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Leverage dynamics and the real burden of debt*

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Abstract

In addition to leverage, the aggregate debt service burden is an important link between financial and real developments. Using US data from 1985 to 2013, we find that it has sizable negative effects on credit and expenditure growth. Strong interactions between leverage and the debt service burden lead to large and protracted cycles in credit and expenditure that match the stylised facts of credit booms and busts. Even with real-time estimates, the predicted adjustment to leverage and the debt service burden from 2005 onwards imply paths for credit and expenditure that closely match actual developments before and during the Great Recession.

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1 Introduction

In retrospect it seems clear that the US economy was on an unsustainable path in the years leading up to the financial crisis. The evolution of credit, the credit-to-GDP ratio and asset prices bore all the hallmarks of what the literature would identify as a credit boom (eg Minsky (1982), Borio and Lowe (2002), Reinhart and Rogoff (2009), Borio and Drehmann (2009) or Jorda et al (2013)). This begs the question - most famously asked by Britain's Queen Elizabeth II - why the vast majority of economists did not see the financial crisis coming. But what seems obvious now was less clear-cut then. Macroeconomic developments looked sustainable when viewed through conventional indicators: real output growth and inflation fluctuated at around around 3%.

The apparent disconnect between credit and GDP at the time is particularly puzzling. Standard macro-finance models, for instance, predict that these two variables should move more or less in lock-step (eg Bernanke et al (1999) or Kiyotaki and Moore (1997)). Yet, the US credit-to-GDP ratio increased rapidly in the run-up to the crisis, with only credit showing unusually fast growth. In fact, this ratio has been trending upwards for more than 30 years, which is most commonly attributed to sustainable financial deepening. The failure of economists, hence, seems more subtle: they were not able to distinguish between sustainable (long-run) and unsustainable (short-run) increases in the credit-to-GDP ratio.

The starting point for this paper is the conjecture that the unsustainable increases in the credit-to-GDP ratio are important for explaining macroeconomic dynamics, in particular during credit boom-bust cycles. This is also suggested by the strong empirical evidence that recessions are much deeper after a credit boom (eg Claessens et al (2009) or Jorda et al (2013)). But to test this conjecture more formally, we first need to properly distinguish between sustainable and unsustainable movements in the credit-to-GDP ratio, a problem we approach from an empirical perspective. And as it turns out, doing so has powerful implications. For one, it helps to explain the puzzling divergence between credit and output growth prior to the crisis. Furthermore, the adjustment to unsustainable movements in the credit-to-GDP ratio is so powerful that it explains much of the severity and length of the Great Recession.

To determine sustainable movements in the credit-to-GDP ratio, we start by specifying two potential long-run relationships for it, building on factors that have been identified by the literature: leverage and the debt service burden. Leverage has taken centre stage in discussions of macro-financial linkages and we measure it by the credit-to-asset ratio. We show that, if relevant, collateral constraints imply a long-run relationship between the credit-to-GDP ratio and real asset prices. The debt service burden, which we proxy by the ratio of interest payments plus amortisations to income, is an important driver of lending decisions[1] and expenditure at the micro level.[2] If it is relevant at the aggregate level, it implies a long-run relationship between credit-to-GDP and lending rates.

We find that the leverage and debt service relationships together determine the long-run value for the credit-to-GDP ratio. Specifically, both relationships produce mean-reverting deviations that are slowly corrected through the credit-to-GDP ratio when they are jointly embedded as possible error correction mechanisms in a vector auto-regressive (VAR) model. We estimate this cointegrated VAR on quarterly US data from 1985 to 2013.[3] Steady-state occurs only when the credit-to-GDP ratio, real asset prices and the lending rate take values that satisfy both relationships simultaneously.[4]

[1] Before credit is granted, borrowers typically have to show that expected income is sufficiently high to service future interest payments and amortisations, ie the expected debt service burden has to below a critical threshold (eg Quercia et al (2003)).

[2] At the micro level, the negative effects of debt service burdens on expenditure in the household sector are documented in eg Olney (1999), Johnson and Li (2010), or Dynan (2012). This also applies to firms, where higher debt service payments reduce investment because of its cash flow sensitivity (eg Rauh (2006), Gan (2007), Campello et al (2011) or Chaney et al (2012)).

[3] 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, which in turn help to explain macro dynamics during credit booms and busts.

[4] Together, the two relationships also imply that real asset prices and lending rates are inversely related over the long run.

The unsustainable deviations from the long-run leverage and debt service relationships are crucial for explaining the dynamics of credit and expenditure. In line with micro evidence and standard macrofinance models, we show that real credit growth increases when leverage is below its long-run value, for example, because of rising asset prices.[5] Going beyond the available evidence, we find that the debt service burden also plays an important role at the aggregate level that has generally been overlooked: it has a strong negative impact on consumption and investment. Given that debt payments of borrowers are income for lenders, this in itself is a surprising result as lenders should make up for the reduced expenditure of borrowers, unless they have a lower marginal propensity to consume. But even if this is the case, a fall in the interest rate should theoretically be able to negate any aggregate effect as it lowers the debt service burden and induces lenders to spend more, unless frictions, such as the zero lower bound, prevent interest rates from falling sufficiently (Eggerston and Krugman (2012), Farhi and Werning (2013) or Korinek and Simsek (2014)). Yet empirically, the negative effect of the debt service burden on expenditure prevails even if we exclude the most recent period where rates have been close to the lower bound.

The strong interactions between leverage and the debt service burden lead to long cycles in credit and output growth, which are consistent with the stylised facts that have emerged from the empirical literature analysing credit booms and financial cycles (eg Mendoza and Terrones (2008, 2012), Reinhart and Rogoff (2009), Schularick and Taylor (2012), Claessens et al (2009, 2011), Drehmann et al (2012), Jorda et al (2013, 2014)). Starting from a situation where both leverage and the debt service burden are below their respective long-run values - conditions that prevailed eg in the late 1980s and mid 2000s - the system adjusts through rapid asset price and credit growth without large gains to real growth.[6] Afterwards the economy enters a deep and very protracted

[5] For instance, Mian and Sufi (2014) show that a large part of the increase in debt in the run-up to the recent crisis came from home equity withdrawals suggesting that home owners actively manage their leverage.

[6] This implies a rapid increase in the credit-to-GDP ratio, which has been identified as a reliable early warning indicator for financial crises (eg Borio and Drehmnn (2009), Gourinchas and Obstfeld (2012) or Jorda et al (2013)).

downturn during which lending rates fall. The adjustment back to equilibrium is slow, taking between 10 and 20 years.[7] Interestingly, expenditure ends up at a lower and credit at a higher level in the new steady-state. Thus, our results also resonate with findings in the literature that recessions after banking crises (which typically follow credit booms) can have permanent effects (eg Cerra and Saxena (2008)).

The adjustment dynamics to leverage and the debt service burden are so strong that knowledge of their long-run deviations would have helped us to anticipate the Great Recession from as early as 2005, even if the model had been estimated in real-time. For instance, given policy reactions embedded in the estimates, the model projects a 3.5% fall in annual credit growth by the end of 2009 in line with the magnitude of the actual minimum observed half a year later. The match for annual private expenditure growth is also good. For example, the model anticipates a very drawn out recession and recovery, with private sector expenditure growth only returning to historical norms in early 2012. It does, however, not fully capture the severity of the crisis in the direct quarters following the Lehman failure: the projected maximum drop in expenditure is -4% compared to nearly -6% in reality. Even so, the results suggest that the recession was not a result of the Lehman failure, nor that the crisis was a "black swan" event. Rather, leverage and the debt service burden were at its core.

The uncovered dynamics 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 financial accounts and the debt service ratio as constructed by Drehmann and Juselius (2012).

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

[7] A cycle length of 10 to 20 years is in line with the literature analysing financial or credit cycles (eg Aikman et al (2014) and Drehmann et al (2012)).

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 rely on a straightforward VAR to distinguish between sustainable (long-run) and unsustainable (short-run) movements in the credit-to-GDP ratio. We start by searching for potential long-run relationships for the credit-to-GDP ratio based on factors that have been found to affect lending and borrowing decisions at the micro level: leverage and the debt service burden. We first show that, if relevant in the aggregate, leverage embeds a relationship between the credit-to-GDP ratio and real asset prices, whereas the debt service burden relate the credit-to-GDP ratio to lending rates.

We embed these two relationships in a VAR to check if at least one of them discipline the credit-to-GDP ratio over the long run. As we find this to be the case for both leverage and the debt service burden, we then check how (unsustainable) deviations from their long-run values feed into output and credit growth, as well as the other variables of the system. As robustness checks, we also add potentially important control variables, such as the real short-term money market rate or the term spread, to assess the value added of leverage and the debt service burden as explanatory factors for credit and output growth.

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 price level.

2.1 Long-run relationship I: 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 ξ of assets, A_t so that leverage, defined here as the credit-to-asset ratio, is lower than ξ, ie $LEV_t = CR_t/A_t \leq \xi$. In the model, constrained borrowers will always operate at maximum leverage, implying that the credit-to-asset ratio is constant and equal to ξ. If asset prices rise, for instance, borrowers will take on more debt, which in turn increases investment and output.

Looking at data from the financial accounts, however, reveals that the aggregate credit-to-asset ratio has been fluctuating over time (see Figure 6 in Section 6.2). This may be driven by several factors. For instance, agent heterogeneity can lead to endogenous leverage cycles (eg Fostel and Geanakopolos (2013)). Furthermore, collateral constraints affect new borrowing but not necessarily outstanding credits with longer maturities as it may not be optimal for borrowers to immediately adjust the stock of credit to changes in the value of collateral. Hence, the credit-to-asset ratio can fluctuate in the short run (eg Brzoza-Brzezina et al (2014)). It thus seems more reasonable to replace the prediction of constant leverage with a weaker empirical condition that leverage should be constant in the long run, ie $LEV_{long\,run} = \xi$.

But how does aggregate leverage relate to the credit-to-GDP ratio? There is an explicit relationship between leverage

$$LEV_t = \frac{CR_t}{A_t} \tag{1}$$

and the credit-to-GDP ratio if the stock of real assets is built up from real output over time. In particular, assume that a fraction τ of real output, $Y^r = Y_t/P_t$, is invested into durable, pledgeable assets and that there is a constant depreciation rate δ in steady state. Then real assets, $A_t^r = A_t/P_{A,t}$, follow $A_t^r = (1-\delta)A_{t-1}^r + \tau Y_t^r$. Or $A_t^r = \lambda Y_t^r$

with $\lambda = \tau/\delta$ and thus

$$A_t = P_{A,t} \left(\lambda \frac{Y_t}{P_t} \right) \tag{2}$$

Substituting (2) into the leverage ratio and rearranging yields

$$LEV_t = \frac{CR_t}{Y_t} \left(\lambda^{-1} \frac{P_t}{P_{A,t}} \right) \tag{3}$$

which links leverage to the credit-to-GDP ratio.

