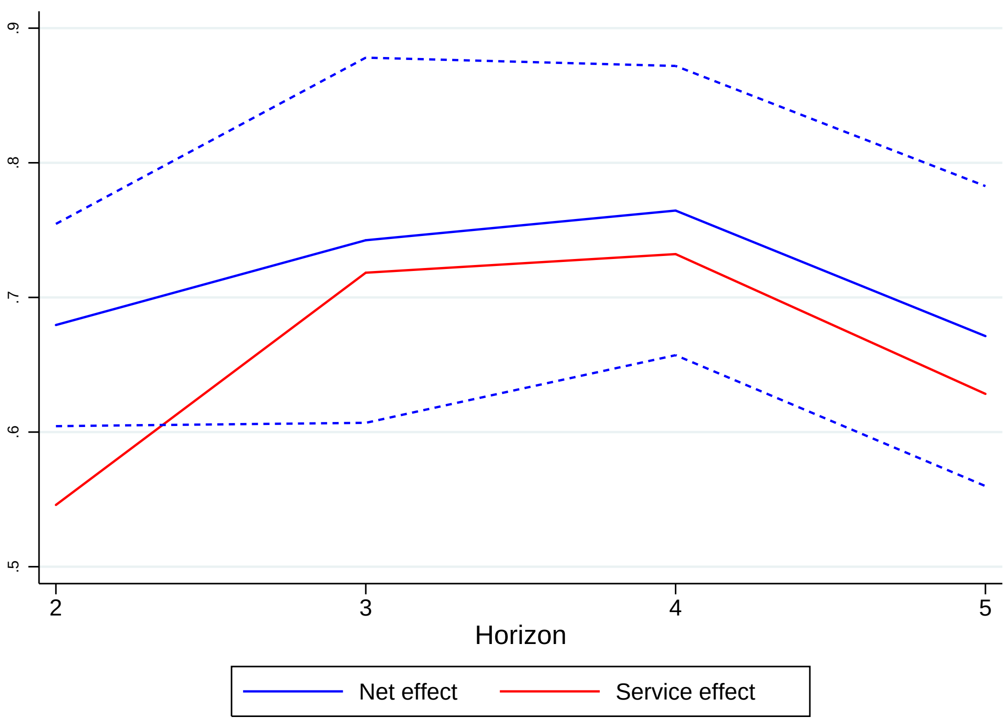

Figure 8: Net effect shows the AUC of the model with only credit growth at $t = 0$. Blue dashed lines are 95% confidence intervals. Service effect is the AUC of the crisis probability implied by the effects of credit growth that go through debt service.

7 Conclusions

Debt service is the key variable linking past credit booms to future macroeconomic outcomes. This paper analyzes this mechanism conceptually and demonstrates its importance empirically. Finally, it shows that a number of interesting recent empirical findings on the consequences of credit booms can be both explained and strengthened by explicitly considering debt service. This includes the link from credit booms to slow growth for several years in the future, to deeper recessions, and to a higher likelihood of financial crises. We thus call debt service the painful legacy of credit booms.

Although our findings on the importance of debt service are an important step forward, there are many questions that remain for future research. First, our paper remains agnostic on whether the future output effects of credit booms are driven by changes in potential output or by shortfalls in aggregate demand that simply were not or could not effectively be offset by monetary policy. Secondly, and assuming that this question has been answered, an important follow-up question is how policymakers should optimally respond, i.e. how they should trade off current output concerns with future debt service obligations. Third, our findings suggest that there are important structural aspects of credit markets that matter greatly for the aftereffects of credit boom, for example the maturity of debt contracts, whether they are fixed- or flexible-rate, and whether they can be refinanced. These aspects therefore need to be included in any optimal policy exercise.

We hope that our findings will be useful for future efforts to better model credit cyles.

Bibliography

Aikman, D, A G Haldane and B D Nelson (2015): "Curbing the credit cycle," *The Economic Journal* 125(585), pp. 1072-1109.

Bernanke B, M Gertler and S Gilchrist (1999): "The Financial Accelerator in a Quantitative Business Cycle Framework," in J Taylor and M Woodford, eds., *Handbook of Macroeconomics* 1C, pp. 1341-1393.

