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## Leverage dynamics and the burden of debt

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Mikael Juselius – Mathias Drehmann

# **Leverage dynamics and the burden of debt**



Bank of Finland Research  
Discussion Paper  
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# Leverage dynamics and the burden of debt<sup>\*</sup>

Mikael Juselius<sup>†</sup> and Mathias Drehmann<sup>‡</sup>

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## Abstract

In addition to leverage, the debt service burden of households and firms is an important link between financial and real developments at the aggregate level. Using US data from 1985 to 2013, we find that the debt service burden has sizeable negative effects on expenditure. Its interplay with leverage also explains several data puzzles, such as the lack of above-trend output growth during credit booms and the depth and length of ensuing recessions, without appealing to large shocks or non-linearities. Using data up to 2005, our model predicts paths for credit and expenditure that closely match actual developments before and during the Great Recession.

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# 1 Introduction

Credit and output often diverged substantially in the United States over the last decades in contrast to the intuition from standard macro-finance models. For instance, the recoveries after the Great Recession and the recession in the early 1990s were largely “creditless”, ie output picked up without an equal pick up in credit. Less noted but more puzzling, the preceding booms were essentially “growthless” as credit grew rapidly while output remained roughly on trend. Hence, the credit-to-GDP ratio surged ahead of the two recessions and fell during the recovery phases. We show that understanding the drivers of these credit-to-GDP developments helps to resolve the data puzzles and clarifies the link between financial and real developments.

Possible links between the credit-to-GDP ratio and real outcomes have been highlighted by several empirical studies. For one, there is ample evidence that above-trend values for the credit-to-GDP ratio signal impending financial crises (eg Borio and Lowe (2002) or Schularick and Taylor (2012)). Similarly, recessions that follow periods of strong credit-to-GDP growth tend to be much deeper than otherwise, even in the absence of financial crises (eg Claessens et al (2011), Jorda et al (2013) or Mian et al (2015)). Yet, it is not clear from this literature why output growth has under-performed during credit booms or, indeed, why credit has outgrown output in the last 30 years.

The literature more broadly has emphasised the role of leverage and the debt service burden. The positive link between changes in leverage, defined here as the credit-to-asset ratio, and expenditure has been extensively documented at the micro level.<sup>1</sup> Equally, high debt service burdens, defined as the ratio of interest payments and amortisations to income, have found to negatively affect consumption of households and, via its cash flow sensitivity, investment.<sup>2</sup> At the macro level, the role of leverage has been emphasised since the seminal work by Kiyotaki and More (1997) and Bernanke et al (1999). More recent work also finds that high debt service burdens can constrain aggregate demand under some conditions such as the zero lower bound (eg Eggerston and Krugman (2012), Farhi and Werning (2013) or Korinek and Simsek (2014)). This suggests that both leverage and the debt service burden may be important for understanding the puzzling behaviour of credit and output in the data.

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<sup>1</sup> See for instance Gan (2007) or Chaney et al (2012) for the corporate sector and in a series of papers by Mian and Sufi (eg 2014) or Johnson and Li (2010) for the household sector.

<sup>2</sup> The negative effect of a high debt service burden on consumption of households has been shown by eg Olney (1999), Johnson and Li (2010), or Dynan (2012). Corporate investment, on the other hand, has been found to be sensitive to cash flows, which in turn are strongly influenced by debt service payments and hence the debt service burden (eg Rauh (2006), Gan (2007), Campello et al (2011) or Chaney et al (2012)).

As a starting point, we empirically model leverage and the debt service burden at the aggregate level to assess how they affect real outcomes. We start from two weak empirical hypotheses. First, if leverage is constant in the long run, it implies that the credit-to-GDP ratio is cointegrated with real asset prices. Second, if the debt service burden is constant in the long run, it implies a cointegration relationship between credit-to-GDP and lending rates.

We then test for and find that these two long-run relationships are in the data. Specifically, estimating a vector auto-regressive (VAR) model in error correction form on quarterly US data from 1985 to 2015, we find that the credit-to-GDP ratio is cointegrated with real asset prices, on the one hand, and with lending rates, on the other. This implies that the trend increase in the credit-to-GDP ratio over the last 30 years can be attributed to falling lending rates and rising real asset prices. The latter two variables are, moreover, inversely related in the long-run.

More importantly, we find that the deviations from the two long-run relationships - *the leverage gap* and *the debt service gap* henceforth - have sizeable effects on credit and output. In line with micro evidence and standard macro finance models, we show that real credit growth increases when the leverage gap is negative, for instance due to high asset prices. And higher credit growth in turn boosts output growth. Going beyond the existing evidence, we find that the debt service gap plays an additional important role at the aggregate level that has generally been overlooked: it has a strong negative impact on consumption and investment. In addition, it negatively affects credit and real asset price growth. While this is broadly in line with recent theoretical contributions, we find this effect to be more generally at work even during episodes where policy rates are substantially above the zero lower bound.

The leverage and debt service gaps hold the key for explaining the divergence of credit and output in recent decades. For instance, in the late 1980s and mid 2000s both gaps were negative boosting credit and asset price growth. This had a positive effect on output, but not one-to-one with credit, which caused the credit-to-GDP ratio to rise. This in turn pushed the debt service gap to positive values, at which point it started to offset the output effects from high credit growth so that output growth returned to trend. Yet, as the leverage gap remained negative, credit growth was still high, ie we observed a “growthless” credit boom. This continued to increase the debt-service gap, which had a growing negative effect on asset prices and expenditure, driving the leverage gap into positive territory. And once both gaps became positive they worked in the same direction, generating a sharp decline in output even without additional large shocks or crises-related non-linearities. The subsequent downturns were deep and

protracted, as the per-period reduction in credit had to be faster than the per-period decline in output in order to lower the credit-to-GDP ratio and thereby close the two gaps. This also implied that the recovery was “creditless”.

These dynamics provide a more structural interpretation of the link between credit-to-GDP ratios and real outcomes. For instance, they explain that rapidly rising credit-to-GDP ratios during credit booms (eg Reinhart and Rogoff (2009) or Mendoza and Terrones (2008)) and creditless recoveries afterwards (eg Abiad et al (2011)) arise from diverging pressures from the leverage and debt service gaps. Equally, the deep and protracted recessions that tend follow credit booms result not only from high leverage depressing credit growth but mainly from households and firms cutting back expenditure to reduce a high debt service burden.

The adjustment dynamics to the leverage and the debt service gaps are so pronounced that they help anticipate the Great Recession. Starting from real-time estimates of the gaps at the end of 2005, the model projects a 3.5% fall in annual credit growth by the end of 2009 in line with the actual drop that occurred half a year later. The implied adjustments also entail a very drawn out recession and recovery matching actual developments. The model does, however, not fully capture the severity of the output losses in the immediate quarters following the Lehman failure: the projected maximum drop in expenditure is -4% compared to nearly -6% in reality.

The effects of the leverage and debt service gaps are very robust. First, they are unaffected by wealth effects as all our specifications control for this. More important, the results hold in samples excluding the recent crisis or if we include a range of controls such as money market rates, 10-year government bonds yields, the term spread or the unemployment rate. Furthermore, the same dynamics emerge if we use more direct measures for leverage and the debt service burden based on the assets-to-credit ratio from the national accounts and the debt service ratio published by the BIS (Drehmann et al (2015)).

The rest of the paper is organised as follows: Section 2 lays down the empirical approach. Section 3 discusses results for the long-run relationships and Section 4 how deviations from the long-run levels impact on credit and output growth. Section 5 predicts the Great Recession in real-time. We undertake robustness checks in Section 6. The final section concludes and discusses policy implications.

## 2 Empirical approach

We first derive two long-run relationships that potentially are helpful for pinning down lasting changes in the credit-to-GDP ratio. We then embed them in a cointegrated VAR which we estimate on US data.<sup>3</sup> This allows us to test the validity of the long-run relationships. As we find that both are valid, we finally check how their deviations feed into output and credit growth, as well as the other variables of the system.

For notation, we use small letters to denote the natural logarithm of a variable, for example  $y_t = \ln(Y_t)$  for the log of nominal GDP (except for interest rates which are in levels), and the superscript  $r$  to denote real variables, for example  $y_t^r = y_t - p_t$ , where  $p_t$  denotes the GDP deflator.

### 2.1 Long-run relationship 1: aggregate leverage

Leverage has been identified as an important variable for understanding macro-financial linkages. Early on, the seminal work of Bernanke et al (1999) and Kiyotaki and Moore (1997) showed that limits to the pledgeability of collateral imply that the aggregate stock of credit,  $CR_t$ , cannot exceed a specific fraction  $\mu_{lev}$  of assets,  $A_t$  so that leverage, defined here as the credit-to-asset ratio, is lower than  $\mu_{lev}$ , ie  $LEV_t = CR_t/A_t \leq \mu_{lev}$ . In the models, constrained borrowers will always operate at maximum leverage, implying  $LEV = \mu_{lev}$ . If asset prices rise, for instance, borrowers will take on more debt, which in turn increases investment and output.

Looking at data from the national accounts, however, reveals that the aggregate credit-to-asset ratio has been fluctuating over time (see Figure A.1 in the Online Appendix). It is thus more reasonable to replace the prediction of constant leverage with a weaker empirical condition that leverage fluctuates around a constant in the long-run, which for convenience can be expressed as  $LEV_t = \mu_{lev} e^{v_{lev,t}}$  where  $v_{lev,t} \sim I(0)$ . In this case, the leverage gap,  $\widetilde{lev}_t$ , ie the per cent deviation from long-run leverage, is given by

$$\widetilde{lev}_t = \ln(CR_t/A_t) - \ln(\mu_{lev}) = v_{lev,t} \quad (1)$$

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<sup>3</sup> There is a large empirical literature estimating VAR models in error correction form using a set of variables similar to ours. Many papers estimate these systems to gain insights into the credit channel of monetary policy (eg Hofmann (2004), Iacoviello and Minetti (2008) or Gambacorta and Rossi (2010)), whereas others try to identify benchmarks for assessing credit developments in particular countries (eg Cottarelli et al (2005), Coudert and Pouvelle (2010)). In contrast to the latter papers, we test and find that the long-run benchmarks can be mapped into two intuitive relationships defined by leverage and the debt service burden and that deviations from these in turn help to explain macro dynamics during credit booms and busts. More recently, Albuquerque et al (2014) estimate the determinants of the household debt-to-income ratios for the US in the long run using panel data.

The leverage gap can be expressed in terms of the credit-to-GDP ratio and real asset prices if in the long run a constant fraction  $\tau$  of real output,  $Y^r = Y_t/P_t$ , is invested into assets and that there is a constant depreciation rate  $\delta$ . Then real assets,  $A_t^r = A_t/P_{A,t}$ , follow  $A_t^r = (1 - \delta)A_{t-1}^r + \tau Y_t^r$  where  $P_{A,t}$  is the nominal asset price. In steady state we have  $A_t^r = \lambda Y_t^r$ , where  $\lambda = \tau/\delta$ , so that long-run nominal assets satisfy  $A_t = P_{A,t} \left( \lambda \frac{Y_t}{P_t} \right)$ . If we further approximate the general asset price - which is unobservable in reality - by a Cobb-Douglas index of  $n$  different observable asset prices, ie  $P_{A,t} = \prod_{i=1}^n P_{A_i,t}^{\psi_{A_i}}$  with  $\sum_{i=1}^n \psi_{A_i} = 1$ , and substitute this together with the expression for long-run nominal assets into (1) we get

$$\widetilde{lev}_t = cr_t - y_t - \ln(\lambda) - \sum_{i=1}^n \psi_{A_i} (p_{A_i,t} - p_t) - \ln(\mu_{lev}) = v_{lev,t} \quad (2)$$

Hence, if leverage is constant in the long-run, the credit-to-GDP ratio and the real asset price indices will be cointegrated. We should also find that  $\widetilde{lev}_t \neq 0$  has a negative effect on  $\Delta(cr_t - y_t)$ , if the credit-to-GDP ratio adjusts to restore the long-run steady-state.