Equation (3) remains difficult to estimate as $P_{A,t}$ is a general asset price index that is not directly observed. However, $P_{A,t}$ can be approximated by a Cobb-Douglas index of n different observable asset prices i, ie $P_{A,t} = \Pi_{i=1}^{n} P_{A_i,t}^{\psi_{A_i}}$ with $\sum_{i=1}^{n} \psi_{A_i} = 1$. Using the Cobb-Douglas price index specifications in (3) and taking logs we get

$$lev_t = cr_t - y_t - \overline{\lambda} - \sum_{i=1}^{n} \psi_{A_i}(p_{A_i,t} - p_t) \tag{4}$$

where $\overline{\lambda} = \ln(\lambda)$, $p_{A_i,t}$ is the log of the price of an asset of class i, p_t is the log of the GDP deflator, and $\sum_{i=1}^{n} \psi_{A_i} = 1$. Following Borio et al (1994), we distinguish between residential real estate, commercial real estate, and equity prices in the empirical section below.

If leverage equals ξ in the long run, as theory suggests, the credit-to-GDP ratio and the real general asset price index should move together over time. This follows from the formal condition that deviations of leverage from the long-run level ξ should be stationary, ie that $\widetilde{lev}_t = lev_t - \xi \sim I(0)$, which together with (4) produces

$$\widetilde{lev}_t = cr_t - y_t - (\overline{\lambda} + \xi) - \sum_{i=1}^{n} \psi_{A_i}(p_{A_i,t} - p_t) \tag{5}$$

and implies that the credit-to-GDP ratio and the real general asset price index are cointegrated.

Provided that leverage is constant in the long run, we can also test whether it helps to specifically pin down a sustainable level for the credit-to-GDP ratio. This will be the case if deviations from long-run leverage have a direct impact on the credit-to-GDP ratio in such a way that it helps to correct the deviations, ie if $\widetilde{lev_t}$ has a negative effect on $\Delta(cr_t - y_t)$. This can be easily tested. And if we find this to be the case, the long-run leverage relationship implies a sustainable credit-to-GDP ratio given prevailing asset prices, with $\widetilde{lev_t} = 0$ and

$$(cr_t - y_t)_{sustainable\,leverage} = (\overline{\lambda} + \xi) + \sum_{i=1}^{n} \psi_{A_i}(p_{A_i,t} - p_t) \tag{6}$$

The flipside of the argument is that values of the credit-to-GDP ratio that deviate from the right hand side of (6) are not sustainable with respect to leverage, and the distance between it and the sustainable level are captured by $\widetilde{lev_t}$.

2.2 Long-run relationship II: the aggregate debt service burden

Micro evidence points to the debt service burden as another potential determinant of sustainable credit-to-GDP for two reasons. First, prospective borrowers typically do not only need to meet a leverage constraint but their future expected income has to be sufficiently high to service future interest payments and amortisations, ie their expected debt service burden has to below a critical threshold (eg Quercia et al (2003)). This is simply the well know transversality condition ruling out Ponzi schemes.[8]

Second, debt service costs enter the budget constraint of existing borrowers and, hence, matter for their expenditure. In particular, if interest payments and amortisations are high relative to income, and it is not possible to roll over debt, borrowers have to cut back on expenditure to avoid default. There is clear evidence that high debt service burdens reduce expenditure at the micro level[9] and Aron et al (2012) find

[8] Empirically, a high debt service burden significantly reduces the likelihood of obtaining credit (eg Johnson and Li (2010)).

[9] 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)).

that such effects extend to aggregate consumption in the case of the UK. However, the aggregate effects are theoretically unclear as the debt service payments of borrowers are income for lenders. Thus, lenders should make up for the reduced expenditure of borrowers, unless they have a lower marginal propensity to consume (or higher levels of wealth). And even so, a fall in interest rates could bring demand back as it lowers the debt service burden and induces lenders to spend more except when there are frictions, such as the zero lower bound (eg Eggerston and Krugman (2012), Farhi and Werning (2013) or Korinek and Simsek (2014)).

We measure the debt service burden, DSB_t, as debt service payments, ie interest payments plus amortisations, divided by income or

$$DSB_t = \frac{Interest\,payments_t + Amortisations_t}{Income_t} \tag{7}$$

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 construct the debt service burden - or debt service ratio in their terminology[10] - for the aggregate household sector (Lucket (1980) and 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 the aggregate debt stock are repaid in equal portions (instalments) over the average remaining maturity of the stock of debt. The justification is that the differences between the repayment structures of individual loans will tend to cancel out in the aggregate.[11] A formula for calculating the debt service costs of an instalment loan is readily available. Using it and dividing

[10] 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. This also has the virtue of easing up the exposition and avoiding ambiguity when, for instance, we refer to the long-run relationship derived in this section.

[11] 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 instalment loan.

by income yields:

$$DSB_t = \frac{r_t}{(1-(1+r_t)^{-m})} \frac{CR_t}{Y_t} \tag{8}$$

where r_t is the average nominal lending rate on the credit stock and m is the average remaining maturity of the credit stock.[12] Taking logs and and defining γr_t as the linear approximation of $\ln(\frac{r_t}{(1-(1+r_t)^{-m})})$ we get

$$dsb_t = cr_t - y_t + \gamma r_t \tag{9}$$

Note that the average lending rate used in (8) and (9) is different from interest rates that are typically included in the literature, such as the short-term money market rate or the interest rate on new lending. The reason is that the stock of debt contains a mix of loans with different maturities and different fixed and floating nominal interest rates attached to them. Hence, the average lending rate reflects not only current interest rate conditions, but also past money market rates, past inflation and interest rate expectations as well as past risk and term premia. But this implies that the lending rate, and hence the debt service burden, is chiefly influenced by current and past monetary policy decisions. This more direct dependence on policy is an important difference between the leverage and the debt service burden relationships from a policy perspective.

If the debt servicing burden helps to determine the sustainable credit-to-GDP ratio at the aggregate level, two testable conditions should be met. First, debt service burden should be constant in the long run, implying that the credit-to-GDP ratio and the lending rate move together over time. Formally, if μ_{dsb} is the long-run value for the debt service burden such that $\widetilde{dsb}_t = dsb_t - \mu_{dsb} \sim I(0)$, with

$$\widetilde{dsb}_t = cr_t - y_t + \gamma r_t - \mu_{dsb} \tag{10}$$

[12] The distinction between interest payments and amortisations as suggested by equation (7) is no longer explicit in equation (8) which uses the instalment loan formula. The reason is that both change with changes in interest rates to generate a stream of debt service payments that are constant over the life of the loan.

then the credit-to-GDP ratio and the lending rate are cointegrated.

Second, given that we find cointegration, we can test, as before, whether the debt service relationship helps to determine the sustainable level of the credit-to-GDP ratio. This happens if the deviations from the long-run level of the debt service burden would push the credit-to-GDP ratio until the long-run is restored, ie if $\widetilde{dsb}_t \sim I(0)$ and it has a negative effect on $\Delta(cr_t - y_t)$. In this case, the sustainable credit-to-GDP ratio given prevailing lending rates is

$$(cr_t - y_t)_{sustainable\, dbs} = -\gamma r_t + \mu_{dsb} \tag{11}$$

and the distance between this level and the current credit-to-GDP ratio are captured by $\widetilde{dsb}_t$.

So far, the discussion has focused on the leverage and the debt service burden relationships separately. But as it turns out we find that both $\widetilde{lev}_t$ and $\widetilde{dsb}_t$ impact negatively on the credit-to-GDP ratio. Thus *both* long-run relationships jointly determine the sustainable level of the credit-to-GDP ratio and have to be simultaneously satisfied for the economy to be in steady-state. If only one holds, the credit-to-GDP ratio, and hence credit and/or GDP, will change, forcing deviation in the other relationship, until the economy converges to equilibrium.

2.3 Data

We use US quarterly time series data for the private non-financial sector covering the sample period 1985q1-2013q4.[13] The data and sources are as listed in Table 1.

Data are readily available for all of the variables, 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). We first calculate the interest rate on new loans for the total

[13] 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) or McConnell and Perez-Quiros (2000)) and the liberalisation of financial markets in the early 1980s allowing for more flexible ways to finance consumption and investment (eg Jermann and Quadrini (2006)).

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 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.

private non-financial sector by taking the weighted average of the conventional 30-year mortgage rate for the household sector and the prime lending rate for the non-financial corporate sector. Weights are given by the outstanding stocks of credit in each sector. We then smooth this series by a auto-regressive component of 0.7 to generate a proxy for the lending rate on the outstanding stock of credit. Alternatively, r can be derived from the financial and national accounts. As we show in Drehmann et al (2015), the simple proxy used in this paper matches the effective lending rates based on data from Bureau of Economic Analysis data very closely.

2.4 Econometric workhorse

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

$$\Delta x_t = \gamma_0 + \Pi x_{t-1} + \sum_{i=1}^{l-1} \Pi_i \Delta x_{t-i} + \Gamma s_t + \boldsymbol{\varepsilon}_t \tag{12}$$

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 VAR model in error correction form is a convenient tool for analysing long-run co-movements between a set of endogenous stochastically trending variables. The parameter matrix Π in (12) captures the cointegration properties of the data. If it has reduced rank with $0 < rank(\Pi) := v < q$, where q is the dimension of x, there are v cointegration relationships and $q - v$ common stochastic trends. In this case Π can be represented as the product of two $(q \times v)$ matrices of full column rank, α and β. That is $\Pi = \alpha\beta'$, where $\beta' x_{t-1}$ describes the cointegration relationships and α 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 Π is equal to a specific integer.[14]

Given a reduced but non-zero rank, it is possible to test linear restrictions on the cointegration space. These can tested by a null hypothesis of the form $\mathcal{H}_0 : \beta = (H_1\varphi_1, ..., H_v\varphi_v)$ against the unrestricted estimates, where the $q \times (q - m_i)$ dimensional matrix H_i imposes $0 \leq m_i < q$ restrictions on β_i, $i = 1, ..., v$, and φ_i is a $(q - m_i)$ dimensional vector of free parameters. The test statistic for the hypotheses is asymptotically chi-square distributed. We will make use of these tests to distinguish between the two hypothesized long-run relationships.

2.4.1 Estimating the long-run relationships for the credit-to-GDP ratio

To check if at least one of our two hypothetical relationships disciplines the credit-to-GDP ratio over the long run, we embed the variables from (5) and (10) in (12) to

[14] The testing sequence that ensures correct overall power and size starts from the null hypothesis of rank zero, successively increases the rank by one, and then stops when the first non-rejection occurs.

get

$$\begin{pmatrix} \Delta(cr-y) \\ \Delta p_H^r \\ \Delta p_C^r \\ \Delta p_E^r \\ \Delta r \end{pmatrix}_t = \gamma_0 + \Pi \begin{pmatrix} cr-y \\ p_H^r \\ p_C^r \\ p_E^r \\ r \end{pmatrix}_{t-1} + \sum_{i=1}^{l-1} \Pi_i \Delta \begin{pmatrix} \Delta(cr-y) \\ \Delta p_H^r \\ \Delta p_C^r \\ \Delta p_E^r \\ \Delta r \end{pmatrix}_{t-i} + \Gamma s_t + \boldsymbol{\varepsilon}_t \quad (13)$$

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.