Borio, C and M Drehmann (2009): "Assessing the risk of banking crises - revisited", *BIS Quarterly Review*, March, pp 29-46.

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

Cerra, V and S C Saxena (2008): "Growth dynamics: The myth of economic recovery", *American Economic Review* 98(1), pp 439-457.

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

Drehmann M, M Juselius (2013): "Evaluating early warning indicators of banking crises: Satisfying policy requirements", *BIS Working Paper* 421.

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.

Farhi, E and I Werning (2016): "A theory of macroprudential policies in the presence of nominal rigidities", *Econometrica*, forthcoming.

Fostel, A and J Geanakoplos (2013): "Reviewing the leverage cycle", mimeo.

Gourinchas, P-O and M Obstfeld (2012): "Stories of the twentieth century for the twenty-first", *American Economic Journal: Macroeconomics* 4(1), pp 226-265.

Iacoviello, M and R Minetti (2008): "The credit channel of monetary policy: Evidence from the housing market", *Journal of Macroeconomics* 30(1), pp 69-96.

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, 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 (2014): "Betting the house", Conference Paper, NBER International Seminar on Macroeconomics.

Kiyotaki, N and J Moore (1997): "Credit cycles", *Journal of Political Economy* 105(2), pp 211-248.

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

Krishnamurthy A and T Muir (2016): "How Credit Cycles across a Financial Crisis," mimeo.

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

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

Mian, A and A Sufi. (2009): "The Consequences of Mortgage Credit Expansion: Evidence from the U.S. Mortgage Default Crisis," *Quarterly Journal of Economics* 124(4), pp. 1449-1496.

Mian, A and A Sufi. (2010): "House Prices, Home Equity-Based Borrowing, and the US Household Leverage Crisis," *American Economic Review* 101(5), pp. 2132-2156.

Mian, A and A Sufi. (2014): *House of Debt.* The University of Chicago Press.

Mian, A, A Sufi and E Verner. (2015): "Household Debt and Business Cycles Worldwide," mimeo.

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.

Quercia, R G, G W McCarthy and S M Wachter (2003): "The impacts of affordable lending efforts on homeownership rates", *Journal of Housing Economics*, 12(1), pp

29-59.

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 NominalWage Rigidity, Currency Pegs, and Involuntary Unemployment," *Journal of Political Economy*, forthcoming.

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 Debt Issuance, Net Cash Flows, and Debt Service

This appendix shows that the results of Proposition 1 on the lag structure between debt issuance, debt service and net cash flows can be proven with strict inequalities when we move to a continuous time framework. We again assume an exogenous hump-shaped process of debt issuance, but now over a continuous interval $[0, T]$ that satisfies $d_0 = d_T = 0$ and $d_t > 0$ 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 $\dot{d} > 0$ for $t \in [0, t^*)$ and $\dot{d} < 0$ for $t \in (t^*, T)$, i.e. debt issuance is increasing up to its peak and decreasing after the peak. Furthermore, we continue to assume that the process of debt issuance 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 $d_t = 0$ for $t > T$.

Given these assumptions, total debt outstanding grows at rate

$$\dot{D}_t = d_t - \delta D_t$$

1. Debt service peaks *after* peak in debt issuance At the peak of debt issuance t^*, debt is still growing $\dot{D}_t > 0$ if new issuance exceeds depreciation, $d_t > \delta D_t$. An upper bound on debt D_{t^*} is $t^* d_{t^*}$. Our analytic condition on timing implies that $\delta D_{t^*} < \delta t^* d_{t^*} < d_{t^*}$ so debt is still growing at the peak of new debt issuance 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 change in 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 debt issuance is over at T, since $\dot{D}_T = -\delta D_T < 0$. In summary, $\hat{t} \in (t^*, T)$.

2. Net cash flow peaks *before* peak in debt issuance Net cash flows in our setting here are given by $n_t = d_t - (\delta + r) D_t$ with derivative

$$\dot{n}_t = \dot{d}_t - (\delta + r) \dot{D}_t \tag{5}$$

At the peak of debt issuance t^*, we find that $\dot{n}_{t^*} < 0$ because the first term $\dot{d}_{t^*} = 0$ 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 debt issuance reaches its peak.