## 2.2 Long-run relationship 2: the aggregate debt service burden

Micro evidence points to the debt service burden as another potential determinant of long-run credit-to-GDP for two reasons. First, prospective borrowers typically do not only need to meet a leverage constraint but their expected debt service burden has to be below a critical threshold as well (eg Quercia et al (2003)). This is simply the well know transversality condition ruling out Ponzi schemes. Second, debt service costs enter the budget constraint of existing borrowers and, hence, can matter for expenditure even at the aggregate level as discussed in the introduction.<sup>4</sup>

We define the debt service burden,  $DSB_t$ , as debt service payments (interest payments plus amortisations) divided by income. While official statistics on interest payments and income are available at the sectoral level, amortisations are not directly recorded. The Fed, however, has proposed a methodology to measure the debt service burden - or debt service ratio in their terminology<sup>5</sup> - for the aggregate household sector (Dynan et al (2003)). The Fed's main assumption is that debt is structured as an instalment loan in the aggregate, meaning that interest payments and amortisations on

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<sup>4</sup>Aron et al (2012) provide evidence that a high aggregate debt service burden reduces consumption in the UK.

<sup>5</sup> We use the terminology "debt service burden" as it better captures the economic concept than the more technical counterpart "debt service ratio" which emphasizes a specific measure.



the aggregate debt stock are repaid in equal portions (instalments) over the average remaining maturity of the stock of debt.<sup>6</sup> Using the standard formula for calculating the debt service costs of an instalment loan and dividing by income yields:

$$DSB_t = \frac{r_t}{(1 - (1 + r_t)^{-m})} \frac{CR_t}{Y_t} \quad (3)$$

where  $r_t$  is the average nominal lending rate on the credit stock and  $m$  is the average remaining maturity of the credit stock.

Note that the average lending rate relates to a mixture of loans with different maturities and repricing conditions attached to them and therefore reflects both current and past money market rates, inflation rates, interest rate expectations, and risk and term premia. Hence, it differs from interest rates that are typically included in the literature, such as the short-term money market rate.

The debt service burden helps to pin down lasting changes in the credit-to-GDP ratio if it fluctuates around some aggregate long-run debt holding capacity, ie if  $DSB_t = \mu_{dsb} e^{v_{dsb,t}}$  where  $v_t \sim I(0)$ . To see this, define the debt service gap as  $\widetilde{dsb}_t = \ln(DSB_t) - \ln(\mu_{dsb}) = v_{dsb,t}$ , and substitute the log of (3) into this expression to get

$$\widetilde{dsb}_t = cr_t - y_t + \gamma r_t - \ln(\mu_{dsb}) = v_{dsb,t} \quad (4)$$

where  $\gamma r_t$  as the linear approximation of  $\ln(\frac{r_t}{(1 - (1 + r_t)^{-m})})$ . Hence, if the debt service burden is constant in the long run, the credit-to-GDP ratio and the lending rate are cointegrated. Moreover, if borrowers adjust their debt holdings or expenditure when they are above or below their long-run debt holding capacity,  $\widetilde{dsb}_t$  should have a negative effect on  $\Delta(cr_t - y_t)$ .

In the following, we check to what extent the leverage and/or the debt service relationships hold in the data.

## 2.3 Data

We use US quarterly time series data for the private non-financial sector covering the sample period 1985q1-2013q4.<sup>7</sup> Data are readily available for all of the variables in

<sup>6</sup> Drehmann et al (2015) show that differences between repayment structures of individual loans tend to cancel out in the aggregate, so that the instalment loan assumption delivers reliable aggregate debt service burden estimates.

<sup>7</sup> We start the estimation in 1985 to avoid two potential structural breaks related to the beginning of the Great Moderation in 1984 (eg Kim and Nelson (1999)) and the liberalisation of financial markets in the early 1980s allowing for more flexible ways to finance consumption and investment (eg Jermann

(2) and (4), except for the average lending rate on the outstanding stock of credit,  $r_t$ . For simplicity, we proxy it as in Drehmann and Juselius (2012) based on a smoothed weighted average between the conventional 30-year mortgage rate for the household sector and the prime lending rate for the non-financial corporate sector. This simple proxy closely matches the effective lending rates on the stock of debt based on data from Bureau of Economic Analysis (see Drehmann et al (2015)). To estimate the general asset price index in (2) we follow Borio et al (1994) and use three observable asset prices indices: residential property, commercial property, and equity prices which we denote by the sub-indices, H, C, and E, respectively. The data and sources are as listed in Table A.1 in the Online Appendix.

## 2.4 Econometric workhorse

Our main empirical workhorse is the VAR model in error correction form, given by

$$\Delta x_t = \gamma_0 + \Pi x_{t-1} + \sum_{i=1}^{l-1} \Pi_i \Delta x_{t-i} + \Gamma s_t + \varepsilon_t \quad (5)$$

where  $x_t$  is a vector of endogenous variables,  $s_t$  a vector of deterministic terms other than the constant (such as seasonal and impulse dummies), and  $\varepsilon_t \sim N_q(0, \Sigma)$  the error term.

The error correction representation is convenient for analysing long-run co-movements between a set of endogenous stochastically trending variables. The parameter matrix  $\Pi$  in (5) captures the cointegration properties of the data. If it has reduced rank with  $0 < \text{rank}(\Pi) := v < q$ , where  $q$  is the dimension of  $x$ , there are  $v$  cointegration relationships and  $q - v$  common stochastic trends. In this case  $\Pi$  can be represented as the product of two  $(q \times v)$  matrices of full column rank,  $\alpha$  and  $\beta$ . That is  $\Pi = \alpha\beta'$ , where  $\beta'x_{t-1}$  describes the cointegration relationships and  $\alpha$  describes how they feed into the left-hand side growth rates. We use the likelihood ratio (LR) test (Johansen (1995)) to test the null hypothesis that the rank of  $\Pi$  is equal to a specific integer. And given a reduced but non-zero rank, it is easy to test linear restrictions on the cointegration space.

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and Quadrini (2006)).

Embedding the the variables from (2) and (4) in (5) we get

$$\begin{pmatrix} \Delta(cr - y) \\ \Delta p_H^r \\ \Delta p_C^r \\ \Delta p_E^r \\ \Delta r \end{pmatrix}_t = \gamma_0 + \Pi \begin{pmatrix} (cr - y) \\ p_H^r \\ p_C^r \\ p_E^r \\ r \end{pmatrix}_{t-1} + \sum_{i=1}^{l-1} \Pi_i \begin{pmatrix} \Delta(cr - y) \\ \Delta p_H^r \\ \Delta p_C^r \\ \Delta p_E^r \\ \Delta r \end{pmatrix}_{t-i} + \Gamma s_t + \epsilon_t \quad (6)$$

where we set  $l = 3$  based on standard information criteria. We include three seasonal dummies and 7 impulse dummies in  $s_t$ . The impulse dummies correspond to large outliers, for instance related to the 1987 stock market crash and the Lehman bankruptcy, and take the value one in a specific quarter and zero elsewhere. These dummies do not have large impacts on the estimates, but are important for the validity of the rank test statistic which is sensitive to misspecification (Bohn Nielsen (2004)).

If the rank of  $\Pi$  is larger or equal to one, we can check if either of the two hypothetical long-run relationships are in the data. For instance, if  $r = 2$  and both relationships hold we should find

$$\beta' = \begin{pmatrix} 1 & -\psi_P & -\psi_C & -\psi_E & 0 \\ 1 & 0 & 0 & 0 & \gamma \end{pmatrix} \quad (7)$$

This also implies that the real asset prices and the lending rate are negatively related in the long run, which can be seen by subtracting, say, the second row in (7) from the first.

### 3 Results for the long-run relationships

Both the leverage and debt service relationships define valid long-run relationships. The rank test statistics indicate that there are two cointegrating relationships in the data, ie  $v = 2$  (Table 1, upper panel). And testing the identifying restrictions in (7) yields a p-value of 0.12, ie they cannot be rejected at the 5% significance level. Testing the additional restriction that  $\psi_P + \psi_C + \psi_E = 1$  corresponding to the Cobb-Douglas specification yields a p-value of 0.02. It is thus rejected at the 5%, but not at the 1% significance level. However, we impose this restriction below as it is economically intuitive; it implies that a 1% increase in collateral values allows borrowers to take on 1% more credit for the same amount of income. Moreover, all results below are qualitatively the same even if we do not impose this restriction.

The coefficient estimates of the identified cointegration vectors are reasonable from

Cointegration results					
Rank test statistic					
	$v = 0$	$v \leq 1$	$v \leq 2$	$v \leq 3$	$v \leq 4$
$p$ -value	<b>0.00</b>	<b>0.04</b>	0.10	0.25	0.73
Identified cointegration vectors, $\beta$					
	$cr_t - y_t$	$p_{H,t}^r$	$p_{C,t}^r$	$p_{E,t}^{r,\dagger}$	$r_t$
$\beta'_{lev}$	1	<b>-0.486</b> (6.44)	<b>-0.451</b> (7.23)	<b>-0.063</b> (2.06)	—
$\beta'_{dsb}$	1	—	—	—	<b>0.062</b> (9.49)
Adjustment coefficients					
	$\Delta(cr_t - y_t)$	$\Delta p_{H,t}^r$	$\Delta p_{C,t}^r$	$\Delta p_{E,t}^r$	$\Delta r_t$
$\widetilde{lev}_t = \beta'_{lev} x_t$	<b>-0.026</b> (-4.70)	0.013 (0.91)	-0.057 (-0.64)	0.152 (1.85)	-0.192 (-1.40)
$\widetilde{dsb}_t = \beta'_{dsb} x_t$	<b>-0.020</b> (-4.24)	<b>-0.027</b> (-2.23)	-0.050 (-0.65)	-0.008 (-0.11)	<b>-0.265</b> (-2.25)

Table 1: Rank test:  $p$ -values of the null hypothesis that the rank is less or equal to  $v$ . Cointegration and adjustment coefficients:  $t$ -values in parenthesis. Boldface values denote rejection of the null at the 5% significance level.  $\dagger$  A test for the null hypothesis that  $p_{E,t}^r$  can be excluded from the cointegration space cannot be rejected at the 5% significance level (p-value 0.46).

an economic perspective as they have the right signs and plausible magnitudes (Table 1, upper centre panel).<sup>8</sup> Both the leverage and the debt service gaps also have significant negative effects on the credit-to-GDP ratio (Table 1, lower central panel) implying that it moves to restore the long-run relationships. But the adjustment is very slow. Only 2-3% of  $\widetilde{lev}_t$  or  $\widetilde{dsb}_t$  are being corrected each quarter. The gaps only have limited effects on the lending rate and the real asset prices suggesting that these drive long-run movements in the credit-to-GDP ratio. Nevertheless, there are some weak negative effects from the debt service gap on real residential property prices and lending rates.

Graphically, the estimated long-run relationships capture the broad trend in credit-to-GDP well (upper panels, Figure 1). And both the leverage and debt service gaps exhibit clear mean reversion (lower panels), in line with the notion that they are  $I(0)$ . As can be seen from the lower left-hand panel, the leverage gap was negative ahead of the current crisis, which is seemingly at odds with the common narrative (Figure 1, lower left-hand panel). For example, micro evidence suggests that new borrowers took up mortgages with higher leverage in the run-up to the sub-prime crisis and some existing borrowers managed their leverage by home equity withdrawals (eg Mian and Sufi (2014)). But the sharp increase in asset prices lowered leverage in the aggregate. This is also evident from the credit-to-asset ratio based on national accounts data (see Figure A.1 the Online Appendix).

Overlaying the estimated debt service burden and (the inverse) leverage gaps reveals an interesting picture (Figure 2). The leverage gap appears to lead the debt service gap by around one to two years. We discuss the mechanics of this pattern in Section 4.2 where we study how the economy adjusts back to steady-state from non-zero values in the gaps.

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<sup>8</sup> The coefficients of the leverage relationship suggests that a 10% increase in real residential or commercial property prices leads to a 4-5% increase in the credit-to-GDP ratio. The coefficients of the debt service burden relationship indicate that a 1 percentage point increase in the average lending rate decreases this ratio by approximately 6%. These may sound like small effects, yet they account for a large part of the increase in the credit-to-GDP ratio since the beginning of our sample: from 1985 to the peak before the recent crisis credit-to-GDP rose by approximately 50% while at the same time real residential property prices nearly doubled and the average lending rate dropped by approximately 7 percentage points.