Given (13), it is easy to test if the leverage and/or debt service burden relationships define sustainable levels for the credit-to-GDP ratio. If both relationships are in the data and there are no other stationary linear combinations between the variables, we should find two cointegrating relationships, ie $v = 2$, so that Πx_t takes the form $\alpha\beta' x_t$ with

$$\hat{\beta} x_{t-1} = \begin{pmatrix} 1 & \psi_P & \psi_C & \psi_E & 0 \\ 1 & 0 & 0 & 0 & \gamma \end{pmatrix} \begin{pmatrix} cr-y \\ p_H^r \\ p_C^r \\ p_E^r \\ r \end{pmatrix}_{t-1} \quad (14)$$

In addition, the adjustment coefficients to deviations from the long-run relationships in the equation for credit-to-GDP growth, α_{11} and α_{12}, should have negative signs. Given that we assume that the aggregate asset price index is a Cobb-Douglas index of three different asset prices, we also test whether $\psi_P + \psi_C + \psi_E = 1$.

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

Table 2: 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.† A test for the null hypothesis that $p^r_{E,t}$ can be excluded from the cointegration space cannot be rejected at the 5% significance level (p-value 0.46).

3 Results for the long-run relationships

In this section, we test if the leverage and debt service relationships derived in Section 2 define empirically valid long-run relationships. The results are summarised in Table 2.

We find that there are two cointegrating relationships in the data, ie $v = 2$ (Table 2, upper panel). Both the hypotheses that there is no cointegration ($v = 0$) and that there is at most one cointegration relationship ($v \leq 1$) are rejected at the 5% significance level. The null hypothesis that there are at most two cointegration relationships ($v \leq 2$) cannot, however, be rejected.[15]

Testing the identifying restrictions implied by (14) suggests that the two cointegration relationships are in line with the leverage and debt service burden relationships. The joint test of these restrictions yields a p-value of 0.12 and cannot, hence, be rejected at the 5% significance level. Furthermore, testing the additional restriction that

[15] The remaining tests for $v \leq 3$ on so on are redundant, but reported for completeness.

$\psi_P + \psi_C + \psi_E = 1$ 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.[16] However, we continue to impose it 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.

The coefficient estimates of the identified cointegration vectors are also consistent with the leverage and debt service burden relationships from an economic perspective (Table 2, upper centre panel). All of the coefficients have the right signs and their magnitudes are plausible. 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.

Both leverage and the debt service burden relationship help to pin down the sustainable level of the credit-to-GDP ratio (Table 2, lower central panel). Not only do they the define cointegrating relationships, but the deviations $\widetilde{lev}_t$ and $\widetilde{dsb}_t$ impact negatively on the credit-to-GDP ratio. Thus, given asset prices and lending rates, these deviations force the the credit-to-GDP ratio back to the sustainable levels defined by (6) and (11). But the adjustment is very slow. Only 2-3% of $\widetilde{lev}_t$ or $\widetilde{dsb}_t$ are being corrected each quarter. These coefficients already imply that the adjustment process is over 10 years long. And interactions between leverage and the debt service burden can lead to even longer swings. When leverage deviations are negative, for instance, credit-to-GDP ratios will rise. This increases $\widetilde{dsb}_t$ over time, which in turn exerts a negative

[16] The results of the paper hold even if we do not impose this restriction. Results are available on request.

drag on the credit-to-GDP ratio. We analyse the adjustment dynamics to leverage and the debt service burden deviations in more detail in Section 4.2 below.

Leverage and the debt service burden deviations have only limited effects on the other variables in the system (Table 2, lower centre panel). $\widetilde{lev}_t$, in particular, does not directly and significantly feed into any of the other variables.

Debt service burden deviations, on the other hand, impact negatively on real residential property prices and lending rates. But these effects are not strong. Interestingly, the effect on the lending rate is error correcting. This 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)).

The unsustainable movements in the credit-to-GDP ratio captured by the deviations from long-run leverage and the long-run debt service burden, $\widetilde{lev}_t$ and $\widetilde{dsb}_t$, play the central role in our analysis. Going forward, we will loosely refer to $\widetilde{lev}_t$ as *leverage* and $\widetilde{dsb}_t$ as the *debt service burden*, rather than using their precise but more cumbersome definitions. And whenever we refer to for example high leverage, we mean that leverage is above its long run value, ie that $\widetilde{lev}_t$ is positive.

Graphically, the estimated long-run relationships capture the broad trend in credit-to-GDP well and deviations are clearly mean-reverting (Figure 1).[17] The upper panels show the credit-to-GDP ratio in relation to the sustainable levels from the estimated long-run relationships given real asset prices (equation (6)) or the lending rate (equation (11)). The lower panels show the deviations between the solid and dotted lines, ie

[17] Given that asset prices and interest rates are more volatile than credit-to-GDP ratios, they explain the bulk of high-frequency movements in deviations from the long-run relationships.

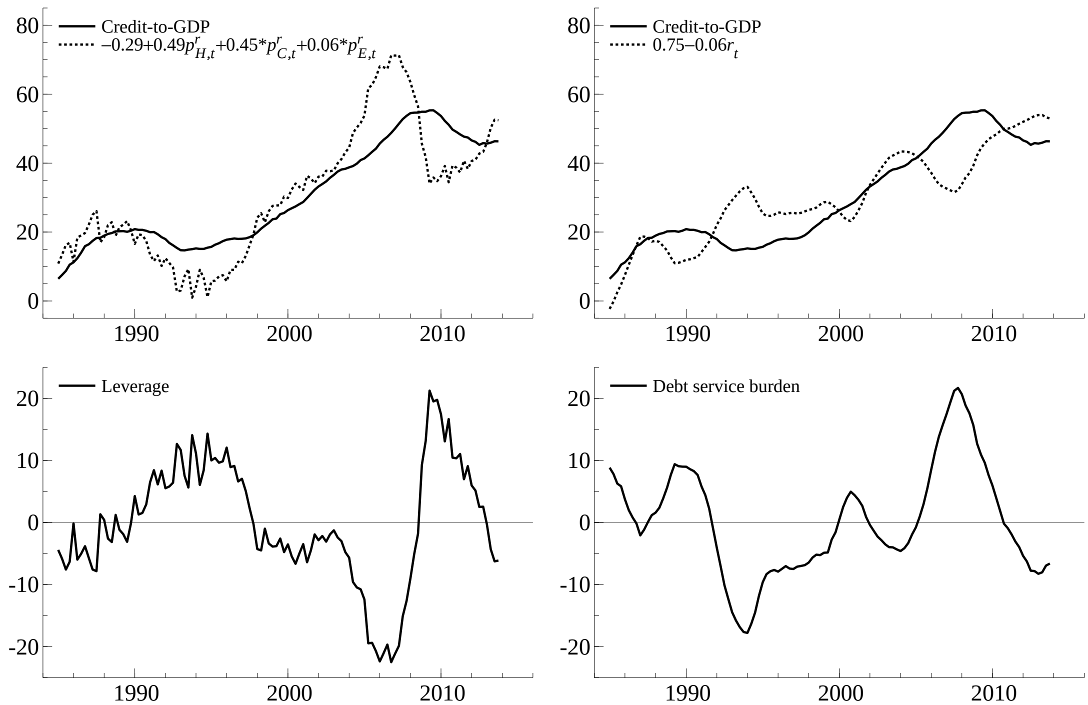

Figure 1: The credit-to-GDP ratio (log) and sustainable levels conditional on real asset prices (6) and the lending rate (11) from the estimated long-run relationships. Leverage and the debt service burden shown in the lower panels are the deviations, $\widetilde{lev_t}$and $\widetilde{dsb_t}$, of the credit-to-GDP ratio from the respective sustainable levels.

leverage ($\widetilde{lev_t}$) and the debt service burden ($\widetilde{dsb_t}$). Both leverage and the debt servicing burden clearly exhibit mean reversion, in line with the notion that high (or low) leverage or debt service burdens capture unsustainable movements in the credit-to-GDP ratio.

The deviations from the estimated long-run values reveal that leverage was low ahead of the current crisis, which is seemingly at odds with the common narrative (Figure 1, left-hand panel). For instance, micro evidence suggests that new borrowers, subprime borrowers in particular, took up mortgages with higher leverage in the run-up to the crisis. In addition, existing borrowers managed their leverage by home equity withdrawals, which were an important component of credit growth (Mian and Sufi (2014)). But our results and these findings are not mutually exclusive. While new borrowers entered with higher leverage, the concurrent increase in asset prices lowered

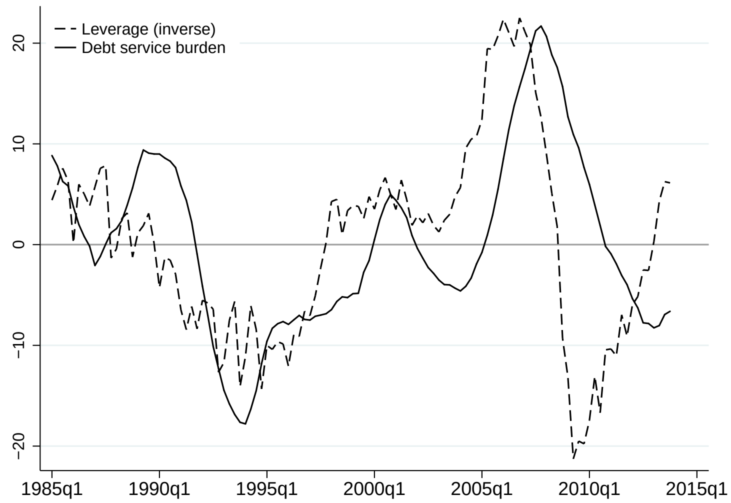

Figure 2: Leverage (inverse) and the debt service burden over time.

leverage for all existing borrowers. And it seems that existing borrowers only gradually took on new credit to reach their target leverage, so that aggregate leverage fell. Further, the most common proxy for aggregate leverage in the literature, the credit-to-GDP ratio, increased rapidly ahead of the crisis. But as real asset prices increased even faster, leverage - as defined by the credit-to-asset ratio - actually decreased. This is also evident from national accounts data of the credit-to-asset ratio (see Figure 6 in section 6.2).

Overlaying the estimated debt service burden and (the inverse) of leverage reveals an interesting picture (Figure 2). Leverage appears to lead the debt service burden by around one to two years. These dynamics will become clearer in Section 4.2 after we discussed the impact of leverage and the debt service burden on credit and output separately.

4 The impact of leverage and the debt service burden on output and credit

From a macroeconomic perspective, the ultimate interest is not the credit-to-GDP ratio but credit and output separately. It is thus useful to disentangle the effects of unsustainable movements in leverage and the debt service burden on real credit and output growth. A natural starting point would be to include cr_t^r and y_t^r separately in x_t in the VAR model.[18] It might be expected, however, that leverage and the debt service burden affect private expenditure (ie personal consumption and private investments) differently than they do government spending and net exports. As we are mainly interested in the former GDP components, we disaggregate Y_t^r into private expenditure, $E_{P,t}^r$, and "other" expenditure, ie $E_{O,t}^r = Y_t^r - E_{P,t}^r$.