3. Net cash flow turns negative *after* peak in debt issuance and *before* end of credit boom Our condition on the timing of debt issuance implies $(\delta + r) D_{t^*} < (\delta + r) t^* d_{t^*} < d_{t^*}$. This implies that $n_{t^*} > 0$ so net cash flow will turn negative *after* the peak in debt issuance. 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 $n_T = 0$.

4. Net cash flow reaches its minimum *after* peak in debt service We observe that net cash flow is still declining when the level of debt and debt service peak at $\hat{t}$ since

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

B Data Appendix

B.1 Description of Variables

[to be completed]

B.2 Construction of Debt Service

An ideal measure of debt service would consist of $(Amortisations_{i,t} + Interestpayments_{i,t}) = (\delta_{i,t} + r_{i,t}) d_{i,t}$ as described in section 2. While interest payments are recorded in national accounts, amortisations are unfortunately not directly observable. For this reason, the BIS imputes debt service by assuming that debt is structured as an installment loan in the aggregate, i.e. interest payments and amortisations are repaid in equal portions (installments) over the average remaining maturity in the stock of debt.[13] This assumes that differences between the repayment structures of individual loans tend to cancel out in the aggregate.[14] Using the formula for calculating the debt service costs

[13]This methodology was originally developed at the Fed (Lucket, 1980). See also Dynan et al (2003).

[14][AK: this is a bit cryptic to me.] For example, consider 10 loans of equal size for which the entire principal is due at maturity, each held for 10 periods and taken out in successive years over a decade. After 10 periods, when the first loan falls due, the flow of repayments on these 10 loans will jointly be indistinguishable from the repayment of a single installment loan.

of an installment loan, the aggregate debt service is derived as:

$$ds_t = \frac{r_t d_t}{1 - (1 + r_t)^{-m}} \tag{6}$$

where m is the average remaining maturity of the debt stock and r_t is the average lending rate on stock of debt.

Drehmann et al (2015) show that the derivation of aggregate debt service using equation (6) is justified even if debt contracts at the micro level are structured in a multitude of fashions with different interest rates and different repayment characteristics. They perform simulations in which they find that using the average maturity in (6) instead of explicitly accounting for the different maturities of individual debt contracts has only negligible impact on the dynamics of debt service for realistic values of m. This is in line with previous Fed findings for the household debt service ratio (Federal Reserve Board, 2013). As a robustness test, to ensure that our results are not meaningfully driven by differences in loan structure, we simply use interest payments $r_t d_t$ as an alternative in Section 5.4. We find the very similar results with this alternative measure of debt service.

	(1) MSV	(2) Only DS	(3) Base	(4) Pre 2000	(5) Macro	(6) Time FE
	Dependent variable: $\Delta y_{i,t+1}$					
$\Delta_3 d_{i,t}$	0.03 (0.04)		0.08** (0.03)	0.09** (0.04)	−0.02 (0.03)	0.02 (0.03)
$ds_{i,t}$		−4.95*** (0.72)	−5.28*** (0.76)	−6.03*** (0.97)	−2.16** (0.98)	−2.22*** (0.50)
Adj. R^2	0.18	0.31	0.32	0.45	0.43	0.69
Obs	455	455	455	203	363	455
	Dependent variable: $\Delta y_{i,t+4}$					
$\Delta_3 d_{i,t}$	−0.16*** (0.05)		−0.13** (0.06)	−0.15** (0.05)	−0.14** (0.05)	−0.04 (0.03)
$ds_{i,t}$		−3.60*** (0.76)	−3.02*** (0.93)	−1.26 (0.98)	−3.27** (1.29)	−2.19** (0.91)
Adj. R^2	0.06	0.07	0.10	0.21	0.14	0.62
Obs	404	404	404	203	327	404
Lags of $\Delta y_{i,t}$	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓
Time FE						✓
Control vars.					✓	

Table 3: Replicating Mian et al. (2016) and adding the debt service burden. Notes: Adj. R^2 refers to the within variation coefficient of determination. All models include country fixed effects and $\Delta y_{i,t}$, $\Delta y_{i,t-1}$ and $\Delta y_{i,t-1}$. Control variables in Model (5): $spr^{nfc}_{i,t}$, $spr^{gov}_{i,t}$, $\Delta cr_{i,t}$, π_t, r^{ffr3}_t, $\Delta u_{i,t}$ and a dummy for 2008. Standard errors in parenthesis are clustered along the country dimension.