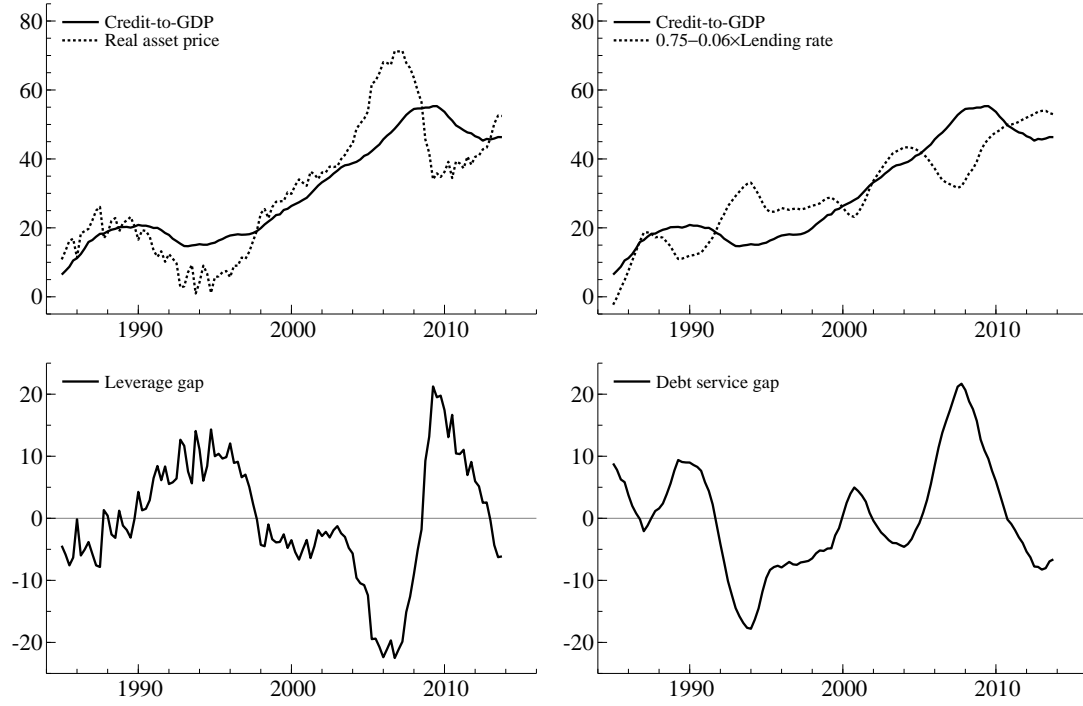


Figure 1: The credit-to-GDP ratio (log) and sustainable levels based on the estimated long-run relationships. Leverage and the debt service burden gaps,  $\widetilde{lev}_t$  and  $\widetilde{dsb}_t$ , shown in the lower panels are the deviations of the credit-to-GDP ratio from the respective sustainable levels.

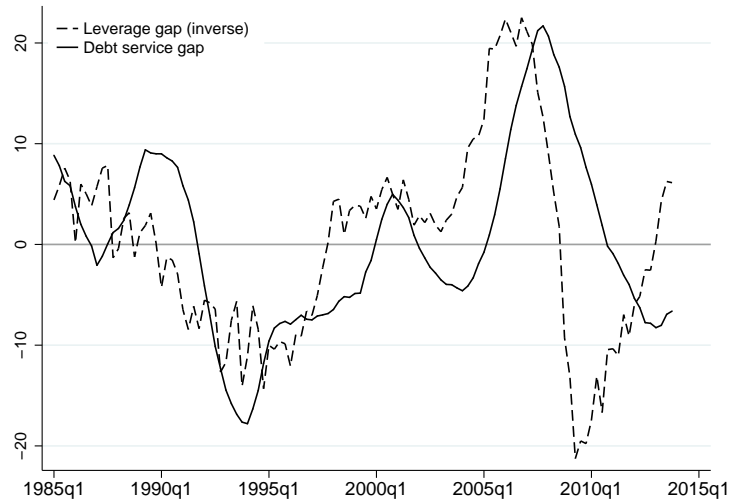


Figure 2: Leverage gap (inverse) and the debt service gap over time.

## 4 The effects of the leverage and debt service gaps on credit and output

From a macroeconomic perspective, the ultimate interest is in the effects of the two gaps on credit and output separately rather than on the credit-to-GDP ratio. A natural starting point for studying these effects is to take the gaps as given and include real credit and output growth,  $\Delta cr_t^r$  and  $\Delta y_t^r$ , separately in  $x_t$  in the VAR model.<sup>9</sup> It might be expected, however, that the gaps affect private expenditure (ie personal consumption and private investments) differently than they do government spending and net exports. Hence, we can further disaggregate  $y_t^r$  into real private expenditure,  $e_{P,t}^r$ , and “other” expenditure, ie  $e_{O,t}^r$ .

A problem with disaggregating the VAR system is that precision is quickly lost as the dimension increases. To keep the dimension low, we use the estimated aggregate asset price index implied by the long-run leverage relationship from Table 1,  $p_{A,t}^r = 0.486p_{H,t}^r + 0.451p_{C,t}^r + 0.063p_{E,t}^r$ , in the place of the individual asset prices. This has the virtue of preserving the cointegrating property  $c_t - y_t - p_{A,t}^r \sim I(0)$  so that no long-run information is lost.

With these modifications, the new information set is  $x_t = (cr_t^r, e_{P,t}^r, e_{O,t}^r, p_{A,t}^r, r_t)'$  and the system becomes

$$\begin{pmatrix} \Delta cr_t^r \\ \Delta e_{P,t}^r \\ \Delta e_{O,t}^r \\ \Delta p_{A,t}^r \\ \Delta r_t \end{pmatrix}_t = \alpha \begin{pmatrix} \widetilde{lev} \\ \widetilde{dsb} \end{pmatrix}_{t-1} + \sum_{i=1}^2 \Pi_i \begin{pmatrix} \Delta cr_{t-i}^r \\ \Delta e_{P,t-i}^r \\ \Delta e_{O,t-i}^r \\ \Delta p_{A,t-i}^r \\ \Delta r_{t-i} \end{pmatrix} + \Gamma s_t + \varepsilon_t \quad (8)$$

We also reconsider the choice of dummy variables, since some of the endogenous variables differ from those in the previous system. In particular, we add 11 impulse dummies in  $s_t$ .<sup>10</sup>

<sup>9</sup> So far, only the credit-to-GDP ratio has appeared in the VAR. To keep the notation simple, we expressed this ratio in terms of nominal credit and GDP. When disaggregating the ratio, we use the real values of these variables. As a robustness check, we also included  $cr_t^r$  and  $y_t^r$  separately in (5). All the results presented above remained qualitatively the same. This also allows us to check whether the assumed unit coefficient between credit and GDP in the base-system (5) is in line with the data. This restriction cannot be rejected at the 5% significance level (p-value 0.09).

<sup>10</sup> This was done by the automatic procedure Autometrix in PcGive, described in eg in Hendry and Doornik (2014). Some of the dummy variables reduce seemingly strong correlation caused by joint large outliers in the variables, but otherwise do not have a large effect on the system.

	Full system					Parsimonious system				
	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta r_t$	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta r_t$
Adjustment coefficients to leverage and the debt service burden										
$\widetilde{lev}_{t-1}$	<b>-0.021</b> -2.86	0.007 0.79	-0.050 -0.91	-0.039 -0.76	<b>-0.004</b> -2.42	<b>-0.020</b> -4.07				<b>-0.003</b> -2.69
$\widetilde{dsb}_{t-1}$	<b>-0.027</b> -3.99	<b>-0.021</b> -2.52	<b>0.152</b> 3.07	<b>-0.108</b> -2.28	<b>-0.003</b> -2.32	<b>-0.025</b> -5.54	<b>-0.026</b> -5.09	<b>0.191</b> 5.92	<b>-0.106</b> -3.75	<b>-0.002</b> -2.15
Short-run dynamics										
$\Delta cr_{t-1}^r$	0.195 1.86	0.082 0.65	-0.874 -1.15	-0.046 -0.06	0.007 0.36	<b>0.275</b> 3.97				
$\Delta cr_{t-2}^r$	<b>0.570</b> 5.59	0.031 0.25	0.266 0.36	0.649 0.92	-0.029 -1.49	<b>0.454</b> 7.01			<b>0.571</b> 2.15	<b>-0.024</b> -2.01
$\Delta e_{P,t-1}^r$	0.168 1.13	<b>0.398</b> 2.22	0.752 0.70	0.926 0.90	0.035 1.23		<b>0.474</b> 7.99			<b>0.061</b> 4.53
$\Delta e_{P,t-2}^r$	-0.166 -1.12	0.055 0.31	1.175 1.09	-0.812 -0.79	-0.041 -1.42			<b>2.192</b> 6.07		<b>-0.037</b> -2.54
$\Delta e_{O,t-1}^r$	0.014 0.66	0.030 1.15	0.030 0.19	-0.036 -0.24	-0.004 -1.03		<b>0.035</b> 3.73			
$\Delta e_{O,t-2}^r$	-0.023 -1.15	-0.025 -1.06	0.202 1.41	<b>-0.265</b> -1.96	-0.002 -0.65			<b>0.112</b> 1.96		
$\Delta p_{A,t-1}^r$	0.008 0.52	0.016 0.85	-0.157 -1.40	-0.152 -1.43	-0.002 -0.80					
$\Delta p_{A,t-2}^r$	-0.005 -0.30	0.020 1.05	-0.110 -0.98	-0.044 -0.41	-0.002 -0.53					
$\Delta r_{t-1}$	-0.442 -1.03	-0.118 -0.23	2.881 0.93	-1.551 -0.52	<b>1.024</b> 12.30					<b>1.033</b> 14.00
$\Delta r_{t-2}$	0.664 1.53	0.157 0.30	-1.129 -0.36	3.301 1.10	<b>-0.147</b> -1.75					<b>-0.174</b> -2.38

Table 2: Estimated coefficients of the error correction system (8). The unrestricted system (left-hand side) does not impose any restrictions on the coefficients, whereas the restricted system (right-hand side) imposes several zero-restrictions. Results for the deterministic components are shown in the Online Appendix, Table A.2.

## 4.1 The dynamics of credit and output growth

The leverage and debt service gaps are important determinants of real credit and private expenditure growth (left-hand panel, Table 2). Only these and auto-regressive terms stand out as significant in the estimated VAR system (8). The full system is, however, quite large and clearly over-parametrised. It is therefore beneficial to impose zero-restrictions on insignificant parameters to obtain a parsimonious system. We do this cautiously, using encompassing tests to ensure that the parsimonious system is not significantly different from the full system.

The parsimonious system clearly reveals that both gaps are highly significant for explaining real credit growth (right-hand panel, Table 2). And the signs are intuitive; in response to a negative leverage gap, eg when asset prices are high relative to the credit-to-GDP ratio, credit increases. Equally, a negative debt service gap also leads to higher credit growth. Thus, non-zero values for the gaps are corrected as borrowers either take on more credit or delever.

The novel result of our analysis is the negative effect of the debt service gap on real



private expenditure growth. As discussed above, the aggregate effects of debt servicing are a priori unclear because reduced expenditure by borrowers can be compensated for by increased expenditure from lenders. But our result highlight that this has not been the case in the past. And this is not driven by wealth effects as we directly controls for these through  $\Delta p_A^r$ . Moreover, we show below that this effect neither depends on the period of the Great Recession nor disappears when controlling for real interest rates or interest spreads. Hence, the depressing effect of a high aggregate debt service burden on output seems to be much more generally at work than hitherto recognised.