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 aggregate asset price index implied by the estimated long-run relationship, $p_{A,t}^r = 0.486p_{H,t}^r + 0.451p_{C,t}^r + 0.063p_{E,t}^r$, in the place of the individual asset prices. With these modifications, the new information set becomes $x_t = (cr_t^r,\, e_{P,t}^r,\, e_{O,t}^r,\, p_{A,t}^r,\, r_t)'$. Note that the long-run relationships estimated in Section 3 are also valid for this system as cointegration relationships are invariant to extensions of the information set (Philips (1991)). Hence, we estimate the

[18] So far, only the credit-to-GDP ratio has appeared in x_t. 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 (12). All the results presented above remained qualitatively the same. This also allowed us to check whether the assumed unit coefficient between credit and GDP in the base-system (12) is in line with the data. This restriction cannot be rejected at the 5% significance level (p-value 0.09).

modified system

$$\begin{pmatrix} \Delta cr^r \\ \Delta e_P^r \\ \Delta e_O^r \\ \Delta p_A^r \\ \Delta r \end{pmatrix}_t = \alpha \begin{pmatrix} \widetilde{lev} \\ \widetilde{dsb} \end{pmatrix}_{t-1} + \sum_{i=1}^{2} \Pi_i \begin{pmatrix} \Delta cr^r \\ \Delta e_P^r \\ \Delta e_O^r \\ \Delta p_A^r \\ \Delta r \end{pmatrix}_{t-i} + \Gamma s_t + \varepsilon_t \qquad (15)$$

where we block out large outliers by adding 11 impulse dummies in s_t.[19]

4.1 The dynamics of credit and output growth

Leverage and the debt service burden are important determinants of real credit and private expenditure growth (left-hand panel, Table 3). Aside from these and auto-regressive terms no other terms stand out as significant in the unrestricted system (15). The system is, however, quite large and clearly over-parametrised. Before we start to interpret the estimates, it is therefore beneficial to impose zero-restrictions on insignificant parameters. In doing so, we proceed in several small steps, starting from variables with very low t-values and gradually increasing the cut-off to ensure that we do no violence to the data. The restricted system is estimated by full information maximum likelihood and we use encompassing tests to ensure that it is not significantly different from the original unrestricted system.

The restricted system clearly reveals that both leverage and the debt service burden are highly significant for explaining real credit growth (right-hand panel, Table 3). And the signs are intuitive; in response to low leverage or a low debt service burden, credit growth increases. Thus, deviations from the long-run relationships are corrected through real credit growth.

The novel result of our analysis is the negative effect of the debt service burden

[19] 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.

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

Table 3: Estimated coefficients of the error correction system (15). 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 Annex A, Table 6.

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 by Δp_A^r. Moreover, we show in Section 5 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 high debt service burden on expenditure also amplifies output losses. Starting from steady-state, a negative shock to output increases the debt service burden. A high debt service burden, in turn, depresses expenditure and thus income, thereby increasing the debt service burden even further. Overall, though, the system is stable as the debt service burden decreases credit growth even faster than income.[20] Hence, the system will converge back to steady-state, although this may take a very long time.

Interestingly, financial accelerator-type effects do not seem particularly strong. For one, leverage has no direct impact on private sector expenditure. Furthermore, while credit growth amplifies asset prices and asset prices credit via changes in leverage, there is no interaction between credit, asset prices and expenditure, except through the debt service burden. This result is, however, somewhat sample-dependent. As we show in Section 5, credit has a significant effect on expenditure if we exclude the last decade of our sample.

The sample-dependency with respect to the effect of credit on expenditure is likely a result of the fact that the data do not allow us to distinguish between new credit

[20] 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 Δy_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*0.87 = 0.23%.

and changes in the outstanding credit stock, which are also driven by defaults and repayments. Ideally, we would exclude repayments from credit growth as these are already captured by the debt service burden. Available Fed data on new credit in the household sector from 2003 also supports the idea that separating credit growth in its components would be beneficial: The simple correlation between lagged household sector credit and private sector expenditure growth between 2003 and 2013 is only 0.17, whereas with the lagged growth of newly issued loans the correlation rises to 0.38 and with lagged newly defaulted loans to 0.5.

In most cases, the impact of leverage and the debt service burdens on other variables stabilises the system. For one, the debt service burden has a significant positive effect on other expenditure. This could reflect both decreases in net-imports or increases in government spending when the debt service burden is high. Be that as it may, this reduces the debt service effect on the overall economy and speeds up the adjustment towards steady-state.

The lending rate also helps to stabilise the system. When private sector expenditure is low and the debt service burden high, lending rates tend to fall, which in turn reduces interest payments and thus the debt service burden. As discussed earlier, this is likely driven by an implicit monetary policy reaction function.

Finally, there seems to be an endogenous limit on the scope for real asset price growth, as it is negatively affected by the debt service burden. This ultimately helps to stabilise leverage and thus also credit growth.

4.2 Adjustment to steady state

How do initial leverage and debt service burden conditions shape future credit and output growth in the absence of any new shocks? Or putting it differently, how does the system adjust back to steady state given deviations from long-run leverage and the debt service burden?

This 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 in the transformation and we choose other expenditure and the lending rate. While the particular choice of variable pair does not change the system algebraically, it nevertheless implies a specific transformation of the residuals and, hence, matters for the impulse response function.[21] In particular, the variables that are used in the transformation take a more passive role do not respond to the other variables in the system. Thus, for our choice, where other expenditure and the lending rate are used in the transformation, the adjustment dynamics that arise from "shocks" to $\widetilde{lev}$ and $\widetilde{dsb}$ emphasizes 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, expect when starting from extreme values for $\widetilde{dsb}$ as neglecting the response in lending rates causes the debt service burden to overshoot.

Given our chosen transformation, we get

$$\begin{pmatrix} \Delta cr^r \\ \Delta e_P^r \\ \Delta p_A^r \\ \widetilde{lev} \\ \widetilde{dsb} \end{pmatrix}_t = \sum_{i=1}^{3} \Psi_i \begin{pmatrix} \Delta cr^r \\ \Delta e_P^r \\ \Delta p_A^r \\ \widetilde{lev} \\ \widetilde{dsb} \end{pmatrix}_{t-i} + \Gamma s_t + \varepsilon_t \tag{16}$$

where Ψ_i are parameter matrices. We begin by analysing how the system adjusts to a 1% negative deviation from long-run leverage or the debt service burden, ie we successively set $\widetilde{dsb}_0$ or $\widetilde{lev}_0$ to -1 in the initial period.

The adjustment dynamics highlight that the debt service burden is the primary link between financial and real developments (Figure 3). Initially, the economy adjusts to a low debt service burden by several years of rapid credit and expenditure growth. As output outgrows credit, the credit-to-GDP ratio falls, lowering the debt service burdens

[21] This is akin to the well known effects of ordering decissions when using a Choleski decomposition

even further. The fall in the credit-to-GDP ratio also lowers leverage, a dynamic which is further amplified by the positive effect of a low debt service burden on asset prices. But low leverage and a low debt service burden accellerate credit growth, bringing the credit-to-GDP ratio back to sustainable levels vis-a-vis the debt service condition after around four years. Yet, leverage is still low causing the credit expansion to continue so that the debt service burden overshoots. The negative drag of a high debt service burden on expenditure pushes the economy into a recession where expenditure and asset prices fall. Credit also falls, albeit with a substantial lag as low leverage and a high debt service burden exerts opposing pressures for some time. Overall, the economy needs around 10 years to converge back to steady state.

The adjustment to low leverage underscores the importance of the debt service burden for understanding the link between financial and real developments. Initial low leverage is followed by rapid credit growth. Yet, the economy sees little gain in output as there is no significant feedback from credit growth to expenditure.[22] We therefore see a "growthless credit boom". The increase in the credit-to-GDP ratio helps the adjustment processes of leverage back to long-run levels. At the same time, though, it pushes the debt service burdens away from its long-run level and this effect is the crucial link between leverage dynamics and real economic outcomes. As a high debt service burden has a negative impact on expenditure as well as asset prices, the economy enters a deep and very drawn out recession that lasts more than five years. Expenditure growth only recovers when the debt service burden returns to zero.

The adjustment back to steady state can have lasting effects on the real economy (Figure 10 in Appendix B). Starting from initially low leverage, for instance, credit and private sector expenditure fall to permanently lower levels. An initially low debt service burden, on the other hand, is followed by a sustained increase in credit and, to a lesser extent, private sector expenditure.

The uncovered adjustment dynamics are fully in line with the stylized facts from

[22] 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 11 in the appendix).

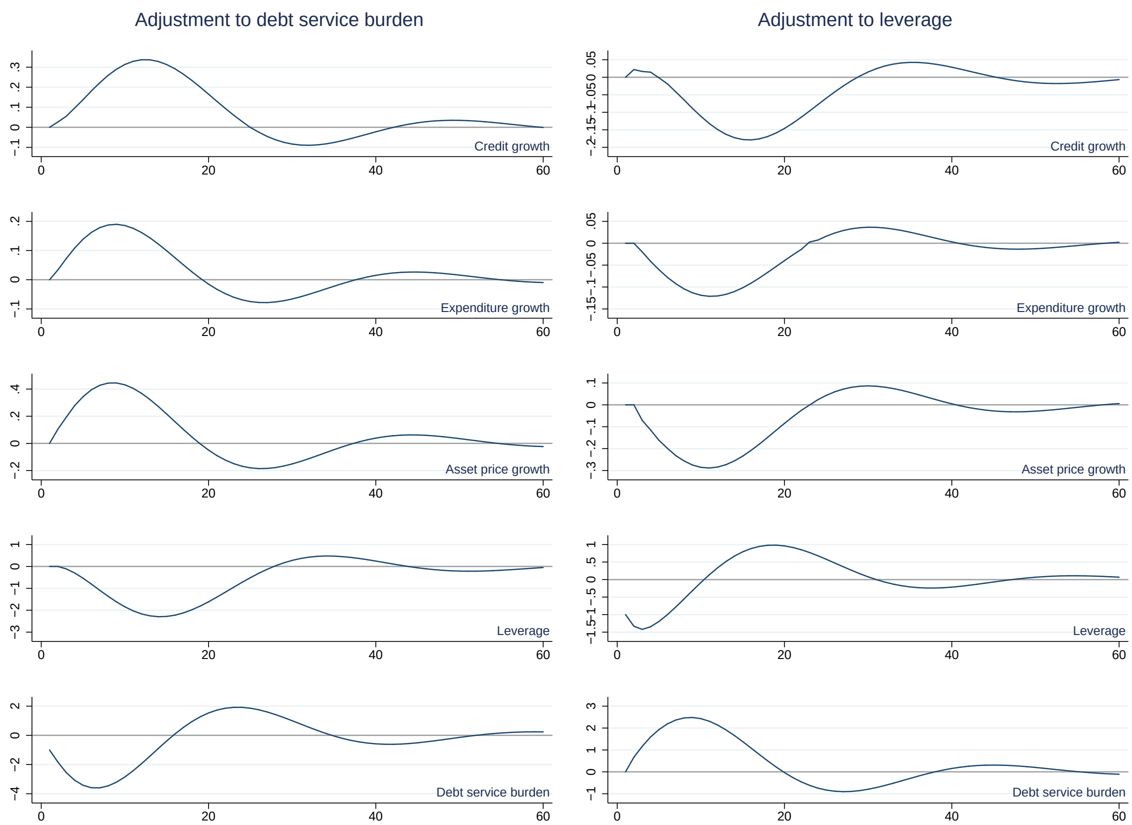

Figure 3: System response to initial negative leverage or debt service burden conditions.

the literature on credit booms and busts and, as such, suggest that leverage and the debt service burden are crucial for explaining them. In line with the literature, we find that rapidly growing credit goes hand-in-hand with surging asset prices and a strong increase in the credit-to-GDP ratio. But our results go further and show that rising credit-to-GDP is a natural outcome in a credit boom, as credit often outgrows GDP when the debt service burden is high while leverage remains low. Furthermore, the literature finds that periods of rapid credit growth are followed by a very deep and protracted recession (eg Claessens et al (2009) or Jorda et al (2013)), which can lead to a permanent loss of output (eg Cerra and Saxena (2008)). Our results corroborate these findings, but suggest that the observed output losses are not a result of a financial crisis or high credit-to-GDP ratios per se, but rather of debt service costs associated with a high stock of credit and tight leverage. Finally, we find that the economy needs around 10 to 15 years to reach steady state in response to deviations from long-run leverage or debt service burdens. This cycle is clearly longer than the average business cycle, but the length is fully in line with the literature on financial cycles (eg Aikman et al (2014) and Drehmann et al (2012)).