C Additional tables and graphs

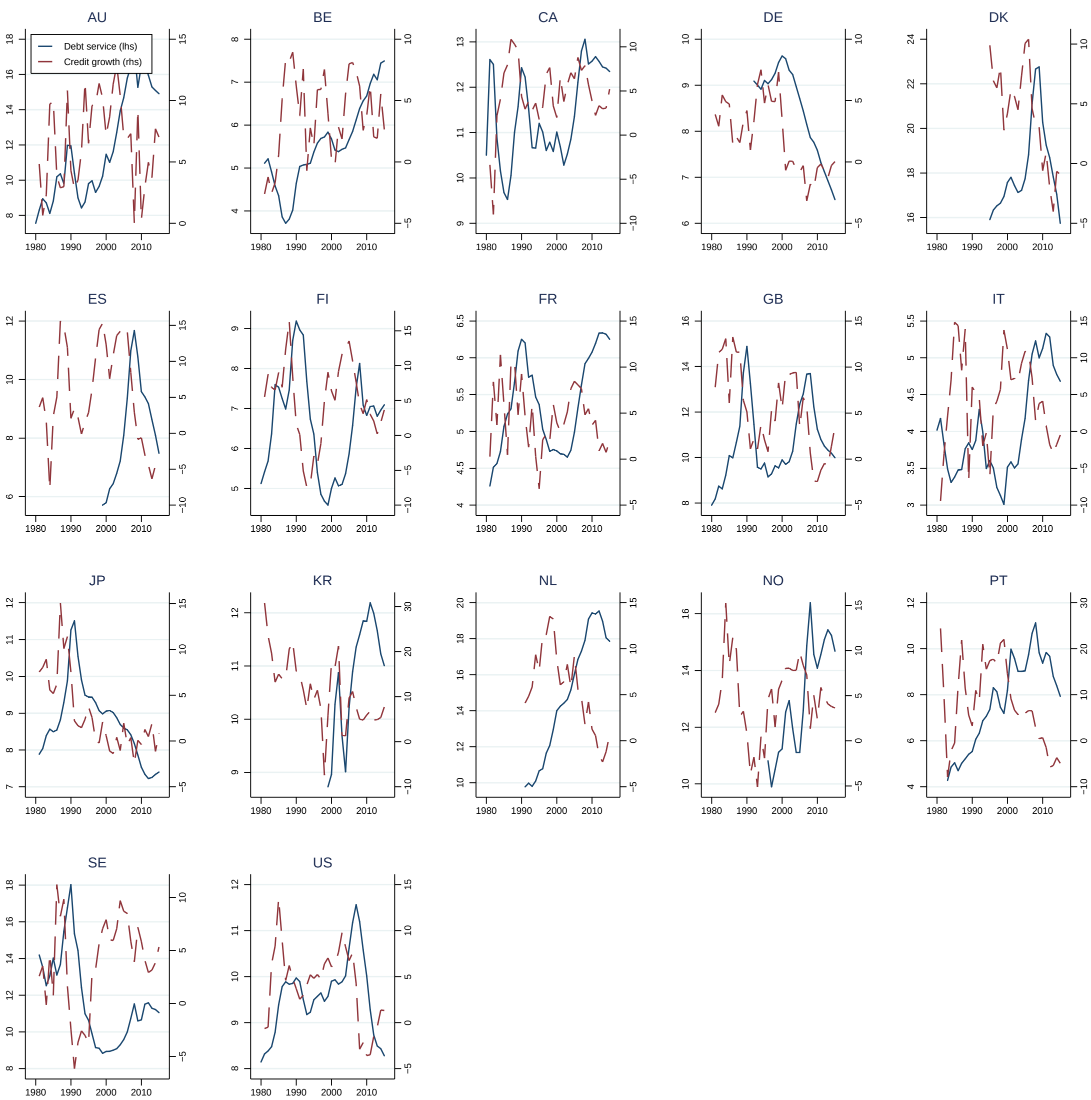

Figure 9: Real credit growth and debt service for the household sector in each country