The negative effect of a positive debt service gap on expenditure also amplifies output losses. For example, starting from steady-state, a negative shock to output increases the debt service gap. This in turn depresses expenditure and thereby income, which increases the gap even further. Overall, though, the system is stable as the debt service gap lowers credit growth even more than it lowers expenditure growth, but the difference is not large implying very drawn out effects.<sup>11</sup> Hence, this simultaneously amplifying negative effect on expenditure and error correcting negative effect on credit implies that a large positive debt service gap is followed by a deep and protracted recession. This also suggests that knowledge of the debt service gap and its effects can be beneficial for predictive purposes - a point which we further substantiate below.

Interestingly, financial accelerator-type effects do not seem particularly strong. For one, the leverage gap has no direct impact on private sector expenditure. Furthermore, while credit growth amplifies asset prices and asset prices credit via changes in the leverage gap, there is no interaction between credit, asset prices and expenditure, except through the debt service burden gap. This result is, however, somewhat sample-dependent and likely due to the fact that we cannot distinguish between new credit, defaults and repayments in credit growth. As we show in Section 5, credit has a significant effect on expenditure if we exclude the Great Recession from the sample.

In most cases, the effects of the debt service gap on the other variables stabilises the system. For one, the debt service gap has a significant positive effect on other expenditure which reduces its overall impact on exaggerate output. Second, is negatively affects real asset price growth, which in turn helps to stabilise the leverage gap. Finally, it has a negative effect on the lending rate which leads to faster error correction. This

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<sup>11</sup> Even if the coefficients of  $\widetilde{dsr}_{t-1}$  in both the real credit and expenditure growth equations are virtually the same, the effect on real GDP is smaller as GDP is also determined by other expenditure. The income identity can be written as  $Y_t^r = E_{P,t}^r + E_{O,t}^r$  and thus the effect of  $\Delta e_{P,t}^r$  on  $\Delta y_t^r$  is  $\Delta e_{P,t}^r (E_{P,t}^r / Y_{O,t}^r)$ . As the average share of private expenditure to GDP is about 0.87 over the sample, a 10% debt service deviation reduces per-quarter credit growth by 0.25% and real GDP growth by  $0.26 \cdot 0.87 = 0.23\%$ .

may be indicative of a systematic monetary policy response to high (low) debt service burdens, in line with past Fed reactions. For example, after the leverage buy-out boom in the late 1980s, the Fed argued that “difficulties faced by borrowers in servicing their debts ... prompted many to cut back expenditures and divert abnormal proportions of their cash flows to debt repayment. This in turn fed back into slower economic growth” (p 3, Greenspan (1993)). And “monetary policy has played a major role in facilitating balance sheet adjustment – and thus enhancing the sustainability of the expansion – by easing in measured steps” (p 6-7, Greenspan (1993)).

## 4.2 Adjustment to steady state

How does the system adjust back to steady state given non-zero values for the leverage and the debt service gaps? This question can be easily assessed by rewriting the VAR system so that  $\widetilde{lev}$  and  $\widetilde{dsb}$  are explicitly modelled.

Following Campbell and Schiller (1987), we transform two of the system variables into  $\widetilde{lev}$  and  $\widetilde{dsb}$  by trivial operations. Any pair of variables can be used for the transformation, but the particular choice implies a specific transformation of the residuals and, hence, matters for the impulse response function.<sup>12</sup> In particular, the variables that are used in the transformation take a more passive role and do not respond to the other variables in the system.

We use other expenditure and the lending rate in the transformation. This choice implies that the adjustment dynamics that arise from non-zero values of  $\widetilde{lev}$  and  $\widetilde{dsb}$  emphasize the role of asset prices rather than the lending rate (or other expenditure). The differences in adjustment dynamics compared to using for instance other expenditure and asset prices in the transformation are not large, except when starting from extreme values for  $\widetilde{dsb}$  as neglecting the response in lending rates causes the debt service gap to overshoot.

Given our chosen transformation, we get

$$\begin{pmatrix} \Delta cr^r \\ \Delta e_P^r \\ \Delta p_A^r \\ \widetilde{lev} \\ \widetilde{dsb} \end{pmatrix}_t = \sum_{i=1}^3 \Psi_i \begin{pmatrix} \Delta cr^r \\ \Delta e_P^r \\ \Delta p_A^r \\ \widetilde{lev} \\ \widetilde{dsb} \end{pmatrix}_{t-i} + \Psi_0 s_t + \varepsilon_t \quad (9)$$

where  $\Psi_i$  are linear transforms of the parameter matrices in (8). We begin by analysing

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<sup>12</sup> This is akin to the well known effects of ordering decisions when using a Choleski decomposition.

how the system adjusts when  $\widetilde{dsb}_0$  or  $\widetilde{lev}_0$  equals  $-1$  in the initial period.<sup>13</sup>

The adjustment dynamics highlight that the debt service gap is the primary link between financial and real developments (Figure 3). For instance, initially a negative leverage gap is followed by rapid credit growth. Yet, the economy sees little output gains as the beneficial effects from credit are outweighed by the negative effects from an increasing debt service gap.<sup>14</sup> We therefore see a “growthless credit boom”. And while the increase in the credit-to-GDP ratio initially helps leverage adjust back to its long-run level, it also pushes the debt service burden above its long-run level, which eventually leads to a deep drawn out recession. The recession lasts more than five years during which expenditure and asset prices fall. Expenditure growth only recovers when the debt service gap returns to zero. But asset prices take longer to recover, implying that the leverage gap remains positive which dampens credit growth, i.e. we see a creditless recovery.

The adjustment back to steady state can have lasting effects on the real economy (Figure A.2 in Online Appendix). Starting from a negative leverage gap, for instance, credit and private sector expenditure fall to permanently lower levels.

## 5 Leverage, the debt service burden and the Great Recession

Given the size and persistency of the responses to the leverage and debt service gaps, it is interesting to ask whether knowledge of the gaps could have helped to anticipate the recent credit boom and the Great Recession. To assess this, we proceed in two steps. First, we re-estimate the whole model including the cointegration relationships using data only up to 2004q4. This date is somewhat arbitrary, but it lies between the periods of the dot.com bust and the worst sub-prime excesses.<sup>15</sup> In the second step, we use this model to calculate the credit and expenditure paths that follow from starting from the observed leverage and the debt service deviations in 2004q4 or 2005q4, assuming that

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<sup>13</sup> We do not consider the nature of the underlying shocks (eg whether it is a demand or a supply shock) that drive  $\widetilde{dsb}_0$  or  $\widetilde{lev}_0$  to  $-1$  as our interest here is not shock propagation but understanding the adjustment dynamics of the economy to a non-zero leverage or debt service gap.

<sup>14</sup> The initial response of the economy to low leverage is somewhat sample dependent. If we estimate the model up to 2004, we find a more pronounced credit boom accompanied by several years of flat output growth (see discussion in Section 5 and Figure A.3 in the Online Appendix).

<sup>15</sup> Using formal parameter stability tests, we show in the Appendix that the long-run relationships and the adjustment coefficients to the gaps are stable across any sample ending between 2000q1 and 2013q4. Some of the short-run coefficients do, however, change.

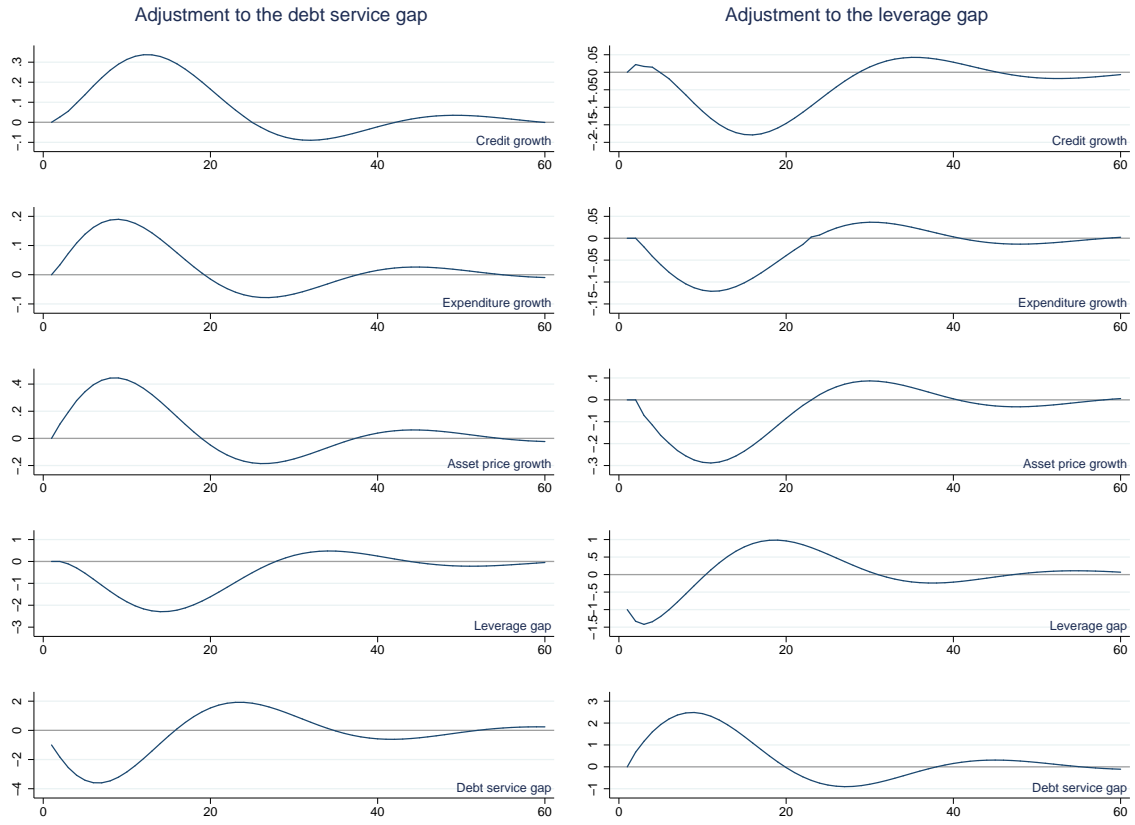


Figure 3: System response to an initially negative leverage or debt service gap.

	1985q1-2004q4 system					1985q1-2013q1 system				
	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta r_t$	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta r_t$
Adjustment coefficients to long-run deviations										
$\widetilde{lev}_{t-1}$	<b>-0.019</b> -2.08				<b>-0.005</b> -2.39	<b>-0.020</b> -4.07				<b>-0.003</b> -2.69
$\widetilde{dsb}_{t-1}$	<b>-0.026</b> -3.52	<b>-0.039</b> -4.86	<b>0.217</b> 4.68	<b>-0.084</b> -2.12	<b>-0.006</b> -3.13	<b>-0.025</b> -5.54	<b>-0.026</b> -5.09	<b>0.191</b> 5.92	<b>-0.106</b> -3.75	<b>-0.002</b> -2.15
Short-run dynamics										
$\Delta cr_{t-1}^r$	<b>0.297</b> 3.47	<b>0.273</b> 3.60	<b>-1.774</b> -3.92			<b>0.275</b> 3.97				
$\Delta cr_{t-2}^r$	<b>0.476</b> 6.02			<b>1.337</b> 3.41		<b>0.454</b> 7.01			<b>0.571</b> 2.15	<b>-0.024</b> -2.01
$\Delta e_{P,t-1}^r$			<b>1.557</b> 4.52		<b>0.066</b> 3.80		<b>0.474</b> 7.99			<b>0.061</b> 4.53
$\Delta e_{P,t-2}^r$			<b>3.033</b> 6.79		<b>-0.048</b> -2.83			<b>2.192</b> 6.07		<b>-0.037</b> -2.54
$\Delta e_{O,t-1}^r$							<b>0.035</b> 3.73			
$\Delta e_{O,t-2}^r$			<b>0.279</b> 3.56					<b>0.112</b> 1.96		
$\Delta p_{A,t-1}^r$				<b>-0.204</b> -2.06						
$\Delta p_{A,t-2}^r$				<b>-0.205</b> -2.03						
$\Delta r_{t-1}$					<b>0.901</b> 22.60					<b>1.033</b> 14.00
$\Delta r_{t-2}$										<b>-0.174</b> -2.38

Table 3: Estimated coefficients of the 1985q1-2004q4 and the full-sample system. The complete estimation results for the 1985q1-2004q4 system are shown in Table A.3 in Online Appendix.

the other variables are at their average levels and that there are no further shocks in the economy. We then compare these paths to actual credit and expenditure developments.