5 Leverage, the debt service burden and the Great Recession

Given that the uncovered adjustment dynamics match all the stylised facts from the literature on financial and credit cycles, it is interesting to ask whether they could have helped us 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 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 subprime excesses. In the second step, we use this model to calculate the credit and expenditure paths that follow from starting from the observed

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

Table 4: Estimated coefficients of the 1985q1-2004q4 and the full-sample system. The complete estimation results for the 1985q1-2004q4 system are shown in Table 9 in Appendix B.

leverage and the debt service deviations in 2004q4 or 2005q4,[23] assuming that 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 samples, despite the fact that the full sample contains the biggest crisis and worst recession since the 1930s. The estimated long-run relationships, for example, do not change much whether the sample ends in 2004q4 or covers all data (Table 8, Appendix B).[24] The same holds for the adjustment coefficients to leverage and the debt service burden in the various growth equations (Table 4).

Some of the short-run coefficients do, however, change in the light of the large dis-

[23] The adjustment patterns starting from 2006q4 are similar in terms of dynamics but somewhat too large in terms of magnitude. The reason is that the projected debt service burden overshoots as lending rate responses are not fully internalised in the system (see discussion above). These results are available upon request.

[24] We show this holds generally for any sample ending between 2000q1 and 2013q4 in Appendix A, using formal parameter stability tests.

ruptions in the economy in recent years. As discussed above, financial accelerator-type effects, for instance, are much stronger in the 2004 sample. Moreover, the somewhat counterintuitive weak negative effect from credit growth on the lending rate in the full-sample dissapears in the 2004 sample, suggesting that lending rates did not decline as much during the Great Recession as in earlier recessions, despite the sharp drop in credit growth. This is likely driven by the zero lower bound and the sharp increase in lending spreads after the crisis. Other expenditure also seems to react differently to credit developments in the two samples.

The differences between the full sample and 2004q4 systems not withstanding, the adjustment dynamics to leverage and debt service burden conditions remain largely the same. This is particularly the case for the debt service burden (Figure 11, Appendix B). Given stronger financial accelerator effects in the pre-crisis sample, the phenomena of a "growthless credit boom" becomes more pronounced during the adjustment process to low leverage. Relative to the full sample results, there is a larger credit boom that lasts for around three years. For the first two years, expenditure growth remains relatively flat, ie the economy experiences a "growthless credit boom". If viewed through the lens of output, the economy would appear on a sustainable path during this period. But flat expenditure growth is simply the result of two opposing forces: the positive feedback from leverage to credit and output growth and the (increasing) negative effect of a high debt service burden. At some point, the latter prevails and the economy enters a recession.

5.1 Predicting the Great Recession in real time

Real-time knowledge of leverage and the debt service burden would have helped us anticipate the 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 conditions, we find that the adjustment dynamics result in a credit boom that is remarkably similar to actual developments. For instance, from the beginning of 2005

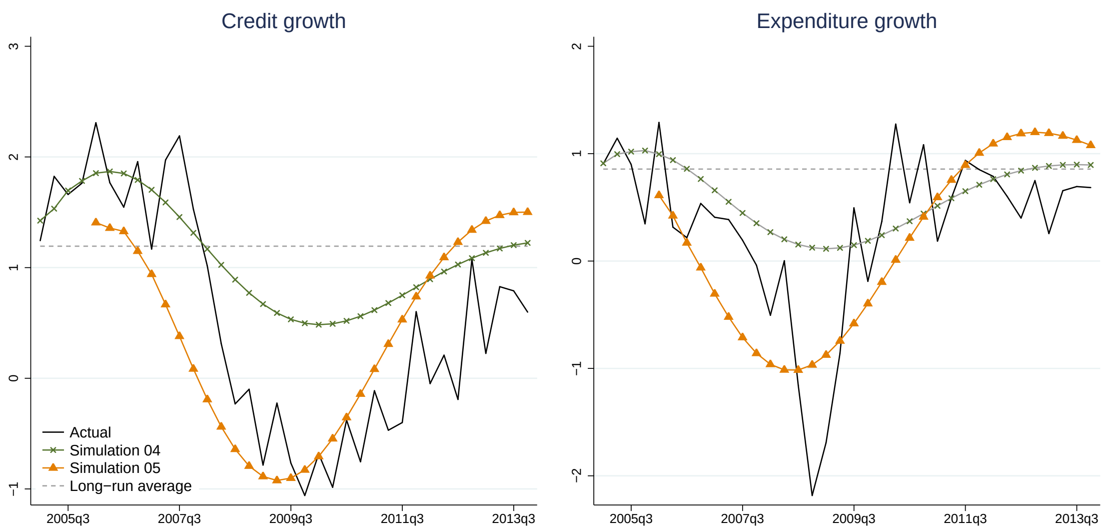

Figure 4: Real quarterly credit and expenditure growth versus growth rates implied by adjustment dynamics to observed leverage and the debt service burden in 2004q4 and 2005q4 respectively. Adjustment dynamics are based on model estimates using only data up to 2004q4.

to the end of 2007, average quarterly real credit growth was 1.74%. The model-implied average is 1.65%. The simulated adjustment path also 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 for this is that the model does a relatively poor job in capturing asset price dynamics, such as the rapid growth during 2005. Thus, the 2004 simulation fails to fully anticipate the dramatic fall in leverage in 2005 and thus also the actual buildup in the debt service burden and its repercussions for the real economy.

Starting from end 2005 reveals how far the adjustment pressures from leverage and the debt service burden help to explain the Great Recession. Even though our simulation excludes all shocks, 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 burden for explaining macroeconomic dynamics, these results suggest that the banking crisis was not a "black swan" event and that the Great Recession did not result from letting Lehman fail. Our analysis supports a different narrative. By 2007, adjustment pressures to leverage and the debt service burden 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 burden, or in other words from a debt overhang.

5.2 The early 1990s recession

Leverage and the debt service burden are relevant for understanding not only the Great Recession but also the early 1990s recession. The Fed argued, as discussed above, that high debt service burdens were an important driver of this recession. And the literature suggests that it followed a boom in the credit cycle (eg Aikman et al (2014) and Drehmann et al (2012)). It is therefore interesting to ask if our model could have generated the observed credit and output patterns during this period as well. While our data do not allow us to do this out-of-sample, the exercise nevertheless serves as a consistency check vis-a-vis the generality of the uncovered dynamics above.

There is again a close match between the simulation and actual developments (see Figure 5). Starting from end-1988 leverage and debt service conditions, 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

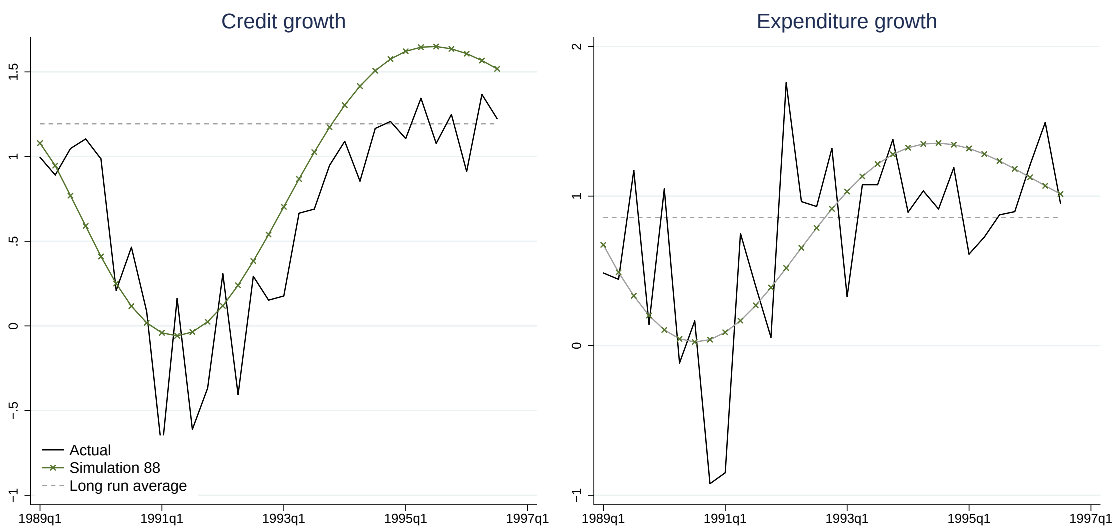

Figure 5: Real quarterly credit and expenditure growth versus growth rates implied by adjustment dynamics to observed leverage and the debt service burden in 1988q4. Adjustment dynamics are based on model estimates using data up to 2004q4.

1993 in line with realised expenditure growth. That said, the match between simulated and realised outcomes is not too good when starting from earlier years. For instance, adjustment to low leverage and a low debt service burden at the end of 1986 implies a credit boom that turns out to be larger than actually observed, even though the model still signals a slow-down in growth for the early 1990s.[25]

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 burden 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.

[25] This is also partly due to the fact that we only set initial conditions for leverage and the debt service burden that are off long-run values. If we set the initial conditions for all the variables in (16), the match would be more consistent.

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 burden 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 (15).