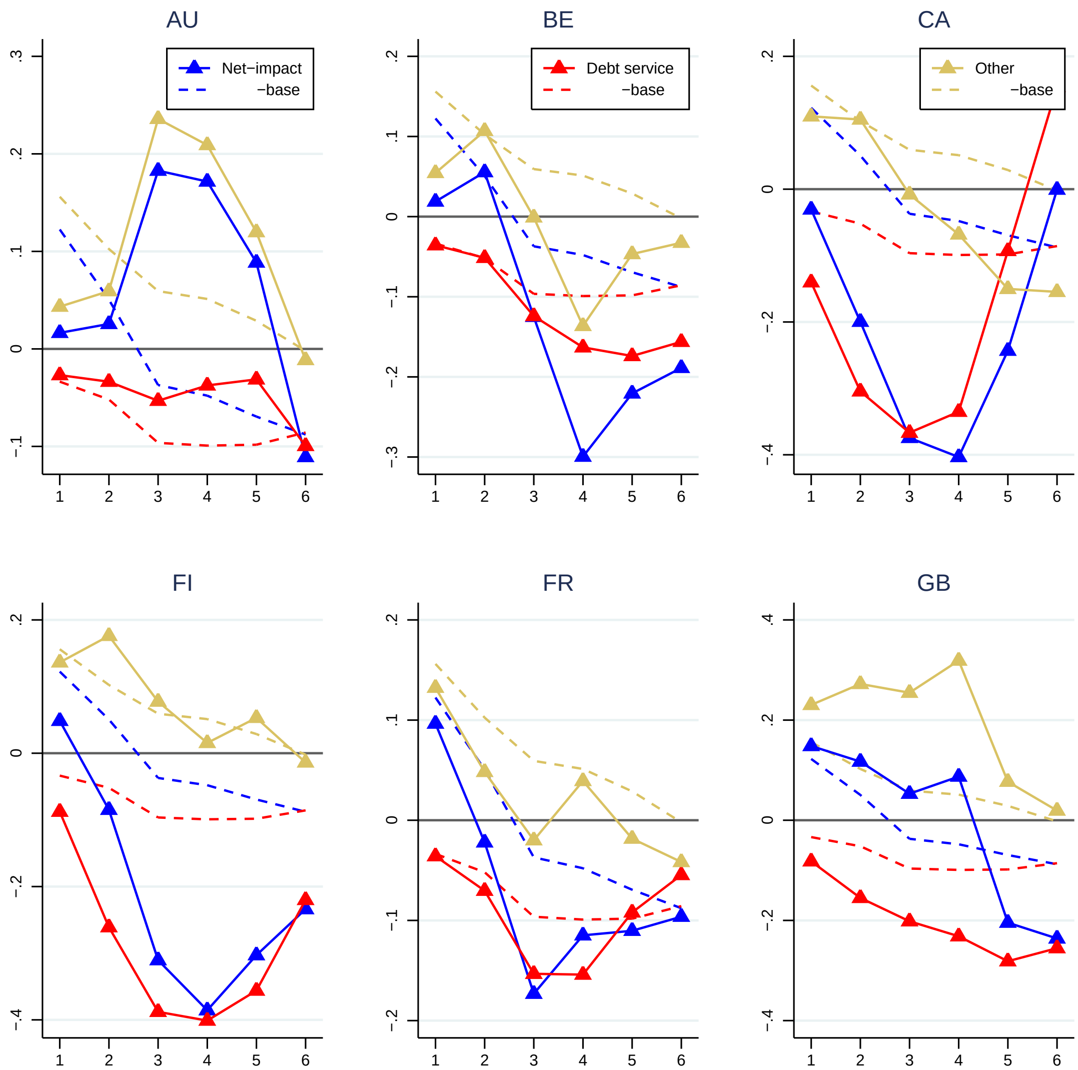

Figure 10: The estimates of net net impact, the debt service effect and other effects at the country level. Lines with diamonds show country results, whereas dotted lines results for the baseline specification. At the cuntry level, we only include $\Delta y_t, \Delta y_{t-1}$ and Δy_{t-2}as controls.