The estimated model is remarkably stable across the two samples, despite the fact that the full sample contains the biggest crisis and worst recession since the 1930s (Table 3).<sup>16</sup> But financial accelerator effects are stronger in the pre-crisis sample, implying that the “growthless credit boom” phenomena becomes more pronounced during the adjustment process to a negative leverage gap (Figure A.3, Online Appendix).

## 5.1 Predicting the Great Recession in real time

Real-time knowledge of the leverage and the debt service gaps would have helped to anticipate the US credit boom as well as the Great Recession (Figure 4). Using the model estimated up to the end of 2004 and starting from the then-prevailing leverage and debt service gaps, we find that the simulated adjustment path provides the correct timing with respect to the boom, drop and recovery of real credit and expenditure growth, but the intensity is not fully captured. A reason is that model fails to anticipate

<sup>16</sup>The long-run relationships for the system estimated up to 2004 are shown in Table A.5 in the Online Appendix.

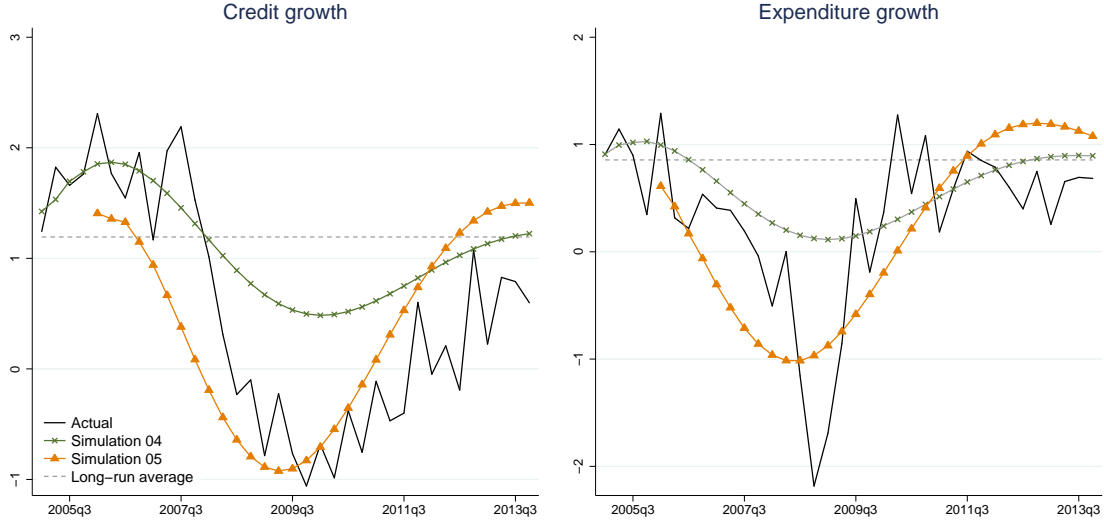


Figure 4: Real quarterly credit and expenditure growth versus growth rates implied by adjustment dynamics to observed leverage and the debt service gaps in 2004q4 and 2005q4 respectively. Adjustment dynamics are based on model estimates using only data up to 2004q4.

a series of positive house price shocks in 2005 which led to a dramatic fall in the leverage gap. This in turn drove up the debt service gap and the associated costs for the real economy.

Starting from the prevailing leverage and debt service gaps at the end of 2005 instead yields a close match between predicted and actual values for the Great Recession. Even though our simulation excludes all shocks and the model is linear, it would have predicted that quarterly real credit growth would fall to nearly -1% at the end 2009 in line with the magnitude of the actual minimum observed half a year later. It would have also anticipated a very drawn out recession and recovery, with private sector expenditure growth only returning to historical norms in early 2012. It does not, however, fully capture the sharp contraction in output during the quarters around the Lehman failure when real expenditure fell by more than 2% in a quarter. Nonetheless, the adjustment dynamics for the 2005 leverage and debt service conditions can explain half of this drop, even though there is no banking crisis in our simulation.

Beyond underscoring the importance of leverage and the debt service gaps for explaining macroeconomic dynamics, the results suggest that the systemic banking crisis was not a “black swan” event that led to the Great Recession. Our linear VAR supports a different narrative. By 2007, adjustment pressures to leverage and the debt service gaps lead to weak demand and falling asset prices. This in turn increased defaults,

putting banks under pressure. Clearly, the heightened uncertainty around the Lehman failure increased output losses even further. But once this was resolved, the economy continued to suffer from a high debt service gap, or in other words from a debt overhang.

Leverage and the debt service gaps are also relevant for understanding developments around the early 1990s recession. While our data do not allow us to do this out-of-sample, we show in the Online Appendix (see Figure A.4) that starting from end-1988 leverage and debt service gaps, the adjustment dynamics match the evolution of actual credit growth very well until the mid 1990s. The simulation would have also anticipated close to zero expenditure growth during the actual recession from July 1990 until March 1991 and a slow recovery lasting until 1993 in line with realised expenditure growth.

## 6 Robustness

In this section we run several robustness checks. We first show that the results remain unaffected when we add additional controls, such as real interest rates or interest rate spreads. We also show that the effects of leverage and the debt service gap on credit and output growth are not dependent on the estimated long-run relationships - the same results emerge from alternative, data-driven proxies for these measures.

### 6.1 Adding controls

We include additional variables in the model to ensure that the estimated deviations from long-run leverage and the debt service gap are not simply proxies for more conventional drivers of real expenditure and credit growth. As mentioned before, our specification already controls for wealth effects as changes in real asset prices are directly included in system (8).

The most obvious candidates for further controls are various real interest rates as well as the unemployment rate,  $u_t$ . The particular interest rates that we consider are the real federal funds rate,  $r_{M,t}^r = r_{M,t} - \Delta p_t$ , and the real yield on 10-year government bonds,  $r_{G,t}^r = r_{G,t} - \Delta p_t$ . And given that we include the short and long end of the yield curve, we therefore also control for the term premia. To avoid expanding the dimension and thereby loosing precision, we only include these variables as competing “cointegration” terms in the system. This modelling choice can also be motivated by a standard Euler equation for consumption that relates consumption growth to the real interest rate level.

The inclusion of the three control variables does not change our previous results

(Table A.4 in the Online appendix). Again, leverage matters only for credit growth, whereas the debt service gap affects both credit and private sector expenditure negatively. Surprisingly, we do not find any strong effects on credit and expenditure growth from the interest rates and unemployment. This is somewhat puzzling and may suggest that a large share of the interest rate effects are indirect, going through the debt service burden and leverage, rather than the other way around.

## 6.2 Direct measures of leverage and the debt service gap

In this section we show that the main results continue to hold when we use more data driven measures of the leverage and the debt service gaps instead of the estimated long-run relationships from the cointegrated VAR.

As an alternative proxy of the debt service gap, we use the debt service ratio (DSR) for the total private non-financial sector in the United States as published by the BIS (Drehmann et al (2015)). This estimate is calculated from equation (3) directly. We assume that the long-run value for the DSR is given by its sample average. As can be seen from Figure A.1 in the Online Appendix, the direct measure and results from the estimated model are very close implying that the linearisation error is not large.

Leverage can be directly measured by the credit-to-assets ratio from the national accounts. Given the low weight of equities in the asset price index  $p_A$ , we use the sum of real estate assets for the household and the corporate sectors as a measure of total assets, but the results also hold then total assets are used. Although there appears to be a slight upward trend in this measure, we again take the sample average as a proxy for its long-run value.<sup>17</sup> As an additional robustness check we also try removing a linear trend from the credit-to-asset ratio of the national accounts.

Our findings are robust to the various leverage and debt service gap measures (Table 4). In particular, the negative impact of the debt service gap on expenditure growth is hardly affected at all. It also continues to have a significant negative impact on credit growth, even though this is somewhat weakened compared to the baseline results. The effect of the the leverage gap on credit growth is also weaker when the credit-to-asset ratio from the national accounts is used, in particular, if this variable is not de-trended. In any case, though, the leverage gap continues to have no direct impact on expenditure growth.

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<sup>17</sup> The upward trend could be related to several factors, such as increasing loan-to-value ratios for first-time home buyers over the past three decades (eg Duca et al. (2013)) or the fact that the value of assets recorded in the national accounts is a mix of book and mark-to-market values (eg Emmons (2006)), and thus does not fully adjust to rising asset prices.



Debt burden:	Main text		BIS-DSR		BIS-DSR	
Leverage:	Main text		FA		FA, de-trended	
	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta cr_t^r$	$\Delta e_{P,t}^r$
$\widetilde{lev}_{t-1}$	<b>-0.021</b> -2.86	0.007 0.79	-0.009 -1.59	-0.003 -0.52	<b>-0.013</b> -3.98	-0.003 -0.42
$\widetilde{dsb}_{t-1}$	<b>-0.027</b> -3.99	<b>-0.021</b> -2.52	<b>-0.013</b> -2.11	<b>-0.028</b> -3.9	<b>-0.018</b> -3.08	<b>-0.028</b> -4.05

Table 4: Estimated effects on credit and private sector expenditure growth from alternative proxies of the leverage and debt service gaps. The alternative measure for the debt service gap, BIS-DSR, uses the debt service ratio published by the BIS (Drehmann et al. (2015)). The alternative measure for the leverage gap uses the credit-to-asset ratio from national accounts (FA) data, both without and with prior de-trending. Deviations are calculated relative to the respective long-run averages over the sample.

## 7 Conclusion and policy implications

Leverage has taken centre stage in explaining macro-financial linkages. But as we show in this paper, this is only part of the story. The debt service burden also plays an important role for credit, consumption, investment, and asset prices at the aggregate level. And the interaction between these two factors turns out to be crucial for understanding macroeconomic dynamics during credit boom-bust cycles, such as the one recently experienced in the United States.

From a practical perspective, our analysis highlights that it is not sufficient to solely look at standard macro indicators, such as output growth or traditional real-time measures of the output gap, to assess whether the economy is on a sustainable path or not. During a “growthless credit boom”, which is driven by a negative leverage and a positive debt service burden gap, two countervailing forces are at work: there is the growth enhancing effect of credit growth and a growth reducing effect of high debt service burdens. These effects push demand in opposite directions. The net effect on output is roughly zero. Yet, over time, a negative leverage gap increases the stock of credit thus raising the debt service burden even further. At some point, the negative effects begins to dominate, asset prices collapse, and a severe recession follows. The length of the credit related recession and the required amount of deleveraging are similarly determined by the deviations from the long-run leverage and the debt service burden. Ultimately, the economy will only be at its new steady-state if both leverage and the debt servicing burden are back at their long-run levels. But this may require a rather lengthy adjustment process.

With the benefit of hindsight, we find that the conditions prevailing in 2004 and 2005 were in line with a “growthless credit boom” and should have raised warning flags: given

the embedded policy reactions in the estimates, the projected adjustments to leverage and the debt service burden gaps already entailed the deep recession to come. But by focusing on standard measures, such as output growth, no one saw it coming. Ex-post it appeared that - to use the much stretched phrase by financial stability practitioners - vulnerabilities were building up in the background and the deep recession was the result of unexpected shocks. In fact, though, it was the result of a necessary adjustment to leverage and the debt service burden gaps.

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## Appendix: Stability tests

The estimated steady-state relationships and their adjustment coefficients are highly stable and essentially unaffected by the financial crisis and the ensuing deep recession. To see this, we first test that the parameters of the estimated cointegration space are stable over time, using a test by Hansen and Johansen (1999). The test recursively estimates a series of cointegration spaces,  $\beta^{(n)}$ , from (6), starting from the training sample 1985q1-1999q4. In each recursion, the null hypothesis that the estimated full-sample cointegration space is contained within the span of  $\beta^{(n)}$  is tested. Figure 5 plots the recursive test statistics, normalised at the 95% critical level. The test statistics remain well below the unit critical level for all recursions, indicating that the null hypothesis cannot be rejected at any point beyond the training sample. In other words the same long-run relationships would have been obtained had the system been estimated, for instance, before the financial crisis.