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, $r^r_{M,t} = r_{M,t} - \Delta p_t$, and the real yield on 10-year government bonds, $r^r_{G,t} = r_{G,t} - \Delta p_t$. 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 modeling 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 7 in the Appendix). Again, leverage matters only for credit growth, whereas the debt service burden affects both credit and private sector expenditure negatively. We do not find any strong effects on credit and expenditure growth from the interest rates and unemployment. Only real asset price growth reacts to changes in the real yield on 10-year government bonds. These results are 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 burden

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

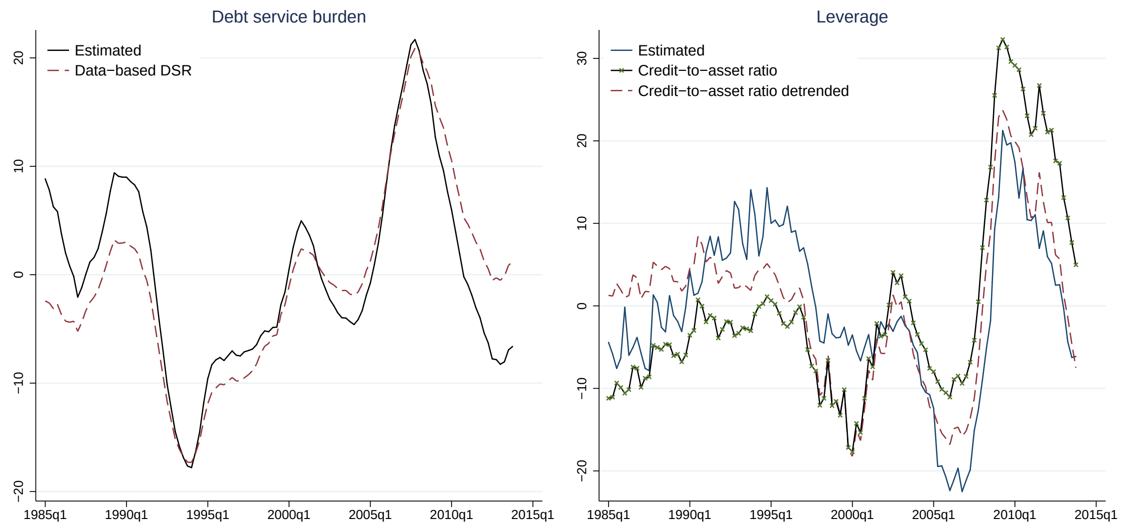

Figure 6: Comparison between the debt service burden and leverage estimated from the VAR and alternative direct measures. For the direct measures, debt service burdens are approximated by the DSR estimated by Drehmann and Juselius (2012) and leverage by the credit-to-asset ratio of assets based on financial accounts data. The credit-to-asset ratio is shown both with and without removing a linear trend. Deviations are calculated relative to the respective long-run averages over the sample.

As an alternative proxy of the debt service burden, we use the debt service ratio (DSR) for the total private non-financial sector in the United States calculated by Drehmann and Juselius (2012). They derive the DSR directly relying on equation (8) rather than from model estimates based on the log-linearised version. Therefore their approach captures the non-linear impact of changing lending rates as well as changing maturity structures. We assume that the long-run value for the DSR is given by its sample average. As can be seen from Figure 6, the direct measure and results from the estimated model are very close.

Leverage can be directly measured by the credit-to-assets ratio from the financial accounts in line with equation (1). Given the low weight of equities as collateral, we use the sum of real estate assets for the household and the corporate sectors as a measure of total assets.[26] Again, we take the sample average as a proxy for its long-run value.

[26] As another robustness test, we also computed the ratio of total assets to credit and undertook the analysis. Results are very similar and available on request.

	Estimated deviations		Direct measures		Direct measures	
Leverage			not de-trended		de-trended	
	Δcr^r_t	$\Delta e^r_{P,t}$	Δcr^r_t	$\Delta e^r_{P,t}$	Δcr^r_t	$\Delta e^r_{P,t}$
$\widetilde{lev}_{t-1}$	**−0.021** −2.86	0.007 0.79	−0.009 −1.59	−0.003 −0.52	**−0.013** −3.98	−0.003 −0.42
$\widetilde{dsb}_{t-1}$	**−0.027** −3.99	**−0.021** −2.52	**−0.013** −2.11	**−0.028** −3.9	**−0.018** −3.08	**−0.028** −4.05

Table 5: Comparison between the impacts of estimated (left-hand panel) and direct measures (centre and right-hand panel) of deviations from long-run leverage and debt service burdens on credit and private sector expenditure growth. For the direct measures, debt service burdens are approximated by the DSR estimated by Drehmann and Juselius (2012) and leverage by the credit-to-asset ratio of assets based on financial accounts data. Deviations are calculated relative to the respective long-run averages over the sample. In addition, a linear trend has been removed from the credit-to-asset ratio in the "de-trended" columns.

The behaviour of this measure (dotted line) and the previously estimated deviations from long-run leverage are quite closely aligned (Figure 6, right-hand panel). However, there appears to be a slight upward trend in the credit-to-asset ratio from financial accounts data. This 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 financial accounts is a mix of book and mark-to-market values (eg Emmons (2006)), and thus does not fully adjust to rising asset prices. Using real asset prices directly - as is done in the estimated long-run leverage relationship - apparently removes these trends. As an additional robustness check we, therefore, also try removing a linear trend from the credit-to-asset ratio (dashed line in Figure 6, right-hand panel).

Our findings are robust to using the more direct measures of leverage and the debt service burden (Table 5). In particular, our most novel finding, namely the negative impact of the debt service burden on expenditure growth, is hardly affected at all. The debt service burden also continues to have a significant negative impact on credit growth, even though this is somewhat weakened compared to the baseline results. It also seems that we measure a weaker impact of leverage on credit growth when the credit-to-asset ratio from the financial accounts is used, in particular, if this is not de-trended. In any case, though, leverage continues to have no direct impact on expenditure growth.

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 and investment 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" that follows from low leverage and a high debt service burden, two countervailing forces are at work: there is the growth enhancing effect of new credit 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, loosened leverage conditions increase 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 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, compelling the Queen to ask her famous question. In fact, though, it was the result of a necessary adjustment to leverage and the debt service burden.

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Appendix A: 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 (13), 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.

The estimated long-run relationships are stable over time. This can be seen from Figure 7, which plots the recursive test statistics, normalised at the 95% critical level. The test statistics remain well below the unit critical level for all recursions, indicting 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.

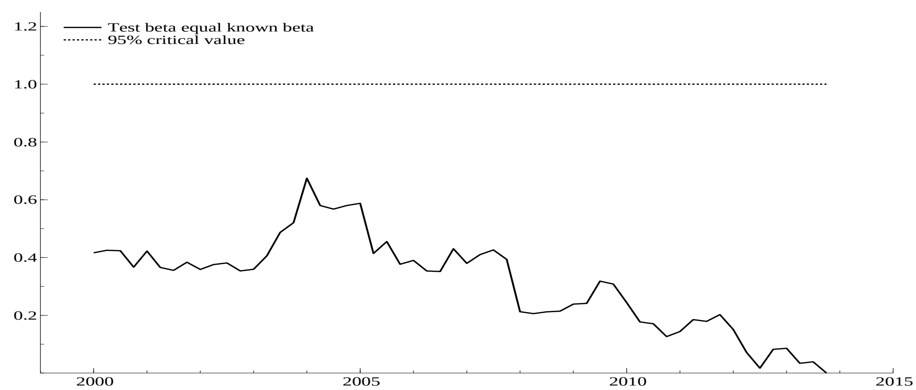

Figure 7: Recursive tests for parameter stability of the cointegration space. The test statistics are scaled so that the 95% critical value takes the value of unity. Values below unity indicate that the null hypothesis of a stable cointegration space cannot be rejected.

Next, we take the long-run estimates as given and test the stability of the adjustment coefficients from the system shown in Table (3) recursively. The training sample is again 1985q1-1999q4.

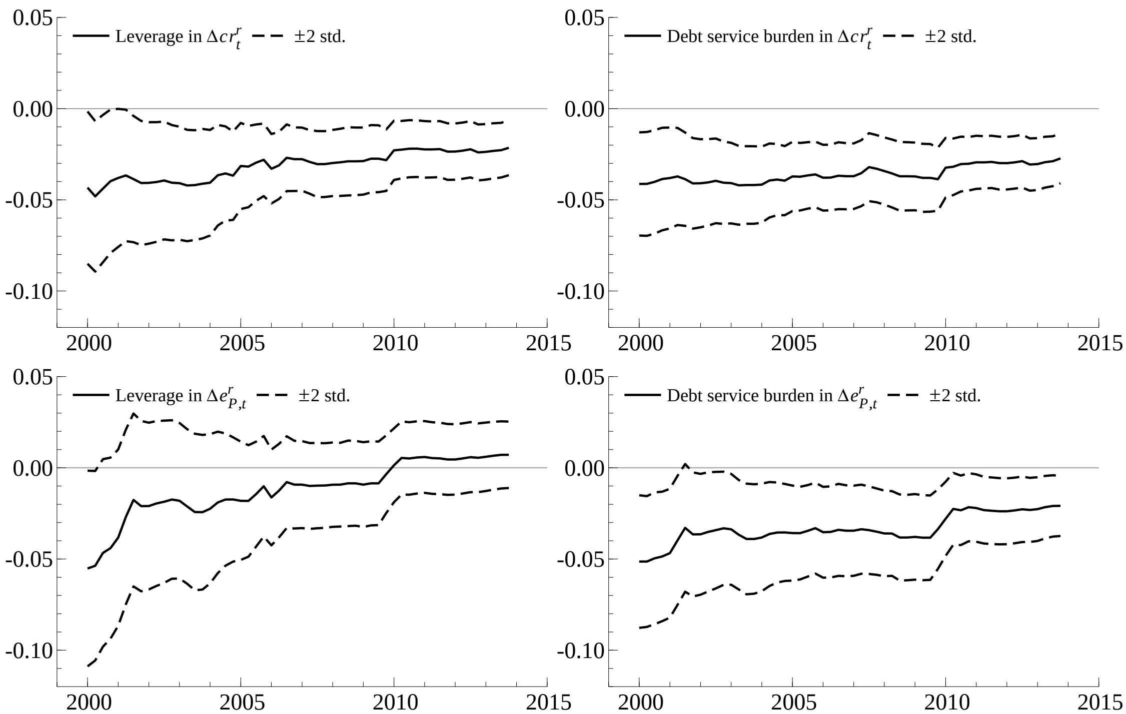

Figure 8: Recursive estimates of the loadings to the leverage and debt service burden in the unrestricted system. The training sample is 1985q1-1999q4.

In the unrestricted system (Figure 8), the effects of leverage and the debt service burden on credit and output are relatively stable. The main difference is that the effect of leverage on expenditure growth is borderline significant during the credit boom.

In the restricted system, though, the effects of leverage and the debt service burden on credit and expenditure growth are highly stable (Figure 9). 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.