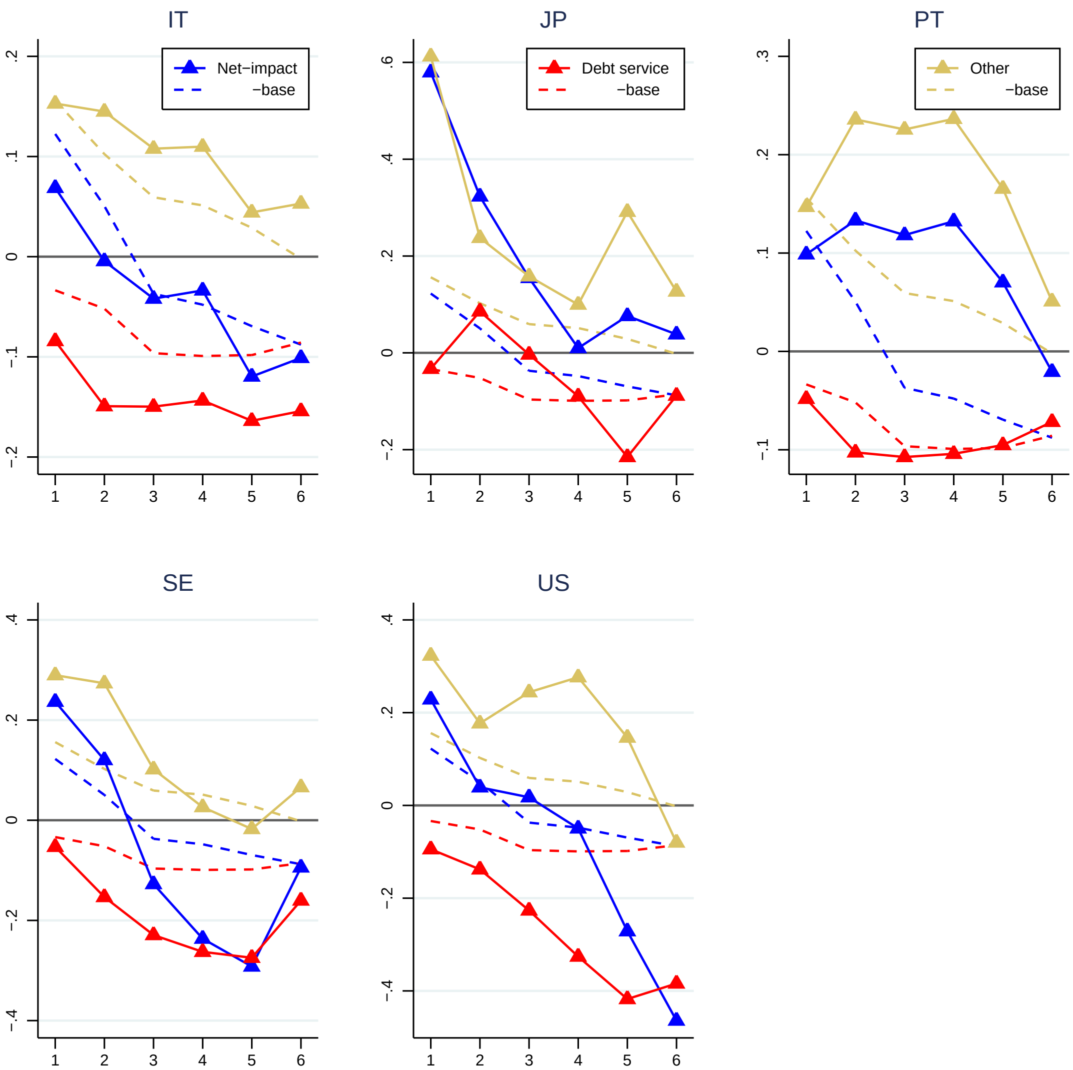

Figure 11: The estimates of net net impact, the debt service effect and other effects at the country level. Lines with diamonds show country results, whereas dotted lines results for the baseline specification. At the cuntry level, we only include $\Delta y_t, \Delta y_{t-1}$ and Δy_{t-2}as controls.