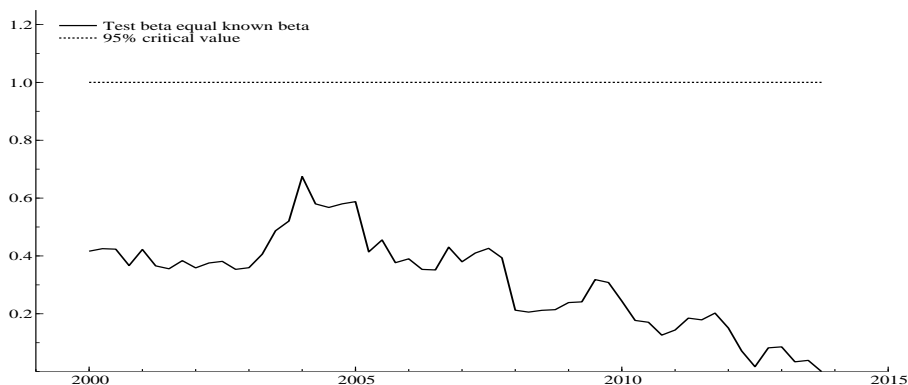


Figure 5: Recursive tests for parameter stability of the cointegration space. The test statistics are scaled so that the 95% critical value takes the value of unity. Values below unity indicate that the null hypothesis of a stable cointegration space cannot be rejected.

Next, we take the long-run estimates as given and test the stability of the adjustment coefficients from the system shown in Table (2) recursively. The training sample is again 1985q1-1999q4. In the unrestricted system (Figure 6), the effects of the leverage and the debt service gaps on credit and output are relatively stable. The main difference is that the effect of the leverage gap on expenditure growth is borderline significant during the credit boom. In the restricted system, though, the effects of the leverage and the debt service gaps on credit and expenditure growth are highly stable (Figure 7). We find virtually the same coefficients in the samples up to 2000, up to 2008, or the full sample that includes deep recession associated with the financial crisis.

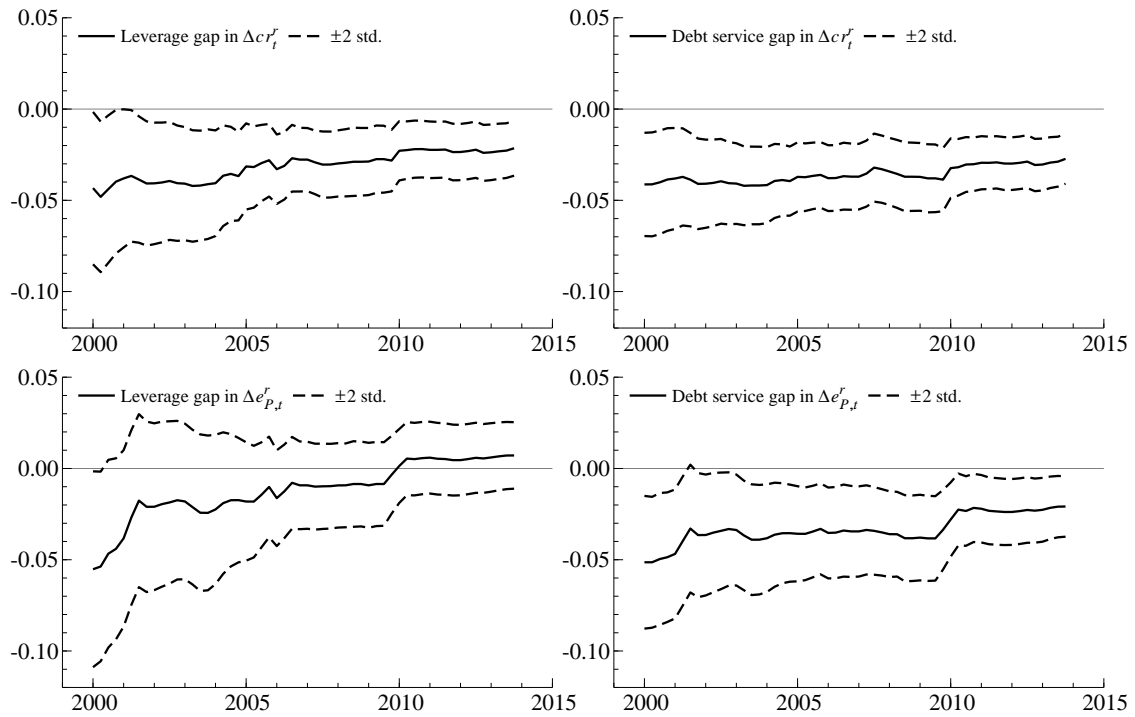


Figure 6: Recursive estimates of the loadings to the leverage and debt service gaps in the unrestricted system. The training sample is 1985q1-1999q4.



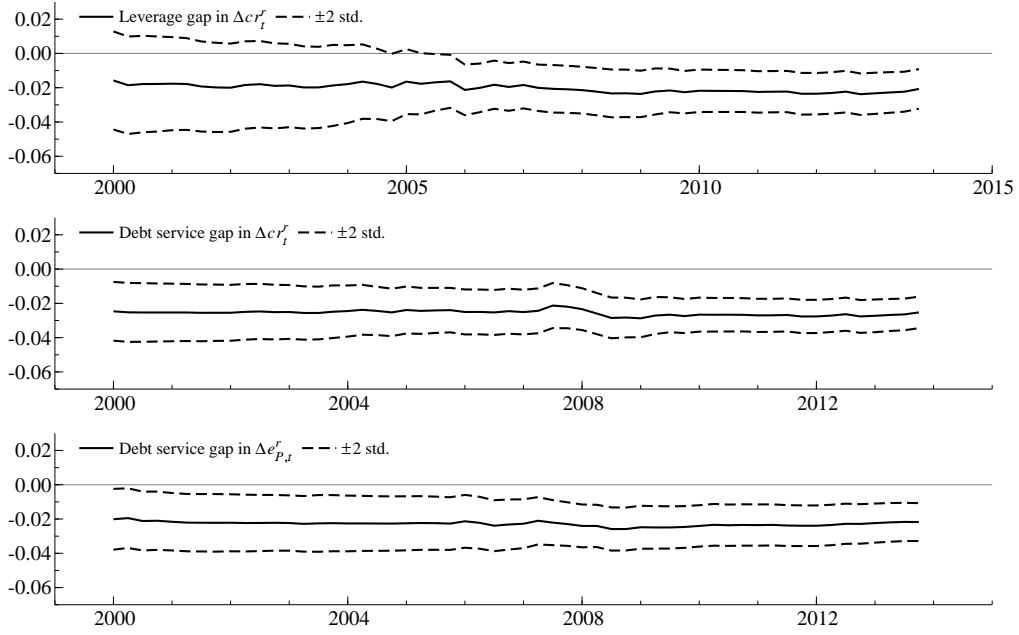


Figure 7: Recursive estimates of the loadings to the leverage and debt service gaps in the restricted system. The training sample is 1985q1-1999q4.

Online appendix for “Leverage dynamics and the burden of debt” by Mikael Juselius and Mathias Drehmann

Additional graphs and tables

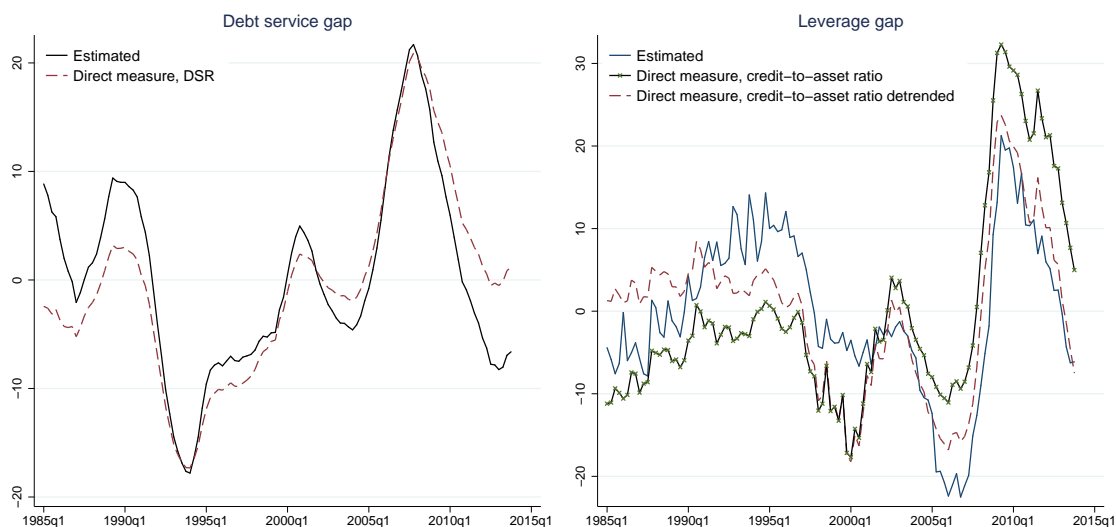


Figure A.1: Comparison between the debt service gap and leverage estimated from the VAR and alternative direct measures. For the direct measures, debt service gaps are approximated by the DSR estimated by Drehmann and Juselius (2012) and leverage by the credit-to-asset ratio of assets based on national accounts data. The credit-to-asset ratio is shown both with and without removing a linear trend. Deviations for the direct measures are calculated relative to the respective long-run averages over the sample.

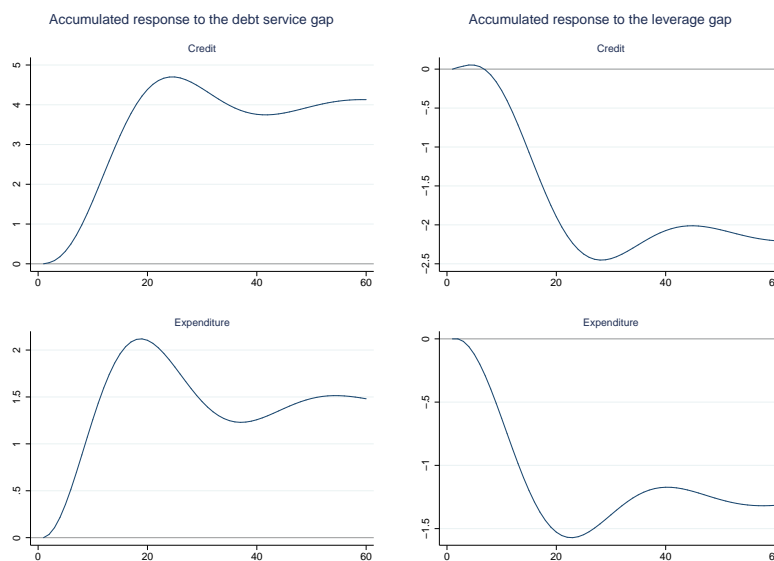


Figure A.2: Accumulated effects of the system response to an initial negative leverage or debt service gap.