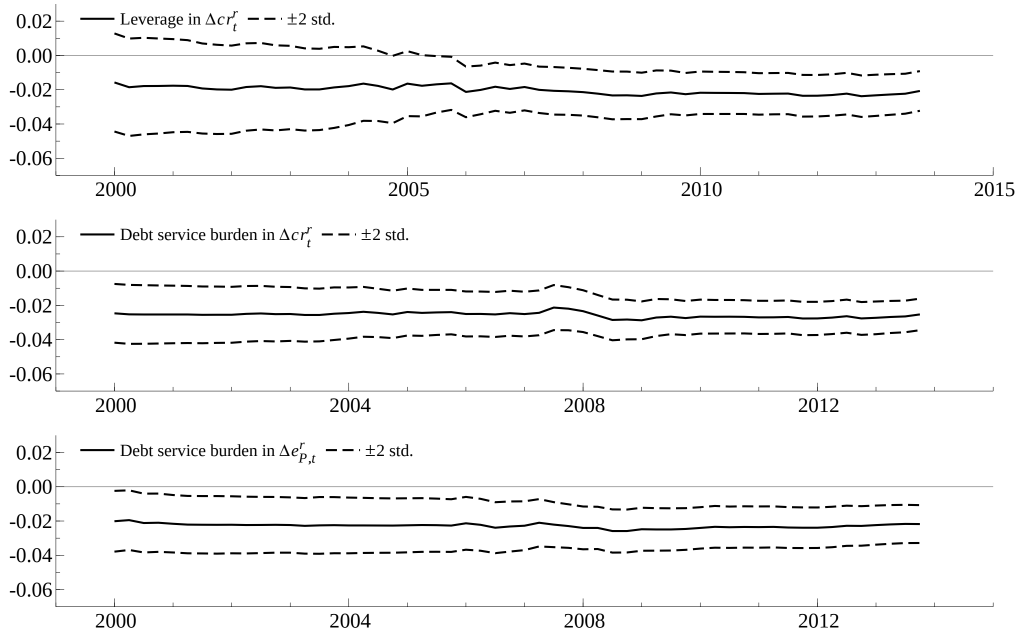

Figure 9: Recursive estimates of the loadings to the leverage and debt service burden in the restricted system. The training sample is 1985q1-1999q4.

Appendix B: Additional tables and graphs

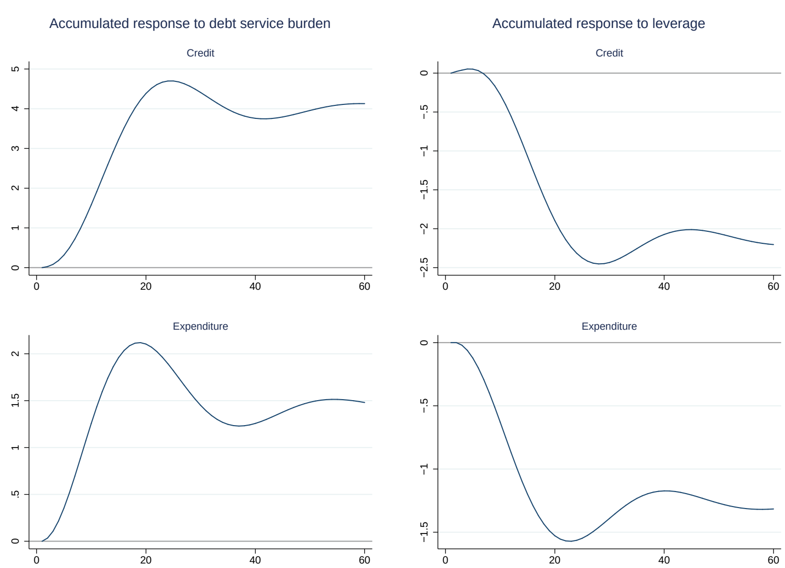

Figure 10: Accumulated effects of the system response to initial negative leverage or debt service burden conditions.

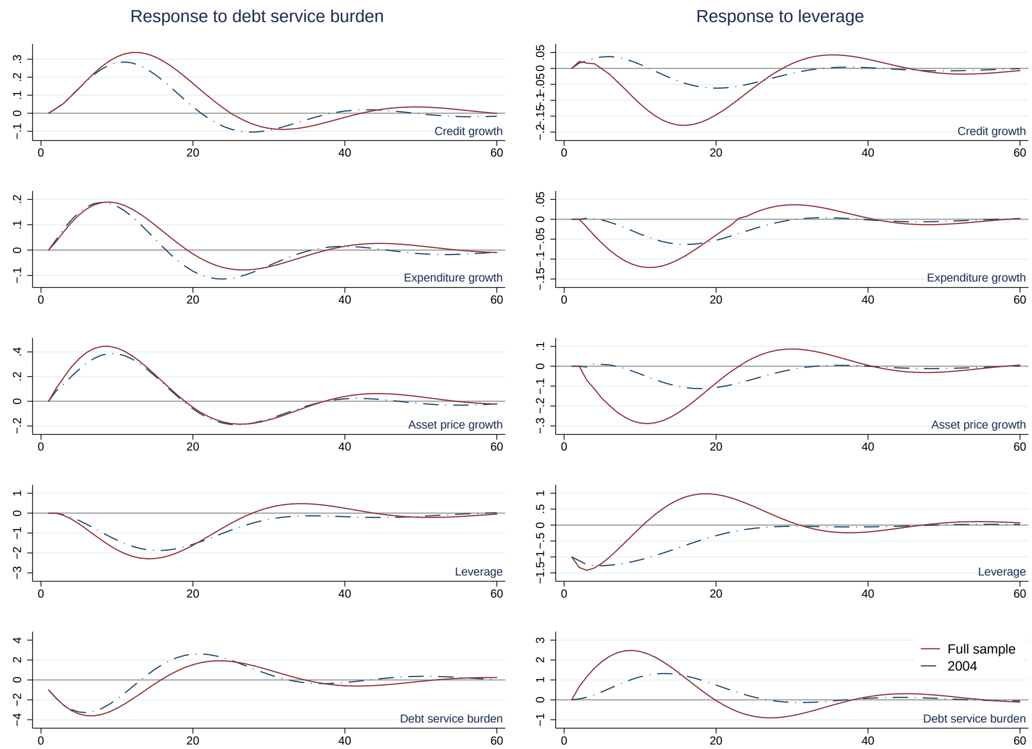

Figure 11: System response to initial negative leverage or debt service burden conditions given the model estimated until 2004q4 or using the full sample.

	Unrestricted system					Restricted system				
	Δcr^r_t	$\Delta e^r_{P,t}$	$\Delta e^r_{O,t}$	$\Delta p^r_{A,t}$	Δr_t	Δcr^r_t	$\Delta e^r_{P,t}$	$\Delta e^r_{O,t}$	$\Delta p^r_{A,t}$	Δr_t
Adjustment coefficients to long-run deviations										
$\widetilde{lev}_{t-1}$	**−0.021** −2.86	0.007 0.79	−0.050 −0.91	−0.039 −0.76	**−0.004** −2.42	**−0.020** −4.07				**−0.003** −2.69
$\widetilde{dsb}_{t-1}$	**−0.027** −3.99	**−0.021** −2.52	**0.152** 3.07	**−0.108** −2.28	**−0.003** −2.32	**−0.025** −5.54	**−0.026** −5.09	**0.191** 5.92	**−0.106** −3.75	**−0.002** −2.15
Short-run dynamics										
Δcr^r_{t-1}	0.195 1.86	0.082 0.65	−0.874 −1.15	−0.046 −0.06	0.007 0.36	**0.275** 3.97				
Δcr^r_{t-2}	**0.570** 5.59	0.031 0.25	0.266 0.36	0.649 0.92	−0.029 −1.49	**0.454** 7.01			**0.571** 2.15	**−0.024** −2.01
$\Delta e^r_{P,t-1}$	0.168 1.13	**0.398** 2.22	0.752 0.70	0.926 0.90	0.035 1.23		**0.474** 7.99			**0.061** 4.53
$\Delta e^r_{P,t-2}$	−0.166 −1.12	0.055 0.31	1.175 1.09	−0.812 −0.79	−0.041 −1.42			**2.192** 6.07		**−0.037** −2.54
$\Delta e^r_{O,t-1}$	0.014 0.66	0.030 1.15	0.030 0.19	−0.036 −0.24	−0.004 −1.03		**0.035** 3.73			
$\Delta e^r_{O,t-2}$	−0.023 −1.15	−0.025 −1.06	0.202 1.41	**−0.265** −1.96	−0.002 −0.65			**0.112** 1.96		
$\Delta p^r_{A,t-1}$	0.008 0.52	0.016 0.85	−0.157 −1.40	−0.152 −1.43	−0.002 −0.80					
$\Delta p^r_{A,t-2}$	−0.005 −0.30	0.020 1.05	−0.110 −0.98	−0.044 −0.41	−0.002 −0.53					
Δr_{t-1}	−0.442 −1.03	−0.118 −0.23	2.881 0.93	−1.551 −0.52	**1.024** 12.30					**1.033** 14.00
Δr_{t-2}	0.664 1.53	0.157 0.30	−1.129 −0.36	3.301 1.10	**−0.147** −1.75					**−0.174** −2.38
Deterministic terms										
μ	**0.245** 2.51	**0.245** 2.07	−0.120 −0.17	0.159 0.24	0.015 0.81	**0.251** 3.93	**0.351** 5.58	**−1.161** −3.00	0.017 0.05	−0.009 −0.59
d_{85q4}	**1.038** 2.60	−0.420 −0.87	4.117 1.42	1.138 0.41	0.085 1.10	**1.130** 3.63				
d_{87q2}	−0.149 −0.36	0.741 1.47	−1.696 −0.56	1.852 0.64	**0.374** 4.62		**0.565** 2.69			**0.365** 4.88
d_{87q4}	−0.647 −1.69	−0.831 −1.79	4.647 1.67	**−10.158** −3.83	0.115 1.55				**−8.214** −3.21	
d_{88q3}	−0.325 −0.85	−0.285 −0.61	0.735 0.26	0.755 0.29	**0.215** 2.88					**0.203** 2.86
d_{92q1}	0.726 1.83	**1.532** 3.19	−3.415 −1.18	2.633 0.96	−0.061 −0.79		**0.775** 3.74			
d_{93q4}	−0.132 −0.34	0.204 0.43	0.061 0.02	**−9.161** −3.39	0.019 0.25				**−9.663** −3.72	
d_{94q2}	−0.357 −0.87	−0.364 −0.73	3.680 1.23	1.673 0.59	**0.271** 3.38					**0.273** 3.77
d_{00q1}	−0.443 −1.11	0.865 1.78	**−9.772** −3.36	−2.407 −0.87	0.129 1.65		**1.113** 2.67	**−10.480** −3.72		
d_{07q1}	−0.448 −1.10	0.358 0.73	**−9.402** −3.18	0.983 0.35	0.007 0.08			**−6.550** −4.55		
d_{08q4}	0.182 0.44	**−1.515** −3.03	**8.807** 2.94	**−6.641** −2.33	−0.064 −0.79		**−1.660** −3.89	**9.689** 3.35	**−8.421** −3.19	
d_{09q3}	0.368 0.84	**1.055** 2.00	**−8.594** −2.71	4.716 1.56	0.108 1.28					**0.169** 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	**0.289** 2.16	−1.343 −1.67	**2.162** 2.83	**0.058** 2.71	−0.035 −0.36	0.230 1.88	−1.124 −1.48	**1.768** 2.56	**0.053** 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 6: Estimated coefficients of the full-sample system (15).

	Unrestricted system					Restricted system				
	Δcr^r_t	$\Delta e^r_{P,t}$	$\Delta e^r_{O,t}$	$\Delta p^r_{A,t}$	Δr_t	Δcr^r_t	$\Delta e^r_{P,t}$	$\Delta e^r_{O,t}$	$\Delta p^r_{A,t}$	Δr_t
					Adjustment coefficients to long-run deviations					
$\widetilde{lev}_{t-1}$	**−0.030** −2.85	−0.004 −0.31	−0.032 −0.41	0.014 0.20	−0.001 −0.59	**−0.020** −4.10				**−0.002** −2.19
$\widetilde{dsb}_{t-1}$	**−0.034** −3.93	**−0.029** −2.71	**0.169** 2.65	−0.100 −1.72	−0.002 −1.06	**−0.025** −5.54	**−0.026** −5.07	**0.191** 5.89	**−0.083** −2.50	−0.002 −1.94
$r^r_{M,t-1}$	0.046 0.95	0.025 0.42	−0.075 −0.21	0.136 0.42	−0.004 −0.42					
$r^r_{B,t-1}$	−0.014 −0.26	0.015 0.22	0.041 0.10	−0.499 −1.36	−0.007 −0.63				**−0.308** −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					
Δcr^r_{t-1}	0.166 1.46	0.075 0.54	−0.980 −1.18	0.671 0.88	0.019 0.88	**0.275** 3.95				
Δcr^r_{t-2}	**0.565** 5.29	0.046 0.36	0.136 0.17	1.192 1.67	−0.024 −1.15	**0.451** 6.93			**0.603** 2.03	−0.020 −1.66
$\Delta e^r_{P,t-1}$	0.111 0.70	0.325 1.71	0.859 0.75	1.313 1.25	0.051 1.68		**0.476** 7.99		**1.042** 2.28	**0.060** 4.34
$\Delta e^r_{P,t-2}$	−0.179 −1.20	0.042 0.23	1.235 1.13	−0.991 −0.99	−0.041 −1.42			**2.160** 5.95		**−0.045** −3.10
$\Delta e^r_{O,t-1}$	0.005 0.21	0.019 0.68	0.042 0.25	0.046 0.30	−0.002 −0.36		**0.035** 3.74			
$\Delta e^r_{O,t-2}$	−0.026 −1.32	−0.029 −1.19	0.209 1.43	**−0.263** −1.97	−0.002 −0.48			0.106 1.85		
$\Delta p^r_{A,t-1}$	0.002 0.13	0.008 0.39	−0.131 −1.09	−0.191 −1.73	−0.002 −0.54				−0.165 −1.94	
$\Delta p^r_{A,t-2}$	−0.007 −0.47	0.015 0.80	−0.092 −0.79	−0.089 −0.83	−0.002 −0.50					
Δr_{t-1}	−0.422 −0.96	−0.158 −0.30	2.871 0.89	−0.835 −0.28	**1.035** 12.20					**1.065** 14.30
Δr_{t-2}	0.683 1.40	0.388 0.66	−1.693 −0.47	3.144 0.96	−0.171 −1.82					**−0.204** −2.77
					Deterministic terms					
μ	0.059 0.19	−0.217 −0.58	1.501 0.66	−2.731 −1.32	0.034 0.57	**0.253** 3.95	**0.349** 5.53	**−1.137** −2.92	0.364 0.69	−0.004 −0.29
d_{85q4}	**1.008** 2.43	−0.544 −1.09	4.400 1.45	1.323 0.48	0.101 1.26	**1.120** 3.58				
d_{87q2}	−0.275 −0.64	0.621 1.19	−1.413 −0.45	1.823 0.63	**0.393** 4.73		**0.566** 2.69			**0.359** 4.69
d_{87q4}	−0.735 −1.83	**−0.985** −2.03	4.878 1.66	**−9.301** −3.47	0.147 1.90				**−7.593** −3.07	
d_{88q3}	−0.283 −0.73	−0.256 −0.55	0.624 0.22	1.035 0.40	**0.213** 2.84					**0.200** 2.75
d_{92q1}	0.658 1.58	**1.490** 2.96	−3.667 −1.20	4.711 1.69	−0.026 −0.32		**0.774** 3.72			
d_{93q4}	−0.155 −0.39	0.189 0.40	0.053 0.02	**−8.899** −3.38	0.025 0.33				**−9.375** −3.75	
d_{94q2}	−0.365 −0.88	−0.388 −0.77	3.818 1.25	1.208 0.43	**0.268** 3.34					**0.283** 3.82
d_{00q1}	−0.412 −1.01	0.914 1.86	**−9.993** −3.36	−1.791 −0.66	0.130 1.66		**1.084** 2.60	**−10.220** −3.62		
d_{07q1}	−0.477 −1.16	0.320 0.64	**−9.387** −3.12	1.446 0.53	0.018 0.23			**−6.508** −4.50		
d_{08q4}	0.273 0.64	**−1.353** −2.63	**8.383** 2.69	**−6.461** −2.27	−0.083 −1.01		**−1.641** −3.82	**9.534** 3.27	**−8.087** −3.11	
d_{09q3}	0.349 0.79	1.020 1.90	**−8.340** −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	**0.301** 2.22	−1.336 −1.62	**1.946** 2.59	**0.053** 2.45	−0.035 −0.35	0.230 1.88	−1.125 −1.47	**1.969** 2.89	**0.051** 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 7: Estimated coefficients of system (15) with additional control variables included. The variables include the real federal funds rate, $r^r_{M,t}$, the real yield on government bonds, $r^r_{B,t}$, 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					
	$cr_t - y_t$	$p^r_{H,t}$	$p^r_{C,t}$	$p^r_{E,t}{}^\dagger$	r_t
β'_{lev}	1	$\mathbf{-0.486}$ (6.44)	$\mathbf{-0.451}$ (7.23)	$\mathbf{-0.063}$ (2.06)	–
β'_{dsb}	1	–	–	–	**0.062** (9.49)
1985q1-2004q4 system					
β'_{lev}	1	$\mathbf{-0.528}$ (−11.60)	$\mathbf{-0.436}$ (−10.91)	$\mathbf{-0.036}$ (−2.99)	–
β'_{dsb}	1	–	–	–	**0.058** (7.10)

Table 8: Estimated long-run relationships of the 1985q1-2004q4 and the full-sample system.

	Unrestricted system					Restricted system				
	Δcr^r_t	$\Delta e^r_{P,t}$	$\Delta e^r_{O,t}$	$\Delta p^r_{A,t}$	Δr_t	Δcr^r_t	$\Delta e^r_{P,t}$	$\Delta e^r_{O,t}$	$\Delta p^r_{A,t}$	Δr_t
					Adjustment coefficients to long-run deviations					
$\widetilde{lev}_{t-1}$	**−0.043**	−0.023	0.163	−0.044	−0.004	**−0.019**				**−0.005**
	−3.31	−1.26	1.66	−0.49	−1.45	−2.08				−2.39
$\widetilde{dsb}_{t-1}$	**−0.047**	**−0.042**	**0.272**	−0.114	−0.005	**−0.026**	**−0.039**	**0.217**	**−0.084**	**−0.006**
	−4.37	−2.77	3.30	−1.51	−1.88	−3.52	−4.86	4.68	−2.12	−3.13
					Short-run dynamics					
Δcr^r_{t-1}	0.203	0.143	−1.426	0.391	0.017	**0.297**	**0.273**	**−1.774**		
	1.65	0.83	−1.51	0.45	0.61	3.47	3.60	−3.92		
Δcr^r_{t-2}	**0.597**	−0.039	0.661	1.522	−0.033	**0.476**			**1.337**	
	4.71	−0.22	0.68	1.72	−1.12	6.02			3.41	
$\Delta e^r_{P,t-1}$	0.050	0.247	1.492	0.423	0.043			**1.557**		**0.066**
	0.30	1.05	1.17	0.36	1.11			4.52		3.80
$\Delta e^r_{P,t-2}$	−0.010	0.203	1.022	−1.015	−0.026			**3.033**		**−0.048**
	−0.06	0.87	0.81	−0.88	−0.68			6.79		−2.83
$\Delta e^r_{O,t-1}$	0.001	0.022	0.083	−0.091	−0.004					
	0.05	0.60	0.41	−0.49	−0.63					
$\Delta e^r_{O,t-2}$	0.014	0.008	0.163	−0.166	0.001			**0.279**		
	0.59	0.22	0.87	−0.98	0.10			3.56		
$\Delta p^r_{A,t-1}$	−0.016	−0.024	0.130	**−0.264**	−0.002				**−0.204**	
	−0.89	−0.93	0.94	−2.08	−0.43				−2.06	
$\Delta p^r_{A,t-2}$	−0.014	0.008	−0.018	**−0.248**	−0.002				**−0.205**	
	−0.77	0.31	−0.13	−1.99	−0.51				−2.03	
Δr_{t-1}	−0.554	−0.455	5.432	−1.916	**1.037**					**0.901**
	−1.30	−0.76	1.66	−0.64	10.60					22.60
Δr_{t-2}	0.853	0.543	−4.930	3.308	−0.146					
	1.93	0.88	−1.46	1.07	−1.44					
					Deterministic terms					
μ	0.139	0.239	−0.490	−1.074	−0.023	**0.191**	**0.408**	−1.036	−1.006	**−0.044**
	1.05	1.28	−0.48	−1.16	−0.76	2.00	3.61	−1.56	−1.79	−2.20
d_{85q4}	**0.948**	−0.405	4.227	0.645	0.067	**1.025**				
	2.63	−0.80	1.54	0.26	0.81	3.41				
d_{87q2}	−0.314	0.651	−1.613	0.808	**0.383**					**0.328**
	−0.79	1.17	−0.53	0.29	4.20					4.19
d_{87q4}	**−0.729**	−0.860	**5.590**	**−9.406**	0.106				**−7.847**	
	−2.07	−1.74	2.08	−3.82	1.31				−3.56	
d_{88q3}	−0.426	−0.350	0.989	0.634	**0.218**					**0.210**
	−1.24	−0.72	0.38	0.26	2.77					2.85
d_{92q1}	**0.973**	**1.666**	−4.348	**5.200**	−0.019		**0.752**			
	2.59	3.15	−1.51	1.97	−0.22		3.18			
d_{93q4}	−0.199	0.231	−0.416	**−7.160**	0.007				**−7.031**	
	−0.55	0.46	−0.15	−2.83	0.09				−3.07	
d_{94q2}	−0.394	−0.304	2.740	1.346	**0.251**					**0.268**
	−1.04	−0.57	0.94	0.51	2.87					3.51
d_{00q1}	−0.418	0.996	**−10.522**	−2.078	0.129		**1.171**	**−10.764**		
	−1.11	1.87	−3.64	−0.79	1.49		2.75	−4.21		
s_1	−0.163	−0.150	0.905	0.306	0.014	−0.102	−0.099	0.493	0.313	0.018
	−1.26	−0.83	0.92	0.34	0.46	−0.89	−0.65	0.58	0.40	0.76
s_2	−0.065	0.304	−1.159	**1.987**	0.056	−0.005	0.252	−0.942	**1.950**	**0.048**
	−0.50	1.66	−1.16	2.17	1.87	−0.04	1.69	−1.13	2.37	1.98
s_3	0.120	**0.383**	−1.826	1.560	−0.018	0.088	**0.296**	−1.337	1.377	−0.018
	0.97	2.20	−1.93	1.80	−0.64	0.79	1.98	−1.61	1.83	−0.79

Table 9: Estimated coefficients of the 1985q1-2004q4 system (15).