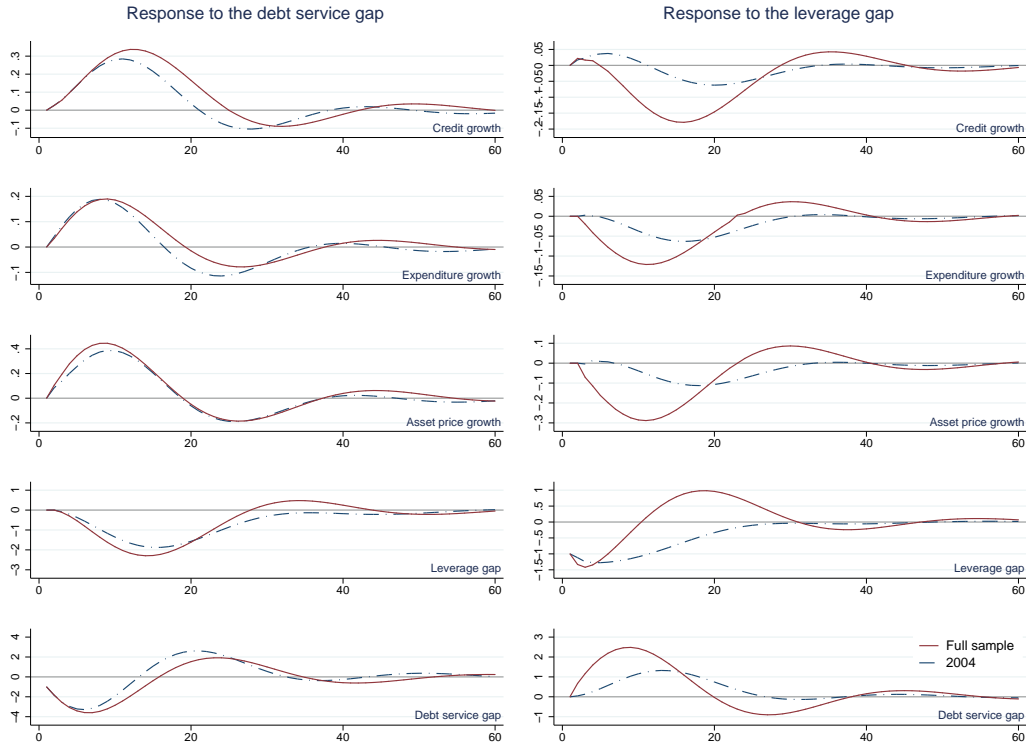
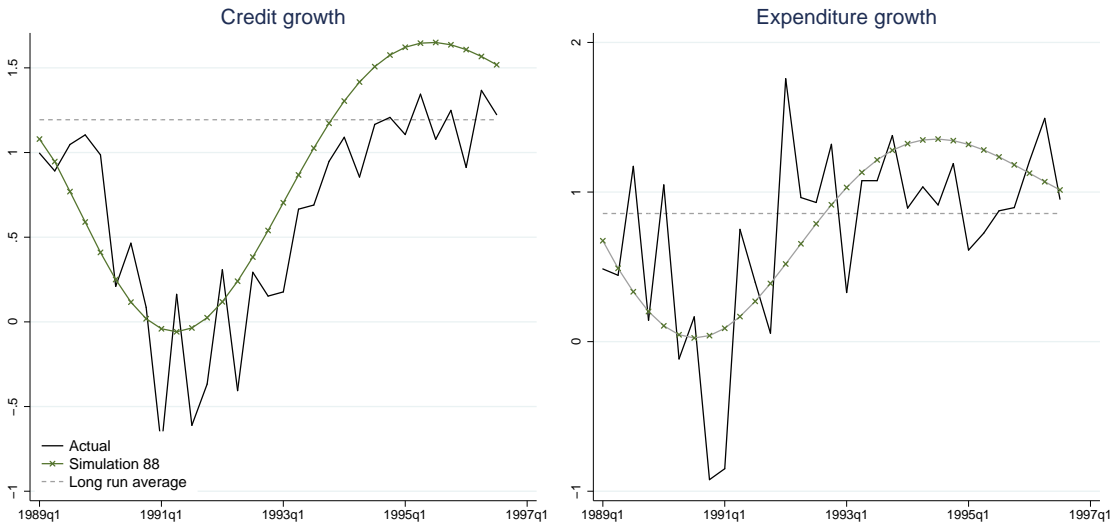


Figure A.3: System response to an initial negative leverage or debt service burden gap given the model estimated until 2004q4 or using the full sample.



no

Figure A.4: Real quarterly credit and expenditure growth versus growth rates implied by adjustment dynamics to observed leverage and the debt service gaps in 1988q4. Adjustment dynamics are based on model estimates using data up to 2004q4.

Data and variables	
$CR_t$ :	Total credit from all sources to the private non-financial sector; Financial Accounts
$Y_t$ :	GDP; Bureau of Economic Analysis
$r_t$ :	Weighted average between the (smoothed) rate on conventional 30-year mortgages and the (smoothed) prime lending rate; FRED database
$A_t$ :	Total private non-financial sector assets; Financial Accounts
$P_t$ :	GDP deflator; Bureau of Economic Analysis
$P_{H,t}$ :	Residential property price index; BIS
$P_{C,t}$ :	Commercial property price index; BIS
$P_{E,t}$ :	Equity price index; BIS
$E_{P,t}$ :	Private expenditure (personal consumption + private investments); Bureau of Economic Analysis
$E_{O,t}$ :	$Y_t - E_{P,t}$
$r_{M,t}$ :	Federal funds rate; Federal Reserve System
$r_{B,t}$ :	Yield on 10-year treasury bills; Federal Reserve System

Table A.1: We use small letters to denote the natural logarithm of a variable, for example  $y_t = \ln(Y_t)$  for the log of nominal GDP (except for interest rates which are in levels), and the superscript  $r$  to denote real variables, for example  $y_t^r = y_t - p_t$  for real GDP.

	Unrestricted system					Restricted system				
	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta r_t$	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta r_t$
Adjustment coefficients to long-run deviations										
$\widetilde{lev}_{t-1}$	<b>-0.021</b> -2.86	0.007 0.79	-0.050 -0.91	-0.039 -0.76	<b>-0.004</b> -2.42	<b>-0.020</b> -4.07				<b>-0.003</b> -2.69
$\widetilde{dsb}_{t-1}$	<b>-0.027</b> -3.99	<b>-0.021</b> -2.52	<b>0.152</b> 3.07	<b>-0.108</b> -2.28	<b>-0.003</b> -2.32	<b>-0.025</b> -5.54	<b>-0.026</b> -5.09	<b>0.191</b> 5.92	<b>-0.106</b> -3.75	<b>-0.002</b> -2.15
Short-run dynamics										
$\Delta cr_{t-1}^r$	0.195 1.86	0.082 0.65	-0.874 -1.15	-0.046 -0.06	0.007 0.36	<b>0.275</b> 3.97				
$\Delta cr_{t-2}^r$	<b>0.570</b> 5.59	0.031 0.25	0.266 0.36	0.649 0.92	-0.029 -1.49	<b>0.454</b> 7.01			<b>0.571</b> 2.15	<b>-0.024</b> -2.01
$\Delta e_{P,t-1}^r$	0.168 1.13	<b>0.398</b> 2.22	0.752 0.70	0.926 0.90	0.035 1.23		<b>0.474</b> 7.99			<b>0.061</b> 4.53
$\Delta e_{P,t-2}^r$	-0.166 -1.12	0.055 0.31	1.175 1.09	-0.812 -0.79	-0.041 -1.42			<b>2.192</b> 6.07		<b>-0.037</b> -2.54
$\Delta e_{O,t-1}^r$	0.014 0.66	0.030 1.15	0.030 0.19	-0.036 -0.24	-0.004 -1.03		<b>0.035</b> 3.73			
$\Delta e_{O,t-2}^r$	-0.023 -1.15	-0.025 -1.06	0.202 1.41	<b>-0.265</b> -1.96	-0.002 -0.65			<b>0.112</b> 1.96		
$\Delta p_{A,t-1}^r$	0.008 0.52	0.016 0.85	-0.157 -1.40	-0.152 -1.43	-0.002 -0.80					
$\Delta p_{A,t-2}^r$	-0.005 -0.30	0.020 1.05	-0.110 -0.98	-0.044 -0.41	-0.002 -0.53					
$\Delta r_{t-1}$	-0.442 -1.03	-0.118 -0.23	2.881 0.93	-1.551 -0.52	<b>1.024</b> 12.30					<b>1.033</b> 14.00
$\Delta r_{t-2}$	0.664 1.53	0.157 0.30	-1.129 -0.36	3.301 1.10	<b>-0.147</b> -1.75					<b>-0.174</b> -2.38
Deterministic terms										
$\mu$	<b>0.245</b> 2.51	<b>0.245</b> 2.07	-0.120 -0.17	0.159 0.24	0.015 0.81	<b>0.251</b> 3.93	<b>0.351</b> 5.58	<b>-1.161</b> -3.00	0.017 0.05	-0.009 -0.59
$d_{85q4}$	<b>1.038</b> 2.60	-0.420 -0.87	4.117 1.42	1.138 0.41	0.085 1.10	<b>1.130</b> 3.63				
$d_{87q2}$	-0.149 -0.36	0.741 1.47	-1.696 -0.56	1.852 0.64	<b>0.374</b> 4.62		<b>0.565</b> 2.69			<b>0.365</b> 4.88
$d_{87q4}$	-0.647 -1.69	-0.831 -1.79	4.647 1.67	<b>-10.158</b> -3.83	0.115 1.55				<b>-8.214</b> -3.21	
$d_{88q3}$	-0.325 -0.85	-0.285 -0.61	0.735 0.26	0.755 0.29	<b>0.215</b> 2.88					<b>0.203</b> 2.86
$d_{92q1}$	0.726 1.83	<b>1.532</b> 3.19	-3.415 -1.18	2.633 0.96	-0.061 -0.79		<b>0.775</b> 3.74			
$d_{93q4}$	-0.132 -0.34	0.204 0.43	0.061 0.02	<b>-9.161</b> -3.39	0.019 0.25				<b>-9.663</b> -3.72	
$d_{94q2}$	-0.357 -0.87	-0.364 -0.73	3.680 1.23	1.673 0.59	<b>0.271</b> 3.38					<b>0.273</b> 3.77
$d_{00q1}$	-0.443 -1.11	0.865 1.78	<b>-9.772</b> -3.36	-2.407 -0.87	0.129 1.65		<b>1.113</b> 2.67	<b>-10.480</b> -3.72		
$d_{07q1}$	-0.448 -1.10	0.358 0.73	<b>-9.402</b> -3.18	0.983 0.35	0.007 0.08			<b>-6.550</b> -4.55		
$d_{08q4}$	0.182 0.44	<b>-1.515</b> -3.03	<b>8.807</b> 2.94	<b>-6.641</b> -2.33	-0.064 -0.79		<b>-1.660</b> -3.89	<b>9.689</b> 3.35	<b>-8.421</b> -3.19	
$d_{09q3}$	0.368 0.84	<b>1.055</b> 2.00	<b>-8.594</b> -2.71	4.716 1.56	0.108 1.28					<b>0.169</b> 2.19
$s_1$	-0.120 -1.05	-0.114 -0.83	0.345 0.42	0.770 0.98	0.018 0.83	-0.127 -1.28	-0.069 -0.55	-0.095 -0.12	0.704 1.01	0.019 1.01
$s_2$	-0.049 -0.45	<b>0.289</b> 2.16	-1.343 -1.67	<b>2.162</b> 2.83	<b>0.058</b> 2.71	-0.035 -0.36	0.230 1.88	-1.124 -1.48	<b>1.768</b> 2.56	<b>0.053</b> 2.80
$s_3$	-0.001 -0.01	0.163 1.23	-0.783 -0.99	0.823 1.09	-0.004 -0.19	0.018 0.18	0.185 1.52	-1.121 -1.48	0.649 0.94	-0.014 -0.74

Table A.2: Estimated coefficients of the full-sample system (8).

	Unrestricted system					Restricted system				
	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta r_t$	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta r_t$
Adjustment coefficients to long-run deviations										
$\widetilde{lev}_{t-1}$	<b>-0.043</b> -3.31	-0.023 -1.26	0.163 1.66	-0.044 -0.49	-0.004 -1.45	<b>-0.019</b> -2.08				<b>-0.005</b> -2.39
$\widetilde{dsb}_{t-1}$	<b>-0.047</b> -4.37	<b>-0.042</b> -2.77	<b>0.272</b> 3.30	-0.114 -1.51	-0.005 -1.88	<b>-0.026</b> -3.52	<b>-0.039</b> -4.86	<b>0.217</b> 4.68	<b>-0.084</b> -2.12	<b>-0.006</b> -3.13
Short-run dynamics										
$\Delta cr_{t-1}^r$	0.203 1.65	0.143 0.83	-1.426 -1.51	0.391 0.45	0.017 0.61	<b>0.297</b> 3.47	<b>0.273</b> 3.60	<b>-1.774</b> -3.92		
$\Delta cr_{t-2}^r$	<b>0.597</b> 4.71	-0.039 -0.22	0.661 0.68	1.522 1.72	-0.033 -0.12	<b>0.476</b> 6.02			<b>1.337</b> 3.41	
$\Delta e_{P,t-1}^r$	0.050 0.30	0.247 1.05	1.492 1.17	0.423 0.36	0.043 1.11			<b>1.557</b> 4.52		<b>0.066</b> 3.80
$\Delta e_{P,t-2}^r$	-0.010 -0.06	0.203 0.87	1.022 0.81	-1.015 -0.88	-0.026 -0.68			<b>3.033</b> 6.79		<b>-0.048</b> -2.83
$\Delta e_{O,t-1}^r$	0.001 0.05	0.022 0.60	0.083 0.41	-0.091 -0.49	-0.004 -0.63					
$\Delta e_{O,t-2}^r$	0.014 0.59	0.008 0.22	0.163 0.87	-0.166 -0.98	0.001 0.10			<b>0.279</b> 3.56		
$\Delta p_{A,t-1}^r$	-0.016 -0.89	-0.024 -0.93	0.130 0.94	<b>-0.264</b> -2.08	-0.002 -0.43				<b>-0.204</b> -2.06	
$\Delta p_{A,t-2}^r$	-0.014 -0.77	0.008 0.31	-0.018 -0.13	<b>-0.248</b> -1.99	-0.002 -0.51				<b>-0.205</b> -2.03	
$\Delta r_{t-1}$	-0.554 -1.30	-0.455 -0.76	5.432 1.66	-1.916 -0.64	<b>1.037</b> 10.60					<b>0.901</b> 22.60
$\Delta r_{t-2}$	0.853 1.93	0.543 0.88	-4.930 -1.46	3.308 1.07	-0.146 -1.44					
Deterministic terms										
$\mu$	0.139 1.05	0.239 1.28	-0.490 -0.48	-1.074 -1.16	-0.023 -0.76	<b>0.191</b> 2.00	<b>0.408</b> 3.61	-1.036 -1.56	-1.006 -1.79	<b>-0.044</b> -2.20
$d_{85q4}$	<b>0.948</b> 2.63	-0.405 -0.80	4.227 1.54	0.645 0.26	0.067 0.81	<b>1.025</b> 3.41				
$d_{87q2}$	-0.314 -0.79	0.651 1.17	-1.613 -0.53	0.808 0.29	<b>0.383</b> 4.20					<b>0.328</b> 4.19
$d_{87q4}$	<b>-0.729</b> -2.07	-0.860 -1.74	<b>5.590</b> 2.08	<b>-9.406</b> -3.82	0.106 1.31				<b>-7.847</b> -3.56	
$d_{88q3}$	-0.426 -1.24	-0.350 -0.72	0.989 0.38	0.634 0.26	<b>0.218</b> 2.77					<b>0.210</b> 2.85
$d_{92q1}$	<b>0.973</b> 2.59	<b>1.666</b> 3.15	-4.348 -1.51	<b>5.200</b> 1.97	-0.019 -0.22		<b>0.752</b> 3.18			
$d_{93q4}$	-0.199 -0.55	0.231 0.46	-0.416 -0.15	<b>-7.160</b> -2.83	0.007 0.09				<b>-7.031</b> -3.07	
$d_{94q2}$	-0.394 -1.04	-0.304 -0.57	2.740 0.94	1.346 0.51	<b>0.251</b> 2.87					<b>0.268</b> 3.51
$d_{00q1}$	-0.418 -1.11	0.996 1.87	<b>-10.522</b> -3.64	-2.078 -0.79	0.129 1.49		<b>1.171</b> 2.75	<b>-10.764</b> -4.21		
$s_1$	-0.163 -1.26	-0.150 -0.83	0.905 0.92	0.306 0.34	0.014 0.46	-0.102 -0.89	-0.099 -0.65	0.493 0.58	0.313 0.40	0.018 0.76
$s_2$	-0.065 -0.50	0.304 1.66	-1.159 -1.16	<b>1.987</b> 2.17	0.056 1.87	-0.005 -0.04	0.252 1.69	-0.942 -1.13	<b>1.950</b> 2.37	<b>0.048</b> 1.98
$s_3$	0.120 0.97	<b>0.383</b> 2.20	-1.826 -1.93	1.560 1.80	-0.018 -0.64	0.088 0.79	<b>0.296</b> 1.98	-1.337 -1.61	1.377 1.83	-0.018 -0.79

Table A.3: Estimated coefficients of the 1985q1-2004q4 system (8).

	Unrestricted system					Restricted system				
	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta r_t$	$\Delta cr_t^r$	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta r_t$
Adjustment coefficients to long-run deviations										
$\widetilde{lev}_{t-1}$	<b>-0.030</b> -2.85	-0.004 -0.31	-0.032 -0.41	0.014 0.20	-0.001 -0.59	<b>-0.020</b> -4.10				<b>-0.002</b> -2.19
$\widetilde{dsb}_{t-1}$	<b>-0.034</b> -3.93	<b>-0.029</b> -2.71	<b>0.169</b> 2.65	-0.100 -1.72	-0.002 -1.06	<b>-0.025</b> -5.54	<b>-0.026</b> -5.07	<b>0.191</b> 5.89	<b>-0.083</b> -2.50	-0.002 -1.94
$r_{M,t-1}^r$	0.046 0.95	0.025 0.42	-0.075 -0.21	0.136 0.42	-0.004 -0.42					
$r_{B,t-1}^r$	-0.014 -0.26	0.015 0.22	0.041 0.10	-0.499 -1.36	-0.007 -0.63				<b>-0.308</b> -2.37	
$u_{t-1}$	0.045 0.87	0.081 1.30	-0.286 -0.76	0.534 1.54	-0.004 -0.39					
Short-run dynamics										
$\Delta cr_{t-1}^r$	0.166 1.46	0.075 0.54	-0.980 -1.18	0.671 0.88	0.019 0.88	<b>0.275</b> 3.95				
$\Delta cr_{t-2}^r$	<b>0.565</b> 5.29	0.046 0.36	0.136 0.17	1.192 1.67	-0.024 -1.15	<b>0.451</b> 6.93			<b>0.603</b> 2.03	-0.020 -1.66
$\Delta e_{P,t-1}^r$	0.111 0.70	0.325 1.71	0.859 0.75	1.313 1.25	0.051 1.68		<b>0.476</b> 7.99		<b>1.042</b> 2.28	<b>0.060</b> 4.34
$\Delta e_{P,t-2}^r$	-0.179 -1.20	0.042 0.23	1.235 1.13	-0.991 -0.99	-0.041 -1.42			<b>2.160</b> 5.95		<b>-0.045</b> -3.10
$\Delta e_{O,t-1}^r$	0.005 0.21	0.019 0.68	0.042 0.25	0.046 0.30	-0.002 -0.36		<b>0.035</b> 3.74			
$\Delta e_{O,t-2}^r$	-0.026 -1.32	-0.029 -1.19	0.209 1.43	<b>-0.263</b> -1.97	-0.002 -0.48			0.106 1.85		
$\Delta p_{A,t-1}^r$	0.002 0.13	0.008 0.39	-0.131 -1.09	-0.191 -1.73	-0.002 -0.54				-0.165 -1.94	
$\Delta p_{A,t-2}^r$	-0.007 -0.47	0.015 0.80	-0.092 -0.79	-0.089 -0.83	-0.002 -0.50					
$\Delta r_{t-1}$	-0.422 -0.96	-0.158 -0.30	2.871 0.89	-0.835 -0.28	<b>1.035</b> 12.20					<b>1.065</b> 14.30
$\Delta r_{t-2}$	0.683 1.40	0.388 0.66	-1.693 -0.47	3.144 0.96	-0.171 -1.82					<b>-0.204</b> -2.77
Deterministic terms										
$\mu$	0.059 0.19	-0.217 -0.58	1.501 0.66	-2.731 -1.32	0.034 0.57	<b>0.253</b> 3.95	<b>0.349</b> 5.53	<b>-1.137</b> -2.92	0.364 0.69	-0.004 -0.29
$d_{85q4}$	<b>1.008</b> 2.43	-0.544 -1.09	4.400 1.45	1.323 0.48	0.101 1.26	<b>1.120</b> 3.58				
$d_{87q2}$	-0.275 -0.64	0.621 1.19	-1.413 -0.45	1.823 0.63	<b>0.393</b> 4.73		<b>0.566</b> 2.69			<b>0.359</b> 4.69
$d_{87q4}$	-0.735 -1.83	<b>-0.985</b> -2.03	4.878 1.66	<b>-9.301</b> -3.47	0.147 1.90				<b>-7.593</b> -3.07	
$d_{88q3}$	-0.283 -0.73	-0.256 -0.55	0.624 0.22	1.035 0.40	<b>0.213</b> 2.84					<b>0.200</b> 2.75
$d_{92q1}$	0.658 1.58	<b>1.490</b> 2.96	-3.667 -1.20	4.711 1.69	-0.026 -0.32		<b>0.774</b> 3.72			
$d_{93q4}$	-0.155 -0.39	0.189 0.40	0.053 0.02	<b>-8.899</b> -3.38	0.025 0.33				<b>-9.375</b> -3.75	
$d_{94q2}$	-0.365 -0.88	-0.388 -0.77	3.818 1.25	1.208 0.43	<b>0.268</b> 3.34					<b>0.283</b> 3.82
$d_{00q1}$	-0.412 -1.01	0.914 1.86	<b>-9.993</b> -3.36	-1.791 -0.66	0.130 1.66		<b>1.084</b> 2.60	<b>-10.220</b> -3.62		
$d_{07q1}$	-0.477 -1.16	0.320 0.64	<b>-9.387</b> -3.12	1.446 0.53	0.018 0.23			<b>-6.508</b> -4.50		
$d_{08q4}$	0.273 0.64	<b>-1.353</b> -2.63	<b>8.383</b> 2.69	<b>-6.461</b> -2.27	-0.083 -1.01		<b>-1.641</b> -3.82	<b>9.534</b> 3.27	<b>-8.087</b> -3.11	
$d_{09q3}$	0.349 0.79	1.020 1.90	<b>-8.340</b> -2.57	3.703 1.25	0.100 1.17					
$s_1$	-0.116 -1.00	-0.116 -0.83	0.408 0.48	0.436 0.56	0.014 0.63	-0.126 -1.27	-0.067 -0.54	-0.111 -0.14	0.778 1.13	0.018 0.95
$s_2$	-0.033 -0.29	<b>0.301</b> 2.22	-1.336 -1.62	<b>1.946</b> 2.59	<b>0.053</b> 2.45	-0.035 -0.35	0.230 1.88	-1.125 -1.47	<b>1.969</b> 2.89	<b>0.051</b> 2.62
$s_3$	0.001 0.01	0.171 1.28	-0.830 -1.03	0.979 1.33	-0.003 -0.14	0.017 0.18	0.186 1.52	-1.129 -1.48	0.976 1.44	-0.011 -0.57

Table A.4: Estimated coefficients of system (8) with additional control variables included. The variables include the real federal funds rate,  $r_{M,t}^r$ , the real yield on government bonds,  $r_{B,t}^r$ , and the unemployment rate,  $u_t$ . The numbers in parenthesis are  $t$ -values. Insignificant coefficients in the reduced system cannot be removed without violating the encompassing tests.



1985q4-2013q4 system					
	$cr_t - y_t$	$p_{H,t}^r$	$p_{C,t}^r$	$p_{E,t}^{r\dagger}$	$r_t$
$\beta'_{lev}$	1	<b>-0.486</b> (6.44)	<b>-0.451</b> (7.23)	<b>-0.063</b> (2.06)	—
$\beta'_{dsb}$	1	—	—	—	<b>0.062</b> (9.49)
1985q1-2004q4 system					
$\beta'_{lev}$	1	<b>-0.528</b> (-11.60)	<b>-0.436</b> (-10.91)	<b>-0.036</b> (-2.99)	—
$\beta'_{dsb}$	1	—	—	—	<b>0.058</b> (7.10)

Table A.5: Estimated long-run relationships of the 1985q1-2004q4 and the full-sample system.

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